THE KINGDOM OF CAMBODIA
MINISTRY OF WATER RESOURCES AND METEOROLOGY

PROJECT FOR DEVELOPMENT OF NATIONAL STANDARD DESIGN DOCUMENTS FOR IRRIGATION AND DRAINAGE IN THE KINGDOM OF CAMBODIA

COMPLETION REPORT (PHASE 1)

MAY 2023

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
NIPPON KOEI CO., LTD.

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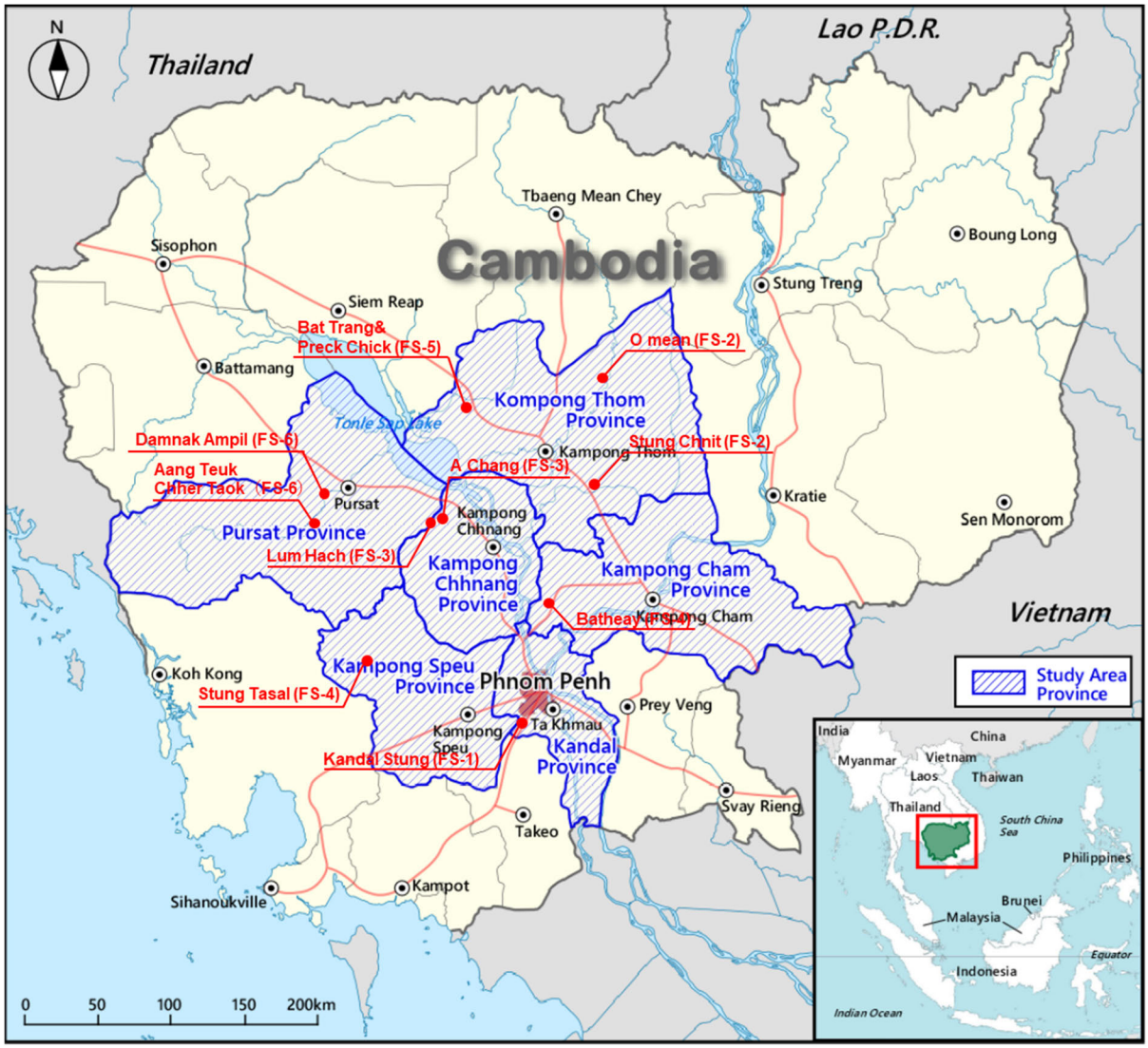


Location Map of Field Survey

Table of Contents

List of Figures

List of Tables

Abbreviations

Page

Chapter 1 Outline of the project

1.1 Background of the project 1-1

1.2 Summary of the Project (Overall Goal, Project Purpose, Outputs to be expected) 1-1

1.3 Project Design Matrix (Version 0) 1-2

Chapter 2 Implemented Project Activities

2.1 Implementation Structure 2-1

2.2 Project Period and Planned Activities（Flowchart, Work Plan & Expert Dispatch Schedule） 2-1

Chapter 3 Project Activities and Results

3.1 Outline of the Project Activities 3-1

3.1.1 Preparation and discussion the Work Plan 3-1

3.1.2 Nomination of the Project Counterpart and Structure of the Project 3-1

3.1.3 Preparation and discussion of the Work Plan 3-2

3.1.4 Assistance in preparing monitoring sheets and consultations 3-2

3.1.5 Participate to the Joint Coordination Committee 3-2

3.2 Collection and distribution of standard design documents for existing projects 3-2

3.2.1 Planning for Collection of standard design documents for existing projects 3-2

3.2.2 Conduct preliminary training on standard design documents for existing projects 3-3

3.2.3 Improvements based on analysis of standard design documents for existing projects 3-4

3.3 Conducting field surveys 3-7

3.3.1 Planning for collection and analysis of information on existing projects 3-7

3.3.2 Findings from the collection and analysis of information on existing projects 3-10

3.3.3 Findings through Field Survey (Headworks) 3-11

3.3.4 Findings through Field Survey (Canal Works) 3-17

3.4 Determination of policy for formulating standard design documents based on information on existing projects and field survey findings 3-20

3.4.1 Basic policy for formulating standard design documents 3-20

3.4.2 Standard Design Document Development Policy (Headworks) 3-22

3.4.3 Standard Design Document Development Policy (Canal Works) 3-22

3.5 Development of design standard documents in accordance with the formulation concept 3-23

3.5.1 Development of design criteria (Headworks) 3-23

3.5.2 Development of design criteria (Canal Works) 3-29

3.6 Collection and analysis of meteorological and hydrological data 3-31
3.6.1 Accumulation status of meteorological and hydrological data 3-31
3.6.2 Methodology of setting design flood discharge 3-33
3.6.3 Irrigation water requirement and irrigation efficiency 3-36
3.7 Collection of information on geology and soil mechanics and the required measures ... 3-38
3.7.1 Data research 3-38
3.7.2 Interview Survey 3-39
3.7.3 Field investigation 3-41
3.7.4 Consideration of soil investigation/laboratory test for understanding of distribution and properties of dispersive and expansive soils 3-43
3.7.5 Consideration of countermeasures on dispersive and expansive soils 3-44
3.8 Planning training on NSDD criteria documents for MOWRAM technical staff..... 3-45
3.8.1 Basic concept for Creating Training Curriculum for MOWRAM Technical Staff 3-45
3.8.2 Proposal of Training Implementation Plan..... 3-49
3.8.3 Proposal of Training Implementation Plan..... 3-50
3.9 Participation in workshops with relevant ministries and related development partners 3-50
3.10 Validation by JCC..... 3-50

Chapter 4 Lessons learned and challenges for future project activities

4.1 Adjustment of C/P Project Activity Participation Period 4-1
4.2 Ingenuity in Information Collection on Existing Projects and Future Prospects 4-1
4.3 Translation of deliverables into Khmer 4-1
4.4 Budgeting for expenses necessary for future training continuation (including lecturer's daily allowance) 4-1
4.5 Responding to challenges in the implementation of the work (second phase)..... 4-2

List of Figures

Page

Figure 3-1 Working Team 3-1
Figure 3-2 List of C/P 3-2
Figure 3-3 Flowchart for Determination of Design Flood Discharge 3-27
Figure 3-4 Flowchart of Determining Design Flood Water of Headworks 3-28
Figure 3-5 Interviews of Laboratories 3-41
Figure 3-6 Field Survey Result (Kandal Stung Irrigation system on January 1, 2023) 3-41
Figure 3-7 Field Survey Result (Kandal Stung Irrigation system on January 19, 2023) 3-42
Figure 3-8 Field Survey Result (Lum Hach Irrigation system on February 8, 2023) 3-43
Figure 3-9 Timing of training (n=11) 3-47
Figure 3-10 Duration of Training (n=11) 3-48
Figure 3-11 Timing of Training for PDWRAM (n=11) 3-48
Figure 3-12 Duration of Training for PDWRAM (n=11) 3-48
Figure 3-13 Flow of Training Implementation 3-49

List of Tables

Page

Table 1-1 Summary of the Project 1-2
Table 1-2 Project PDM 1-2
Table 3-1 Target Items and Conditions of Data Collection and Field Survey 3-3
Table 3-2 List of Preliminary Guidance Concluded to Counterparts during Consulting Services (Phase- I) 3-4
Table 3-3 Summary of Info Collection Results from MPWT & MRD on Design Standard and Examination System 3-5
Table 3-4 Design Flood Discharge (Headworks) 3-6
Table 3-5 Canal Bed Slope (Canal Works) 3-7
Table 3-6 Target Items and Condition of Field Survey 3-8
Table 3-7 List of Field Survey Schedule and Selected sites 3-9
Table 3-8 Project Outline and Design Document Availability of Selected Sites (Projects Funded by Development Partners) 3-9
Table 3-9 Project Outline and Design Document Availability of Selected Sites (National Projects Funded by MOWRAM) 3-10
Table 3-10 Point of Field Observation, Cause Analysis of Problem, Consideration for NSDD 3-11
Table 3-11 Good Practice and Problem to be reflected in NSDD (Headworks) 3-11
Table 3-12 Comparison of Return Period of Design Flood Discharge 3-14
Table 3-13 Comparison of Design Flood Discharge and Freeboard 3-15
Table 3-14 Riverbed and Riverbank Protection Works (incl. Apron and Side Slope Protection) 3-16
Table 3-15 Problems to be Reflected on in NSDD (Canal) 3-17
Table 3-16 Design Velocity 3-19
Table 3-17 Canal Side Slope 3-20
Table 3-18 Freeboard 3-20
Table 3-19 Structure of Design Criteria 3-22
Table 3-20 Points to be Considered for Formulation of NSDD (Headworks) 3-22
Table 3-21 Points to be Considered for Formulation of NSDD (Canal Works) 3-22
Table 3-22 Draft Table of Contents (Headworks) and Points to be Considered under the Relevant Chapter 3-23
Table 3-23 Draft Table of Contents (Headworks) and Points to Consider under the Relevant Chapter 3-24
Table 3-24 Draft Table of Contents (Canal Works) and Points to be Considered under the Relevant Chapter 3-29
Table 3-25 Draft Table of Contents (Headworks) and Points to Consider under the Relevant Chapter 3-30
Table 3-26 Obtained Meteorological Data from AWS 3-32
Table 3-27 Obtained Hydrological Data 3-33
Table 3-28 Process and Analytical Method Employed for Design Flood Discharge in the Project in Cambodia 3-34
Table 3-29 Comparison of Characteristics of Runoff Analysis Methods (1) 3-36
Table 3-30 Comparison of Characteristics of Runoff Analysis Methods (2) 3-36
Table 3-31 Design Values of Irrigation Efficiency for Existing Paddy Irrigation Projects 3-38
Table 3-32 Summary of interview survey (Date, Destination and Achievements) 3-40

Table 3-33 Survey and Test Items Considered Effective for Understanding the Distribution and Properties of Dispersive Soil/Expansive Soil 3-44
Table 3-34 Countermeasure Work Considered Effective for Dispersive and Expansive Soil 3-45
Table 3-35 Experience of as an Instructor of the Training at TSC-2 and TSC-3 3-46
Table 3-36 Number of Engineers in MOWRAM and PDWRAM 3-47
Table 3-37 Goal of the training 3-49

Abbreviations

ADB	Asia Development Bank
AFD	The Agence Française de Développement
Aus-Aid	Australian Agency for International Development
ARI	Average Recurrence Interval
C/P	Counterpart
EDCF	Korea Economic Development Co-operation Fund
FWUC	Farmer Water Users Community
FWUG	Farmer Water Users Group
ITC	Institute of Technology of Cambodia
JCC	Joint Coordination Committee
MAFF	Ministry of Agriculture, Forestry and Fisheries
MOWRAM	Ministry of Water Resources and Meteorology
MPWT	Ministry of Public Works and Transport
MRD	Ministry of Rural Development
NaSDeP	Project for Development of National Standard Design Documents for Irrigation and Drainage in Cambodia
NSDD	National Standard Design Document
O&M	Operation and Maintenance
PDWRAM	Provincial Department of Water Resources and Meteorology
R/D	Record of Discussion
SD	Standard Document
SDD	Standard Design Document
TS	Technical Standard
TSC	Technical Service Center

Chapter 1 Outline of the project

1.1 Background of the project

The Government of Cambodia contemplates the development of the agriculture sector and rural development as the important issues in the national development plans, “Rectangular Strategy Phase IV 2018-2023” and “National Strategic Development Plan 2019-2023” for sustainable development of Cambodia. In response to the above situation, the “Agricultural Sector Strategic Development Plan 2019-2023” prepared by the Ministry of Agriculture, Forestry and Fisheries (hereinafter referred to as “MAFF”) raised the importance of irrigation and drainage systems which are directly linked to agriculture production and strengthening of operation and maintenance of the systems as well as improvement and diversification of agricultural productivity, and commercialization of agriculture.

In addition, Cambodia has experienced a lot of issues such as the change of government, civil disorder and shortage of budget. As a result, there are many irrigation and drainage structures which are deteriorated, and are not working well, since they were constructed using inadequate technology during the Pol Pot regime. Therefore, in the “Water Resources and Irrigation Sector Strategic Development Plan 2019-2023” prepared by the Ministry of Water Resources and Meteorology (hereinafter referred to as “MOWRAM”), it is delineated that MOWRAM will proceed on the efficient rehabilitation of existing irrigation and drainage structures which are deteriorated or not working well, improve the agricultural productivity, and expand the irrigable area by developing the irrigation structures.

Since there have been no national standard design criteria for the designing of irrigation and drainage structures, the structures have been designed based on the knowledge and experience of technical staff of MOWRAM and the Provincial Department of Water Resources and Meteorology (hereinafter referred to as “PDWRAM”), and private consulting companies, or by using the standards prepared by the development partners who are assisting the irrigation sector. Consequently, there are many differences in the structural quality/durability and the cost of the structures between the projects. Furthermore, there are problems in the structures such as complication of operation and maintenance caused by inconsistent structural shape, difficulty of quality inspection caused by parameters of design criteria used in the projects and obstruction of effective budget allocation caused by increasing structure operation and management cost of MOWRAM. Therefore, in “Roadmap and Investment Program for Irrigation and Water Resources Management 2019-2023”, MOWRAM cites the differences of design/construction quality of reservoirs and irrigation structures caused by no national standards for design, construction and supervision of irrigation and drainage structures as a key development issue, and the needs for the development of the standard design documents suitable for Cambodia.

1.2 Summary of the Project (Overall Goal, Project Purpose, Outputs to be expected)

The summary of the project is shown in the following Table 1-1.

Table 1-1 Summary of the Project

Items	Contents
Overall goals	National standard design documents for irrigation and drainage structures are authorized as the national standard and applied to irrigation and drainage projects in the Kingdom of Cambodia.
Project purpose	System of formulation and utilization of national standard design documents for irrigation and drainage structures is established in MOWRAM.
Output	1. National standard design documentations (design criteria, design drawings, technical specifications, and design manuals) for irrigation and drainage structures are developed. 2. MOWRAM's and PDWRAM's capacity for applying national standard design documents for irrigation and drainage structures is strengthened. 3. Examination system for national standard design documents in MOWRAM is established.
Project site / Target area	Phnom Penh the capital of Cambodia (MOWRAM)/ Entire Cambodia (For Standard design document)
Project-related Agencies	1. Executing agency: Technical Service Center (TSC) in MOWRAM, Engineering department, Irrigated agriculture Department, Farmer Water Utilization Committee 2. Related government agency: Ministry of Agriculture, Forestry and Fisheries (MAFF), Ministry of Public Works and Transport (MPWT), Ministry of Rural Development (MRD), Ministry of Economy and Finance 3. Development partner: Asian Development Bank (ADB), The Agence Française de Développement (AFD), Australian Agency for International Development (AusAID）, government development agency in Korea and China.

1.3 Project Design Matrix (Version 0)

Table 1-2 shows the Project Design Matrix (PDM) of this project.

Table 1-2 Project PDM

Project Title: Project for Development of National Standard Design Documents for Irrigation and Drainage
Implementing Agency: Ministry of Water Resources and Metrology (MOWRAM)
Target Group: Engineering staffs of Technical Service Center (TSC), Engineering Dept., Irrigated Agriculture Dept., FWUC Dept. of MOWRAM, Engineering staffs of PDWRAMs
Period of Project: March 2022 - March 2026 (Tentative)
Project Site: Phnom Penh, Cambodia

Version 0
Dated January 5, 2022

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption
Overall Goal National standard design documents for irrigation and drainage structures are authorized as national standard, and applied to irrigation and drainage projects in the Kingdom of Cambodia.	1. Authorized standard design documents are published by MOWRAM. 2. Number of irrigation and drainage projects based on national standard design documents. 3. Examination committee is regularly held to review the national standard design.	1. Published National Standard Design Documents 2. MOWRAM Annual Report on Water Resource Management and Development 3. MOWRAM Meeting documents	・There is no drastic change in the government policy in agriculture and water sector or irrigation sector.
Project Purpose System of formulation and utilization of national standard design documents for irrigation and drainage structures is established in MOWRAM.	1. At least XX standard design documents of irrigation and drainage structures are formulated by MOWRAM.	1. Standard design documents 2. Training records 3. Meeting	・Other ministries, consultants and development partners, which are

	2. Understanding on National Standard Design Documents of engineering staff in MOWRAM and PDWRAMs increases XX% based on the capacity assessment. 3. Examination committee is held at least XXX times.	documents	related to irrigation sector, accept and apply the standard to the irrigation and drainages projects.
Outputs 1. National standard design documentations (design criteria, design drawings, technical specifications, and design manuals) for irrigation and drainage structures are developed.	1.1 Draft National standard design documents are developed.	1.1 Project Documents	・Engineering staff who participated in formulation and training of standard design documents remain in MOWRAM.
2. MOWRAM's and PDWRAM's capacity for applying national standard design documents for irrigation and drainage structures is strengthened.	2.1 XX trainers can conduct a training program on application of standard design documents. 2.2 XX% of engineering staff in MOWRAM and PDWRAM participated to new training course on standard design documents. 2.3 More than XX% of trainees achieved goals set up in the training course.	2.1 Training record 2.2 Training record 2.3 Training record	
3. Examination system for national standard design documents in MOWRAM is established.	3.1 Examination committee is established. 3.2 Draft design standard documents are provisionally approved.	3.1 MOWRAM documents 3.2 MOWRAM documents	

Activities	**Activities**		**Pre-Conditions**
	The Japanese Side	**The Cambodian Side**	
1-1 Establish working groups and clarify roles and responsibilities of each group to formulate standard design documents 1-2 Analyze problems on designs of existing structures in the irrigation and drainage systems through field surveys 1-3 Review standard design documents applied to the existing structures, and analyze the problems 1-4 Determine policies for formulation of standard design documents based on the results of Activity 1-2 and 1-3 1-5 Formulate the draft standard design criteria based on the formulation policy in Activity 1-4 1-6 Formulate the draft standard design drawings based on the formulation policy in Activity 1-4 1-7 Formulate the draft standard design manuals based on the formulation policy in Activity 1-4 1-8 Conduct consultative workshops with relevant ministries and development partners regularly to share the formulation of draft standard design documents 2-1 Develop a training curriculum based on the design manuals for engineering staff of MORAM	1) Dispatch of experts - Chief Advisor - Coordinator/ Training/ Public Relations - Experts in the field of (1) Design criteria for Headworks (2) Design criteria for Canals & Structures (3) Meteorology/Hydrology (4) Geology (5) Soil Mechanics (6) Criteria for Gate (7) Survey and Training Planning - Other experts necessary to implement the activities 2) Provision of machinery and equipment - Equipment necessary for Project activities 3) Training in Japan and third countries	1) Counterpart - Project Director - Project Manager - Deputy Project Manager - Counterpart Personnel 2) Office space and facilities for Japanese experts 3) Operational cost such as administrative expenses, electricity, water, fuel, etc.	・Other ministries, consultants and development partners, which are related to irrigation sector, accept and apply the standard to the irrigation and drainages projects.

2-2 Develop training materials on the standard design documents for engineering staff of MOWRAM 2-3 Conduct training programs on the standard design documents for engineering staff of MOWRAM 2-4 Revise the training materials depending on a degree of comprehension of trainee and questionnaire results, if necessary 2-5 Design the selected irrigation structures to apply the standard design documents by engineering staff of MOWRAM 2-6 Support TSC to conduct training programs to PDWRAMs on standard design documents 2-7 Conduct a capacity assessment to check the level of understanding of trainees. 3-1 Identify procedures to examine the standard design documents. 3-2 Prepare the guidelines of examination committee to approve the standard design documents 3-3 Establish the examination committee for standard design documents. 3-4 Examine the draft standard design documents in the examination committee. 3-5 Provide a guidance on provisionally approved standard design documents to relevant ministries and development partners.			 <Issues and countermeasures>

Source: NaSDeP

Chapter 2 Implemented Project Activities

2.1 Implementation Structure

Regarding this work, in addition to the contractor of this contract (hereinafter referred to as "short-term expert"), a long-term expert (chief advisor / examination system construction) by the recommendation of the Ministry of Agriculture, Forestry and Fisheries in Japan and a long-term expert (business coordination/training/public relations) by the separate contract of JICA will be dispatched. The Chief Advisor/Evaluation System Development will mainly be in charge of providing general overview and advice on the overall project based on his knowledge of Japanese legal and administrative systems, and the matters related to an evaluation committee for Output 3. Short-term experts will mainly be responsible for the development of standard design documents for Output 1 and training for MOWRAM and training for PDWRAM for Output 2. Another long-term expert, Business Coordinator/Training/Public Relations, is mainly in charge of logistics and budget management (payment, accounting, etc.) related to long-term experts and the entire project, in addition, planning and management of training in a third country and in Japan, and handle activities related to public relations. However, the logistics and expense processing of the short-term experts and local staff hired within the contract shall be handled by the short-term experts. The short-term expert also supports the training for PDWRAM conducted mainly by TSC.

Long-term experts and short-term experts (both experts are collectively referred to as the “expert team”) shall build a joint system while promoting sufficient information sharing in the implementation of any work.

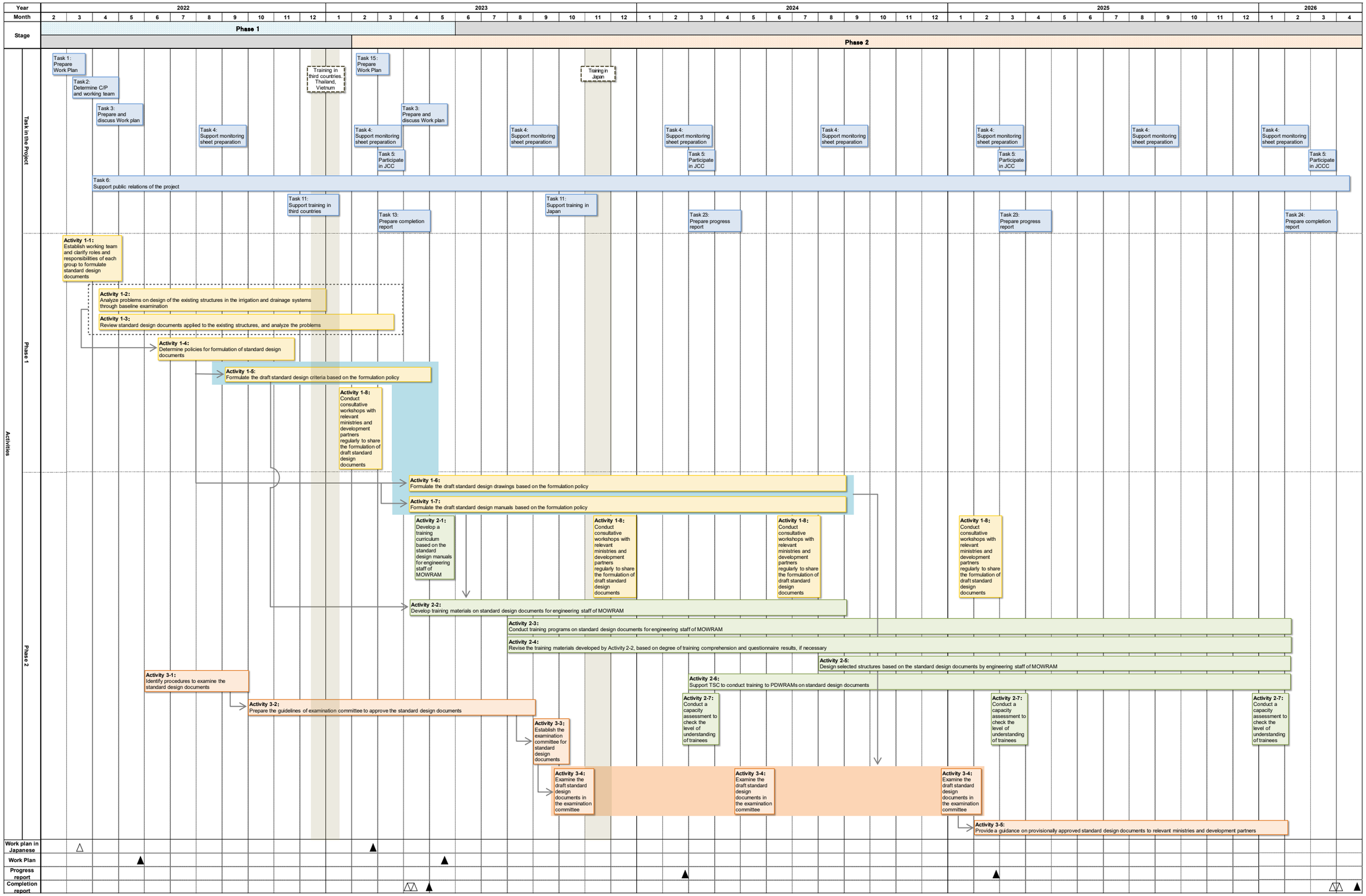
2.2 Project Period and Planned Activities（Flowchart, Work Plan & Expert Dispatch Schedule）

This project will develop national standard design documents consisting of standard design standards, standard design manuals, and standard design drawings for MOWRAM irrigation and drainage facilities over a period of four years and strengthen the capacity to utilize the standard design documents of MOWRAM and PDWRAM.

At the same time, after establishing an examination system for the standard design documents, provisional certification of the same documents will be carried out. The work period is divided into two phases. Phase 1: 14 months from February 2022 to May 2023 to formulate standard design criteria, Phase 2: from February 2023 to April 2026[1], while developing standard design manuals and standard design drawings over a period of 38 months, concurrently strengthen the capabilities of MOWRAM and PDWRAM through training, and provisionally certify the standard design drawings formulated by the examination committee (provisional name).

Taking into account the above, the work implementation method for effectively and efficiently implementing this work is detailed below for each item shown in the workflow chart in Figure 2-1.

[1] Delays in collecting design documents for existing irrigation projects and implementation of technology transfer to the C/Ps caused delays in the progress of the project during the phase 1. Therefore, the term of phase 1 has been extended to prepare the draft design criteria. Consequently, the term of the phase 1 and phase 2 overlapped from February to May 2023.



Source: NaSDeP

Figure 2-1 Flowchart of the Activities of the Project

Chapter 3 Project Activities and Results

3.1 Outline of the Project Activities

3.1.1 Preparation and discussion the Work Plan

Based on the common specification, the work plan (Phase 1) was submitted to the client and approved.

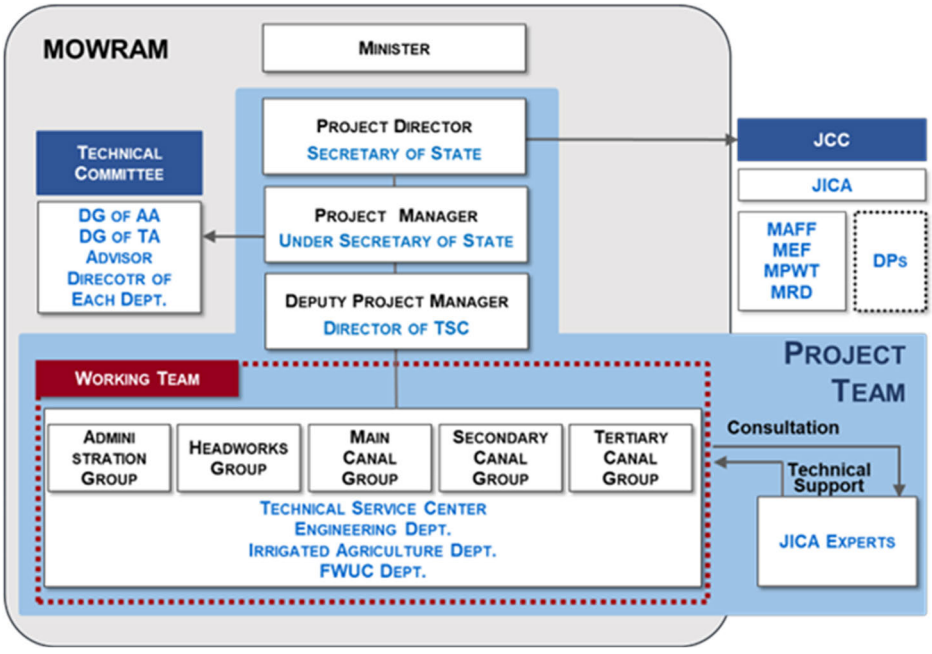
3.1.2 Nomination of the Project Counterpart and Structure of the Project

(1) Determination of C/P and organization of working team

In this project, on the premise of building a cross-sectional collaboration system within MOWRAM, with the approval of the Minister of MOWRAM, 23 counterparts were selected from the Technical Service Center (hereinafter referred to as "TSC"), the Engineering Department, the Irrigated Agriculture Department, and the Farmers Water Users Association.

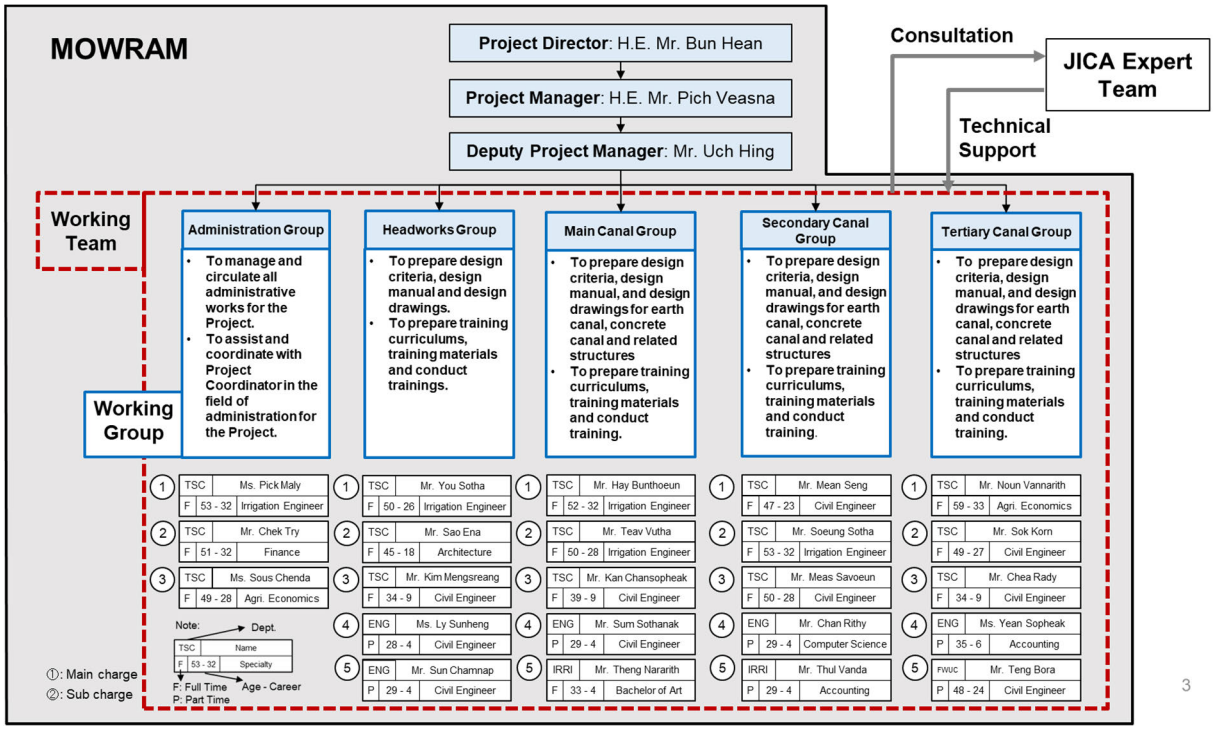
(2) Working team formation

In addition, depending on the activities and objectives of this project, C/Ps were assigned to consist of the following five teams: 1) head works team, 2) main canal team, 3) secondary canal team, 4) tertiary canal team, 5) administration team on May 17, 2022, and a main and sub-person in charge was appointed to each team. By organizing working teams by department in this way, instructions and orders from the project director (Secretary of State of MOWRAM), project manager (Under secretary of state of MOWRAM), and deputy project manager (Director of TSC of MOWRAM) for this work can be accurately delivered to the C/P through the main person in charge of each working team. Figure 3-1 shows the working team formed, and Figure 3-2 shows the list of counterparts.



Source: NaSDeP

Figure 3-1 Working Team



Source: NaSDeP

Figure 3-2 List of C/P

3.1.3 Preparation and discussion of the Work Plan

Based on the results of detailed planning surveys related to this work, grasp of the overall picture of the project, basic policies (implementation system, activity content, implementation method, work schedule plan, etc.) and areas in charge of the work plan for the first phase (work policy, content, schedule, working team composition, roles, responsibilities, etc.) was discussed and reviewed with the long-term expert and MOWRAM. The above discussions and considerations were explained to MOWRAM by the JICA expert and approved, on April 22, 2022, and the kick-off meeting was held on May 5, 2022.

3.1.4 Assistance in preparing monitoring sheets and consultations

The plans and work items for each person in charge were summarized in the monitoring sheet to help Chief Advisor who was in charge of the compilation. A monitoring sheet as of March 2023 is attached to ANNEX-1.

3.1.5 Participate to the Joint Coordination Committee

Chief Advisor held the 1st JCC on March 22, 2023. Three short-term experts (Iwamoto, Yano, and Obara) attended the meeting and explained the activity results of the 1st term and the plan of the 2nd term. The meeting materials are attached to ANNEX-2.

3.2 Collection and distribution of standard design documents for existing projects

Data and information were collected both in Japan and overseas, and field surveys were conducted in order to formulate policies for the National Irrigation and Drainage Standard Design Documents (hereinafter referred to as “NSDD”) and to prepare related documents.

3.2.1 Planning for Collection of standard design documents for existing projects

The data as well as information collection from both inside and outside Cambodia and field survey have been carried out for formulating the concept of the NSDD of Cambodia and preparing the

relevant documents. For formulation of the NSDD, data collection and field survey have been planned and implemented considering the following target items and conditions as shown in Table 3-1, also in consideration of the natural environment, technical level, economic situation, farming pattern, etc., of Cambodia.

Table 3-1 Target Items and Conditions of Data Collection and Field Survey

Items of data collection	Collecting Target	Conditions/Confirmation	Suggestions
1. Standard Design Documents used in the Existing Irrigation and Drainage Projects	1) Projects: Domestic projects, projects funded by key development partners (JICA, ADB, AFD, China Korea, India and Australian AID) 2) Collection data: Standard design criteria applied or adopted. 3) Target group: Departments of TSC, Engineering, Irrigated Agriculture, and FWUC.	• Clarification of source of data • Clarification of availability of data • Reliability and accuracy of data	Based on the results of the survey for formulation of detailed plan, the Project Management Units (PMU) implementing the projects funded by the development partners were also included in the target group.
2. Standard Design Criteria and Standard Design Drawings in South-East Asian countries.	1) Target countries: Thailand, Vietnam 2) Collection data: Standard design criteria and standard design drawings for irrigation and drainage development projects 3) Target group: Departments involved in planning, designing and supervising irrigation and drainage projects	• The material collection will be requested from the target department on an email basis with the support of JICA Cambodia office and JICA long-term experts • Third-country training is planned and is to be conducted by the JICA long-term experts	The survey had been implemented in 2 countries - Thailand, Vietnam. (Myanmar: Due to the political instability it was difficult, Lao PDR: Due to the difference in the natural condition)
3. Field survey in Cambodia	1) Target structures of the field survey (9-10 systems in total) Domestic projects: Each small, medium and large-scale structure Projects funded by Development partners: 6-7 systems 2) Structures to be included in the system: Water sources and intake structures (headworks and reservoirs), main and secondary canals, and all the related structures 3) Target group: PDWRAM, Farmers' Water User Cooperatives (FWUC) and farmers' Water User Groups (FWUG) in the target districts and development partners.	• Areas that have not been developed into residential areas or plantations. • Areas which are reachable within a day trip/ one night two days trip from Phnom Penh • Areas which are handed over at least one year before. • Areas approved for field survey implementation by MOWRAM and/ or development partners	1. Through discussion with MOWRAM, most of the field survey trips have been arranged with “two-sites/ trip” with “1 night two days” considering the time necessary for both interview survey and field survey. The following 6 provinces had been considered. 1) Kampong Cham (124 km); 2) Kampong Chhnang (91 km); 3) Kampong Speu (48 km); 4) Prey Veng (90 km); and 5) Svay Rieng (122km) and 6) Takeo (77 km). (): distance from Phnompenh 2. Preferably systems with hydro-meteorological data

Source: NaSDeP

3.2.2 Conduct preliminary training on standard design documents for existing projects

In order to enhance the understanding of the counterparts on NSDD as well as fill the gap between the anticipated knowledge level and the actual knowledge level of the counterparts, preliminary guidance had been conducted as an additional scope. The following preliminary guidance have been conducted to increase the capacity of counterparts towards familiarity with the contents of NSDD and future collaboration for the formulation of NSDD.

Table 3-2 List of Preliminary Guidance Concluded to Counterparts during Consulting Services (Phase- I)

No.	Date	Contents of Guidance/ Training	Trainers	Number of C/Ps
1	26-Apr'22	Questionnaire Forms for the Field Survey	Mr. YAMASHITA, Dr. IWAMOTO	18
2	4-May'22	Introduction of Engineering Manual for Irrigation & Drainage (JIID) for Head Works and Canal Works	Dr. Murugaboopathi, Dr. IWAMOTO	19
3	18-May'22	Field Investigation Items & Objectives (Headworks and Canal Works)	Dr. IWAMOTO, Dr. Murugaboopathi, Mr. ITO	16
4	16-Jun'22	- Documentation of Findings of Field Survey - Additional explanation on Canal and Headworks	Mr. ITO, Ms. OBARA	13
5	6, 8-Jul'22	Irrigation Terminology/ Definition of Canal Works	Ms. OBARA, Mr. ITO	10, 6
6	13-Jul'22	Irrigation Terminology/ Definition of Headworks	Mr. ITO	12
7	05-Aug'22	Findings of FS-2 (O-Mean and Stung Chinit Irr. Sch.)	Mr. ITO, Dr. IWAMOTO	12
8	10-Aug & 16-ug'22	Finalization of Irrigation Terminology/ Definition of Canal works/ Headworks	Dr. IWAMOTO, Mr. ITO, Mr. UCHIMURA	12, 14
9	26-Aug'22	Findings of FS-3 (Lum Hach & A Chang Irr. Sch.)	Mr. TOKUWAKA, Dr. IWAMOTO, Mr. ITO, Mr. UCHIMURA	12
10	30-Aug'22	Pre-Guidance of FS-4 (Bantheay & Stung Tasal Dam)	Mr. ITO, Ms. Obara	15
11	13-Sep'22	Pre-Guidance of FS-5 (Bat Trang & Preck Chick Canal)	Ms. Obara, Mr. ITO	10
12	14,15-Sep'22	Findings of FS-5 (Bat Trang & Preck Chick Canal)	Mr. TOKUWAKA, Dr. IWAMOTO, Mr. ITO, Ms. OBARA	9
13	10 ct.'22	Findings of FS-4 (Bantheay & Stung Tasal Dam)	Canal & HW Team Mr. Tokuwaka, ITO	12
14	17 Oct. '22	Findings and Analysis of Field Survey Results Report on WRM Training In Korea	Mr. Tokuwaka, Mr. ITO, Ms. Obara, Mr. Sophak	15
15	13 Feb. '23	Short Lecture on Hydro-Meteorology Investigation and Flood discharge calculation	Mr. TSUCHIDA	8
16	24 Feb. '23	Short lecture on irrigation water requirement	Mr. TSUCHIDA	14
17	2 Mar. '23	Special Lecture by short term expert (Headworks, Hydrological Analysis, Geological Test)	Mr. ITO, Mr. TSUCHIDA, Mr. HAGI	14
18	Mar.-Apr. '23	Lecture and discussion on Design Criteria for Headworks Canal Works	Mr. ITO (5 sessions) Ms. OBARA (5 sessions)	12 (Average)

Source: NaSDeP

3.2.3 Improvements based on analysis of standard design documents for existing projects

(1) Review of Design Documents of previous projects

Comparison of design documents for previous irrigation projects developed by MOWRAM and the development partners is mentioned in 3.3 Conducting field surveys.

(2) Review of Standard Design Documents of Ministry of Public Works and Transport (MPWT) and Ministry of Rural Development (MRD)

Purpose of Review of Standard Design Documents (hereinafter referred to as "SDD") of Ministry of Public Works and Transport (hereinafter referred to as "MPWT") and Ministry of Rural Development (hereinafter referred to as "MRD") are as follows, with a result as shown in Table 3-3:

- NSDD of Cambodia will be formulated suitable for the actual condition in Cambodia.

- The structure and the procedure for enforcement of the standard design documents previously formulated and commenced by MPWT/ MRD will be examined and will be reflected in the formulation and commencement of NSDD.

Table 3-3 Summary of Info Collection Results from MPWT & MRD on Design Standard and Examination System

Item \ Ministry	MPWT	MRD
List of Technical Standard (TS)	1) Road Design Standard Part 1 Geometry (2003) Part 2 Pavement (2003) Part 3 Drainage (2003) 2) Bridge Design Standard (2003) 3) Standard Drawings Part 1 Road (2011) Part 2 Road Structure (2013) 4) Construction Specification (2003) 5) Construction Cost Analysis (2006)	1)Rural Road Standard (2013) ("RRS") Section 1 Introduction Section 2 Classification of Rural Roads Section 3 Geometric Design Section 4 Earthworks Section 5 Pavement Section 6 Structure Section 7 Road Furniture Section 8 Unexploded Ordnance Section 9 Miscellaneous <Note: Final-Draft RRS was prepared in 2006> 2)Construction Specification for MPWT
Dev. Partners assisted	AusAID: Road/Bridge Design Standard JICA: Standard Drawings	ADB
Revision Chronology	None	2016: Translation to KH w/ minor revision only
Legal basis	Prakas	Prakas - Prakas for English Version 2013 - above Prakas also for Khmer Version 2016
Process for establishment / revision of TS	Technical team formed for establishment of a draft TS (Members: each department of MPWT).	Process for establishment/ revision of TS

Source: NaSDeP

(3) Review of Standard design documents in South-East Asian Countries

The purposes of Review of Standard design documents in South-East Asian Countries are as follows:

- The NSDD of Cambodia will be formulated suitable to the actual condition in Cambodia.
- Cambodia has some common conditions with Thailand and Vietnam such as climate, topography, and soil characteristics. Therefore,
- The parameters of each SDD formulated in Thailand and Vietnam will be compared.

1) Review of Standards in South-East Asian Countries (Headworks)

Regarding the design parameters of headworks, determination of design flood discharge is the most important point since it will govern the scale and type of the diversion weir constructed in the target river. Therefore, the procedure of determination of design flood discharge has been compared among those of Japan, Thailand and Vietnam, as shown below:

Table 3-4 Design Flood Discharge (Headworks)

Japan	Thailand	Vietnam
The design flood discharge is determined in accordance with the flood control plan / river improvement plan of the river, if applicable. In other cases, the design flood discharge is determined based on the known actual discharge of the relevant similar river. If no reliable river water level / discharge measurement is conducted, the flood discharge is to be estimated by a selected calculation method, such as Rational formula, Tank model method, Storage function method, etc., based on the characteristics of the upper catchment / river basin of the headworks (Land Improvement Project Plan Design Standard "Headworks")[2]	Target drainage area Less than 3.2 km^2, up to 800 km^2 (Standard for calculating the design of water supply and drainage systems, page 37) Rational formula Q = 0.278 CIA Q: discharge m^3/s C: runoff-coefficient I: rainfall intensity (mm/h) A: catchment area (km^2) (Standard for calculating the design of water supply and drainage systems, page 36)	cases of catchment area (CA) =F 1) CA ≤ 100 km^2 2) CA > 100 km^2 *(22TCN220:1995, page 3)* For case 1) Limiting strength formula $Q_p=A_p \cdot \varphi \cdot H_p \cdot F \cdot \delta_1$ (m^3/s) (22TCN220:1995[3], page 3) For case 2) Reduction formula *(22TCN220:1995, page 14)*

Source: NaSDeP

In general, in Cambodia, a flood control plan and/or a river improvement plan (flood control/ river improvement plan, hereinafter) of a river were rather limited and not available with many rivers as sources of irrigation water. Therefore, for the design parameter of headworks, the determination procedure of the design flood discharge would be compared among SDD of Japan, Thailand and Vietnam. It was also thought that the design flood discharge would be reasonably determined by either flood frequency analysis and/or run-off analysis.

2) Review of Standards in South-East Asian Countries (Canal Works)

In the Japanese standard, a canal bed slope shall be determined so that problems, including scouring or significant wear, are avoided. On the other hand, the canal bed slopes of 1/10,000 or more are used in Thailand and Vietnam, where the Chao Phraya delta and Mekong delta have gentle slopes, and in addition to scouring, sediment shall be considered to set the canal bed slope. Especially, the zero slope can be chosen in the Vietnamese standard. The canal cross section is determined by using the non-uniform flow calculation method if the canal has zero slope and the design discharge is more than 50 m^3/s. Since the canals constructed during the Pol-Pot regime in Cambodia has gentle or reverse gradients, the Thai and Vietnamese standards in Thailand can be used as a reference for rehabilitation of the canals.

[2] https://public-comment.e-gov.go.jp/servlet/PcmFileDownload?seqNo=0000235512
[3] http://cucqlxd.gov.vn/quy-chuan-tieu-chuan/chi-tiet/21

Table 3-5 Canal Bed Slope (Canal Works)

Japan	Thailand	Vietnam
7-6 Condition for facilities and their layout Layout of canal structures and facilities in a canal system shall be determined upon confirmation of requirements such as curvature, longitudinal slope, and earth cover of a canal considering topographical or other site condition. (Explanation) The longitudinal slope for canals of various conveyance structures is normally determined based on the topographic slope and necessary water level for each point. When using the velocity considered, scouring may happen or structural and hydrological limitation may be required. Therefore, the flow velocity shall be within a limit so that problems, including scouring or significant wear, are avoided depending on the materials used for the canal. * There is description of sediment in the technical document. (Land Improvement Project Plan Design Standard "Canal Works")	Normally, the slope of canal bed (S) is between 1:1,000 and 1:10,000 depending on 1) lay the land along the canal, 2) characteristics and amount of sediment flowing with the water, 3) at the designer's discretion. There were several points of damage caused by the sediment into the canal. 1) The cross-sectional area of the canal is smaller, making it unable to deliver the required amount of water. 2) Fee for dredging the canal How to prevent gravel sediment from entering the canal may be done in the following order: ……. (Design standard for irrigation and drainage systems)	1) i = 1/2,000 to 1/3,000: when the canal route passes through the terrain with steep slope, and flow in the canal has a large amount of alluvium. 2) i = 1.3,000 to 1/5,000: when the terrain is not too steep, canal delivers water from the reservoir. 3) i = 1/5,000 to 1/15,000: canal route runs the plains, and the terrain is relatively flat. For dynamic irrigation canals, in special cases, it is possible to choose zero slope along the canal bed, but there must be a satisfactory argument as follows: 1) head loss along canal length is not large, 2) no sedimentation or canal bed erosion occurs, and, 3) minimum volume of excavation and embankment of canals and works on canals. (TCVN4118-2021)

Source: NaSDeP

3.3 Conducting field surveys

3.3.1 Planning for collection and analysis of information on existing projects

The data as well as information collection for the field survey have been carried out for formulating the concept of the NSDD of Cambodia and preparing the relevant documents. For formulation of the NSDD, data collection and field survey have been planned and implemented considering the following target items and conditions as shown in Table 3-6, also in consideration of the natural environment, technical level, economic situation, farming pattern, etc., of Cambodia.

Table 3-6 Target Items and Condition of Field Survey

Items of data collection	Collecting Target	Conditions/Confirmation	Suggestions
Field survey in Cambodia	1) Target structures of the field survey (9-10 systems in total) Domestic projects: Each small, medium and large-scale structure Projects funded by Development partners: 6-7 systems. 2) Structures to be included in the system: Water sources and intake structures (headworks and reservoirs), main and secondary canals, and all the related structures 3) Target group: PDWRAM, Farmers' Water User Cooperatives (FWUC) and farmers' Water User Groups (FWUG) in the target districts and development partners.	• Areas that have not been developed into residential areas or plantations. • Areas which are reachable within a day trip / one night two days trip from Phnom Penh • Areas which are handed over at least one year before. • Areas approved for field survey implementation by MOWRAM and / or development partners	1. Through discussion with MOWRAM, most of the field survey trips have been arranged with "two-sites/ trip" with "one night two days" considering the time necessary for both the interview survey and the field survey. The following 6 provinces had been considered. 1) Kampong Cham (124 km); 2) Kampong Chhnang (91 km); 3) Kampong Speu (48 km); 4) Prey Veng (90 km); and 5) Svay Rieng (122 km) and 6) Takeo (77 km). 2. Preferably systems with hydro-meteorological data

Source: NaSDeP

Especially for site selection of the existing projects for field survey with comparison of the standard design applied, the following selection criteria was considered:

- Completed Irrigation schemes with headworks/reservoir.
- One - two sites preferably from each active development partner
- Applicable with one night two days (for single site) / two nights three days (for two sites or more)
- Especially for the Domestic/National projects, applicable with recommendations by MOWRAM and data/information collected from Engineering Department who is generally in charge of design and construction of MOWRAM funded projects.

After selection of field survey sites, a design overview report had been prepared prior to implementation of the field surveys, based on the collected/available data and information, such as design report, drawings, design calculation, etc. As shown in Table 3-7, the field surveys have been conducted in the following ten (10) project sites where 8 (eight) projects were funded by development partners while 2 (two) national projects were funded by MOWRAM. Further, reviews of design documents were made for other 3 (three) sites of national projects.

Table 3-7 List of Field Survey Schedule and Selected sites

No.	Date	Site Name/ Province/ (Fund)	Component/ Year completed	Number of C/Ps
A.	**Development Partners Funded Project**			
FS-1	25-Apr'22	1. Kandal Stung Irrigation Sch./ Kandal/ (JICA)	1. Headworks (HW) Irrigation networks (NW) (2007)	19
FS-2	27-Jul '22 28-Jul '22	2. O Mean Irrigation Sch. / Kampong Thom/ (ADB) 3. Stung Chinit Irrigation Sch./ Kampong Thom/ (ADB-AFD)	2. Dam, Irri. NW (2016) 3. Dam, Irri. NW (2008)	12
FS-3	17-Aug '22 18-Aug '22	4. Lum Hach Irr. Sch./ Kampong Chhnang/ (JICA) 5. A Chang Irr. Sch./ Kampong Chhnang / (China)	4. HW, Irri. NW (2020) 5. HW, Irri. NW (2019)	13
FS-4	31-Aug '22 01-Sep '22	6. Batheay Flood Control (FC) & Irr. / Kampong Cham/ (KOICA) 7. Stung Tasal Dam/ Kampong Speu/(India)	6. FC Dike, Irr. NW (2010) 7. Dam (2016)	16
FS-6	09-Feb '23	8. Damnak Ampil Irr. Sch./ Pursat/(JICA)	8. HW, Irr. NW (2020)	13
B.	**MOWRAM Funded National Project**			
FS-5	14, 15-Sep '22	9. Bat Trang HW & Preck Chick Main Canal/ Kampong Thom	9. Headworks (HW) (2019) Irri. Networks (2020)	9
FS-6	09-Feb '23	10. Chher Taok Headworks Project	10. Headworks (HW) (2021)	13

Source: NaSDeP

As show in Table 3-8 and Table 3-9, the outlines of the project/site condition as well as availability condition of design documents were summarized for the selected ten (10) projects for the field survey, while three (3) projects for the document were review only.

Table 3-8 Project Outline and Design Document Availability of Selected Sites (Projects Funded by Development Partners)

Items \ Site	Kandal Stung	Lum Hach	O mean	Stung Chinit	Achang	Batheay	Stung Tasal Dam
1.Fund	JICA	JICA	ADB	ADB-AFD	China	KOICA	India
2.Province	Kandal	Kampong Chhnang	Kampong Thom	Kampong Thom	Kampong Chhnang	Kampong Cham	Kampong Speu
3.Completion Year	2007	2020	2016	2008	2019	1. 2008 (Flood control) 2. 2010 (Irrigation system)	2016
4. Command Area (ha)	1,950	3,289	764	2,960	10,300	8,000	Potential 10,000 (Dry season) 25,000 (Rainy season)
5.Irrigation Scale	Medium	Medium	Medium	Large	Large	Large	Large
6.Water Sources	Prek Thnaot River	Boribo River	Stung Sen River	Boribo River	Boribo River	Tonle Sap River	Stung Tasal River
7.Design Documents (Availability)							
- Design Report	A	A	A	A	- (F/S, partial)	-	-
- Design Standard Documents	A	A	A (Draft)	A (Draft)	-	-	A
- Design Drawing	A	A	A	A	-	-	-
8.Field Survey	Implemented	Implemented	Implemented	Implemented	Implemented	Implemented	Implemented

Source: NaSDeP

Table 3-9 Project Outline and Design Document Availability of Selected Sites (National Projects Funded by MOWRAM)

Items \ Site	Bat Trang Headworks	Preck Chick Main Canal	Aang Teuk Chher Taok Headworks	Ang Teuk Ronesh Dam	Aang Teuk Koun Satv Dam	Aang Teuk Pack Sla Dam
1.Fund	MOWRAM	MOWRAM	MOWRAM	MOWRAM	MOWRAM	MOWRAM
2.Province	Kampong Thom		Pursat	Kep	Kampot	Kampot
3.Completion Year	2019	2020	2021	2019	2020	2021
4.Command Area (ha)	499 (Rainy season) 772 (Dry season) 10 (Other crops)		2,018 (Rainy season) 182 (Dry season) 20 (Other crops)	820 (Rainy season) 320 (Dry season) 20 (Other crops)	2,000 (Rainy season) 680 (Dry season) 320 (Other crops)	758 (Rainy season) 195 (Dry season) 410 (Other crops)
5.Irrigation Scale	Medium		Medium	Medium	Medium	Medium
6.Water sources	Stoung River		Streams of Cardamom Mountain range (Tributary of Pursat River)	Vor Mountain	Vor mountain, Bos Nhinh Mountain, Knol mountain, Ou Thom mountain	Vor mountain, Ta Cham stream, Chruos Speu stream, Jorng Kor stream
7.Design Documents (Availability)						
- Design report	-	-	-	-	-	-
- Design standard documents	-	-	-	-	-	-
- Design drawing	A	A	A	A	A	A
8.Field Survey	Implemented	Implemented	Implemented	N.A	N.A	N.A

Source: NaSDeP

For JICA funded projects and some ADB funded projects implemented recently, the design documents have been provided from PMU so that the design procedure was clearly tracked and reviewed. However, for projects funded by other development partners, only limited information was collected mostly through websites, such as preliminary (pre-) feasibility study reports, post evaluation reports, typical drawings, and site photos. Therefore, "design overview reports" of these sites had been prepared based on the available limited information, and confirmation of the type, the number and locations of canals/related structures as well as structural dimension, appearance and condition, etc., were made at the relevant sites when conducting the field surveys. On the other hand, for the national projects, design drawings were available and provided from the Engineering Department of MOWRAM with brief project outline reports, and verbal information on the design condition, e.g., design was carried out by following JICA procedure/method for canal works and related structures (TSC-1 - TSC-3[4], Japanese standard), while Russian procedure/method for headworks, respectively.

3.3.2 Findings from the collection and analysis of information on existing projects

(1) Observation points in the Field Survey for Comparison and Analysis

In the field survey of the existing projects, both problems/issues and good practices were carefully identified through field observation at respective sites as well as in an interview survey with the relevant PDWRAM officers and FWUC board members who were in charge of operation and maintenance (hereinafter referred to as "O&M"). Further analysis was made based on the following points and procedures (overall, classification of identified issues/good practices of "design", "construction", "O&M" stages) as shown in Table 3-10, then consideration items and points to be reflected to the NSDD have been extracted, especially from "design stage" for improvement in design

[4] Technical Service Center for Irrigation System Project

condition as necessary.

Table 3-10 Point of Field Observation, Cause Analysis of Problem, Consideration for NSDD

Point of Field observation	Cause of Problem Identified			Consideration for NSDD
	Design Stage	Construction Stage	O&M Stage	
<Headworks> • Overall condition & function (civil structure) • Gate Operation condition & Function • Riverbed & riverbank condition in D/S • Structure type Selection/ location • Other findings	Whether design conducted with adequate calculation method and specifications	Whether construction implemented with adequate method and specifications in accordance with Design (dimension, specification)	Whether operation is done with adequate manner and maintenance is done properly	If the main cause of identified problem is under "Design Stage", what needs to be considered for improvement (e.g., calculation method (hydraulics condition, length, stability), specifications)
<Canal works> • Overall condition & function (civil structure) • Gate Operation condition & Function • Canal bed & side slope condition in D/S • Structure type Selection/ location • Other findings				

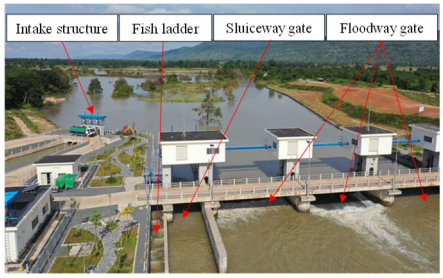
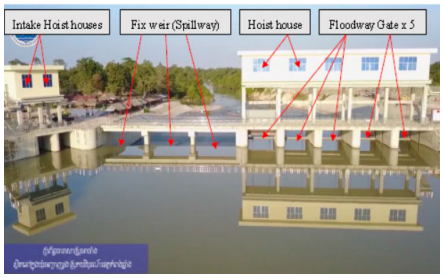
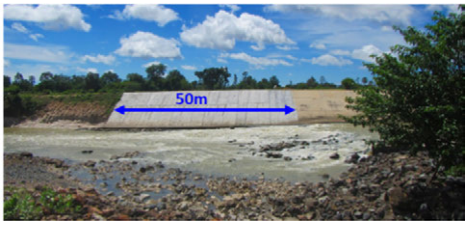
Source: NaSDeP

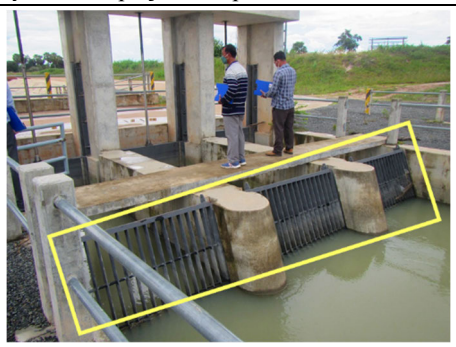
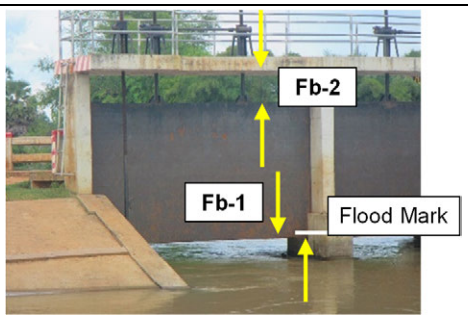
3.3.3 Findings through Field Survey (Headworks)

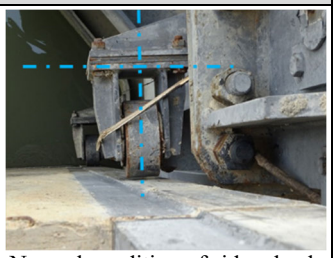
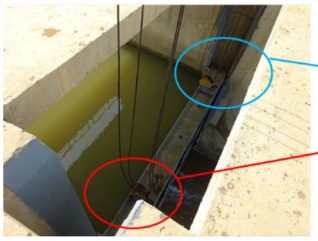
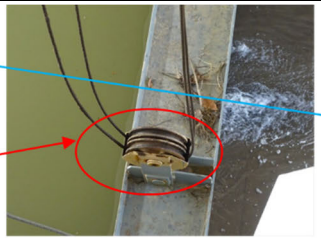
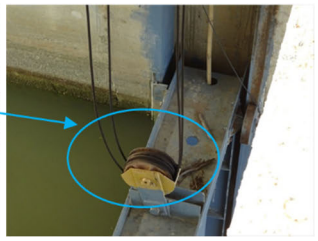
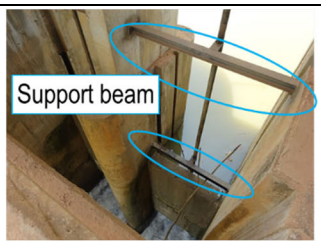
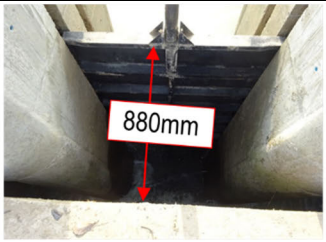
(1) Findings through Field Survey

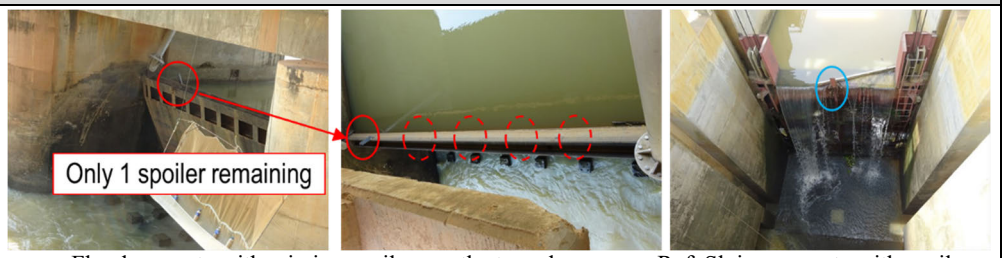
Based on the observation points, problem identification and cause analysis, important points of design stage have been extracted and summarized as shown in Table 3-11:

Table 3-11 Good Practice and Problem to be reflected in NSDD (Headworks)

Important points for feedback	Analysis and Consideration for Design Stage/ Reference Site Photo for comparison	
Composition of gate structures and fish ladder (fish way/pass) at diversion weir of headworks	 With Fish Ladder and Sluiceway Gate (Good)	 No Fish Ladder nor Sluiceway Gate (Issues)
	- Sluiceway gate shall be designed and installed near the intake structure to flush out the sediment and to prevent sediment from entering to the irrigation system as much as possible. Monitoring of sediment deposition shall be also conducted regularly. - Fish ladder shall be designed and installed to secure the ecologies in the river. The criteria for necessity of fish ladder installation shall also be clarified.	
Riverbed and Riverbank protection works against river flow / geological condition	 Erosion at DS riverbed of headworks (Issues)	 Erosion at DS riverbank of headworks (Issues)
	- Erosion and local scouring were observed under the stilling basin and the connecting riverbed. - Severe erosion along the riverbank side slope and damages to the riverbank protection works were	

<table>
<tr><th>Important points for feedback</th><th>Analysis and Consideration for Design Stage/ Reference Site Photo for comparison</th></tr>
<tr><td></td><td>observed.
- The length of protection works for the stilling basin and riverbank was not sufficient against river flow/geological conditions at the time of project completion.
- Extension of the length of protection works was conducted by MOWRAM/PDWRAM only a few years after project completion.</td></tr>
<tr><td rowspan="2">Composition of Intake Structure for prevention debris, etc., from entrance</td><td> 
Trash Rack installed in front of Intake Gates (Good)
 
No Trash Rack installed at Intake Gates (Issue)</td></tr>
<tr><td>- To prevent/reduce trash & debris from entering the irrigation canal system as much as possible,
i) a trash rack shall be designed and installed in front of the gate for the intake structure.
ii) Intake sill elevation shall be designed higher than the riverbed elevation.</td></tr>
<tr><td rowspan="2">Protection of electrical equipment/ devices from lightning especially for the modernization of management facilities</td><td> 
Lightning Rod installed over Hoist House (Good)
 
No Lightning Rod installed over Hoist House (Issue)</td></tr>
<tr><td>- Lightning rods shall be designed and installed at/ near by the hoist house and control house to protect electrical system (especially for the case of introduction of permanent electrical driven gate system under the modernization of management facilities).</td></tr>
<tr><td rowspan="2">Adequate freeboard for safe discharge operation of flood flow (not disturbing flood flow by gate leaves and protection of gate leaves and piers from excess static pressure load)</td><td> 
Adequate freeboard below & above gates (Good)
 
Inadequate freeboard below & above gates (Issue)</td></tr>
<tr><td>- Design and setting of freeboard below (Fb-1) and above (Fb-2) gate leaves shall be adequate, so that design flood discharge as well as exceedance flood discharge could be safely flown down the headworks without damaging gates/applying excess static water pressure loads to piers:
(If DFWL touches the gate leaves, extra static pressure load will apply to piers and in danger against stability)
i) Fb-1: Below Gate leaves = between design flood water level and bottom elevation of gate leaves to be adequate based on the design flood discharge (refer to Table 3-11 in next sub-section).
ii) Fb-2: Above Gate leaves = between top elevation of gate leaves and bottom elevation of operation deck.
- Design flood water level as well as irrigation water level fully consider freeboard at bridge in the upstream of headworks, e.g., National Road bridges</td></tr>
</table>

Important points for feedback	Analysis and Consideration for Design Stage/ Reference Site Photo for comparison
Findings from inspection of hydromechanical works (gate and other equipment) and issues to be improved/ repaired	 Floodway Gate (Wheel type)  Deformation of side wheel  Normal condition of side wheel - Side wheel on the left bank side of wheel gate is deformed. Due to the uneven alignment of the gate leaf, the lateral load received from the gate leaf cannot be transmitted to the weir pier evenly, there is a risk that it will be damaged and affect the opening and closing operation in the future. - Repair work and realignment of gate is required and recommended.
Slacking of wire rope of floodway gate	 Floodway gate: Slacking of wire rope  Sheave (right side)  Sheave (left side) - The wires are slacking, and there is a concern that the wire will come off from the sheaves in the future, and the gate operation may become impossible. - It is necessary to restore the tension of the wire as soon as possible. Also, as a countermeasure, it is desirable to install a detection sensor for slacking.
Deformation of spindle due to large stroke heigh, lack of spindle support beam, inadequate spindle diameter size	 Intake gate (large stroke height)  Spindle shaft is deformed  Ref: Spindle with support beam (Good Practice) - The spindle shaft is deformed. In the future, repeated opening and closing operations may cause the deformation to be worsen, and risk prevention of opening and closing. - It is necessary to repair/replace it so it may be straightened. Also, in order to prevent deformation of the shaft, it is desirable to add a support beam (ref. Sluiceway gate with support beam). - The size of spindle diameter needs examination against maximum total acting load to spindle shaft
Lack of safety handrail at large spaced between gate and road edge	 Floodway gate without handrail  Large space betw/gate & road  Ref: Installation of safety handrail - There is no safety handrail between the floodway gates and the edge of the road, very dangerous (residents may fall). - It is urgently important to install a safety handrail to protect operators/community/children/traffic from falling into the river.

Important points for feedback	Analysis and Consideration for Design Stage/ Reference Site Photo for comparison
Missing of spoilers on the top edge of gate for stabilizing overflood flow	 Floodway gate with missing spoilers on the top edge　　Ref. Sluiceway gate with spoiler - The spoiler installed at the top of the Floodway gate is missing, which may be due to rusting and being flushed away. Without spoilers, abnormal vibrations will occur with regular overflow of water and lead to malfunctions of the gate leaf, accessory, equipment and switchgear. - It is desirable to re-install the spoilers, to reduce the abnormal vibrations occurring during overflow to avoid further issues of the gate leaf and accessories

Source: NaSDeP

(2) Comparison of Important Design Parameters

Based on the review on the design documents and the field observation, a comparison of important design parameters for the headworks design have been summarized, such as a) return period of design flood discharge, b) design flood discharge, c) corresponding freeboard, etc., as shown in Table 3-12, Table 3-13 and Table 3-14, respectively:

As shown below, differences in the design parameters were found among the selected projects, due to unclear in criteria for determination.

1) Comparison of Return Period (Average Recurrence Interval (ARI)) and Design Flood Discharge

Return period (or Average Recurrence Interval (ARI)) for determination of design flood discharge was found to be different among projects, therefore a reasonable criteria of ARI application is necessary. It is noted that ARI are to be specified based on the existing important infrastructure(s), such as road bridges and railroad bridges upstream and/or downstream of a new headworks.

Table 3-12　Comparison of Return Period of Design Flood Discharge

Site Name / Items	Kandal Stung	Lum Hach	O mean	Stung Chinit	Achang
Fund	JICA	JICA	ADB	ADB-AFD	China
Design Flood Discharge:	240 m^3/s (Movable Weir)	430 m^3/s	216 m^3/s	1,985 m^3/s	322 m^3/s
Return Period: T	100 years	100 years	100 years	50 years	20 years
Remarks	National Road (NR) No.3/ Bridge in the immediate downstream (DS) of the Headworks	NR No.5/ Bridge in the DS of the Headworks	Provincial Road/ Bridge in the DS of the Headworks	-	NR No.5/ Bridge in the DS of the Headworks

Source: NaSDeP

- Return Period (Japan) i) For dams, a return period of T = 100 years or more is generally applied. ii) For headworks, the design condition and protection of assets (e.g., bridge, railroad, cities) especially located in the U/S of headworks are highly considered. - Return period (Design document review/Field survey) However, the criteria for setting of return period for headworks has not been clearly set. Therefore, a reasonable criteria of ARI application is necessary	 Kandal Stung Headworks (Flood in Oct. 2020) Source: https://www.facebook.com/mowramcambodia/posts/1455509947974240 An exceedance flood (estimated to be T = 200 ~ 300 years) occurred in October 2020, but the headworks was not over-topped/damaged.

Source: NaSDeP

2) Comparison of Design Flood Discharge and Freeboard

Freeboard based on the design flood discharge range was found to be different among projects, therefore reasonable criteria for setting freeboard is necessary. As explained in the above sub-section, Kandal Stung Headworks, which applied the freeboard criteria of Japan, has proved the effectiveness of the freeboard (within a freeboard of 1.0 m for T = 100 years design flood discharge, could successfully flown down the estimated flood of T = 200~300 years), it is thought to adopt the freeboard criteria of Japan to NSDD.

Table 3-13 Comparison of Design Flood Discharge and Freeboard

Items \ Site Name	Kandal Stung	Lum Hach	O mean	Stung Chinit	Achang
Fund	JICA	JICA	ADB	ADB-AFD	China
Design Flood Discharge:	830 m^3/s (Prek Thnot River)	430 m^3/s	216 m^3/s	1,985 m^3/s	322 m^3/s
Freeboard:	1.00 m	0.60 m	0.55 m	0.50 – 0.60 m	1.75 m

Source: NaSDeP

Freeboard (Japan)

- Freeboard is determined based on the volume range of design flood discharge, based on the national ordinance acknowledged by the Ministry of Land, Infrastructure, Transport and Tourism (MLITT).

No.	Design flood discharge (Q): (Unit: m^3/s)	Value to be added to design flood water level (Unit: m)
1	$Q < 200$	0.6
2	$200 \leqq Q < 500$	0.8
3	$500 \leqq Q < 2{,}000$	1.0
4	$2{,}000 \leqq Q < 5{,}000$	1.2
5	$5{,}000 \leqq Q < 10{,}000$	1.5
6	$10{,}000 \leqq Q$	2.0

Source: Structural Ordinance, acknowledged by the Ministry of Land, Infrastructure, Transport and Tourism (MLITT) of Japan

3) Comparison of Riverbed and Riverbank Protection Works

To secure the structural stability of the main part of a headworks and floodway, the length of both riverbed protection works as well as riverbank protection works, especially in the downstream of the headworks, are highly important. However, the criteria of these lengths are not clearly set and are different among projects. Therefore, reasonable criteria for setting the length of these protection works is necessary, based on the maximum head difference between upstream and downstream of a headworks as well as consideration of flood flow condition. In general, the formula below is applied for design of the apron at downstream, which is determined after considering the creep length. In addition, it is necessary to consider some specific conditions, such described as sample conditions in the "Remarks" of Table 3-14.

Table 3-14 Riverbed and Riverbank Protection Works (incl. Apron and Side Slope Protection)

Items \ Site Name	Kandal Stung	Lum Hach	O mean	Stung Chinit	Achang
Fund	**JICA**	**JICA**	**ADB**	**ADB-AFD**	**China**
Design Flood Discharge:	240 m^3/s (Movable Weir)	430 m^3/s	216 m^3/s	1,985 m^3/s	322 m^3/s
Riverbed/ Riverbank	No critical issues	Bed: No critical/ Bank: erosion	Riverbank: erosion	Piping seemed occurred	Riverbed/bank: erosion
Remarks	-	Riverbank consists of dispersive soil Shape of river is curving to left	Length and formation of Riverbank may not be adequate	Side-spillway along the river is very long (750m) Head difference (D1) of DFWL and riverbed outlet is rather big	Riverbank consists of dispersive soil

Source: NaSDeP

➢ Design of Apron (Japan)

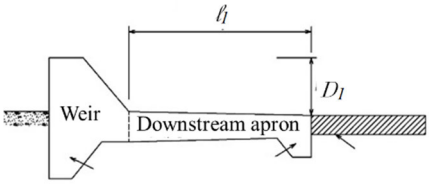
$$l_1 = 0.6C\sqrt{D_1}$$

Where

l_1 : length of downstream apron (m)

D_1: height from top surface of downstream end of apron to weir crest (m)

C : Bligh's C



➢ Consideration of creep length (Bligh's theory): to ensure the necessary creep length to prevent piping

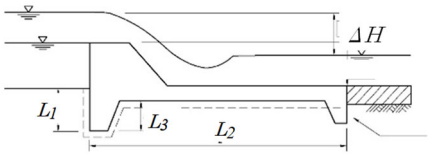
$$S \geq C \cdot \Delta H,\ S = L_1 + L_2 + L_3$$

Where

S : Creep length (m)

C : Coefficient of creep

ΔH : Maximum head between upstream and downstream



Spillway in Stung Chinit Project

In Stung Chinit Project site, a long spillway (L=750 m) has been having a severe leakage (piping) along the sub-layer of spillway structure; the cause of this is considered to be under estimation of C and D_1.

Source: NaSDeP

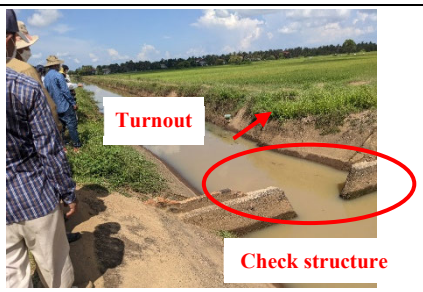
3.3.4 Findings through Field Survey (Canal Works)

(1) Findings through Field Survey (Canal Works)

Based on the observation points, problem identification and cause analysis, important points of the design stage have been extracted and summarized as shown in Table 3-15.

Table 3-15 Problems to be Reflected on in NSDD (Canal)

<table>
<tr><th>Important Points for Feedback</th><th colspan="2">Analysis and Consideration for Design Stage/Reference Site Photo for Comparison</th></tr>
<tr><td rowspan="2">Necessity of measures for dispersive soil</td><td> 
Collapse of canal side slope after the project</td><td> 
Canal side slope at field survey</td></tr>
<tr><td colspan="2">- The concrete block lining has collapsed because of the dispersive soil.
- The appropriate measures for dispersive soil shall be considered. (The concrete block lining was adopted so that only the broken parts could be repaired.)</td></tr>
<tr><td rowspan="2">Installation of ancillary structures</td><td colspan="2">  
The steps were installed in the Main canal.</td></tr>
<tr><td colspan="2">- Steps were installed along the canal so that people can access the canal water
- The structures affected by construction or rehabilitation of the canal such as washing areas and bridges shall be considered when designing the canal.</td></tr>
<tr><td rowspan="2">Consideration of allowance for hoisting gates and freeboard for check structures</td><td> 
Freeboard and allowance for hoisting gate</td><td> 
No Freeboard and allowance for hoisting gate (Water mark is under the bottom of the gates)</td></tr>
<tr><td colspan="2">- Check structures should be designed in consideration of the freeboard and allowance for the hoisting gate to protect the structure and gates.</td></tr>
</table>

Important Points for Feedback	Analysis and Consideration for Design Stage/Reference Site Photo for Comparison
Setting of proper design water level	 Water level is higher than top of gates
	- It is assumed that the load larger than expected is applied to the gates. The design water level shall be set before design the structures.
Installation of appropriate joint	 Leakage between structures
	- The joint (water stop) shall be installed to keep water-tightness of structures.
Installation of appropriate check structure	 Check structure along secondary canal
	- It is difficult for farmers to control water level. - Gate or stop-log should be installed in check structures to control water level easier.
Measure for concrete cracks	  Cracks at the top slab of turnout  Gauge of turnout
	- The strength of the slab is not enough for opening/closing loads of the gate. Or the slab was overloaded when closing the gate tightly. - Thickness of members shall be decided considering loads. The gauge is installed to indicate the closing limit.

Important Points for Feedback	Analysis and Consideration for Design Stage/Reference Site Photo for Comparison
Adequate compaction around structure	  Hole behind of turnout (Leakage)
	- Compaction shall be implemented carefully around structures and in narrow area considering equipment.

Source: NaSDeP

(2) Comparison of Important Design Parameters (Canal Works)

Based on the review on the design documents and the field observation, a comparison of important design parameters for the Canal Works design have been summarized in Table 3-16, Table 3-17, and Table 3-18, respectively.

1) Allowable velocity

The velocity of the canal shall be determined so that suspended sediment is not accumulated and water weeds affecting the flow capacity of the canal don't grow from the viewpoint of canal maintenance. In general, it is desirable to set velocities that don't cause sediment deposition at a mean velocity of 0.45 - 0.9 m/sec and to prevent water weed growth at a mean velocity of 0.45 - 0.9 m/sec. However, the design velocities of each project are shown in Table 3-16 since the projects which the team could obtain the design documents for, were to rehabilitate irrigation systems with gentle slopes constructed during the Pol-Pot regime. In this case, the measure for preventing inflow of the sediment and regular maintenance such as dredging are required.

Table 3-16 Design Velocity

Site Name / Items	Kandal Stung	Lum Hach	O mean	Stung Chinit
Fund	JICA	JICA	ADB	ADB-AFD
Velocity	0.2m/s (Main canal)	0.4～1.0m/s (Main canal) *Allowable velocity (Design documents) Earthen canal : 0.3～0.9m/s Lining canal: 0.5～1.5m/s	0.2m/s (Main canal)	- *Allowable velocity (Design manual) Earthen canal : 0.5～0.9m/s

2) Canal side slope

The canal side slopes are determined based on the design discharge or soil type in below projects. It is necessary to set proper canal side slope based on soil properties (fill material for bank) and canal height which are factors for the stability of soil.

Table 3-17 Canal Side Slope

Items \ Site Name	Kandal Stung	Lum Hach	O mean	Stung Chinit
Fund	JICA	JICA	ADB	ADB-AFD
Side slope (1:m)	1:1.5 (Main canal)	1:1.5 (Main canal) *Side slope is determined based on design discharge and soil type (Desitin documents) 1:10～1 :2.0	1: 1:1.5 (Main canal)	- *Side slope is determined based on design discharge (Design manual) Q < 5 m^3/s: 1:1.0 Q≧5 m^3/s: 1:1.5

3) Freeboard

The freeboard which set for ensuring the canal safety, is determined based on the design discharge and lining types in the projects. In particular, the value of the freeboard in the Stung Chinit project is smaller than those in other projects.

Table 3-18 Freeboard

Items \ Site Name	Kandal Stung	Lum Hach	O mean	Stung Chinit
Fund	JICA	JICA	ADB	ADB-AFD
Design discharge	2.73m^3/s	2.73m^3/s	0.665m^3/s (MC1) 1.218m^3/s (MC2)	8.54m^3/s (North MC) 9.41m^3/s (South MC)
Freeboard	0.5m (Main canal)	0.45～0.75m (Main canal) *Freeboard is determined based on design discharge and lining type (Desitin documents	0.5m (Main canal)	- *Freeboard is determined based on design discharge (Design manual) Q < 1.5 m^3/s: 0.15m Q < 10 m^3/s: 0.25m

3.4 Determination of policy for formulating standard design documents based on information on existing projects and field survey findings

3.4.1 Basic policy for formulating standard design documents

(1) Definition of National Standard Design Documents (NSDD)

The National Standard Design Documents (NSDD) will be defined as follows:

NSDD shall consist of three documents: design criteria, design manual, and standard design drawings.

1) Design criteria shall contain common items to be followed in the design and/or construction works of the structures.

   All design and construction works related to irrigation and drainage structures in Cambodia (both projects funded by the Cambodian government and projects supported by development partners) shall comply with the design criteria issued by MOWRAM.

2) Design manual will contain detailed and concrete procedures and sample calculations on every important stage in the design works. The probability calculation, hydraulic calculation and structural calculation will be explained by use of MS Excel. And

3) Standard design drawings will be prepared in the following manner:

- made as reference for common designers who design open canals and related structures in accordance with the actual site condition,
- used within given flow range for general purpose,
- combinedly used with design manual above mentioned by designers.

[Supplement]

Output 1 which is described in the Record of Discussion (R/D) of the Project agreed among MOWRAM and JICA, had been revised as follow and, the revised output 1 was agreed in the JCC.

<Before> Output 1. National standard design documentations (design criteria, design drawings, technical specifications, and design manuals) for irrigation and drainage structures are developed.

<After> Output 1. National standard design documents (design criteria, design manual and standard design drawings) for irrigation and drainage structures are developed.

(2) Basic Concept for Formulation of NSDD

Basic Concept for Formulation of NSDD has been considered as follows:

1) NaSDeP will develop NSDD for two facilities, i.e., “headworks”, and “Canal Works” including open canals and related structures.
   However, for headworks, only design criteria and design manual will be formulated, and standard design drawings will not be prepared.
2) NSDD for headworks and open canals shall be formulated by reference to the Japanese design standard.
3) NaSDeP will formulate draft design criteria by April 2023, and draft design manual and draft standard design drawings by around August 2024.
4) Standard design drawings for canal works will be prepared for those selected by 1st Joint Coordinating Committee (JCC) from the maximum of 16 structures.
5) NSDD shall be issued by MOWRAM after being examined by the Examination Committee and approved by the minister of MOWRAM.
6) The publishment of NSDD shall be notified by Prakas (ministerial ordinance).
7) NSDD shall be presented in Khmer language. The official version for NSDD shall be in Khmer, not in English. An English version must be equivalent to the Khmer version in terms of technical contents and structures.
8) Formation and typography of NSDD will be determined with reference to that of Vietnam's National Technical Standards as well as Japan’s.

[Supplement]

Regarding 1), 2) & 3),
- Design drawings for headworks can be referred to explanation figures in the design manual.
- Formulation of draft design criteria is included in the Work Plan Phase-1, and formulation of draft design manual / standard design drawings are included in the Work Plan Phase-2.

Regarding 4),
- It was agreed that the design drawings for a total of 14 canal and related structures as follow would be prepared: open channel type canal (1) earthen canal and 2) concrete limning canal) and related structures (3) road crossings (box culvert type), 4) road crossings (siphon type), 5) siphons, 6) vertical drops, 7) check structures, 8) check structures with drops, 9) turnouts, 10) division box, 11) wasteway, 12) side spillway, 13) cross drainage (culvert type), and 14) cross drainage (siphon type)).

Regarding 5) & 6),
- Examination Committee is shown in 5. (Basic policy for establishment of examination system for NSDD) below.
- The Prakas for publishing NSDD refers to the case of MPWT / MRD design standard.

Regarding 7) & 8),

- In NaSDeP, an English version of NSDD will be formulated first and then translated into Khmer.
  Both the Khmer and English version of NSDD will be examined by the Examination Committee.

(3) Structure of Design Criteria

Based on the comparison of structure of SDD of Japan, Thailand, Vietnam as well as other line ministry in Cambodia, the structure of design criteria has been determined and proposed in Table 3-19:

Table 3-19 Structure of Design Criteria

Component	Description
Criteria	Universal and normative matters to be strictly followed regarding design
Operation of Criteria	Detailed matters to be observed in operation of design criteria
Explanation of Criteria	Detailed explanation on application of operation of design criteria

Source: NaSDeP

3.4.2 Standard Design Document Development Policy (Headworks)

Through the field survey observation, identification of issues as well as analysis on causes of issues and consideration on points to be reflected to the NSDD, the following items in Table 3-20 will be considered as typical and specific conditions in Cambodia, thus, to be adjusted or modified from the SDD of Japan.

Table 3-20 Points to be Considered for Formulation of NSDD (Headworks)

Items	Contents
Apply Cambodian laws, regulations, and plans	River related laws, Environment protection related law, Pollution prevention related laws, Disaster prevention related laws (including regulation of bridges under transport sectors), etc.
Determination procedure of design flood discharge and flood water level	Basic policy for flood control/ river improvement plan (Flood discharge, ARI, Freeboard, Calculation method) considering the area (road/urban area), etc.
Protection of riverbed / riverbank	Impact of backwater, Calculation method, geological characteristic of riverbed/riverbank, etc.
Modernization of control & management facilities	Reduction of O&M costs, Disaster prevention, Environment protection, Specification of electrical equipment & facility, etc.
Consideration of climate change adaptation	Guideline for climate change adaptation of MOWRAM, MRC

Source: NaSDeP

3.4.3 Standard Design Document Development Policy (Canal Works)

Through the field survey observation, identification of issues as well as analysis on causes of issues and consideration on points to be reflected to the NSDD, the following items in Table 3-21 will be considered as typical and specific conditions in Cambodia, thus, to be adjusted or modified from the SDD of Japan.

Table 3-21 Points to be Considered for Formulation of NSDD (Canal Works)

Items	Contents
Apply Cambodian laws, regulations, and plans	Environment protection related law, Pollution prevention related laws, Disaster prevention related laws, etc.
Consideration of dispersive and expansive soils	Necessary survey and test items, countermeasures, etc.

Items	Contents
Method of irrigation water requirement, irrigation and drainage discharge	Irrigation efficiency, calculation methods of Irrigation water requirement, irrigation, drainage discharge. etc.
Rehabilitation of Pol-pot canal	Hydraulic calculation of Pol-pot canal, rehabilitation methods of Pol-pot canal etc.
Lining adoption	Criteria for adopting lining canals
Consideration of climate change adaptation	Water requirement calculation, Drainage discharge calculation, consideration of the inflow of rainwater from areas around irrigation system

Source: NaSDeP

3.5 Development of design standard documents in accordance with the formulation concept

3.5.1 Development of design criteria (Headworks)

(1) Draft Table of Contents (Headworks, outline)

Based on the above concept as well as "Points to be considered for formulation of NSDD (Headworks)", the Draft Table of Contents (Outline) of design criteria for Headworks has been formulated as shown in Table 3-22.

Table 3-22 Draft Table of Contents (Headworks) and Points to be Considered under the Relevant Chapter

Draft Table of Contents (Outline)	Points to Consider
Chapter 1 Justification of the Criteria	
Chapter 2 Definition of Headworks	
Chapter 3 Basic Principles of Design	
Chapter 4 Compliance with relevant Laws and Regulations	Apply Cambodian laws, regulations, and plans
Chapter 5 Design Procedure	
Chapter 6 Investigation	
Chapter 7 Basic Design	・ Determination procedure of design flood discharge and design flood water level, return period (Average Recurrence Interval (ARI)), considering the given condition of infrastructure as well as the relevant regulation/ design standards, especially in the upstream of headworks for protection of infrastructure ・ Consideration of climate change adaptation
Chapter 8 Detailed Design	
Chapter 9 Intake Structure	
Chapter 10 Diversion Weir	Protection works of riverbed/riverbank
Chapter 11 Related Structures	
Chapter 12 Management Facilities	Modernization of control & management facilities

Source: NaSDeP

(2) Draft Table of Contents (Headworks, detailed)

Based on the above concept as well as "Points to be considered for formulation of NSDD (Headworks)", the Draft Table of Contents (detailed) of design criteria for Headworks has been formulated as shown in Table 3-23.

Table 3-23 Draft Table of Contents (Headworks) and Points to Consider under the Relevant Chapter

Draft Table of Contents (Detailed)		Points to Consider
Chapter 1	Justification of the Criteria	
Chapter 2	Definition of Headworks	
Chapter 3	Basic Principles of Design	
Chapter 4	Compliance with relevant Laws and Regulations	
4.1	Compliance with relevant Laws and Regulations	・ Introducing List of Cambodian laws, regulations related to design and construction of headworks
4.2	Conformity with related Plans	・ Applying Cambodian plans related to design and construction of headworks
Chapter 5	Design Procedure	
Chapter 6	Investigation	
6.1	Survey Items	
6.2	Survey of River Conditions	
6.3	Survey on Flood Control and Water Utilization	
6.4	Meteorological Survey	
6.5	Topographic Survey	
6.6	Geological Survey	
6.7	Environmental Survey	
6.8	Survey on Construction Conditions	
6.9	Survey on Facility Control and Management	
Chapter 7	Basic Design	
7.1	Basic Design Items	
7.2	Design Intake Discharge	
7.3	Design Intake Water Level	
7.4	Design Flood Discharge	・ Determination procedure of design flood discharge and design flood water level, return period (Average Recurrence Interval (ARI)), considering the given condition of infrastructure as well as the relevant regulation/design standards, especially in the upstream of headworks for protection of infrastructure. ・ Consideration of climate change adaptation
7.5	Design Flood Water Level	
7.6	Position of Headworks	
7.7	Intake Method of Headworks	
7.8	Type and Arrangement of Component Facilities of Headworks	
7.9	Crest Elevation of Diversion Weir	
7.10	Sill Elevation, etc. of Diversion Weir	
7.11	Clear Span Length of Movable Portion of Diversion Weir	

Draft Table of Contents (Detailed)	Points to Consider
Chapter 8 Detailed Design	
Chapter 9 Intake Structure	
9.1 Structural Requirement of Intake Structure	
9.2 Design of Intake Structure	
Chapter 10 Diversion Weir	
10.1 Formation Type of Diversion Weir	
10.2 Foundation Type of Diversion Weir	
10.3 Basic Dimension of Fixed Weir	
10.4 Loads Acting of Fixed Weir	
10.5 Stability Analysis of Fixed Weir	
10.6 Modification of the Basic Dimension of the Fixed Weir	
10.7 Apron of Fixed Weir	
10.8 Components and Functions of Movable Weir	
10.9 Design of Floodway	
10.10 Design of Sluiceway	
10.11 Configuration of Movable Weir	
10.12 Structural Requirement of Piers of Movable Weir	
10.13 Top Elevation of Piers of Movable Weir	
10.14 Thickness of Piers of Movable Weir	
10.15 Length of Piers of Movable Weir	
10.16 Cross-sectional Shape of Piers of Movable Weir	
10.17 Load Acting on Piers of Movable Weir	
10.18 Stability Calculation of Piers of Movable Weir	
10.19 Design of Gate	
10.20 Base Slab and Apron of Movable Weir	
10.21 Structural Requirement of Cut-off wall and Dwarf Wall	
10.22 Design of Cut-off Wall	
10.23 Design of Dwarf Wall	
10.24 Structural Requirement of Riverbed Protection Works	・ Protection works of riverbed/ riverbanks with consideration on hydraulic condition with gate operation of movable weir and specific soil condition such as dispersive/ expansive soil
10.25 Design of Riverbed Protection Works	
Chapter 11 Related Structures	
11.1 Type of Related Structures	
11.2 Structural Requirement of Foundation Works	
11.3 Design of Foundation Works	
11.4 Design of Fishway	
11.5 Settling Basin	
11.6 Riverbank Protection Works and Floodway / Flood Fringe Protection Works	・ Protection of riverbank/floodway with consideration on specific soil condition such as dispersive/ expansive soil

Draft Table of Contents (Detailed)	Points to Consider
Chapter 12 Management Facilities	・ Modernization of control & management facilities, such as management system, management level, characteristic of hydromechanical, electric & electronic devices and equipment
12.1 Control and Management Facilities	
12.2 Operation and maintenance Bridge	
12.3 Other Management Facilities	

Source: NaSDeP

(3) Improvement of Design Criteria based on "Points to Consider"

Based on the above mentioned "Points to be considered for formulation of NSDD (Headworks)", as shown in Table 3-20, the Draft Design criteria for headworks has been prepared as shown below.

1) Introduction of List of Cambodian laws, regulations related to headworks (Operation 4.1)

Cambodian laws, regulations related to design and construction of headworks have been listed and summarized based on the categories such as "river", "environment", "pollution", "disaster prevention", "hazard prevention", "labor", and "others".

2) Design Flood Discharge (Operation 7.4)

Based on the actual condition in Cambodia that a flood control/ river improvement plan is not formulated in most of the rivers, the specified design flood discharge in the Plan is also lacking. While, if any flood control/ river improvement plan is formulated in prior to implementation of design/ construction of a headworks along any target river, it is necessary to incorporate (enable to adopt the flood discharge specified in the flood control/ river improvement plan as the "design flood discharge"). Therefore, a flowchart for determination of design flood discharge has been introduced in the Explanation of Criteria and Operation as shown below.

It is noted that:

- if any flood control/ river improvement plan is formulated in prior to the implementation of design/ construction of a headworks along any target river, the flood discharge specified in the Plan shall be adopted as the "design flood discharge". Consideration shall be also given to any existing important infrastructure.
- if any important asset such as national/provincial road bridge, railroad, etc., is located upstream of the headworks location, the specified average recurrence interval (ARI, or return period) of the design flood discharge would be referred to and in compliance with the standards of the relevant ministries/agencies.
- To overcome the condition of the lack of flood control/ river improvement plan nor the specified flood discharge, flood frequency analysis is introduced based on the reliable river regime data of 30 – 50 years or more.
- If such reliable river regime data is not available, estimation would be conducted based on one or combinations of i) – iii).
  i) flood frequency analysis with a limited river regime data,
  ii) direct estimation using river flow section and the flood marks along the river,
  iii) run-off analysis.

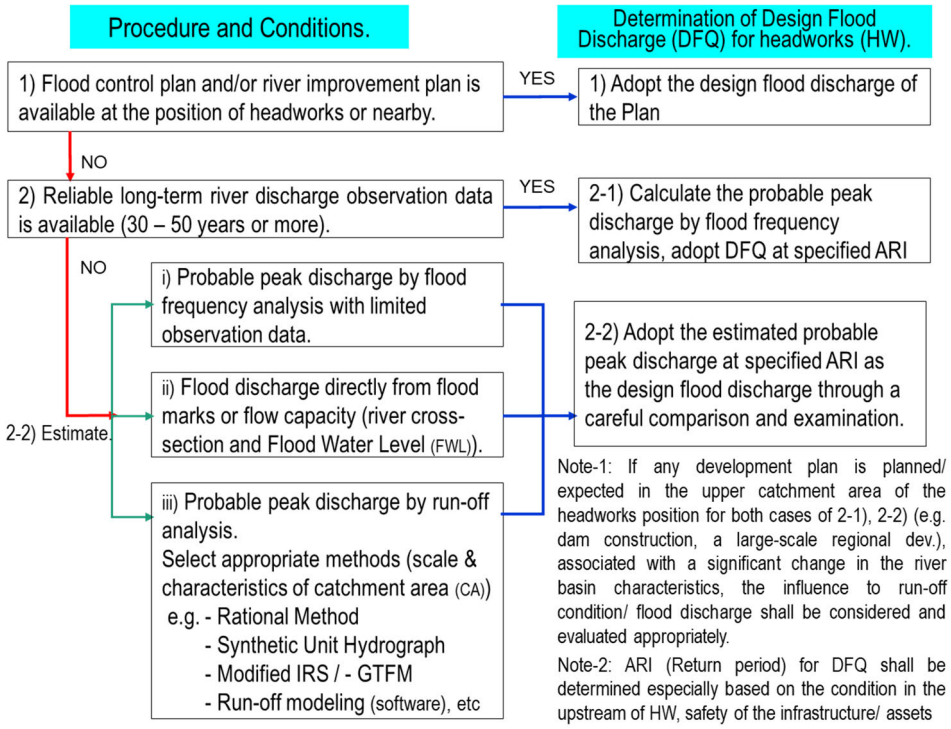


Figure 3-3 Flowchart for Determination of Design Flood Discharge

3) Design Flood Water Level (Operation 7.5)

Based on the actual condition in Cambodia that a flood control/ river improvement plan is not formulated in most of the rivers, the specified design flood water level is also lacking. While, if any flood control/ river improvement plan is formulated in prior to implementation of design/ construction of a headworks along any target river, it is necessary to incorporate (enable to adopt the flood water level specified in the flood control/ river improvement plan as the "design flood water level". Therefore, a flowchart for determination of design flood water level has been introduced in the Explanation of Criteria and Operation as shown below.

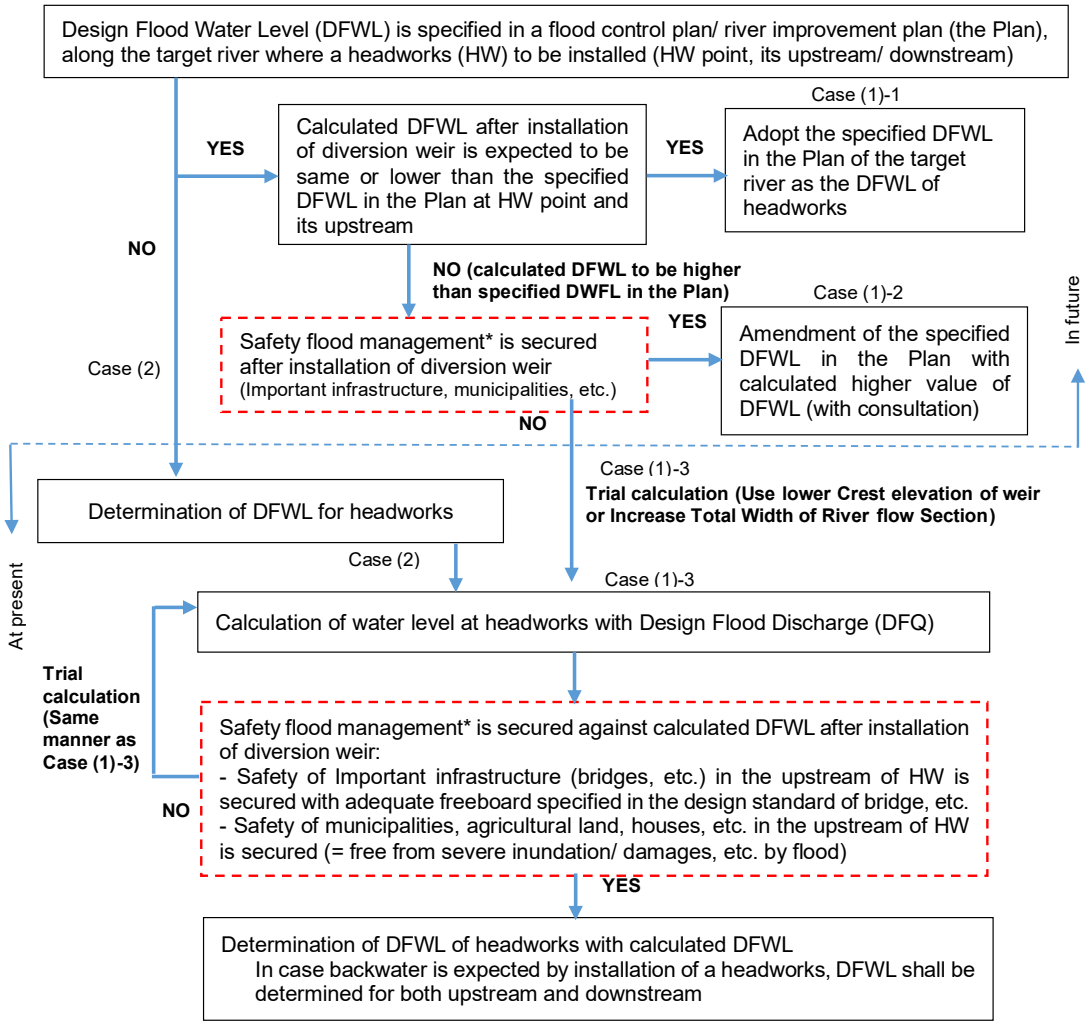


Figure 3-4 Flowchart of Determining Design Flood Water of Headworks

It is also noted that:

- if any flood control/ river improvement plan is formulated in prior to the implementation of design/ construction of a headworks along any target river, the flood water level specified in the flood control/ river improvement plan shall be adopted as the "design flood water level". Consideration shall be also given to any existing important infrastructure.
- if any important asset such as national/provincial road bridge, railroad, etc., is located upstream of the headworks location, the calculated design flood water level based on the specified design flood discharge after installation of the headworks condition shall be examined together with the specified freeboard in compliance with standards of the relevant ministries/agencies.

4) Consideration of climate change adaptation (Operation 7.4, 7.5)

It was explained that for adaptation to the future "climate change", "the Climate Resilient Design Guidelines for Structural Flood and Drought Mitigation Measures in Cambodia (MOWRAM, 2020, "the Guideline") shall be used as reference, based on the comment from the Chairperson of the Technical Committee-2. The detailed procedure would be explained in the "Design Manual", which will be formulated during Phase II of NaSDeP in FY2023-2024.

5) Riverbed/riverbank protection with consideration on hydraulic/soil conditions (Operation 10.24, 25, 11.6)

Regarding the riverbed/riverbank protection works, it was explained that consideration of both hydraulic phenomena as well as specific soil conditions would be made referring to the Design Manual, such as:

- gate operation condition would be considered, especially the concentrated unit discharge ($m^3/s/m$) (= flood discharge divided by gate width) as well as phenomena of hydraulic jump, when a single gate operated alone,
- if the river flow section has been increased for safety discharge of the design flood flow, the transition angle between headworks installation point and the original river width section shall be carefully examined,
- if the river shape is curving in the downstream of the headworks, river training shall be carefully considered to mitigate the flow direction for prevention from severe erosion on the riverbank,
- Economical treatment shall be considered for the case of specific soil condition of riverbed/ riverbank.

6) Modernization of control & management facilities (Operation 12.1, 12.3)

It was explained that for an introduction of modernized control and management facilities, such as electric driven gates, sensors, remote control system, remote monitoring system and devices, etc., a necessary operation and maintenance (O&M) system, O&M manual, O&M budget are to be carefully considered and proposed in the detailed design stage/construction supervision stage,.

3.5.2 Development of design criteria (Canal Works)

(1) Draft Table of Contents (Canal Works, outline)

Based on the above concept as well as "Points to be considered for formulation of NSDD (Canal Works)", the Draft Table of Contents (Outline) of design criteria for Canal Works has been formulated as shown in Table 3-24

Table 3-24 Draft Table of Contents (Canal Works) and Points to be Considered under the Relevant Chapter

Draft Table of Contents (Outline)	Points to Consider
Chapter 1 Justification of the Criteria	
Chapter 2 Definition of Headworks	
Chapter 3 Basic Principles of Design	
Chapter 4 Compliance with relevant Laws and Regulations	Apply Cambodian laws, regulations, and plans
Chapter 5 Design Procedure	
Chapter 6 Investigation	
Chapter 7 Basic Design	
Chapter 8 Detailed Design	
Chapter 9 Intake Structure	
Chapter 10 Diversion Weir	
Chapter 11 Related Structures	
Chapter 12 Management Facilities	

Source: NaSDeP

(2) Draft Table of Contents (Canal Works, detailed)

Based on the above concept as well as "Points to be considered for formulation of NSDD (Canal Works)", the Draft Table of Contents (detailed) of design criteria for Canal Works has been formulated as shown in Table 3-25.

Table 3-25 Draft Table of Contents (Canal Works) and Points to Consider under the Relevant Chapter

Draft Table of Contents (Detailed)	Points to Consider
Chapter 1 Justification of the Criteria	
Chapter 2 Definition of Canal Works	
2.1 Canal System	
2.2 Classification of Canals	
Chapter 3 Basic Principles of Design	
Chapter 4 Compliance with relevant Laws and Regulations	
4.1 Compliance with relevant Laws and Regulations	・ Introducing List of Cambodian laws, regulations related to design and construction of headworks
4.2 Conformity with related Plans	・ Applying Cambodian plans related to design and construction of headworks
Chapter 5 Design Procedure	
Chapter 6 Investigation	
6.1 Topographical Investigations and Surveys	
6.2 Soil and Geological Investigations	・ Description of dispersive and expansive soils investigation in addition to normal soil investigation.
6.3 Meteorological and Hydrological Investigations	
6.4 Investigations of Site Conditions	
6.5 Environmental survey	
6.6 Investigations for operation management	
Chapter 7 Basic Design	
7.1 Design Discharge and Design Water Level	
7.2 Characteristics by Canal Types	
7.3 Canal Route Selection	
7.4 Canal Structure Selection for Water Conveying Facilities	・ Minimum radius of curve considering land acquisition.
7.5 Layout of canal structures and facilities	
7.6 Head Allotment	
Chapter 8 Detailed Design	
8.1 Conveyance Structures	
8.2 Regulating Structures	

Draft Table of Contents (Detailed)	Points to Consider
8.3 Protective Structures	
8.4 Water measurement structures	
8.5 Confluent structures	
8.6 Safety facilities	
8.7 Management facilities	
Chapter 9 Hydraulic Design	
9.1 Allowable Flow Velocity	・ Confirmation of the MPWT standard.
9.2 Uniform Flow Calculation and Coefficient of Roughness	
9.3 Non-uniform Flow Calculation	
9.4 Head Loss and Changes of Water Level	
9.5 Freeboard	
Chapter 10 Structural Design	
10.1 Load	
10.2 Reaction of Foundation	
10.3 Load applied to Canals	
10.4 Load applied on Embedded Structures	
10.5 Review of Foundation Design	
10.6 Stability Analysis	
10.7 Member Design	
10.8 Structural Details	
Chapter 11 Ancillary Structures	
Chapter 12 Management	-

Source: NaSDeP

3.6 Collection and analysis of meteorological and hydrological data

3.6.1 Accumulation status of meteorological and hydrological data

Based on the results of interviews and collection of information at the Department of Meteorology (DOM) and Department of Hydrology and Rivers (DOHRW) of MOWRAM which were conducted in October 2022, the status of meteorological and hydrological observations and data availability in Cambodia were confirmed. Furthermore, the Prek Thnot River basin was selected as the target river basin for the sample calculations in the Design Manual[5], and those data of the basin were collected and organized.

[5] In selecting target river basin for sample calculations of the Design Manual, candidates were reviewed from the following selection perspectives: (1) the meteorological and hydrological data (type and duration) that MOWRAM can provide, (2) the availability of meteorological and hydrological data collected and organized in past projects to supplement the MOWRM data, (3) the availability of information on the basin collected and organized in past projects, and (4) ease of access in the event that a site visit is required to confirm the status of the basin, etc. As a result of discussions with counterparts, the Prek Thnot basin was selected as the target basin because of the high availability of observation data, the availability of information on the basin from past projects, etc., and the relatively close proximity to Phnom Penh, which facilitates inspection visits to the basin as necessary.

(1) Meteorological data

Rainfall and general meteorological data required for calculating irrigation water requirement were provided by DOM from automatic weather stations (AWS).

A list of AWS network and information on data availability were obtained, as well as data from the following AWS stations. The data of rainfall stations other than AWSs data, the rainfall data of the Kampomg Speu Station (1996-2021) under MOWRAM was provided.

Table 3-26 Obtained Meteorological Data from AWS

No.	Station name	Period of data requested
-	Pochentong	2016-2022
7	Kampong Speu	2014-2022
31	Basedth	2016-2022
32	Aoral	2016-2022
39	Phnum Srouch Dsitrict	2018-2022
40	Tasal Dam	2018-2022
41	Thpong	2018-2022
42	Bati District	2018-2022

The meteorological data provided were from the period since the installation of the AWS, which is limited to a period of 4 to 8 years. Therefore, the following data was obtained and organized in addition to the data provided by DOM for this project as data for a longer time-series.

- Source: Detail Design Report of the Southwest Phnom Penh Irrigation and Drainage Rehabilitation and Improvement Project (JICA ODA Loan No. CP-P14)
- Obtained data: Pochentong Station (rainfall and general meteological data 1981-2015), Basedth Sation (rainfall 1987-1994, 2000-2007), Tonel Bati Station (rainfall 1987-1991, 2003-2007)

Long-term data from the Pochentong Station will be used in the sample calculations to calculate irrigation water requirement. Since there is a lack of long-term data on rainfall in the watershed for the calculation of the drainage requirement and design flood discharge, it is necessary to use rainfall data of point data as a substitute in the sample calculation.

(2) Hydrological data

The availability of hydrological data on river flow conditions is shown below. The river flow data for studying the design flood discharge was provided by DOHRW, which provided water level and flow data at the Peam Khley and Thnous Loung stations on the Plek Thnot River.

Table 3-27 Obtained Hydrological Data

Station	Year											
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1. Peam Khley												
Daily Water Level	A	A	A	A	A	M	-	A	A	A	A	A
Daily Dsicharge	A	A	A	A	A	M	-	A	A	A	A	A
2. Thous Loung												
Daily Water Level	A	A	A	A	A	M	-	A	A	-	A	M
Daily Dsicharge	A	A	A	A	A	M	-	A	A	-	A	M
Station	Year											
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1. Peam Khley												
Daily Water Level	A	A	A	A	A	A	A	A	A	A	A	
Daily Dsicharge	A	A	A	A	A	A	A	A	A	A	A	
2. Thous Loung												
Daily Water Level	A	A	-	A	A	A	A	A	A	A	A	
Daily Dsicharge	A	A	-	A	A	A	A	A	A	A	A	

A: Availabe through the year, M: Partially missing data, -: Not available

The meteorological and hydrological data collected will be used in the preparation of the sample calculations of design flood discharge/water level and irrigation water requirement in the Design Manual. Furthermore, the difficulties in obtaining long-term data on river flow conditions identified during the data collection process were used as the basis for the priority of the method (e.g., flood frequency analysis based on long-term data, flood frequency analysis based on insufficient periodic data, or a combination of runoff analysis) in the procedure for determining design flood discharge/water level for head works, which will be described in the Design Manual.

3.6.2 Methodology of setting design flood discharge

(1) Examination of process and methodology of determining design flood discharge and design flood level

According to the Japanese Technical Standard for Land Improvement, the design flood discharge and design flood level of the headworks are to be determined based on the various parameters specified in the relevant higher-level plans for river management, such as the Basic Policy for River Improvement, the Provisional Implementation Plan for River Work, and the River Improvement Plan. However, in Cambodia, no such high-level plan has been established, and the design flood of each project is determined by conducting flow analysis individually. In many cases, there is no accumulation of reliable long-term observation data, which is the most basic data for analyzing river flow conditions, and which is necessary for statistical analysis of the 50-year or 100-year probabilities of the design flood magnitude. Therefore, the NSDD to be developed in this project, while based on the Japanese technical standards for land improvement, needs to incorporate determination methods that are in line with the actual conditions in the country.

In this phase of the project, through the collection and analysis of existing data, case studies were conducted on the process of determining the design flood discharge and water level adopted in past projects in Cambodia, and the process and adopted runoff analysis methods in those projects were examined. The detail of the determination process and runoff analysis methods will be described in the Design Manual.

(2) Case study of design flood discharge of headworks of projects in Cambodia

In Cambodia, there is no high-level plan for river management, and in many cases, there is insufficient data to analyze the flow condition, as mentioned above. Therefore, in determining the design flood

discharge for river structures such as headworks in the country so far, various methods have been adopted for each project depending on the available data and its reliability. Due to the low reliability of the data, in most cases, the design flood discharges are set after calculations with multiple approaches and comparisons of results are made.

In this phase, design documents and other materials of the headworks projects, as listed below, and the process and analysis of design flood conditions were compiled and summarized. Due to the limited number of headworks examples that could be collected, examples of similar facilities such as spillway of dam were also included in the analysis.

1. Southwest Phnom Penh Irrigation and Drainage Rehabilitation and Improvement Project [JICA]
2. West Tonle Sap Irrigation and Drainage Rehabilitation and Improvement Project [JICA]
3. Water and Agriculture Sector Project (WASP) [AFD]
4. Flood Damage Emergency Reconstruction Project [ADB]
5. Uplands Irrigation and Water Resources Management Sector Project [ADB]
6. Irrigation Development and Flood Mitigation Project in Banteay Meanchey Province [EDCF]
7. Feasibility study on the development of Sala Ta Orn Dam [EDCF]

In addition, since similar runoff analysis methods are used, examples of design flood conditions for road drainage and bridge projects were combined.

8. National Road No. 2 and No. 22 Improvement Project (EDCF Loan KHM-15) MPWT
9. Assessment of Flood Analysis for the Road KSP1 in Kampong Speu Province MRD

The analytical methods employed in these projects range from flood frequency analysis, Rational Method, GTFM (Generalized Tropical Flood Model Tropical Flood Model), IRS and Revised IRS methods, unit hydrograph, direct estimation by flow capacity or flood record, and flood transposition by specific run-off. The employed process and analytical method in those projects are summarized below.

Table 3-28 Process and Analytical Method Employed for Design Flood Discharge in the Project in Cambodia

Project and subproject	Type of facilities	Catchment area (km^2)	Flood frequency analysis	Rational Method	GTFM	IRS / Revised IRS	Unit Hydrograph	Direct estimation	Flood transposition
1. Southwest Phnom Penh IDRIP 1-1 Roleang Chrey	HW	3,911						X	
1-2 Upper Slakou	SW					x	X		
1-3 Kandal Stung-Bati	SW	240,148		x		x	X		
1-4 Main Canal 35	SW	98,923				x	X		
1-5 Daun Pue	HW	225,344		x		x	X		
2. West Tonle Sap IDRIP 2-1 Ream Kon	HW							X	x
3. WASP 3-1 Tumnub Kask	SW		X 16years						
3-2 Trav Kod	SW		X 20years						
4. Flood Damage Emergency Reconstruction Project [ADB] 4-1 Tumnub Luok	SW	291			x	X		x	x
4-2 Tumnub O Ang Krang	SW	127			X	x		x	x

Project and subproject	Type of facilities	Catchment area (km^2)	Flood frequency analysis	Rational Method	GTFM	IRS / Revised IRS	Unit Hydrograph	Direct estimation	Flood transposition
5. Uplands Irrigation and Water Resources Management Sector Project	HW	932			X				
6. Irrigation Development and Flood Mitigation Project in Banteay Meanchey Province	HW, Canal	150 – 1,379					X		
7. Feasibility study on the development of Sala Ta Orn Dam	SW	3,720					X		
8. National Road No. 2 and No. 22 Improvement Project (MPWT)	Brd, Cvt	68		X <10 km^2	X ≥10 km^2				
9. Assessment of Flood Analysis for the Road KSP1 in Kampong Speu Province (MRD)	Brd, Cvt						X		

Source: NaSDeP

Note: 1) Type of facilities HW: Headworks, SW: Spillway of dam, Canal: Spillway of canal, Brd, Cvt: Bridge and culvert
2) Status of employment X: method employed in determining parameters, x : method employed in comparison analysis

(3) Comparison of run-off analysis methods

Based on the review of the process and analytical methods for design flood conditions mentioned above, the runoff analysis methods to be adopted in the NSDD were examined. In the review, the characteristics of each analytical method, the data required and their availability, and the applicability and limitations of application under the natural conditions of Cambodia were considered.

It should be noted that some of the counterparts have textbook knowledge of the basics of runoff analysis methods through past training at MOWRAM, including lectures in TSCs and training in Japan, as well as lectures in their student days. However, very few of them have practical experience in runoff analysis and determining design flood discharge/water level for headworks. Therefore, the following considerations were made in the selection of the analysis method, taking into account the technical acceptability of the counterpart.

- The method should be based on a single watershed, which is the basis for runoff analysis.
- The calculation method must be simple (i.e., calculations can be done with a Microsoft Excel spreadsheet), and the types of data to be examined must be small.
- Computer simulation runoff analysis methods for complex watersheds are not eligible. (This does not preclude their adoption at the practice of design, but does not make them manual.)

As a result, the following runoff analysis methods were selected as candidates for inclusion in the Design Manual.

- Rational Method
- Unit Hydrograph Method
- Modified IRS Method
- GTFM Method

A comparison of the applicable characteristics of each selected method is shown in the following table.

Table 3-29 Comparison of Characteristics of Runoff Analysis Methods (1)

Criteria	Rational Method	GTFM	Modified IRS
Catchment area	0 – 25 km^2	10 – 200 km^2	~15,000 km^2
Topography	• Any slope conditions, for rural area	• Any slope conditions	• Elevation below 100 m, basically catchments which are large low-lying plains
Land use/cover	• From bare soil to dense vegetation cover • From rural to urban area, variation of C values	• From bare soil to dense vegetation cover • From rural to urban area, variation of C values	
Adaptability in Cambodia	High adaptability for use in Cambodia because: • Application condition is valid for Cambodia. • Little input required. • Very simple calculation • Not entirely empirical parameter • Good for estimating wet weather flow. • Widely used in neighboring countries like Thailand with similar climate and land/soil conditions	Fairly high adaptability for use in Cambodia because: • Application condition is valid for Cambodia. • Basic input requirement • Simple calculation • Quite principally based physical parameters. • Cambodian catchments relatively uniform hydrological characteristics • Complement to the Rational method for CA > 10 km^2	Very high adaptability for use in Cambodia because: • Application condition is valid for Cambodia. • Very little input requirement • Very simple calculation • Validation in the Mekong basin part of Thailand having similar catchment characteristics to Cambodia. • Many large low-lying plains with low elevation

Source: NaSDeP

Table 3-30 Comparison of Characteristics of Runoff Analysis Methods (2)

Criteria	Synthetic Unit Hydrograph	
	SCS	Snyder
Catchment area	• Any size	• 30 – 30,000 km^2
Catchment shape	• Any shape	• Good for fan-shape catchment
Topography	• Low-lying area	• Fairly mountainous area
Land use/cover	• Agricultural watershed	
Adaptability in Cambodia	Fairly high adaptability for use in Cambodia because: • Application condition is valid for Cambodia. • Easy to use (very simple calculation process and can be done using MS Excel) • Basic input requirement (good for ungauged region like Cambodia and cost effective in terms of data collection) • Quite principally based (many parameters have a physical meaning)	Fairly high adaptability for use in Cambodia because: • Application condition is valid for Cambodia • Easy to use (very simple calculation process and can be done using MS Excel) • Basic input requirement (good for ungauged region like Cambodia and cost effective in terms of data collection) • Quite principally based (many parameters have a physical meaning)

Source: NaSDeP

3.6.3 Irrigation water requirement and irrigation efficiency

(1) Irrigation water requirement in design criteria and design manual

The irrigation water requirement (IWR) is a fundamental parameter in determining the size of an irrigation system, and it is important that it be properly determined. The specific calculation methods and parameters to be referenced for IWR are to be described in the Design Manual, not in the Design Criteria. This is to avoid mandating the application of specific calculation methods and parameters in the design work, because the Design Criteria shall be strictly followed, while the status of the Design Manual is more flexible in its application.

First, in the past in Cambodia, MOWRAM and the development partners have used not united calculation methods to determine IWR for each project. For example, in the Design Manual for Small and Medium Scale Irrigation Hydraulic Design (MOWRAM, 2004), the irrigation system and canals are designed based on the "flow rate of 2 L/s/ha". This simple assumption was employed in

consideration of the limited data/information and human resources, and it was reasonable under such conditions. NSDD to be developed does not reject this empirical design process. However, while it would be desirable in the future to use uniform methods and parameters for all projects, we believe that a mixture of both is inevitable within the scope of the activity period of this project.

Second, the various parameters for calculating IWS proposed in the design manual are general values based on FAO guidelines and other sources and are not optimized for use in Cambodia. Such parameters should reflect the situation in the country, region, and project site. Therefore, it is important to accumulate the results of actual measurements, research and development activities, and project monitoring, and to continuously update them to reflect Cambodia's characteristics.

In this sense, it was decided to proceed with the discussion with counterparts on the assumption that the methods and parameters described in the Design Manual are recommended as guidelines and their application is not mandatory.

(2) Methodology of determination of irrigation water requirement

After consultation with counterparts, it was decided that the methodology for calculating irrigation water requirement would be based on the methodologies applied in the guidelines of FAO, which is widely used in irrigation projects in Cambodia. The guidelines referred to are as follows:

- Calculating IWR: Irrigation Water Management Training Manual No3. Irrigation Water Needs
- Calculation of crop evapotranspiration (ETc): Irrigation and Drainage Technical Paper No.24 and No.56
- Calculation of reference evapotranspiration (ETo): Irrigation and Drainage Technical Paper No.56

The overall concept of calculating IWR is summarized below:

NIWR = CWR + PERC + SAT + WL – Pe for Paddy irrigation
NIWR = CWR – Pe for upland crop irrigation

NIWR: Net irrigation water requirement
CWR: Crop water requirement
PERC: Percolation and seepage loss
SAT: Water use to saturate the soil for land preparation by puddling
WL: Water use to pond water in paddy fields and establish a water level
Pe: Effective rainfall

CWR = ETc = ETo x Kc

ETc: Crop evapotranspiration
ETo: Reference crop evapotranspiration
Kc: Crop coefficient

DIWR = NIWR / Ef

DIWR: Design irrigation water requirement = Gross unit irrigation water requirement
NIWR: Net irrigation water requirement
Ef : Irrigation efficiency

(3) Parameters for determining irrigation water requirement

As mentioned above, the parameters are those that need to be optimized to reflect the conditions in Cambodia and need to be discussed not only during formulation but also continuously throughout the operation of the Design Manual. Therefore, the parameters presented in the Design Manual are to be considered as a starting point and need to be updated by accumulating the results of measurements in the field, research and development activities, and project monitoring during the operation of the NSDD. The various parameters to be included as reference values in the Design Manual will be discussed continuously throughout the work period of the following phase.

(4) Case study of irrigation efficiency of projects in Cambodia

In the calculation of IWR, the irrigation efficiency is an important factor that significantly affects the determination of size of irrigation system and facilities. Therefore, information was collected on the irrigation efficiency employed in the design of existing irrigation projects in Cambodia. The irrigation efficiencies of collected samples are shown in the table below, with a wide range from 45% to 66% in the overall irrigation efficiency (OER).

Table 3-31 Design Values of Irrigation Efficiency for Existing Paddy Irrigation Projects

Project Items	Lum Hach	O mean	Stung Chinit
Irrigation efficiency	a) Field application: 100% b) Tertiary canal: 85% c) Secondary canal: 88% d) Main canal: 88%	a) Field application: - % b) Tertiary canal: - % c) Secondary canal: - % d) Main canal: - %	a) Field application: and Tertiary canal: 75 % c) Secondary canal: 90 % d) Main canal: 90 %
	Overall efficiency: 66%	Overall efficiency: 65%	Overall efficiency: 60%
Project Items	**KSAK Subproject of WASP**	**Punley subproject of Northwest Irrigation Sector Project**	**Roleang Chrey (CP-P14) in D/D**
Irrigation efficiency	a) Field application: 80% b) Tertiary canal: 85% c) Secondary canal: 90% d) Main canal: 90%	a) Field application: 60% b) Water management: 85%	a) Field application: 60% b) Conveyance: 75%
	Overall efficiency: 55%	Overall efficiency: 51%	Overall efficiency: 45%

Source: NaSDeP

3.7 Collection of information on geology and soil mechanics and the required measures

Summary

The following steps 1 through 5 were taken to develop a design standard and manual that would be consistent with the topography, geology, and other natural conditions in Cambodia.

1. Data research
2. Interviews
3. Field investigation
4. Consideration of soil investigation/laboratory test for understanding of distribution and properties of dispersive and expansive soils
5. Consideration of countermeasures on dispersive and expansive soils

3.7.1 Data research

Data research includes a collection of available data, a general understanding of the subject area's soil/geological conditions, and an understanding of case studies on dispersive and expansive soils (including soil properties and countermeasures of dispersive and expansive soils).

In data research, the following data has been collected.

(1) Geological map

A geological map of Cambodia (open database[6]) was obtained from the website. In addition, during the interview described below, we obtained data from the Geological Map of Cambodia (scale 1:1,000,000, 2010) from the ITC (Institute of Technology of Cambodia).

[6] https://data.opendevelopmentcambodia.net/en/dataset/soils-types-of-cambodia

From the obtained geological map, we were able to identify areas based on basalt, which is considered to be the parent rock of expansive soil. This information was used to estimate the distribution area of expansive soils in Cambodia from a geological point of view.

(2) Soil map

Soil maps (open database[7]) for Cambodia were obtained from the website.

The obtained soil map was used to estimate the distribution area of dispersive and expansive soils in Cambodia from a soil science point of view, referring to soil names related to dispersive and expansive soils (e.g., Sodosol and Alluvial Lithosol for dispersive soils, and Vertisol and Regurs for expansive soils). The results were used to estimate the distribution areas of dispersive and expansive soils in Cambodia from a soil science perspective.

(3) Earthquake

Documents were obtained regarding the seismic evaluation of Cambodia on the website[8]. From the obtained data, it was found that Cambodia is a country with very few earthquakes and the magnitudes of the earthquakes that have occurred are small (3 earthquakes with a maximum magnitude of 4.6).

The seismic risk in Cambodia is low compared to that in Japan, and the standards and manuals in Cambodia to be developed based on the Japanese standards shall be considered in this point.

(4) Literature survey

Research papers on the characteristics of dispersive and expansive soils and how to deal with them in construction works in countries and regions where dispersive and expansive soils are distributed were obtained from the website[9].

The obtained papers were used as a reference for understanding and organizing the contents of the papers and for considering countermeasures for dispersive and expansive soils.

3.7.2 Interview Survey

The purpose of the interviews survey was to visit universities and soil testing laboratories of government agencies and private companies in Phnom Penh to understand the status and capacity of soil investigation, soil testing, and soil-related works (foundation works and ground improvement works) in the city, and to gather examples of dealing with dispersive and expansive soils in past projects.

In the interviews, some C/Ps were accompanied, which provided an opportunity to develop an awareness of the issues and to improve their skills.

As a side note, the capacity to carry out soil investigation/laboratory on the interviewee was tabulated, along with the capacity of other private geotechnical investigation firms that were confirmed using the website.

The summary of the interview is listed in Table 3-32.

[7] https://data.opendevelopmentcambodia.net/en/dataset/soils-types-of-cambodia

[8] https://reliefweb.int/map/american-samoa/asia-pacific-regional-hazard-map-earthquake-risk-modified-mercalli-scale
https://www.irric.co.jp/pdf/risk_info/thailand/2015_02.pdf

[9] https://nre.tas.gov.au/Documents/DPIW_DSM_Manual_April2009.pdf
http://www.ijirset.com/upload/2015/december/159_42_Characterization1.pdf

Table 3-32 Summary of interview survey (Date, Destination and Achievements)

Date	Destination	Achievements
Jan/17(Tue)	MOWRAM Engineering Department Soil Quality Analysis Office	・The existence of MOWRAM's original crumb test method and procedure for the evaluation of dispersive soils were understood. ・The distribution area of dispersive soils based on their experience was identified. ・The capacity of soil testing for dispersive soils was identified. ・The standard for soil testing normally used in their laboratory were identified.
Jan/17(Tue)	Royal University of Agriculture (RUA), Soil Science Laboratory	・The capacity of chemical analysis for dispersive soils was identified. ・The distribution area of dispersive soils based on their experience was identified. ・Information was ascertained on the institutions performing chemical analyses other than RUA.
Jan/18(Wed)	ITC (Institute of Technology of Cambodia)	・The capacity of soil testing and chemical analysis for dispersive and expansive soils was identified. ・The capacity of general soil testing was identified. ・The distribution area of expansive soils based on their experience was identified. ・Soil test for evaluating expansive soils and the countermeasure for expansive soils in the past road construction project in Cambodia was collected as one example. ・Geological map of Cambodia was provided. ・The standard for soil testing normally used in their laboratory were identified.
Jan/24(Tue)	MPWT Lab. (Ministry of Public Works and Transport)	・Soil test for evaluating dispersive soils and the countermeasure for dispersive soils in the past road construction project in Cambodia was collected as one example. ・The capacity of soil testing and chemical analysis for dispersive and expansive soils was identified. ・The capacity of general soil testing and soil survey was identified. ・The standard for soil testing normally used in their laboratory were identified.
Jan/26(Thu)	Private Lab. (EcoA Co., Ltd.)	・The actual situation of drilling work in Cambodia was grasped by site observation. ・The capacity of general soil testing and soil survey was identified. ・The capacity of soil testing and chemical analysis for dispersive soils was identified. ・The standard for soil testing normally used in their laboratory were identified. ・The formula for calculating bearing capacity by SPT N-value, which is widely used in Cambodia, was understood.
Jan/31(Tue)	Private Lab. (Cast Laboratories Co., Ltd.)	・The capacity of general soil testing and soil survey was identified. ・The capacity of soil testing and chemical analysis for dispersive soils was identified. ・The standard for soil testing normally used in their laboratory were identified. ・The type of pile foundation work that is available in Cambodia was identified.

Pic-1 MOWRAM Laboratory

Pic-2 RUA

Pic-3 ITC

Pic-4 MPWT Laboratory

Figure 3-5 Interviews of Laboratories

3.7.3 Field investigation

The field survey aimed to understand the function of existing irrigation and drainage structures and to confirm the damage to structures caused by dispersive and expansive soils.

C/Ps were accompanied during the field survey, which provided an opportunity for on-the-job training.

The following are the results of each field investigation.

(1) Kandal Stung irrigation system

On the afternoon of Jan/11 (Wed), a half-day visit was made to irrigation and drainage facilities (headworks and canal works) in the Kandal Stung district. This was the first opportunity for Japanese experts (Engineering geology and Engineering for soil mechanics) to see the headworks and canal works facilities in Cambodia. One C/P participated.

As a result of the investigation, deformation of the concrete blocks covering the slope of the main canal was observed. A small-scale sinking of the maintenance road surface was also observed in the vicinity of the deformation.

Due to the deformation of the concrete blocks, gaps were created between the concrete blocks, and these gaps provided a route for water to enter the back of the revetment.

The distribution of dispersible and expansive soil could not be directly confirmed at the site.

Pic-5 Deformation of concrete blocks

Pic-6 Sinking of maintenance road surface

Figure 3-6 Field Survey Result (Kandal Stung Irrigation system on January 1, 2023)

(2) Prey Veaeng Sangkat Area & Kandal Stung irrigation system

On the morning of Thursday, January 19, we spent half a day visiting irrigation and drainage facilities (headworks and canal works) and surrounding areas in Kandal Stung district. This time, we used Google Maps photos to estimate the distribution area of dispersible and expansive soils in advance and made efforts to directly confirm dispersible and expansive soils at the site. Three C/Ps participated in the survey.

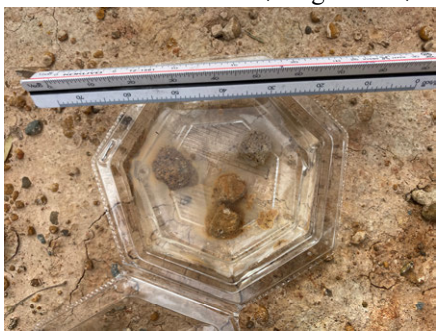
As a result of the survey, areas of sinking, gully erosion, collapse, and development of dry cracks were identified near the ground surface. The sinkholes are continuous underground cavities, known as dragon holes.

Dragon holes, gully erosion, and collapse are typical examples of damage forms that occur in dispersive soils. In addition, dry cracks on the ground surface are one of the features found in the distribution area of expansive soils. These facts suggest that the identified ground surface deformations may be caused by the distribution of dispersive and expansive soils in the area.

Samples were collected in the vicinity of the surface deformation and a simple crumb test was demonstrated to counterpart personnel to evaluate the dispersibility of the soil.

Pic-7 Tunnel erosion（Dragon hole）

Pic-8 Field investigation



Pic-9 Pilot crumb test

Pic-10 Collapse of the slope

Figure 3-7 Field Survey Result (Kandal Stung Irrigation system on January 19, 2023)

(3) Pursat & Kampong Chhnang Province

The field survey was a joint visit by MOWRAM, counterpart officials, and a team of Japanese experts from JICA to check the structures of irrigation and drainage facilities designed and constructed according to different standards. The team confirmed the structures of the irrigation and drainage facilities, which were designed and constructed according to different standards.

As an example, the results of the survey in Lum Hach are shown below. A riverbank failure due to erosion was observed on the left bank downstream of the intake weir. Factors contributing to the failure of the riverbank included flood flow and normal river flow paths as triggers, dispersive soil distribution, bank structure (without erosion protection), and erosion-susceptible geology (tuff) as predisposing factors.

Pic-11 Overview of riverbank（Lum Hach）

Pic-12 Riverbank collapse（Lum Hach）

Figure 3-8 Field Survey Result (Lum Hach Irrigation system on February 8, 2023)

3.7.4 Consideration of soil investigation/laboratory test for understanding of distribution and properties of dispersive and expansive soils

Based on the results of the aforementioned (1) data research, (2) interviews, and (3) field investigation, the investigations and tests that are considered effective in determining the distribution and properties of dispersive and expansive soils were reviewed.

In selecting the investigation and testing items, it is desirable to consider the type, scale, and importance of the structure, as well as the cost-effectiveness of the investigation and testing, and to select items with reference to the items listed in Table 3-33.

The following is an overview of each item.

(1) Data research

Data research includes a collection of available data and a general understanding of the distribution of dispersive and expansive soils in the subject area. The data includes a geological map and a soil map.

The focus of the data research includes the distribution of basalt, which is the parent rock of expansive soils, and soil names associated with dispersive and expansive soils (e.g., Sodosol and Alluvial Lithosol for dispersive soils, and Vertisol and Regurs for expansive soils).

(2) Field investigation

Field investigations shall be conducted in the field to confirm the overview of the area obtained from the data research and to collect samples as necessary. For large hydrographic projects, especially with the addition of geological experts, extensive and macroscopic observations should be made. It is desirable to be accompanied by a variety of technical specialists during the survey.

Points of interest during the field survey include deformation of existing structures, near-surface deformation (cavities/sinks, gully erosion), slope conditions, outcrop geology and soil properties, etc.

(3) Sampling

Sampling shall be performed to obtain samples for soil testing and chemical analysis. Samples shall be obtained from borings. The depth of sampling shall be determined by considering the depth of the target structure.

(4) Crumb test

Soil samples are immersed in water and their dispersion is visually observed and classified as dispersibility.

(5) Physical test

Activity of a cohesive soil (A) is obtained by a calculation formula using C and PI where C represents clay contents percentage and PI represents plasticity index. Accordingly, a degree of expansibility of

the cohesive soil is evaluated by using a parameter called Swelling Potential (Sp) which is obtained from the calculation formula using C and A.

(6) Double hydrometer test

In the normal particle size test (sedimentation method), the results of (i) the use of dispersant and (ii) distilled water only are compared. Calculate the ratio of the passing weight of 0.002 mm.

(7) Free Swell Index Test

The same amount of the sample is placed in each cylinder filled with distilled water and kerosene, and the soil's expandability is evaluated based on the volume change after 24 hours.

(8) Chemical analysis

The amount of Na, Ca, Mg and K exchangeable ions in soil and the CEC (cation exchange capacity) is measured and the dispersibility is classified using the ESP (Exchangeable Sodium Percentage) and SAR (Sodium Adsorption Rate).

(9) X-ray diffraction

After the sample is powdered, the powder is subjected to X-rays to examine the diffraction pattern. The crystals (minerals) contained in the sample are identified, the relative amount ratio is determined, and the presence or absence of swelling minerals (smectite, etc.) is ascertained.

Table 3-33 Survey and Test Items Considered Effective for Understanding the Distribution and Properties of Dispersive Soil/Expansive Soil

Phase	Dispersive soil	Expansive soil
Investigation for Planning	1. Data research	1. Data research
	2. Field investigation	2. Field investigation
Overall design investigation	3. Sampling	3. Sampling
	4. Crumb test	4. Physical test
	5. Double hydrometer test	5. Free Swell Index Test
	6. Chemical analysis	6. X-ray diffraction

Source: NaSDeP

3.7.5 Consideration of countermeasures on dispersive and expansive soils

The distribution and properties of dispersive and expansive soils in the proposed irrigation and drainage facilities shall be thoroughly examined in advance, and the need for countermeasures (e.g., ground improvement and impervious construction) shall be considered. If the results indicate that the soil will adversely affect irrigation and drainage facilities, appropriate countermeasures should be taken.

Appropriate countermeasure methods shall be selected in consideration of ground conditions, loading conditions, construction conditions, etc.

The aforementioned (1) Data research, (2) interviews, and (3) field investigation results were used to examine the methods for dealing with dispersive and expansive soils.

Table 3-34 shows the countermeasure works considered effective for dispersive and expansive soils.

The countermeasures shall be appropriately selected considering the ground conditions, loading conditions, and construction conditions.

Table 3-34 Countermeasure Work Considered Effective for Dispersive and Expansive Soil

Principle \ Soil type		Dispersive soil	Expansive soil
Removal		・Replacement (good quality soil, non-dispersible soil) *Not suitable when the area (extension) to be treated is large.	・Same as on the left
Treatment	Chemical	・Ground improvement (Cement, lime, gypsum, etc.) (Including mix testing, post-improvement soil testing, and test construction) *The strength of the soil can also be expected to increase.	・Same as on the left
	Physical	・Cover with lining concrete (for canal work), impervious sheeting, or non-dispersive soil (to prevent contact with water).	・Same as on the left ・Prevents expansion by increasing the overburden load (soil pressure resistance) and resisting the expansion pressure of the soil.
Other		・Avoid construction during the rainy season. ・Avoid using as fill material as much as possible. (If used, add improvement materials to improve the properties.)	・Avoid construction during the rainy season. ・Avoid use as fill material as much as possible (use inside the fill is acceptable).

Source: NaSDeP

3.8 Planning training on NSDD criteria documents for MOWRAM technical staff

3.8.1 Basic concept for Creating Training Curriculum for MOWRAM Technical Staff

The purpose of the training to be implemented in this project is to strengthen the ability to utilize the NSDD to be formulated. MOWRAM requested that the NSDD be widely disseminated within MOWRAM. For this reason, the target trainee is not only design departments within MOWRAM, but also engineers involved in design-related departments. In addition, since the NSDD includes procedures for data collection at the site, relevant departments of PDWRAM that are in charge of on-site work will also be targeted for training.

On the other hand, it is difficult for trainees to take lectures in English, so it is not possible for only Japanese experts to give lectures to all trainees. Therefore, in this training, the lecture will be conducted in two languages which are English and Khmer. Lectures in English will be conducted mainly by Japanese experts, and lectures in Khmer will be conducted by training engineers within MOWRAM as lecturers.

Regarding the preparation of the training curriculum, information on training in previous projects were collected from the C/P about their wishes regarding training. Based on this information, the basic concept of the training curriculum was created after discussions with the C/P regarding the detail implementation outline of the training. The basic concept of the training curriculum was discussed at the first JCC on March 2023 and agreed among the parties concerned.

(1) Outcomes of previous JICA technical cooperation projects for TSC staff

With the aim of training C/Ps as instructors in this project, the experience of C/Ps as training instructors for PDWRAM engineers, the number of times, etc., were summarized by analyzing the previous JICA projects already implemented, Phase 2 and Phase 3 of the "Irrigation Technical System Planning Project" (hereinafter referred to as TSC-2, TSC -3)). As a result, there were nine (9) C/Ps who had experience as instructors of the training for PDWRAM staff at TSC-2 or TSC-3 (Table 3-35).

Table 3-35 Experience of as an Instructor of the Training at TSC-2 and TSC-3

Section		Name	Department	Age	Career	Specialty	Number of lectures at TSC		
							TSC-2	TSC-3	Total
Administration	1	Ms. Pick Maly	TSC	53	32	Irrigation Engineer	-	-	
	2	Mr. Chek Try	TSC	51	32	Finance	-	-	
	3	Ms. Sous Chenda	TSC	49	28	Agri Economics	-	-	
Headworks	4	Mr. You Sontha	TSC	50	26	Irrigation Engineer	-	12	12
	5	Mr. Sao Ena	TSC	45	18	Architecture	10	13	23
	6	Mr. Kim Mengsreang	TSC	34	9	Civil Engineer	-	-	
	7	Ms. Ly Sunheng	ENG	28	4	Civil Engineer	-	-	
	8	Mr. Sun Chamnap	ENG	29	4	Civil Engineer	-	-	
Main Canal	9	Mr. Hay Bunthoeon	TSC	52	32	Irrigation Engineer	7	7	14
	10	Mr. Teav Vutha	TSC	50	28	Irrigation Engineer	7	6	13
	11	Mr. Kan Chansopheak	TSC	39	9	Civil Engineer	-	-	
	12	Mr. Sum Sothanak	ENG	29	4	Civil Engineer	-	-	
	13	Mr. Theng Nararith	IRRI	33	4	Bachelor of Art	-	-	
Secondary Canal	14	Mr. Mean Seng	TSC	47	23	Civil Engineer	13	14	27
	15	Mr. Soeung Sotha	TSC	53	32	Irrigation Engineer	-	11	11
	16	Mr. Meas Savoeun	TSC	50	28	Civil Engineer	14	15	29
	17	Mr. Chan Rithy	ENG	29	4	Computer Science	-	-	
	18	Mr. Thui Vanda	IRRI	29	4	Accounting	-	-	
Tertiary Canal	19	Mr. Noun Vamanth	TSC	59	33	Agri Economics	9	9	18
	20	Mr. Sok Kom	TSC	49	27	Civil Engineer	5	7	12
	21	Mr. Chea Rady	TSC	34	9	Civil Engineer	-	-	
	22	Ms. Yean Sopheak	ENG	35	6	Accounting	-	-	
	23	Mr. Teng Bora	FWUC	48	24	Civil Engineer	-	-	

Source: NaSDeP

The total number of trainees in TSC-2 was 503, of which 12 belonged to MOWRAM and 491 belonged to PDWRAM. The total number of trainees at TCS-3 was 1,065, of which 98 belonged to MOWRAM and 967 belonged to PDWRAM.

(2) The number of engineers with a bachelor's degree or higher among MOWRAM's technical staff

TSC staff had thirty-three (33) engineers with master’s degree (MBA/MSs) and bachelor’s degree (BA). Table 3-36 shows the number of engineers with MBA/MSs and BAs in the Engineering department, Irrigated Agriculture department, and FWUC.

Of all MOWRAM staff (873), 665 (76%) were engineers with MBA/MSc and BA. The Engineering Department had the highest number of engineers with a BA degree or higher, followed by the Irrigation and Agriculture Department.

Table 3-36 Number of Engineers in MOWRAM and PDWRAM

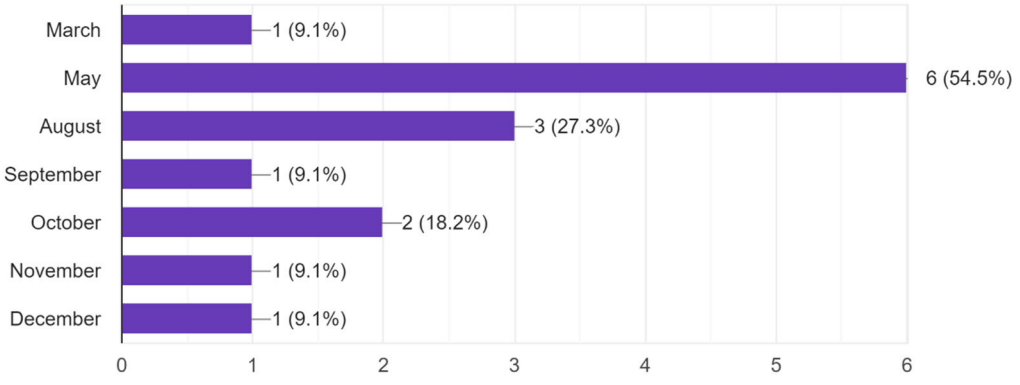
		Engineer			Technician	Others	Total
		MBA/MSc	BA, Engineer	Total			
MOWRAM	TSC	9	24	33	0	4	37
	Engineering Dept.	11	170	181	44		225
	Hydrology and River Work Dept.			60			
	Meteorology Dept.			49			
	Water Management and Conservation Dept.	3	17	20			
	Irrigated Agriculture Dept.	14	52	66	13	8	87
	Water Supply and Sanitation Dept.	6	26	32	1	0	33
	FWUC Dept.	1	28	29	13		42
	Others			195	45	80	449
	Total	-	-	665	116	92	873
PDWRAM		-	-	277	70	166	513
Total		-	-	942	186	258	1,386

(Unit: person)
Source: NaSDeP

(3) Survey for training contents

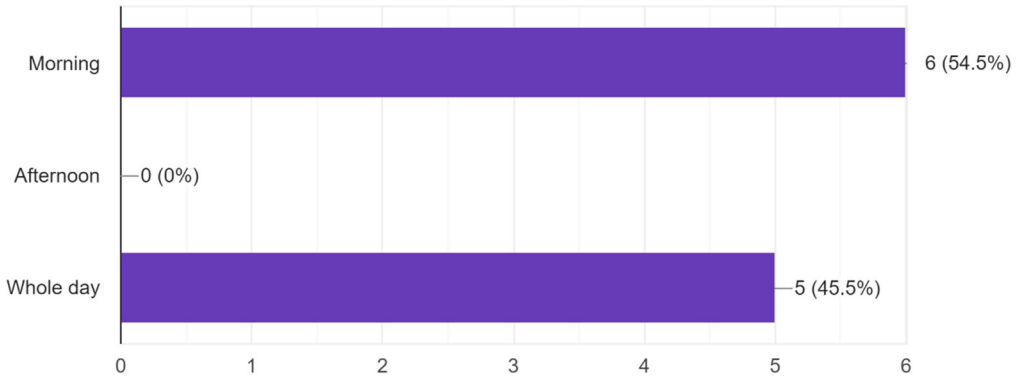
Cambodian government officials, including C/P, needed to participate in the campaign activities for local assembly elections held in July 2022 during the first period of the project. They were absent from Phnom Penh because they stayed in the province in charge. In 2023, local elections are scheduled for July 23, and it will be the same this term, so it is necessary to confirm whether C/P will be able to participate. For this reason, an interview survey was conducted on the content of the training, training implementation period, number of times, requests for time, etc., as well as the intentions of technical departments other than TSC and PDWRAM's technical staff for training.

The timing of training was highest in May before the local elections, followed by August after the elections (Figure 3-9). As for the training duration, only the morning or whole day are preferred but there was no opinion that included only the afternoon (Figure 3-10).



Source: NaSDeP

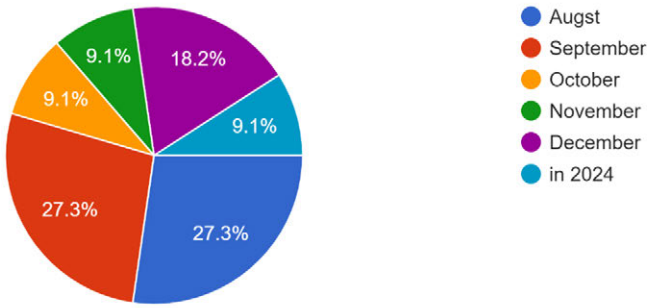
Figure 3-9 Timing of training (n=11)



Source: NaSDeP

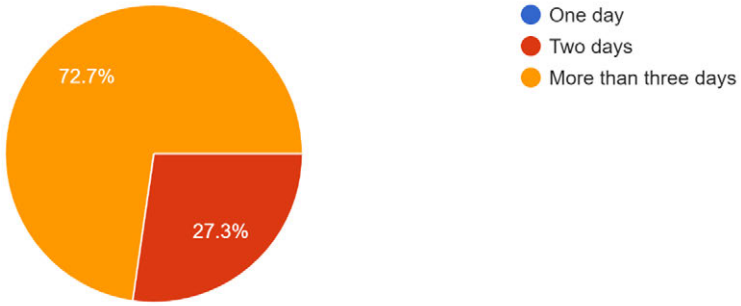
Figure 3-10 Duration of Training (n=11)

PDWRAM training accounted for more than 50% of the total in August and September (Figure 3-11). 73% of the total as a training duration were for 3 days or more, and the rest were 2 days. There was no opinion that one day was enough (Figure 3-12).



Source: NaSDeP

Figure 3-11 Timing of Training for PDWRAM (n=11)



Source: NaSDeP

Figure 3-12 Duration of Training for PDWRAM (n=11)

(4) Proposal of training implementation basic policy

Among the technical departments of MOWRAM, the department to which staff members who are expected to be involved in design work are assigned is the Department of Engineering. Also included are the Irrigated Agriculture department, TSC, FWUC department, Engineering department, Meteorology department, Hydrology and River Works department are organizations that play a role in collecting and managing information that contributes to design work.

NSDD design standards, design manuals, and design drawings will be used as training materials for

generally understanding NSDD. In order for engineers who have taken the training to master the contents of the NSDD to a level where they can give appropriate guidance to engineers except for themselves, close communication should be maintained between the training instructor and the trainees. For this reason, as a basic concept for implementing training, a JICA expert will have a primary lecture and conduct training in English for the C/P.

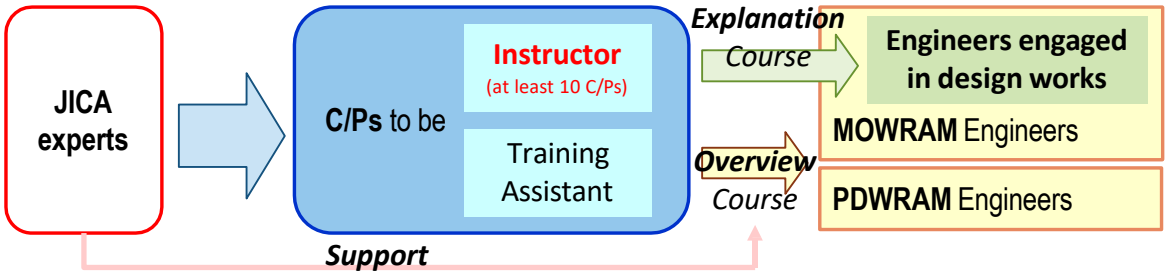
In this way, a series of scenarios was assumed that C/Ps who fully understand the contents of NSDD will be trained as training instructors (instructors), and the trained instructors will conduct training for design workers and those who provide information related to design. The training aims to ensure that MOWRAM understands NSDD and fully utilize it in subsequent design work and build an organizational structure and train engineers that can update the contents of NSDD according to changes in social and natural conditions.

3.8.2 Proposal of Training Implementation Plan

(1) Flow of training implementation

The training consists of the three stages shown below, prioritizing training for the C/P (Figure 3-13).

1. "Instructor training course"
2. "NSDD Overview course"
3. "NSDD Explanation Course"



Source: NaSDeP

Figure 3-13 Flow of Training Implementation

Table 3-37 shows the goals of the training.

Table 3-37 Goal of the training

Target	*Instructor Training (by English)*	*Overview Course (by Khmer)*	*Explanation Course (by Khmer)*
C/Ps for NaSDeP	**100%** (20/20)	— (Included in Instructor Course)	— (Included in Instructor Course)
Engineering staff in **MOWRAM**	Not applicable	**50%** (191/382)	Not applicable
Engineers engaged in design works	Not applicable		**100%** (TBC)
Engineering staff in **PDWRAM**	Not applicable	**26%** (72/277)	Not applicable
Total	**100%** (20/20)	**40%** (263/659)	**100%** (TBC)

Source: NaSDeP

(2) Contents of instructor training course

The purpose of this is to train C/Ps as instructors or training assistants. C/Ps who became instructors are for engineers from other departments of MOWRAM. Conduct NSDD explanation courses and NSDD overview course training.

A Japanese expert will be in charge of the instructor training course, and the training will be conducted in English.

(3) Contents of the NSDD overview course

This course is intended for engineers engaged in design work at MOWRAM and provides an understanding terminology of the design composition of the NSDD.

The training instructors for the NSDD commentary course will be independently provided by the C/Ps who became instructors in the above-mentioned instructor training course, and the Japanese experts will support indirectly.

(4) Contents of NSDD explanation course

This course is intended for engineers engaged in design work at MOWRAM and provides an understanding of the design standards, the contents of the design manual, and the design drawings shown in the NSDD.

The training instructors for the NSDD commentary course will be independently provided by the C/Ps who became instructors in the above-mentioned instructor training course, and the Japanese experts will support indirectly.

3.8.3 Proposal of Training Implementation Plan

At the start of the project, the short-term experts as instructors, conducted preliminary training in English with using English training materials. The lessons learned are as follows.

According to the request from the C/P, the training related to the explanation of the contents of the Japanese design standard documents, regardless of the difficulty of the training content, the local consultant interpreted into Khmer or additional explanation in Khmer.

In addition, except for the Director General of Technical Directorate and technical advisors, etc., it was difficult to communicate in English and necessary to translate in Khmer when conducting interviews with MOWRAM's technical departments other than TSC, such as the Engineering Department, the Irrigated Agriculture Department, and the Farmers Water Users Association Department, etc.

For this reason, it became clear that it is important to conduct lecture and prepare training materials in Khmer to the MOWRAM and PDWRAM training except for the C/Ps.

3.9 Participation in workshops with relevant ministries and related development partners

On February 21, 2023, Cambodian related ministries and agencies such as MAFF, MARD, MEF, etc., development partners such as ADB, AFD, Aus-Aid, WB, etc., related research institutes such as the Cambodian Institute of Technology, related departments of MOWRAM and the first workshop was held with the attendance of PDWRAM on February 21, 2023.

Mr. Miyahara, Deputy Director General of JICA Cambodia Office gave a speech, and H.E. Mr. Bun Hean, Project Director and Secretary of State, gave opening remarks, followed by an overview of the project, the policy for formulating National Standard Design Documents for Irrigation and Drainage (NSDD) in Cambodia, and future activities of the project was explained.

A question-and-answer session was held with the participants in response to these explanations.

3.10 Validation by JCC

The Joint Coordination Meeting (JCC) was held on March 22, 2023, to explain the outline of the activities and outputs of this project in FY2022, discuss the PDM and PO, propose changes to the PDM, and agree on the changes.

The annual activity plan for 2023 was explained, and a question-and-answer session was held with the participants.

Chapter 4 Lessons learned and challenges for future project activities

4.1 Adjustment of C/P Project Activity Participation Period

When local council elections were held in July 2022, a continuous election campaign was carried out for about a month before the election day, and all C/Ps did not show up the MOURAM office due to mobilization. It is also customary to take consecutive holidays during the Khmer New Year (mid-April) and Water Festival (October). In this way, it is necessary to grasp in advance the provision of services and vacations that the C/P has no choice but to cooperate with politically other than project activities, and need to consider to ensure that project activities and inputs exclude this period.

4.2 Ingenuity in Information Collection on Existing Projects and Future Prospects

Information and data collection on the existing projects was carried out through the issuance of the request letter by the Minister to Project Management Units of the relevant projects. Regarding financial cooperation projects under JICA (all) and ADB (the mid-2010s onwards) information was obtained from the concerned parties, such as design drawings, design reports (including design criteria), design manual, etc. On the other hand, regarding those projects under South Korea, China, and India, despite the issuance of the request letter, only little information was obtained. Therefore, most of the additional information was collected through web search, such as project post-appraisal reports, preliminary feasibility study reports, enlargement of scheme area using google map, etc., for grasp of the project outline. Then, it was supplemented with actual field measurements during the field survey (number of major structures, dimensional specifications) for estimation of the design condition. For the domestic projects implemented by MOWRAM, brief project overview reports with some basic design level drawings were provided from the Engineering Dept., and conditions of design and as built as well as the gaps between design and construction stages were analyzed. Finally, through the identification on good practices, current defects and issues, the adequacy of the facility specifications in all surveyed existing projects was evaluated based on comparison with the design criteria of Japan. In the second phase work, some additional field surveys will be conducted as per necessary, and it is expected that the above know-how will be used to evaluate the validity of existing projects.

4.3 Translation of deliverables into Khmer

In this project's activities, communication with the C/P is possible in English for daily conversation, but for presentations and handouts containing technical content, it is necessary to interpret and translate into Khmer one by one.

Already, with regard to the explanation of the draft of the design standards, it is required that the local staff immediately explain in Khmer after the experts have explained the materials and slides prepared in English to promote understanding of the content.

In addition, a researcher who is a lecturer in ITC for basic technical training related to meteorology and hydrology worked as local staff temporally and have lectured in Khmer. Not only from C/Ps but also H.E. Mr. Pich Vesna, Project Manager and Under Secretary of State, has highly expected and requested for training in this procedure.

The pamphlet for the project, which was created by the long-term experts as part of public relations activities, was translated into Khmer by an outsourced translator after it prepared in English, but it required proofreading and finalization with special wording and expressions by Director Vesna who has years of experience in official documents. For this reason, if the Khmer translation is outsourced to a private company, it should be assumed that sufficient proofreading for finalization will be added.

4.4 Budgeting for expenses necessary for future training continuation (including lecturer's daily allowance)

A basic scenario for the training plan is to develop the C/Ps as training instructors in Khmer and to implement training for MOWRAM's technical staff by the C/P. It can be an obstacle to continuing implementation of the training if it needs to hire from outside MOWRAM, such as local consultants, during development instructors or until training is completed.

In addition, regardless of whether the training for PDWRAM engineers is implemented in Phnom Penh or in each local city where PDWRAM is located, it is necessary for securing a budget in parallel with the training of instructors to estimate expenses such as travel expenses for dispatching trainees or instructors, daily allowances, and rental fees for conference rooms.

Attachments

1. Draft Design Criteria for Headworks
2. Draft Design Criteria for Canal Works
3. Draft Terminology for Headworks and Canal Works

4.5 Responding to challenges in the implementation of the work (second phase)

We believe that the biggest challenge is that MOWRAM's technical staff, as members of the government agency in charge of river management in the country do not understand how to store and organize design-related data and how to utilize these data for future management of social infrastructure. However, we believe that small impacts, such as the transmission and sharing of the mindset with those who are within our access as experts through project activities, will lead to major reforms in the future. In the implementation of work in the second period, the JICA expert team will create opportunities for close communication, such as by collaborating work with C/P.

On the other hand, in terms of coordination and involvement of other development partners cooperating in the irrigation and drainage projects, MOWRAM officials were cautious about sharing information without a certain level of prospect of success, and for this reason, meetings with individual donors were delayed. In the first Consultative Workshop held in February 2023, field survey results of case studies, issues, and analyzed improvement measures was presented by NaSDeP to the relevant ministries and development partners while keeping the project name anonymous, so that to create an atmosphere for their future smooth agreement to comply with the NSDD. Lessons learned from these situations will be used to promote coordination with individual development partners.