DEVELOPING NATIONAL DESIGN STANDARD FOR IRRIGATION AND DRAINAGE TO SUPPORT WATER AND FOOD SECURITY IN CAMBODIA

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ABSTRACT

Irrigation plays a very important role in rice and other crops production in rural Cambodia where over 75% of the people are residing and depend on agriculture as a source of livelihood and family incomes. Cambodia has an ancient tradition of irrigated agriculture dating back to Angkor Era started in9th Century. After several decades of civil wars, the country aims to become one of the major rice exporters and is therefore investing heavily in the expansion and restoration of its irrigation systems. Several of these multi-million-dollar projects are built by different foreign contractors/developers using their preferred design standard in the absence of national technical standards to apply across all development projects. Cambodia's irrigation and drainage has many similarities with other countries but also has some unique characteristics, which do not permit the automatic transfer of design standards from other countries to be applied in Cambodia. The draft of Cambodian 2019-2033 National Irrigation Program acknowledged this serious challenge to the sustainable irrigation development. There is a need for Cambodian design standard for irrigation and drainage to bring all irrigation projects under one common standard. The developed standard should be applicable in terms of climate, geology, hydrology, geography, economic condition, human resources and local practices and livelihood in Cambodia.

The Wuhan University (WHU) and Institute of Technology of Cambodia (ITC) have worked in partnership with the Cambodian Ministry of Water Resources and Meteorology, Cambodia Agriculture Value Chain Program (CAVAC) and Cambodian University of Agriculture, in assessing, testing and producing a Cambodian Irrigation Design Standard. The project reviewed existing standards applied by various developers and proposed a draft standard for consideration of the Government and the partners. The existing irrigation standards of neighbouring countries and other countries with similarity in terms of environmental and economic condition were reviewed. The methods and design parameters applicable in Cambodian context were adopted. Key findings include: such standards should be carefully specified for the range of agro-ecologies and contexts of irrigation and drainage in Cambodia. Further refinement and interim improvement of some design and feasibility criteria could be achieved by establishing irrigation research stations in each agro-ecological zone, and within representative irrigation areas.

Keywords: Cambodia water and food security, Sustainable Irrigation and Drainage, Irrigation Technical Design Code, Rice, Crop water requirement.

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1. INTRODUCTION

Irrigation plays a very important role in rice and other crops production in rural Cambodia where livelihood and family incomes of majority of the people depend on agriculture. Over the last decade the agriculture sector contributed between 30 to 40 percent to the Gross Domestic Product (GDP), employed around 50 percent of the total labour force, and provided livelihoods to around 80 percent of the Cambodian population (World Bank 2017). Aiming to become one of the major rice exporters, Royal Government of Cambodia (RGC) prioritized and heavily invested in irrigation sector. Over 200 million USD by RGC and over 630 million USD by Development Partners were invested in irrigation project in Cambodia focusing mainly on rehabilitation of existing irrigation schemes, and construction of new irrigation schemes (World Bank 2017).

By November 2016, there were2544 irrigation schemes registered in Cambodian Irrigation Scheme Information System (CISIS) yet more than 50 percent are not operating or partially operating while 1926 schemes potentially need to be fully rehabilitated (ADB 2018). Many of the irrigation schemes were built in the troubled period of the 1970s without irrigation design standard relevant to local condition. Recent irrigation schemes funded by foreign development partners are designed and built using their preferred design standards and methods in the absence of national technical standard to apply across all development projects. It requires detail study on each foreign standard in order to evaluate the proposed design and conduct the quality control of the construction of the irrigation schemes funded by foreign development partners. It becomes a big challenge for the government to approve and accept the irrigation schemes due to limited human resource in this field. Without national standard for irrigation and drainage and sufficient understanding of local standard, development of human resource in this field becomes onerous. Indeed, Cambodia's irrigation and drainage has many similarities to other countries but also has some unique characteristics, which do not permit the automatic transfer of design standards from other countries to be applied in Cambodia. The draft of Cambodian 2019-2033 National Irrigation Program acknowledged this serious challenge to the sustainable irrigation development. There is a need for Cambodian design standard for irrigation and drainage to bring all irrigation projects under one common standard applicable to Cambodian context in terms of climate, geology, hydrology, geography, economic condition, human resources and local practices and livelihood.

For these reasons, the purpose of this paper is to raise the key points to be considered in the process of developing Cambodian Irrigation Design Standard by collecting the lesson learnt and technical issues in irrigation projects from the stake-holders in irrigation sector in Cambodia through the interview, seminar and reviewing technical report. The existing irrigation code of neighbouring countries and other countries with similarity in terms of environmental and economic condition were reviewed in order to make a synthesis relevant to Cambodian Context.

2. METHODS

This study focuses on identifying the issues and challenges in irrigation sector in Cambodia located in south-east Asia and sharing the border with Thailand on the western and northern part, Laos on the northern part, Vietnam on the eastern part and Thailand gulf on the south-western part. The site investigation was conducted on three irrigation schemes to understand the issues on the real fields. The interviews with the key stakeholders were conducted and the seminar on Development of Irrigation Design Standard was further organized in order to collect the experience and lesson learnt. The existing irrigation and drainage standards of other countries

with similar environment and agricultural condition were reviewed in order to collect the existing methods used to address these finding issues.

3.5 2.1 Investigation on Existing Irrigation Scheme in Cambodia 4.5

Three of the largest irrigation schemes in Cambodia located in Battambang province and Oddar Meanchey province: KampingPouy Irrigation Scheme, Kanghot Irrigation Scheme and SteungSreng Irrigation Scheme, were selected for this study (Figure 2). Interviews with the staffs of Provincial Department of Water Resource and Meteorology (PDOWRAM) responsible for each scheme and the staffs responsible for the operation and maintenance of the scheme were arranged and the challenges of each irrigation scheme were recorded.

Kanghot irrigation scheme is located in Battambang province in western part of Cambodia. This irrigation scheme provides irrigation water for 47,000 ha of paddy in rainy season and 12,000 ha of paddy in dry season. It is comprised of three phases. The first two phases (2010-2014) focus on the canal system while the third phase (2014-2017) focuses on the multipurpose reservoir with the storage capacity of 193 MCM and the annual water supply of 280 MCM. This project was built by Guangdong Construction Co Ltd with China's Loan.

KampingPouy irrigation scheme was built by the forced labour during Khmer Rouge regime between 1976-77. The main dam is located about thirty-five kilometres west of Battambang city. It is six meters high and 1,900 meters long. The reservoir covers some 4,800 ha at the full design capacity of 110 MCM. It became shallower with an average depth of 2.5 meters. The water is used primarily for agriculture in the surrounding area of some 10,000 ha in rainy season and 5,500 ha in dry season.

Stung Sreng irrigation scheme is located in three districts: Chongkaldistrict of Oddar Meanchey, SreySnom district of Siem Reap, and Phnom Srok district of Banteay Meanchey. The total irrigated area of the scheme is 25,000 ha in rainy season for supplementary irrigation and 3,750 ha in dry season. The irrigation scheme is comprised in three phases. The first phase (2011-2015) focused on the construction of the irrigation canal. The second phase (2013-2018) was the construction of the reservoir of the storage capacity of 258 MCM for supplying water to the first phase. These two phases were funded by China's loan. The third phase is in the feasibility study stage of building 80 km long main canal to divert the irrigated water to over 15,000 ha of paddy field located between Samrong district and TrapaingThmor reservoir.

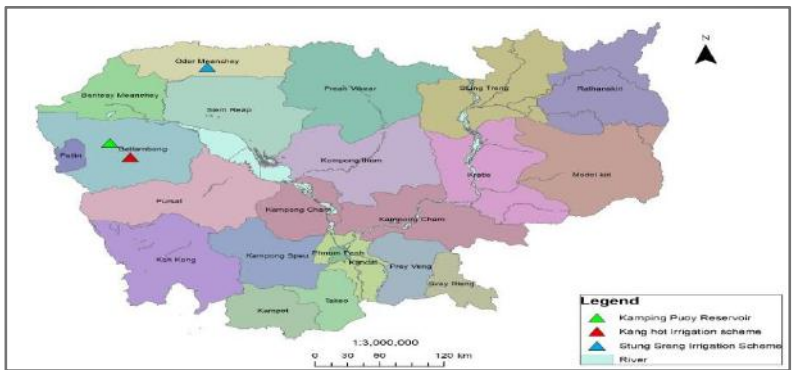

Figure 2. Locations of investigated irrigation schemes

5.5 2.2 Interview and Seminar

To understand and collate all the issues and challenges in irrigation sector in Cambodia, involvement from key stake holders was indispensable. Interviews with General Department of Technical Affair o`f MOWRAM and Unit of Agriculture, Rural Development, Infrastructure and Environment of AFD were arranged in order to conduct the survey on the issues and challenges in the irrigation projects under MOWRAM and ask for their opinion on their future action plan to overcome these challenges. MOWRAM is the main government agency involved in the irrigation sector responsible for irrigation water supply. AFD is a French development agency who has long history working on development of irrigation system in Cambodia. Following these interviews, a seminar on Development of Irrigation Design Standard was organized, with participation of key stakeholders: ITC, WHU, RUA, MOWRAM, DFAT, AFD, JICA, ADB, CAVAC, in order to confirm the idea from the interviews with MOWRAM and AFD. The results from the interviews were presented and discussed by the participants. More information and challenges were synthesized from participants' opinion.

6.5 2.3 Review of Existing Design Standard

Most of irrigation schemes in Cambodia were designed and built by Development Partners using broad range of foreign standards. The infrastructure of the scheme is similar to the existing schemes in other countries. Recently, most of the large-scale irrigation schemes in Cambodia were built with Chinese investment representing 70 percent of total investment by 2015. China has very detailed standards for the design of large-scale irrigation structures. USDA and FAO have rich background in irrigation in many countries in North Africa with similar climate condition to Cambodia. These standards address wide range of issues in irrigation. These three well-known irrigation standards in Cambodia: Chinese design standard for irrigation and drainage engineering (GB 50288-2018), FAO Irrigation and Drainage Paper sand Irrigation guide of USDA were reviewed in order to understand more deeply the range of application in Cambodian context.

3. RESULTS AND DISCUSSION

As the result of the investigation of the existing irrigation schemes and the seminar of the interview with the stakeholders, the challenges and issues in the irrigation in Cambodia were synthesized. The methods from the reviewed design standards that address these issues were raised and the possibility of adopting these were discussed.

7.5 3.1 Challenges and Issues in Irrigation Sector in Cambodia

The study shows that the challenges and issues in irrigation sector in Cambodia extend across wide range of aspects including engineering, environment, social and economic. Each aspect involves in different stage of the irrigation development project and need to be considered holistically.

Local data on crop pattern, soil properties and hydro-meteorology are very necessary parameters for the design. Crop water requirement is used to estimate the amount of water for the irrigated area. Crop coefficient K_c is an indispensable parameter for determining the crop water requirement. There is not much data or study in Cambodia about K_c for specific crop pattern in local climate and soil. The uncertainty of K_c value results in inaccurate crop water requirement in each growth stages of the crop as well as the total crop water requirement. This will affect the irrigation capacity of the irrigation scheme and the crop yield.

The hydro-met data is incomplete with the water data record less than 20 years old and the hydro-met network are still in poor condition. Lack of data on water limit the water resource monitoring and assessment for irrigation and other use and disaster prevention. Water shortage occurs in some part of the country in dry season while extensive flooding occurs in rainy season. Without proper water resource management, the water becomes an issue in both dry season and rainy season. As an example, the dam of KampingPouy irrigation scheme was severely damaged during the flood in October 2013. As another example, the power shortage occurred in April and May 2019 due to water shortage for supplying hydropower. Big cities like Phnom Penh and SiemReap experienced electricity blackout. Poor planning and decision-making process and lack of proper advance warning system were considered to be the cause of this damage.

The water demand for agriculture, industry, hydropower and domestic use are increasing from time to time. With the sparse distribution of reservoirs across the country, the water stored in rainy season will no longer be able to supply the demand in dry season. In this context, the water shortage in dry season will be the big issue in the very near future. Limited number of reservoirs, hydro-met data shortage and lack of integrated water resource management between reservoirs in each river basin are the challenges for holistic water resource management in Cambodia.

The national soil survey in 2002 showed that 28 percent of the country (5,000,000 ha) had high soil fertility, 19 percent (3,400,000 ha) had medium soil fertility and 53 percent (9,400,000 ha) had low soil fertility. Most of the fertile soil regions are located in alluvial floodplains around the Tonle Sap Lake and Mekong Delta River Basin Group (RBG) while most of the canal systems in Cambodia lie in the flood plain so that inundation of the scheme during flood season commonly occurs which results in damage to earth channel. Almost half of Cambodia's land is covered in sandy soils with low fertility and high permeability which drain rapidly after rainfall. With low water retention capacity, the nutrients are easily washed out of these soils which results in relatively high levels of chemical fertilization. Unlevelled soil is also an issue in soil fertilization. The plot of paddy field is relatively small due to small landholding size. The soil is mostly unlevel in each plot and the levels are different from plot to plot. As a result, the farmer spends more effort on regulating water level in the plot and the yield of paddy is 10 to 15 percent less than the yield of paddy in the level plot.

The design and construction of structural component of the irrigation system in Cambodia are based on the standards that the project consultant familiar with which means the quality of the irrigation project depends mainly on the knowledge and experience of the consultant. The quality control specification and site safety regulation for the construction of irrigation project are also prepared by the consultant in the absence of national guideline for quality control for construction. Without specific national guideline or standard for irrigation in Cambodia, it is difficult to evaluate the proposed design and the quality control specification of the consultant.

The road along the canal is an important part of the irritation projectthat allow the transportation of the agricultural product. Somehow, most of the road way alongside the main channels are not properly designed for the smooth transportation of the agricultural product and smooth connection to the existing infrastructure. Most part of the irrigation scheme infrastructures such as canal, bridge across the canal, road way along the canal and other concrete structures of the irrigation scheme can be found in the guideline of the Ministry of Public Works and Transportation. Somehow, consideration of these guideline cannot be found often in the irrigation project, leading to unsmooth integration between irrigation scheme to other existing infrastructure.

Kanghot is a very large scheme (over 60,000 ha for both wet and dry seasons), and a multipurpose dam is a major hydraulic structure. It requires a very strong and capable professional water management, skills and technology for proper planning, water allocation and operation, and the functional FWUCs to manage the branch and water distribution canals. Somehow, very limited number of PDOWRAM staffs have been assigned to run the main sluice gate and several kilometres of irrigation canal – each of them must run around 15,000 ha which is much more than the maximum requirement of 1,000 ha per staff. SteungSreng irrigation scheme, an even more complex and transboundary scheme, only around 10 PDOWRAM staffs have been assigned to run the scheme while there are totally 23 PDOWRAM staffs and contractual part-time staffs in Oddar Meanchey PDOWRAM. KampingPouy irrigation scheme also faces the same situation of understaffing and limited resources for operation of the scheme – financial, staff capacity, transportation and equipment. Insufficient functionality of many irrigation schemes can be attributed to lack of proper Management, Operation and Maintenance (MOM). MOM guideline relevant to the local practice and human resource required to maintain the sustainability of the irrigation schemeisin need.

8.5 3.2 Review of Chinese Design Standard for Irrigation and Drainage

2018 Chinese design standard for irrigation and drainage (GB 50288-2018) take into account many aspects of irrigation and water resource management that make it become more comprehensive compared to its previous version in 1999 (GB50288-99).

The version in 1999, named “Code for design of irrigation and drainage engineering”, includes 12 chapters, i.e. General provisions, Classification of engineering projects, Design criteria, General design, Water storage, diversion and lifting project, Irrigation water delivery system, Drainage system, On-farm projects, Structures for irrigation and drainage, Sprinkler and micro-sprinkler irrigation, Environmental monitoring and protection, and Ancillary engineering facilities. It covered all aspects of irrigation and drainage engineering design except structural design, and has been applied for new irrigation projects, and restoration and modernization of existing irrigation schemes in China nearly 20 years.

The new version was just issued in 2018 with a new title “Design standard for irrigation and drainage engineering”. The content of new version has 20 chapters, including General provisions, Terms, Classification of engineering projects, General design, Water sources projects, Irrigation canal (pipeline), Drainage ditches (pipeline), Basic rules for canal system structures, Aqueduct, Inverted siphon, Culvert, Hydraulic drop and steep slope, Flood discharging structures, Water gate, Tunnel, Agricultural bridge, On-farm projects, Monitoring, Information technology for irrigation districts and Management facilities. More attentions have been placed to hydraulic structures and information technology application for irrigation schemes compared with the version of 1999.

Chinese design standard for irrigation and drainage has the following special features: (1) taking the overall design of the irrigation drainage system as a whole, as well as the design of individual irrigation or drainage structures; (2) providing not only the conventional design content, i.e. water source engineering, water distribution channels, drainage ditch and border irrigation, furrow irrigation, etc., but also new technologies such as channel seepage prevention, pipeline water delivery and sprinkler irrigation, micro-irrigation and water saving technologies; (3) considering the requirements from environmental protection and information technology application of irrigation schemes, and the future modernization management.

China covers almost all climatic zones, from frigid to tropic zone, and there are large/medium-sized irrigation schemes located in each zone. Especially, rice cultivation areas are distributed across most of the country. Many large rice-based irrigation schemes from south of China, such as Guangdong and Guangxi Province, have similar climatic, topographic conditions to Cambodia, and constructed and operated based on the national design standard/code of irrigation and drainage engineering. The proven techniques and successful experiences of irrigation system design and operation from China will be an importance reference and guideline to Cambodia.

9.5 3.3 Review of USDA National Engineering Handbook

United States Department of Agriculture (USDA) National Engineering Handbook (NEH) is divided into parts covering various branch of engineering and technology. Among them, Part 624, 632 and 652 are devoted to irrigation and drainage engineering. NEH Part 652, “Irrigation Guide”, provides an overview of the irrigation engineering including the soil and crop characteristics, water requirement, design of various type of irrigation system and farm distribution components, project and farm irrigation water requirement and management, conservation management system and irrigation planning, economics evaluation, energy use and conservation, quality of water supply, environmental concern and resource planning and evaluation. Engineering, environment, social and economic aspect are considered in this handbook.

NEH Part 623 with title “Irrigation” provides detail technical aspect of irrigation engineering overviewed in NEH Part 652. The content of NEH Part 623 has eleven chapters including: Soil - Plant - Water Relationships, Irrigation Water Requirement, Planning Farm irrigation systems, Border Irrigation, Surface Irrigation, Furrow Irrigation, Contour-Levee Irrigation, Trickle Irrigation, Irrigation Pumping Plants, Water Measurement manual, Sprinkle Irrigation, and Land Leveling. Eight out of eleven chapters are devoted to irrigation water and irrigation methods while three remaining chapter are devoted to component of irrigation system and irrigated land.

NEH Part 624, “Drainage” is devoted to the drainage of agricultural land. The content of this handbook includes drainage investigation, surface and subsurface drainage, open ditches for drainage, dikes, drainage pumping, drainage of organic soil, drainage of tidal lands and water table control in humid area. This handbook details various types of drainage system for different area and soil type and design, construction and maintenance of the components of drainage systems are also considered.

NEH Part 624, 632 and 652 focus only on irrigation and drainage design. The detail of construction and structural design can be found in NEH Part 636, 641 and 646. NEH Part 636, “Structural Design” provide design philosophy for reinforced concrete, steel and wooden structures that can be usually found in structural component of the irrigation scheme such as gate, culvert, agricultural bridge, aqueduct and canal. NEH Part 641 focuses on drafting and drawing while NEH Part 646 focuses on construction inspection.

USDA National engineering handbooks address most of the challenges and issues in irrigation sector in Cambodia mentioned in Section 3.1. They take into account the whole aspect of irrigation and drainage system including irrigation and drainage design, structural design, construction, operation and maintenance, management and economic evaluation and environmental conservation. USDA handbooks cover not only irrigation and drainage engineering but also other disciplines related to water and environment such as hydrology, hydraulic engineering, environmental engineering

and soil engineering which are useful for the long-term development of irrigation standard considering adaptation of climate change and sustainable development. These multidisciplinary handbooks will be a necessary reference for the development of national design standard for irrigation and drainage.

10.5 3.4 Review on FAO Irrigation and Drainage Paper

FAO has developed many guidelines and programs in irrigation and drainage, named "FAO IRRIGATION AND DRAINAGE PAPERS" since 1971. Up to date, FAO has released the latest paper number 66 in 2012. Particularly in designing of irrigation and drainage, the papers includes all aspects such as designing and evaluating surface irrigation systems (Walker 1989), crop water requirement (Allen et al. 1998), Design and operation of irrigation systems for smallholder agriculture in South Asia (Mallampalli 2014), planning and design of land drainage systems (van der Molen et al. 2007), small earth dams (Stephens 2010), small hydraulic structure (Kraatz and Mahajan 1982), pressurized irrigation (Lamaddalena and Sagardoy 2000), Environmental impact assessment (Dougherty et al. 1995). The guidelines have been applied and adopted in various countries of the world.

NIPPON KOEI, JICA 2012 has proposed irrigation design manual, "Manual on Execution of preliminary feasibility study for small-scale irrigation project "with detailed irrigation system design frame work for MOWRAM. The manual is based on guidelines, manuals and reference books including "Design manual for small and medium scale irrigation system planning", April 2004, "Planning guidelines for rehabilitation and reconstruction of irrigation systems", March 2002, "handbook for incorporation of social dimensions in projects", ADB 1994, "Environmental impact assessment for developing countries", ADB 1997, "hydraulic gates and valves", 2001, "Design manual for hydraulic calculation of small scale irrigation canal", JICA and especially FAO irrigation design manual. For sustainable irrigation development, irrigation design standard should be developed by standardizing the sufficient data. Actually, the limited data is the constraint for irrigation standard development. Remarkably, the data should be quality-maintained.

3.5 Preliminary framework for Cambodian Standard

The preliminary framework of Cambodian standard for irrigation and drainage is the synthesis of the parts of the reviewed standards which is relevant to the local context. Base on the finding in terms of challenges and issues in irrigation sector, Cambodian design standard for irrigation and drainage should cover all stages of the irrigation project including Site Selection, Design, Construction and Operation and Maintenance.

To assure the efficiency and cost-effectiveness of the scheme and the social impact of the project the standard for site selection of the irrigation project should take into account the topography, soil type, water source, socio-economic and environment. The design standard should cover all components of the whole irrigation scheme, the basic data requirement for the design and cost-effectiveness analysis between construction cost and operation and maintenance cost. This part includes: Basic data requirement, Crop water requirement and water scheduling, Irrigation method (Border Irrigation, Surface Irrigation, Furrow Irrigation, Contour-Levee Irrigation, Trickle Irrigation Sprinkle Irrigation), Irrigation and drainage canal system, Hydraulic structures (Aqueduct, Inverted siphon, Culvert, Hydraulic drop and steep slope, Flood discharging structures, Water gate, Tunnel, Agricultural bridge), Dam and reservoir, Water measurement structure, Pumping Plant, Land levelling, Structural design criteria and Economic evaluation. The structural components of the irrigation scheme are not much different from other reinforced concrete and steel structures. The

general construction standard can be applied for the irrigation project; it includes: quality control construction material, guideline for drafting and drawing, construction inspection and site safety. For the sustainable and full functionality of the irrigation scheme, the standard for the operation and maintenance should include: Maintenance schedule and guideline, Management facilities, Monitoring system (safety monitoring, water quantity and water quality monitoring, environment monitoring), Hydro-met data stationandInformation technology for irrigation.

4. CONCLUSIONS

The study shows that the challenges and issues in irrigation sector in Cambodia can be summarized as following: limited soil, crop and hydro-met data increase of water demand and limited integrated water resource management; difficulty in evaluation of the proposed design and construction of irrigation scheme; lack of proper management, operation and maintenance; unsmooth integration between irrigation scheme and other existing infrastructure; unlevel ground and sandy soil and damage of earth canal in flood plain. From this result, it is clear that there is a need for Cambodian standard for irrigation and drainage which considers all stages of the irrigation project: Site Selection, Design, Construction and Operation and Maintenance.

Chinese standard GB 50288, USDA National Engineering Handbook and FAO Irrigation and Drainage Papers are comprehensive standards which cover many aspects of irrigation and drainage engineering. The preliminary framework of Cambodian standard is developed base on the content of these three standards and the common structures and issues of the local irrigation project in order to cover the whole aspects of the irrigation and drainage system in Cambodia. Even though Cambodian standard is the synthesis of these three standards, the whole framework cannot be automatically transferred from each of them. Parts of them can be directly adopted but others need to be modified to suit local condition base on the local data from the field experimental station and national data centre for hydro-meteorological data.

To avoid redundancy of the standards and to remain well prepare for the integrated infrastructure development, the standard for the structural design and construction of the structural component of the scheme and the standard for water quality and environment should be in harmony with the existing national standards or guideline of the Ministry of Public Works and transportation and the Ministry of Environment.This preliminary result provides main concept that is useful in designing the road map of development of Cambodian standard for irrigation and drainage.

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