COUNTRY ASSESSMENT REPORT FOR CAMBODIA

Strengthening of Hydrometeorological Services in Southeast Asia

ACKNOWLEDGMENTS

This Country Assessment Report for Cambodia is part of a study that aimed to strengthen the hydro-meteorological services in South East Asia. The production was a collaborative effort of the World Bank, the United Nations Office for Disaster Risk Reduction (UNISDR), the National Hydrological and Meteorological Services (NHMS) and the World Meteorological Organization (WMO) with financial support from the Global Facility for Disaster Reduction and Recovery (GFDRR).

The study investigated the capacity of the NHMS of five ASEAN Member States, namely Lao PDR, Cambodia, Indonesia, the Philippines and Viet Nam - to respond to the increasing demands for improved meteorological and hydrological information by various socio-economic sectors. Taking a regional approach, it recommended investment plans to improve the NHMS with the ultimate goal for reducing losses due to natural hazard-induced disasters, sustainable economic growth and abilities of the countries to respond to climate change.

The Department of Meteorology (DOM) under the Ministry of Water Resources and Meteorology (MOWRAM) supported the country assessment and coordinated the participation of various ministries and departments, including the National Committee for Disaster Management (NCDM), the Department of Hydraulic Work, MOWRAM, the Ministry of Agriculture, Forestry and Fisheries (MAFF), the Ministry of Industry and Energy (MIME), Ministry of Environment, Cambodia Red Cross and others, to provide information, particularly on the sector needs.

The Disaster Risk Reduction Division of the WMO provided technical inputs and facilitated peer review of the draft reports, which have resulted in significant quality improvements.

The final draft report was reviewed by concerned national agencies and DOM supported the report finalization.

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ACRONYMS

ADPC	Asian Disaster Preparedness Center
AusAID	Australian Agency for International Development
AWS	Automatic Weather Stations
CCCO	Cambodian Climate Change Office
CNMC	Cambodia National Mekong Committee
CRS	Cambodia Red Cross
DHRW	Department of Hydrology and River Works
DE	Department of Engineering
DIA	Department of Irrigated Agriculture
DOM	Department of Meteorology
DWRM&C	Department of Water Resource Management and Conservation
DWSS	Department of Water Supply and Sanitation
EAC	Electricity Authority of Cambodia
EdC	Electricity du Cambodge
EIA	Environmental Impact Assessment
EPL	Environmental Protection Law
GDP	Gross domestic product
GFDRR	Global Facility for Disaster Reduction and Recovery
GTS	Global Telecommunication System
IAH	International Association of Hydrologists (of UNESCO)
ITC	Technical Institute of Cambodia
IWRM	Integrated water resources management
JICA	Japan International Cooperation Agency
KOICA	Korea International Cooperation Agency
LDC	Least Developed Countries
MAAF	Ministry of Agriculture, Forestry and Fishery
MIME	Ministry of Industry and Energy
MLSW	Ministry of Labour and Social Welfare
MRC-Hycos	Mekong River Commission Hydrological Cycle Observation System
MOE	Ministry of Environment
MOWRAM	Ministry of Water Resources and Meteorology
MPWT	Ministry of Public Works and Transport
MRC	Mekong River Commission
MTSAT	Meteorological Satellite
NAPA	National Adaptation Programme of Action
NCCC	National Climate Change Committee
NCDM	National Committee Disaster Management
NMHS	National Meteorological and Hydrological Services
NWP	Numerical weather prediction
NWRMC	National Inter-ministerial Water Resources Management Committee
OFDA	US Office of Foreign Disaster Assistance
PDWRAM	Provincial Department of Water Resource and Meteorology
RCAF	Royal Cambodian Armed Forces
RFMMC	Regional Flood Management and Mitigation Centre (of MRC)
SEA	Southeast Asia
UNFCCC	United Nations Convention on Climate Change
UNISDR	United Nations Office for Disaster Risk Reduction
USAID	United States Agency for International Development
WB	The World Bank
WIS	WMO Information System
WMO	World Meteorological Organization

The role of hydro-meteorological services

All human activities are linked to weather and climate. As a matter of fact, various economic sectors have started to appreciate the value of weather forecasts due to worsening impacts of hydrometeorological related hazards as a result of changing weather patterns. The extreme events that were experienced in recent years are precursors of the impacts of a changing climate. With climate change, the impacts will exacerbate and will continuously affect all sectors in unprecedented ways, particularly in many areas where water is a limited resource. On the other hand, tropical cyclones can generate extreme rainfall event resulting to catastrophic flooding. The attendant weather extremes manifested in floods and droughts considerably decrease agricultural productivity and aquaculture. Accelerated sea level rise will expose more people to the risk of coastal flooding while increased exposure to vector-borne infectious diseases and heat stress will threaten human health. Moreover, tourism which is an important source of income would be affected by severe disruption from climate change and sea level rise.

As more weather extremes start to unfold, demand for more accurate, timely and effective weather forecasts and climate prediction at all time scales and other crucial information will be sought for the human safety and well being and for planning. Hence, national meteorological and hydrological services (NMHS) will need to expand to meet the emerging needs of the various economic sectors.

To achieve or address such demand, it is urgent to put in place or enhance the very basic requirements for an NMHS to function effectively: 1) adequate networks to monitor hydrometeorological parameters; 2) a robust communication system for data transmission, disseminate of forecasts and sharing of information; 3) high speed computing system for data assimilation and ensemble forecasting; 4) human resource equipped with appropriate trainings; and 5) more interaction with users of weather and climate information. But the transboundary nature of weather-causing phenomena would require collaboration among NMHS in the region; hence there is now an urgent need to enhance regional cooperation and data sharing which is currently being undertaken by the World Meteorological Organization (WMO) through its WMO Information System (WIS).

Assessment of needs of improved hydrometeorological services in Cambodia

In its current capacity, the Department of Meteorology (DOM) is mandated to provide the basic services needed for disaster risk reduction in Cambodia. It has recently undergone a major change in leadership. After some internal administrative problems, the new acting Director is making his best effort to cope with the challenges facing the department. Compared to other countries in the region, DOM is lagging behind in terms of equipment and forecasting technologies such as numerical weather and climate modeling as well as human resources and institutional capacity. It has a research and development unit but it does not work on the advancement of their services. With its current state of physical and human resources, it cannot cope with the increasing demand from different socio-economic sectors.

After the Typhoon Ketsana that hit Cambodia in 2009, DOM faces a great challenge to improve on its tropical cyclone forecasting. All sectors of the society were seriously affected by the typhoon, leading to a massive rehabilitation program. Assistance from foreign donors came in. However, the upgrading of DOM's capabilities was not given due consideration in the rehabilitation program. Accurate and advance forecast of the cyclone's track could have saved lives and properties. Advance warning would enable the people to move to safer grounds and make precautionary measures. There are large spatial, temporal and parameters data gaps for effective integrated water resource development and planning as well. This study hopes to highlight the importance of DOM's services.

There is the lack of knowledge of the available hydrometeorological services in more economically advanced countries and the possibilities to produce more end-user specific services have not been well recognized by most of the socio-economic sectors in Cambodia. Also the sectors have not yet appreciated the importance of hydrometeorological services for the improvement of their production and productivity. It seems that DOM is performing its task as a separate entity and not linked with the other sectors. The DOM has no annual budget. It has no program to network or link with the end users and stakeholders of weather services. It does not have a well defined linkage with many of the potential users of hydrometeorological services despite the increasing need and potential market for improved meteorological services especially after the passage of Tropical Cyclone Ketsana. There is a need to increase dialogue and partnerships between DOM and the socio-economic sectors. This gap on communication and cooperation with the stakeholders and users of weather and climate information should therefore be reduced if not eliminated. This would yield better services and obviously also promote private sector participation to invest in the establishment or enhancement of meteorological observation network.

National set-up for production of hydro-meteorological services in Cambodia

The DOM is under the Ministry of Water Resources and Meteorology (MOWRAM) which is mandated to provide weather services for Cambodia. It is responsible for the operation and maintenance of all the meteorological observation and measurements, issuance of weather forecasts and severe weather warnings all over the country. It provides weather services to aviation and land transportation, agriculture and other sectors. It plays a vital role in disaster management being a member of the National Committee for Disaster Management (NCDM) to assist in decision making for taking prompt actions toward hydro-meteorological induced disasters. It assists the National Climate Change Committee (NCCC) by providing climatological information particularly for climate change projections.

The local visibility of the DOM to the public and in the science community is poor. MOWRAM and DOM officials should exert efforts to communicate with the media to publicize their services. Currently, DOM has no website to publish its activities and services to the public. DOM's activities are mostly confined to provision of weather forecasts and meteorological data to other sectors and provision of lectures. Collaborative projects with other government agencies like the Ministry of Environment (MOE), Ministry of Agriculture, Forestry and Fisheries (MAFF), etc. should be enhanced. Most importantly, the DOM should work closely with the Department of Hydrology and River Works (DHRW), also under MOWRAM to expand flood forecasting currently covers only three days forecast for five stations along the Mekong mainstream to cover vulnerable areas on major tributaries.

The Kingdom of Cambodia, as an agrarian country, is highly vulnerable to the impacts of extreme climate events. It is vulnerable to weather and water related hazards as more than 80 percent of its population is subsistence farmers. Adverse impacts are already being felt and these include increased flood and drought damages, reduction in crop yields, decrease water availability and increase in the number of people exposed to vector and water-borne diseases. Based on data from the past five years, Cambodia's paddy production was destroyed by as much as 70 percent by floods, and 20 percent and 10 percent, respectively by droughts and diseases. The recent strong typhoon Ketsana was a manifestation of a severe weather event that devastated the country. It is therefore important to upgrade the capabilities of the DOM and DHRW to provide quality products and services such as timely and accurate forecasts and warnings.

The Department of Hydrology and River Works (DHRW) is responsible for hydrological services in Cambodia. It maintains and monitors hydrological stations along the rivers systems of Cambodia particularly the major rivers of Mekong, Bassac and Tonle Sap. It provides three days water level and flood forecasting for seven stations along the Mekong-Tonle Sap- Bassac rives using simple regression models.

In order to cope up with the growing demand for hydrometeorological information/services and the fast technological advancement, automation in the DOM is a necessity. It is therefore critical that there is a national vision, development plan and strategy to improve the network of monitoring and production of weather and climate services in order to meet the basic need of environment protection through the provision of accurate weather forecasts.

State of affairs of the DOM

Compared to most of the NMHSs in the Southeast Asian countries, DOM has relatively limited technical, human and financial resources to carry out its mission. Its observation network, production system and its current financial resources are not adequate to ensure the expected quantity and quality of data to meet the rapidly growing needs of global and regional weather forecasting, early warning systems for natural hazards, and of national public and ifferent socio-economic sectors.

The DOM is one of the six technical departments of the MOWRAM, which is mandated to install and manage the weather monitoring network throughout Cambodia; monitor weather condition happening in the region; and issue weather forecast and provide warning on weather condition to relevant ministries and public via media. In dealing with hydrometeorological hazards, DOM partners with the DHRW, which is responsible for flood forecasting and warning. As regards to its duties and responsibilities, DOM has special relationships and responsibilities with several ministries and state bodies such as Ministry of Environment, Ministry of Agriculture Forestry and Fishery, National Committee for Disaster Management, Ministry of Public Works and Transport (MPWT), Ministry of Labor and Social Welfare (MLSW), Ministry of Industry, Mines and Energy (MIME), and the Cambodian Red Cross (CRS).

The DOM is headed by a Director who reports directly to the Minister. It is composed of six offices namely: Administrative Office, Observation Office, Equipment Office, Forecasts and Researches Office, and Climate Office and Hydrometeorological Office.

In each of the 24 provinces and municipalities, the Hydrometeorological Offices are established under the Provincial Department of Water Resource and Meteorology (PDWRAM). The DOM's head-quarters is presently housed at the ground floor of a new 3-storey building of MOWRAM located and at the Doppler Radar building at M.V. Preah Monivong, Phnom Penh, Cambodia.

DOM employs a total of 44 staff at the Headquarters in Phnom Penh distributed in 5 offices: Administration = 5, Observation = 10, Research and Forecasting = 9, Climate = 9, and Equipment Management = 9. There are 34 males and 10 females. Five staffs are trained as professional meteorologists (with bachelor or master degree) other three undergraduates were trained in other disciplines, and 35 technicians. All the Master's Degree holders obtained their diploma from Russian universities through scholarship grants and the engineers and Bachelor Degree holders from Belgium, Viet Nam, Russia some twenty years ago and Cambodia (technicians meteorolo-gists CL3). There are only one or two technicians meteorologists or hydrologists in some of the Provincial Hydrometeorological offices, totaling only 13 staffs, retired staffs are not replaced. DOM has recently recruited five IT staffs to handle the technical requirements of the newly installed Doppler rainfall radar. There is a big gap to fill in terms of the personnel complement of DOM. There is a need to increase the number of staff with higher academic education (MSc and PhD), employ more young technical staff and promote the retention of the newly recruited IT staff.

The DOM's observation network in its current status is not capable of providing high quality information and services to the people. In the as-sessment made by the Asian Disaster Preparedness Center (ADPC) of the 13 surface meteorological observatories in Cambodia in July 2007, all the observatories are reported to be in primitive stage. Observed data consists mainly of temperature and rainfall. Other instruments i.e. cup anemometers, barographs, are not working. The main constrains in the observation and monitoring network are the lack of automatic meteorological stations (some 10 automatic weather stations installed between 2001 and 2002 are no more operational), no upper-air observing station, the new weather radar could still not effectively operated and lack fast and modern telecommunication system. Moreover, DOM is not running any NWP models resulting to the low accuracy of the forecasts.

The Government is exerting efforts to upgrade the capability of DOM. The provision of new headquarters office[1] is a proof to this. There have also been some significant changes related to hydrometeorological network development and management in Cambodia. In terms of meteorological equipment, the Asian Disaster Preparedness Center (ADPC) provided 10 sets of semi-automatic weather stations in 2009. Nevertheless, these stations have not been installed due to lack of funds and expertise.

In 2012, MOWRAM installed and put into operation under the government budget a Doopler Rainfall radar (C band), which is expected to improve weather and rainfall forecasting. However, it is still facing with many difficulties, mainly the lack of experience and dedicated meteorologist to operate the system including conversion software.

The DOM is negotiating for the provision of 24 Automatic Weather Stations (AWS) to be installed at each of the province/municipalities, including training.

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[1] *It is to be noted that the DOM new office building includes office space in the new radar tower is merely office space. As a technical service, the DOM needs more space as store room, for calibration and maintenance of equipment that are yet available at the current location. For activities expansion, DOM would need space for upper air station, national standard synoptic/ agro-meteorological stations, training facilities etc. The new site of the Pochentong (relocated station) must be carefully planned.*

For hydrology, the Mekong River Commission Hydrological Cycle Observation System (MRC-Hycos) is under discussion for its extension. In terms of policy and institutional reform, the ADB in collaboration with a number of donors is financing the capacity technical assistance by providing specialist support to MOWRAM to:

i. Develop its capacity to manage water resources through strengthening the strategy, policy and legal framework for integrated water resources management (IWRM);
ii. Improve coordination and cooperation with other ministries and agencies, and at the river basin level; and
iii. Strengthen MOWRAM's technical capacity to promote IWRM and climate change adaptation; and develop human resources capacity.

Component (ii) will establish the National Inter-ministerial Water Resources Management Committee (NWRMC) and component (iii) intends to support the training of some 300 water resources engineers in collaboration with the Technical Institute of Cambodia (ITC) in the next five years and the strengthening the capacity of MOWRAM in climate change policy and strategy. DOM and DHRW should in the same way try to plan and train their new staffs to enable them to deliver expected services.

The Government cannot fully support all the financial requirements of DOM to produce increased and improved hydrometeorological services to support economic growth and the safety and wellbeing of the citizens. As a Least Developed Country (LDC), Cambodia has been striving for DOM's enhancement through bilateral cooperation schemes. For instance, the grant assistance from the Government of Japan facilitated the transfer of knowledge and upgraded facilities, resulting in better forecasts. This also included the re-installation of the MTSAT in the new building and retraining of DOM's staff. Regional and international initiatives on disaster risk management are being implemented. Donors include World Bank, AusAID, UNDP, ADPC, among others. International support to DOM and other NMHSs in the SEA countries is a must to provide an opportunity to enhance the hydrometeorological measurements and services in Cambodia and in the region to a level sufficient to meet the national and regional needs for sustainable development of DOM and other NMHSs. However, on the contrary to DHRW, the DOM has never received a project but only some patchy technical assistance on an ad-hoc basis. It does not even have vehicles for field works such as station installation and inspections.

Project proposal to strengthen the DOM

To strengthen DOM and DHRW institutional and human capacity, a medium to long term plan is required to fill in the significant professional generation gaps of some twenty years and shortage of qualified staffs at all level as well as lack of leadership. This might need up to twenty years.

The first five years would be to focus on the restructuration planning of the DOM and DHRW in line with the Policy and Institutional Reform and Capacity Development in Water Sector of the MOWRAM. In this period, to enhance the capability of DOM as a warning institution for hydrometeorological hazards, it is proposed to upgrade its physical and human resources. It needs to upgrade the 12 synoptic stations and manual or analogue instruments be replaced with automatic observation system[2]. An upper-air observation station, one radar facility[3] and about 3 lightning detectors[4] should

[2] *JICA has proposed the provision of new AWS including training. The 10 semi-automatic stations provided by ADPC must also be installed immediately.*

[3] *The installed Doppler radar must be put to work more effectively requiring extra software and training as well as incentive to retain staff.*

[4] *Are essentials to make Doppler radar more effectively by detecting rainstorm activities*

also be established for better assessment of the vertical structure of the atmosphere especially during occurrence of tropical cyclones and deep mesoscale convective systems such thunderstorms and tornadoes. Composite radar images from all radar equipment from the neighbouring countries should be utilized through stronger regional cooperation. Advanced telecommunication system is necessary for the transmission of data from field stations and for fast dissemination of forecasts and warnings to the public and other end-users. A website should also be developed to make the weather forecasts readily available to the public. DOM needs to hone the skills of its human resources through the conduct of specialized and highly technical training courses to keep abreast with the fast pace of technology.

Climate change is another challenge for Cambodia. In addition to the increased reliability and timely weather forecasting and dissemination, information is also required for the grass root level to understand and adapt to the imminent foreseen impacts of climate change. Rainfall data collection is far from being adequate for flood/drought forecasting as well as medium to long term water availability in each of the sub-basin. The DOM and DHRW must review, upgrade and expand the national rainfall network at least to cover half of the country 1620 communes. A total of 800 manual raingauges are proposed to be installed in 800 communes to be the asset of the communes that can report near real time data for flood/drought forecasting for each of the major sub-basin in the country. This also includes the existing raingauges that need complete review.

Investment plan

The proposed project is designed to enable the DOM to provide reliable, timely, and accurate forecasts and warnings on weather related hazards for the safety and well being of the people and to promote the economic growth of Cambodia. This can be achieved through upgrading and modernization of the facilities, capacity building and establishment of a strong research and development arm. This entails a significant investment particularly on the automation of the meteorological observing network including telecommunication facilities and other equipment. Investment will be reduced if cooperation with other Asian countries is strengthened through data sharing and training on compositing of all radar data and images available in the region. Joint projects on climate change and other global issues could also be considered to promote cooperation. Scholarship grants from international funding institutions can also reduce the required investment.

An investment plan is designed which includes funding for operation and maintenance cost during the implementation of the project. Two options for investment are proposed:

A) Strengthening of NHMS as “Stand-alone system”,
B) Planning and implementing the strengthening as part of the cooperative project.

CAMBODIA	A (USD)	B (USD)
International cooperation of experts	200,000	100,000
Communication systems		
- Hardware + software	600,000	600,000
IT Center		
- Hardware	150,000	150,000
- Consulting	50,000	50,000
Data management		
- Hardware and installation	610,000	610,000
- Storage 30 TB	125,000	125,000
- Consultation and training	100,000	50,000
Meteorological observation network [5]		
- 24 Automatic Weather Stations (AWS) and training	6,309,590	6,309,590
- Installation of manual and rehabilitation of existing raingauges [6]	400,000	400,000
- Installation of 10 Semi-automatic weather stations [7]	10,220	10,220
Hydrological observation network		
- Automatic hydrological stations	550,000	550,000
- Data communication + maintenance	110,000	110,000
Remote sensing network		
- Upper air observations	445,000	445,000
- Upper-air operation and maintenance (5 years)	1,000,000	1,000,000
- New weather radars (including towers)	6,200,000	2,050,000
- Lightning detection	10,500	10,500
- Satellite receiving station	135,000	135,000
Calibration and maintenance	100,000	75,000
Forecasting and manufacturing tools		
- Visualization system	400,000	400,000
- Training	20,000	10,000
Capacity Building		
- Training of forecasters, technicians and IT staff	100,000	50,000
- Formal training of professional staff [8]	2,500,000	2,500,000
Research and development		
- Impacts of climate change	100,000	50,000
- Socio economic impacts	100,000	50,000
- National seminar on socio-economic benefits	100,000	100,000
- End-user seminar	75,000	20,000
- Website	50,000	30,000
Project management		
- Consultant	200,000	100,000
- Local project coordinator	100,000	100,000
Total	20,740,310	16,080,310

5 *These include (i) the 24 AWS proposed by JICA (Table 14.2) and the 800 near real time manual raingauges.*

6 *Existing rainfall station networks is in a very bad shapes since there was no systematic inspection, maintenance and repair as well as station history records and documentation*

7 *There were some 10 semi automatic weather stations provided by ADPC that are not yet installed due to lack of funds and technical capacity*

8 *Since the last 20 years there were no single staffs trained in Hydrology and Meteorology. The impact of investment in equipment will be minimal with declined number of well trained staffs (retirement and leaving for other better paid jobs)*

It should be noted that the proposed investment plan has changed from the first draft, proposed by the consultant as the result of a national workshop to review the draft report. The changes include: adding the proposed installation of the 24 AWS by JICA (US$ 6,309,590), the cost to install and make operational the 10 semi-automatic weather stations (US$ 10,220) and the installation of manual and rehabilitation of existing raingauges. Specifically, a long-term professional training totaling US$ 2,500,000 was also added, recognizing the urgent and challenging task to build technical human resources.

Economic value of weather forecasts and hydro-meteorological services in Cambodia

For the stand alone option, the results of the computations show that using a 10 percent reduction in damages as a measure of benefits, the total costs of NMHS improvements are $20.74 million, discounted total benefits are $24.98 million, discounted net benefits are $4.24 million and C/B ratio is 1:1.20.

For a regional integration option, the results of the computations show that using a 10 percent reduction in damages as a measure of benefits, the total costs of NMHS improvements are $16.08 million, discounted total benefits are $24.98 million, discounted net benefits are $8.90 million and C/B ratio is 1:1.55.

Table 1 Options, Costs, Discounted Total Benefits, Discounted Net Benefits and Cost-Benefit ratios for improvements in NMHS in Cambodia, 2010-2029

Option	Total Costs (Million US$)	Discounted Total Benefits (Million US$)	Discounted Net Benefits (Million US$)	Cost/benefit Ratio (C/B)
Stand alone	20.74	24.98	4.24	1:1.20
With regional cooperation	16.08	24.98	8.90	1:1.55

In retrospect, the following are the main findings of the computations done for Cambodia:

- The discounted net benefits due to the improvements in the NMHS of Cambodia, based even only on the decrease in damages due to the improvements, are high and more than enough to pay for the cost of improvements;
- The C/B ratios based on the actual costs of NMHS improvements and the discounted values of the total benefits from the improvements, however, are inferior to the 1:7 ratio set by the WMO;
- The C/B ratio for the system with regional integration are better than the ratio for the stand alone system which implies that being more efficient the former system is also more desirable; and
- The C/B ratios would improve further if the indirect benefits of the NMHS improvements, productivity gains in the economy and the benefits beyond 2029 are included in the computation of benefits.

Environmental impacts of enhancement of the observation network

Automation of observation network does not produce harmful effects on the environment. The only activity that relates to this is the operation of upper-air observation and weather radars. The upper-air observation involves tracking of a pilot weather balloon in the atmosphere through an attached transmitter. Weather radars emit radioactive waves which is a threat to public health hence they must be located over remote and high areas.

Financing of the proposed project

Funds for the implementation of the project will be a big burden for DOM hence out sourcing is necessary. Foreign donors such as JICA, KOICA, USAID, AusAID or World Bank could be tapped. Assistance from neighboring countries who will be sharing the data and the products should also be sought.

CAMBODIA IN A NUTSHELL

1

The following data and information presented in the following sections are mainly taken from the World Factbook of the Central Intelligence Agency, USA.

Cambodia is generally populated by Khmers who are the descendants of the Angkor Empire that extended over much of Southeast Asia and reached its peak during the 10th to the 13th centuries. After the Japanese occupation in World War II, Cambodia gained full independence from France in 1953. In 1975, Communist Khmer Rouge forces took over Cambodia but were later driven out by Vietnamese invasion in 1978. About 13 years of civil war followed. In 1991, the Paris Peace Accords was negotiated which mandated democratic elections. Elections were held first held in 1993 followed by a second one in 1998 and a third one in 2003. These elections led to coalition governments which were initially stable but later on became more cohesive. In 2004, King Norodom Sihanouk abdicated the throne and his son, Prince Norodom Sihamoni succeeded. Local elections were held in Cambodia in 2007 while national elections were conducted in 2008 both of which were relatively peaceful compared to previous ones.

1.1 General Description

Cambodia is located on mainland Southeast Asia between Thailand to the west and north and Viet Nam to the east and southeast. It shares a land border with Laos in the northeast. Cambodia has a sea coast on the Gulf of Thailand. The Dangrek mountain range in the north and Cardamom Mountains in the southwest forms natural boundaries. Principal physical features include the Tonle Sap Lake and the Mekong and Bassac Rivers. Cambodia remains one of the most heavily forested countries in the region, although deforestation continues at an alarming rate.

Figure 1.1 Geographical location of Cambodia (www.state.gov/r/pa/ei/bgn/2748.htm)

Ninety percent of Cambodia's population is ethnically Cambodian. Other ethnic groups include Chinese, Vietnamese, hill tribes, Cham, and Lao. Theravada Buddhism is the religion of 95% of the population; Islam, animism, and Christianity also are practiced. Khmer is the official language and is spoken by more than 95% of the population. Some French is still spoken in urban areas, and English is increasingly popular as a second language.

Geography and land Use

- Location: Southeastern Asia, bordering the Gulf of Thailand, between Thailand, Vietnam, and Laos
- Total area: 181,035 sq km; land area: 176,515 sq km; water area: 4,520 sq km
- Total land boundaries: 2, 572 km
- Coastline: 443 km
- Maritime claims: territorial sea-12 nm; contiguous zone-24 nm; exclusive economic zone-200 nm; continental shelf-200 nm
- Climate: tropical climate; rainy, monsoon season (May to November); dry season (December to April); little seasonal temperature variation
- Terrain: mostly low, flat plains; mountains in the southwest and north
- Elevation extremes: lowest point-Gulf of Thailand; highest point-Phnom Oral 1,810 m
- Land use: arable land-20.44%; permanent crops-0.59%; other-78.97% (2005)
- Irrigated land: 2,700 sq km (2003)
- Total renewable water resources: 476.1 cu km (1999)
- Freshwater withdrawal (domestic/industrial/agricultural): total-4.08 cu km/yr (1%/0%/98%); per capita-290 cu m/yr (2000)
- Natural hazards: monsoonal rains (June to November); flooding; occasional droughts
- Environment-current issues: illegal logging activities and strip mining have resulted in habitat loss and declining biodiversity; soil erosion; in rural areas, low or no access to potable water; declining fish stocks because of illegal fishing and overfishing

People

- Nationality:
  Noun and adjective--Cambodian(s), Khmer.
- Population: 14,494,293
- Life expectancy at birth, total population: 62.1 years
- Avg. annual growth rate (2008 census)1.54%.
- Ethnic groups: Khmer 90%, Vietnamese 5%, Chinese 1%, other 4%, small numbers of hill tribes, Cham, and Lao.
- Languages: Khmer (official) 95%, French, English Literacy (definition: age 15 and over can read and write): total population-73.6%
- Religions: Theravada Buddhism 95%; Islam; animism; Christian.
- Education: Years compulsory--nine years. Enrolment--primary school, 94.4%; grades 7 to 9, 33.9%; grades 10 to 12, 16.4%; and tertiary, 2.8%. Completion rates--primary school, 85.58%; lower secondary school, 49.05%; upper secondary school, 20.58%; university, 6%. Literacy (total population over 15 that can read and write, 2007)--75.1% (male approx. 85%; female approx. 64%).

Government

- Government type: multiparty democracy under a constitutional monarchy
- Capital: Phnom Penh
- Administrative divisions: 23 provinces and one municipality (Phnom Penh)
- Independence: November 9, 1953.
- Constitution: September 24, 1993; amended March 6, 1999 and March 2, 2006.
- Branches: Executive--King Sihamony (head of state since October 29, 2004), prime minister (Hun Sen since January 14, 1985), ten deputy prime ministers, 16 senior ministers, 26 ministers, 206 secretaries of state, and 205 undersecretaries of state. Legislative--National Assembly, consisting of 123 elected members; Senate, consisting of 61 members. Judicial--Supreme Court and lower courts.

Administrative subdivisions: 23 provinces and 1 capital municipality.

- Political parties and leaders: Ruling parties--A coalition government of the Cambodian People's Party (CPP), led by Samdech Chea Sim; and the National United Front for an Independent, Neutral, Peaceful, and Cooperative Cambodia (FUNCINPEC), led by Keo Puth Reasmey. Norodom Ranariddh Party representatives will serve out their term in parliament but announced in June 2009 their renaming as the Nationalist Party, which plans to join in a coalition with FUNCINPEC prior to 2012 commune elections. Opposition parties--The Sam Rainsy Party (SRP), led by Sam Rainsy; Human Rights Party, led by Kem Sokha.

Transnational issues

- Cambodia and Thailand land border dispute: Thailand accuses Cambodia of obstructing inclusion of Thai areas near Preah Vihear temple ruins, awarded to Cambodia by ICJ decision in 1962, as part of a planned UN World Heritage site; dispute over sovereignty over offshore islands with Vietnam

1.2 Economy-overview

From 2004 to 2007, the economy of Cambodia grew about 10% per year, driven largely by an expansion in the garment sector, construction, agriculture, and tourism. Growth dropped to below 7% in 2008 as a result of the global economic slowdown. With the January 2005 expiration of a WTO Agreement on Textiles and Clothing, Cambodian textile producers were forced to compete directly with lower-priced countries such as China, India, Viet Nam, and Bangladesh. The garment industry currently employs more than 320,000 people and contributes more than 85% of Cambodia's exports. In 2005, exploitable oil deposits were found beneath Cambodia's territorial waters, representing a new revenue stream for the government if commercial extraction begins. Mining also is attracting significant investor interest, particularly in the northern parts of the country. Rubber exports declined more than 15% in 2008 due to falling world market prices. The tourism industry has continued to grow rapidly, with foreign arrivals exceeding 2 million per year in 2007-08. The global financial crisis is weakening demand for Cambodian exports, and construction is declining due to a shortage of credit.

The GDP growth performance of the country significantly decreased from 10.2 percent in 2007 to 5.2 percent in 2008 which was directly attributable to the prevailing global financial crisis. Other economic indicators are as follows:

Gross Domestic Product

- GDP (purchasing power parity): $27.92 billion (2009 est.)
- GDP (official exchange rate): $10.9 billion (2009 est.)
- GDP – growth: -1.5% (2009 est.)
- GDP - per capita (PPP): $1,900 (2009 est.)
- GDP - composition by sector
  - agriculture: 29%
  - industry: 30%
  - services: 41% (2007 est.)
- Budget:
  - revenues: $1.186 billion
  - expenditures: $1.748 billion (2009 est.)

Labor market

- Labor force: 8.6 million (2008 est.)
- Labor force - by occupation
  - agriculture: 75%
  - industry: NA%
  - services: NA% (2004 est.)
- Unemployment rate: 3.5% (2007 est.)
- Population below poverty line: 35% (2004)
- Agriculture - products: rice, rubber, corn, vegetables, cashews, tapioca, silk
- Industries: tourism, garments, construction, rice milling, fishing, wood and wood products, rubber, cement, gem mining, textiles
- Industrial production growth rate: -6.5% (2009 est.)

Energy

- Electricity
  - production: 1.273 billion kWh (2007 est.)
  - consumption: 1.272 billion kWh (2007 est.)
  - exports: 0 kWh (2008 est.)
  - imports: 167 million kWh (2007 est.)
- Oil
  - production: 0 bbl/day (2008 est.)
  - consumption: 4,000 bbl/day (2008 est.)
  - proved reserves: 0 bbl (1 January 2009 est.)
- Natural gas
  - production: 0 cu m (2008 est.)
  - consumption: 0 cu m (2008 est.)
  - exports: 0 cu m (2008 est.)
  - imports: 0 cu m (2008 est.
  - proved reserves: 0 cu m (1 January 2009 est.)

Exports and imports

- Exports - commodities: clothing, timber, rubber, rice, fish, tobacco, footwear
- Exports – partners: US 54.5%, Germany 7.7%, Canada 5.9%, UK 5.5%, Vietnam 4.5% (2008)
- Imports – commodities: petroleum products, cigarettes, gold, construction materials, machinery, motor vehicles, pharmaceutical products
- Imports – partners: Thailand 27.1%, Vietnam 19.2%, China 14.7%, Hong Kong 8.2%, Singapore 7%, Taiwan 5.6% (2008)
- Natural resources: oil and gas, timber, gemstones, iron ore, manganese, phosphates, hydropower potential

Reserve, Debt, Aid

- Reserves of foreign exchange and gold: $2.951 billion (31 December 2009 est.)
- Debt - external: $4.157 billion (31 December 2009 est.)

Communications

- Telephones - main lines in use: 45,100 (2008)
- Telephones - mobile cellular: 4.237 million (2008)
- Radio broadcast stations: AM 1, FM 50, shortwave NA (2008)
- Television broadcast stations: 9 (including 2 TV relay stations with French and Vietnamese broadcasts); excludes 18 regional relay stations (2009)
- Internet hosts: 2,480 (2009)
- Internet users: 74,000 (2008)

Transportation

- Airports - with paved runways
  - total: 6
  - 2,438 to 3,047 m: 3
  - 1,524 to 2,437 m: 2
  - 914 to 1,523 m: 1 (2009)
- Airports - with unpaved runways
  - total: 11
  - 1,524 to 2,437 m: 1
  - 914 to 1,523 m: 9
  - under 914 m: 1 (2009)
- Heliports: 1 (2009)
- Railways, total: 602 km
  - narrow gauge: 8,529 km 1.067-m gauge (565 km electrified) (2008)
- Roadways: 38,093 km
  - paved: 2,977 km
  - unpaved: 35,116 km (2007)
- Waterways: 2,400 km (mainly on Mekong River) (2008)
- Merchant marine: total – 626; by type: bulk carrier 41, cargo 530, carrier 3, chemical tanker 10, container 8, passenger/cargo 6, petroleum tanker 11, refrigerated cargo 15, roll on/roll off 1, vehicle carrier 1; foreign-owned: 467 (Canada 2, China 193, Cyprus 7, Egypt 13, Gabon 1, Greece 3, Hong Kong 8, Indonesia 2, Japan 1, South Korea 22, Latvia 1, Lebanon 8, Netherlands 1, Romania 1, Russia 83, Singapore 4, Syria 48, Taiwan 1, Turkey 26, Ukraine 34, UAE 2, US 6) (2008)
- Ports and terminals: Phnom Penh, Kampong Saom (Sihanoukville)

SOCIO-ECONOMIC BENEFITS OF HYDRO-METEOROLOGICAL SERVICES

2

2.1 Weather and climate-dependent economic sectors

Of the weather and climate-dependent economic sectors of Cambodia, manufacturing and agriculture have been the most dominant contributors to the national economy. In 2007, these sectors contributed 20.5 percent and 18.1 percent to the GDP respectively (Table 2.1). In totality the weather and climate-dependent economic sectors contributed 65.4 percent to the GDP in the same year. Because of this large contribution, improvements in the NMHS that would reduce the damages due to weather and climate-related natural disasters will have significant impacts on the overall economy.

Table 2.1 Percent share of value added by weather and climate-dependent economic sector to Gross Domestic Product at 1990 constant prices of the Cambodia, 2000-2007

Sector	2000	2001	2002	2003	2004	2005	2006	2007
Agriculture, hunting and related service activities	21.7	20.7	18.7	20.2	18.2	19.5	18.7	18.1
Forestry, logging and related service activities	3.5	3.2	2.9	2.6	2.3	2.2	2.1	1.9
Fishing	10.8	10.5	9.9	9.3	8.3	7.7	7.3	6.6
Mining and quarrying	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4
Manufacturing	16.0	17.1	18.3	18.9	20.2	19.6	20.8	20.5
Electricity, gas and water supply	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6
Construction	5.2	4.7	5.6	5.8	5.9	6.4	6.9	6.7
Hotels and restaurants	3.7	4.2	4.7	3.6	4.0	4.3	4.4	4.4
Transport storage and communication	6.6	7.1	7.1	6.8	6.7	6.8	6.2	6.1
Total	68.1	68.2	67.9	67.9	66.4	67.3	67.3	65.4

Source: United Nations Statistics Division.

Retrieved from http://data.un.org/Data.aspx?d=SNA&f=group_code%3a202

2.2 Methodology for computing socio-economic benefits

The methodology employed here for computing the potential socio-economic benefits from planned improvements in the NMHS of a country is based on secondary data available from institutional sources. These secondary data were enhanced by informed assumptions provided by institutional key informants.

The monetized net socio-economic benefits from planned improvements in the NMHS of a country are defined as the monetized total decrease in socio-economic damages due to weather and climate-related natural disasters less the cost of the NMHS improvements as follows:

$$b = \Delta D - C$$

where: b = discounted net benefits from planned improvements in the NMHS; ΔD = discounted total decrease in socio-economic damages due to the planned improvements; and C = discounted total costs of the planned improvements.

The socio-economic sectors of a country and the potential direct socio-economic damages due to weather and climate-related natural disasters on each sector are outlined in Table 2.2. In addition to the potential direct damages, there are potential indirect damages on the other sectors that have backward and forward linkages to the mainly affected sectors. For instance, damages in agriculture may impact on the other sectors of the economy through increases in the prices of agricultural input and output goods and services in the market.

The secondary data available from the institutional sources for this work, however, measures only the direct damages on a country due to weather and climate-related natural disasters. Thus, the estimated of damages considered here are conservative and just a fraction of total actual socio-economic damages.

In addition to the above, aside the socio-economic benefits arising from the reduction in damages, improvements in NMHS may also have productivity effects on the national economy of a country. In particular, better forecasting of weather and climate-related events will allow economic sectors to operate better and increase their productivity. This productivity effect is likewise not included in the measurement of socio-economic benefits done here.

In the case of the costs of NMHS improvements, the total costs include the sum of all expenditures related to the improvements made. If some of these costs occur beyond the first year of the project, these are discounted. If all expenditures occur in the first year, then the actual and undiscounted cost figures apply.

After the computation of the discounted costs and benefits, the cost-benefit ratios (C/B) are computed as follows:

$$C/B = C/\Delta D$$

where the variables are defined as before. The computed C/B ratios are then compared to the C/B ratio of at least 1:7 set by the WMO.

2.3 Results and analysis

Natural hazard-induced disasters

Based on “EM-DAT: The OFDA/CRED International Disaster Database”, the data on total number of disasters, number of persons who died, number of persons who were rendered homeless, number of persons who were injured and total number of persons affected by natural hazard induced disasters in Cambodia for the period 1990-2009 are presented in Table 2.3. In this period, the country had 19 such disasters causing death to more than 1,000 people and injury to more than 50 persons. The disasters also affected more than 16 million individuals and rendered homeless more than 275 thousand persons. In the same period, annually on average, there was one disaster which occurred, 59 people who died, 13,790 persons who were rendered homeless, 7 persons who were injured and 813,085 people who were affected.

Table 2.2 Socio-economic sectors and the potential direct damages due to weather and climate-related natural disasters on different economic and social sectors	
Sector	Potential Direct Impacts
Economic Sectors	
Agriculture	Lost income, disruption in operations, damaged irrigations, dams and other agricultural infrastructure and facilities, etc.
Transportation & Communication	Lost income, disruption in operations, damaged transportation and communication infrastructure and facilities, etc.
Energy	Lost income, disruption in operations, damaged energy infrastructure and facilities, etc.
Tourism	Lost income, disruption in operations, damaged tourism infrastructure and facilities, tarnished image as a tourist destination, etc.
Social Sectors	
Human Settlements	Lost and impaired human lives and property, reduction in land and property values in affected areas, etc
Health	Lost income due to death or injury, disruption in operations, psychic costs due to death or injury, cost of rehabilitation, etc.
Education	Lost income, disruption in operations, opportunity costs of cancellation of classes, rehabilitation costs of damaged schools and related property, etc.
Water	Diminished water access and water availability, water pollution control and management costs, etc.

In terms of types of disasters, these were mainly floods, storms and droughts. From 2005 to 2009, there were a total of 4 floods causing death to 23 people, 2 storms causing death to 19 people and one drought causing no death (see Appendix Tables 1 and 2).

Total socio-economic damages

The value of direct socio-economic damages caused by weather and climate-related disasters in Cambodia for the 1990-2009 period and the estimated damages for the 2010-2029 period are presented in Table 2.4. The annual estimated socio-economic damages for 2010-2029 were computed as the average of the annual actual damages for the 1990-2009 period adjusted to inflation taken from the World Development Indicators of the World Bank. The total actual socio-economic damages for the 1990-2009 period were US$467 million while the annual average was $23 million. In the absence of 2010 data the annual average of $23 million is reflected as the estimated damages for that year. From 2010-2029, the total undiscounted estimated damages was $855 million while the annual average was $43 million.

The available data indicated that in terms of type of disaster, floods caused $1 million economic damages from 2005 to 2009 while the other disasters caused no economic damages (See Appendix Table 3).

Table 2.5 presents the estimated reductions in the socio-economic damages, or the socio-economic benefits, due to improvements of the NMHS of Cambodia. The reduction in damages is assumed to start in 2012 and increases up to 2016. A reduction in the economic damages of 1 percent annually from 2012 to 2015 and 5 percent thereafter is further assumed meaning that the effects of the improvement gradually occur in equal increments until it reaches maximum effect by 2016 and onwards. This assumption of 10 percent reduction in damages is based on informed opinion of key informants. From 2010-2029, the estimated reduction in damages or the socio-economic benefits amount to $76 million and the average annual amount is $3.8 million at 10 percent reduction.

Table 2.3 Selected statistics related to weather and climate-related disasters in the Cambodia, 1990 to 2009

Year	Number of disasters	Number of persons dead	Number of persons homeless	Number of persons injured	Total number of persons affected
1990	0	-	-	-	-
1991	1	100	250,000	-	900,000
1992	0	-	-	-	-
1993	0	-	-	-	-
1994	2	506	-	-	5,029,000
1995	0	-	-	-	-
1996	1	59	-	-	1,300,000
1997	1	25	-	-	-
1998	0	-	-	-	-
1999	2	7	25,805	-	660,379
2000	1	347	-	53	3,448,053
2001	2	56	-	-	1,969,182
2002	2	29	-	-	2,120,000
2003	0	-	-	-	-
2004	1	-	-	-	-
2005	2	16	-	-	600,000
2006	2	5	-	-	38,000
2007	1	2	-	-	19,000
2008	0	-	-	-	-
2009	1	3	-	1	34,300
Total	19	1,155	275,805	54	16,117,914

Source of data: EM-DAT: The OFDA/CRED International Disaster Database.
Retrieved from http://www.emdat.be/advanced-search

Notes:

a) In this table and the succeeding ones, the weather and climate-related natural disasters specifically include drought, extreme temperature, flood, mass movement wet, storm and wildfire. Mass movement wet includes rockfall, landslide, avalanche and subsidence.

b) EM-DAT is a global database on natural and technological disasters that contains essential core data on the occurrence and effects of more than 17,000 disasters in the world from 1900 to present. EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the School of Public Health of the Université catholique de Louvain located in Brussels, Belgium. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. Priority is given to data from UN agencies, governments and the International Federation of Red Cross and Red Crescent Societies.

Table 2.4 Actual and Estimated economic value of damages due to weather and climate-related natural disasters in Cambodia, 1990-2029 (million US dollars)			
Actual Damages		Estimated Damages	
Year	Value	Year	Value
1990	-	2010	23
1991	150	2011	26
1992	-	2012	26
1993	-	2013	27
1994	100	2014	29
1995	-	2015	31
1996	2	2016	33
1997	0.01	2017	35
1998	-	2018	37
1999	0.5	2019	39
2000	160	2020	42
2001	15	2021	44
2002	38	2022	47
2003	-	2023	50
2004	-	2024	53
2005	-	2025	56
2006	-	2026	59
2007	1	2027	63
2008	-	2028	67
2009	-	2029	71
Total	467		855
Average	23		43

Sources of data: EM-DAT: The OFDA/CRED International Disaster Database; World Development Indicators, World Bank

Note: There is no explanation from the source on what the specific damages are so it is assumed that these include monetized direct damages. Average annual inflation rate is 6.1 percent from 1990-2009.

Table 2.5 Estimated reduction in the socio-economic damages, or the socio-economic benefits, due to improvements in NMHS in Cambodia, 2010-2029 (million US dollars)												
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Value	0.00	0.00	0.53	1.12	1.78	2.51	3.33	3.53	3.75	3.98	4.22	4.48
Year	2022	2023	2024	2025	2026	2027	2028	2029				
Value	4.75	5.04	5.35	5.68	6.02	6.39	6.78	7.19				

Source of data: Table 2.4

The total estimated reduction is US$76 million while the estimated annual average reduction is US$ 3.8 million from 2010 to 2029.

Table 2.6 presents the discounted or net present value of the estimated reductions in the economic damages, or the socio-economic benefits, due to improvements of the NMHS of Cambodia. The social discount rate used in 12 percent which is within the 10 to 12 percent used by the ADB for public projects (Zhuang, et al. 2007). The results show that based on a 20 percent reduction in damages, the total socio-economic benefits from 2010 to 2029 is $40.64 million. Based on a 30 percent reduction in damages the total benefits increase to $60.95 million.

Table 2.6 Discounted value of the estimated reduction in socio-economic damages, or the socio-economic benefits, due to improvements in NMHS in Cambodia, 2010-2029 (million US dollars)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Value	0.00	0.00	0.43	084	1.21	1.56	1.88	1.81	1.65	1.69	1.63	1.57
Year	2022	2023	2024	2025	2026	2027	2028	2029				
Value	1.51	1.46	1.41	1.36	1.31	1.26	1.22	1.17				

Source of data: Table 2.5

The total discounted value of the estimated reduction is US$24.98 million while the estimated annual average discounted value is US$ 3.8 million from 2010 to 2029.

Table 2.7 presents the options that can be taken for the NMHS improvements, costs of the improvements, discounted total benefits from the improvements, discounted net benefits from the improvements and the C/B ratio. The stand alone option implies that the improvements are separate investment of the country while the regional cooperation option means that the improvements are done as part of an integrated regional system. Because of the efficiency effects of integration, the costs of the latter are lower than the former. The costs of the NMHS improvements are actual costs since these are assumed to be spent at the beginning of the project and therefore are not discounted. The discounted total benefits are taken from Table 2.6. The discounted net benefits are discounted total benefits minus costs. The C/B ratio is as defined earlier.

Table 2.7 Options, Costs, Discounted Total Benefits, Discounted Net Benefits and Cost-Benefit ratios for improvements in NMHS in Cambodia, 2010-2029

Option	Costs (US$ Millions)	Discounted Total Benefits (US$ Millions)	Discounted Net Benefits (US$ Millions)	Cost/benefit Ratio (C/B)
Stand Alone	20.74	24.98	4.25	1:1.20
Regional Cooperation	16.08	24.98	8.91	1:1.55

Source of data: Table 2.5 and 2.6.

For the stand alone system, the total cost of NMHS improvements is $20.74 million while the discounted total benefits due to NMHS improvements is $24.98 million benefits (Table 2.7). Therefore, the discounted net benefits are $4.25 million while the C/B ratio is 1:1.20.

For a system based on regional cooperation, the total cost of NMHS improvement is $16.08 million which is lower than the cost of a standalone system. Again, the discounted total benefits due to the NMHS improvements are $24.98 million. Therefore, the discounted net benefits are $8.91 million and the C/B ratio is 1:1.55.

It is noted that the mentioned C/B ratios generated above for both of the two systems considered are inferior to the C/B ratios computed by other studies on benefits of meteorological and hydrological services. These studies derived C/B ratios which are better than the WMO minimum accepted ratio of 1:7 (Hautala et al., Tammelin 2007, Leviakangas et al. 2007). It should also be noted that the computed C/B takes into consideration only direct benefits from reduced disaster losses. In reality there are indirect benefits such as from improved decision making in water resource management and climate change etc.

Sectoral damages

The physical data of the damages for the various social and economic sectors of Cambodia, including social, agriculture and infrastructure for the period 2000 to 2009 are presented in Appendix Table 4. It is shown that the physical damages are pervasive and have great impacts on the country and population. There are no available data, however, on the economic value of these sectoral physical damages that can be used to compute the expected benefits from NMHS improvements by sector. There are also no data on the estimated total value of damages in Cambodia over the years.

Sectorally, the main qualitative benefits and impacts of meteorological and hydrological information services in general level for a given country are presented in Appendix Table 5.

2.4 Summary of findings

In retrospect, the following are the main findings of the computations done for Cambodia:

- The discounted net benefits due to the improvements in the NMHS of Cambodia, based even only on the decrease in damages due to the improvements, are high and more than enough to pay for the cost of improvements;
- The C/B ratios based on the actual costs of NMHS improvements and the discounted values of the total benefits from the improvements, however, are inferior to the 1:7 ratio set by the WMO;
- The C/B ratio for the system with regional integration are better than the ratio for the stand alone system which implies that being more efficient the former system is also more desirable; and
- The C/B ratios would improve further if the indirect benefits of the NMHS improvements, productivity gains in the economy and the benefits beyond 2029 are included in the computation of benefits.

3 NEEDS ASSESSMENT OF SERVICES AND HYDROMETEOROLOGICAL INFORMATION

3.1 Agriculture and food production

The contribution of agriculture, hunting and related service activities to the GDP of Cambodia in 2007 was 18.1 percent (Table 2.1). Cambodia has a predominantly rural population, with some 85 per cent of people living in rural areas. Half of its work force is employed in agriculture. Despite most farming activity being at a subsistence level, Cambodian rice production has seen large increases over the past decade-a result of the introduction of new varieties. Output of other crops, meanwhile, has been fairly static. Not surprisingly, use of mechanisation is limited, but draft animals are commonly used both for cultivation and transporting produce.

Access to land is one significant facto also impinging on the potential of Cambodia for agricultural development, particularly among the poorest. A lack of credit systems in rural areas makes breaking out of the cycle of subsistence production more difficult while limited access to market information and inadequate infrastructure and transport hinder the activities of those farmers who are in a position to produce commercially.

The whole of Cambodia depends on agriculture for food production However, the bulk of the agricultural lands are concentrated over the south central part as illustrated in Fig. 3.1. The major agricultural products of Cambodia are rice, maize and cassava. Rice is the staple food of Cambodia so it is the top agricultural product; about 80% of the country's total production. The rice fields in Cambodia are predominantly non-irrigated and dependent on rainfall, hence, greatly vulnerable to climate change.

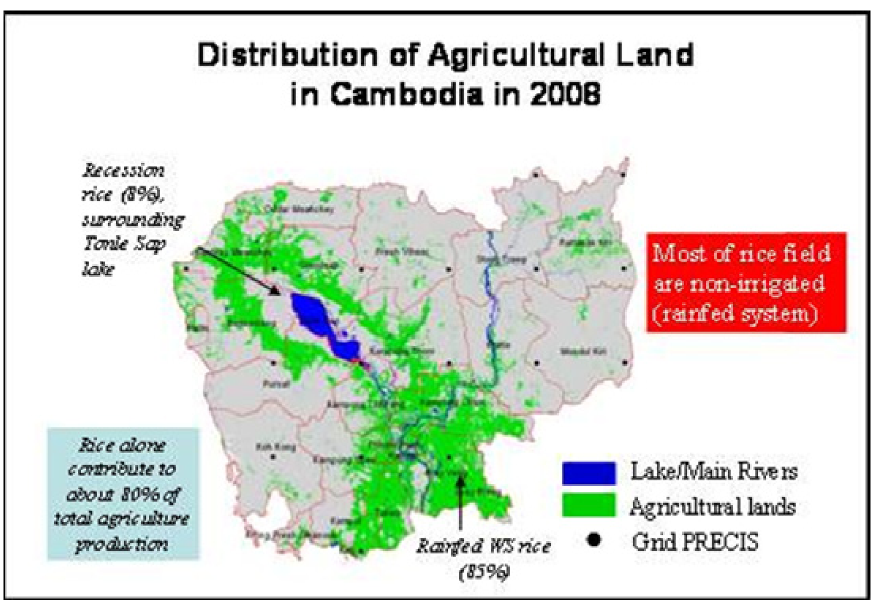


Figure 3.1 Distribution of agricultural lands in Cambodia

The rice yearly production is illustrated (graph) in Fig. 3.2. The produce remarkably increased from 1.7 MT in 1980 to 6.3 MT in 2006

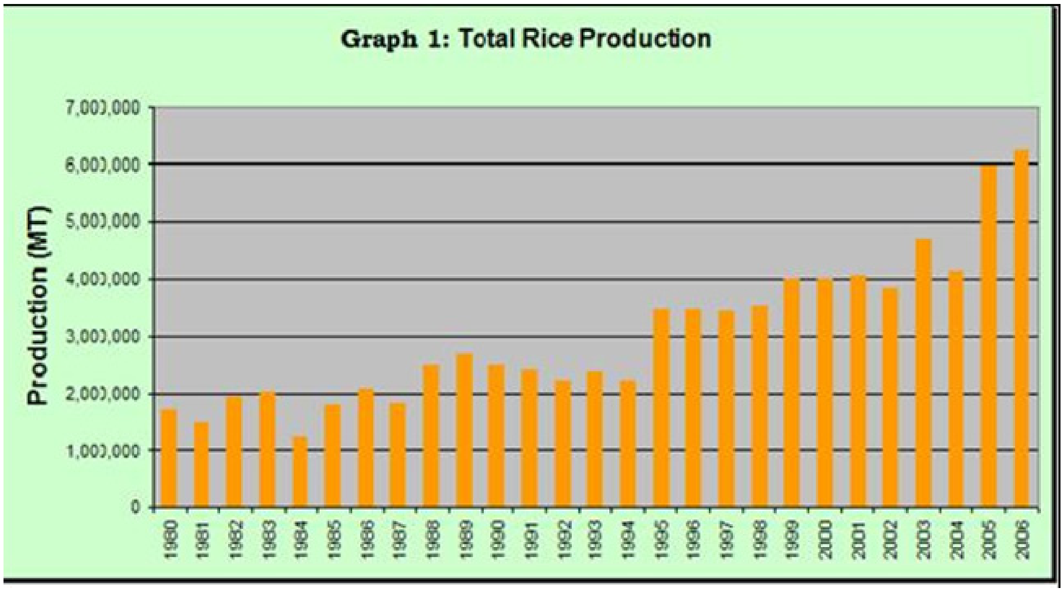


Figure 3.2 Total rice production in Cambodia from 1980 to 2006

Agricultural crop production is dependent on weather condition hence the planning of cropping activities by the Department of Agriculture are based on the climate and seasonal weather forecast of the area or province. They also advice the farmers on the type of crop/variety to plant based on the forecast (drought, floods, delayed/early rainy season, etc.). In case of pests/insects that destroy crops, wind data is important for early preparation.

The sector needs are:

- Seasonal weather outlook
- More site specific long time historical hydro-meteorological data for planning
- Better and more site specific short term and medium term (1-5 days), and long term weather forecasts
- Data and forecasts on evapotranspiration, temperature
- Data on humidity, wind speed & direction, rainfall
- Monthly, yearly, normal values of met-hydro parameters
- Crop specific forecasts
- Fast communication link of DAFF with DOM for data transport
- Strong coordination with DAFF & other agencies
- Access of met-hydro data from regional centers
- Historical data for land resources planning

3.2 Fishery

The contribution of fishing to the GDP of Cambodia in 2007 was 6.6 percent (Table 2.1). With fishing an important source of livelihoods, the majority of the population is concentrated in the most productive fishing areas, namelythe Mekong Delta in the centre of the country and the Tonlé Sap Lake.

In Cambodia, fish products are a major source of food like rice. Especially the freshwater fisheries are one of the most productive in the world due to the presence of large floodplains around the Great Lake and along the Tonle Sap and the Mekong

Rivers. Marine fishery and aquaculture are small compared to the inland fishery.

Cambodia has a small coastline of 435 km. The marine fishing grounds are located on the eastern bank of the Gulf of Thailand. Marine fisheries were slowly developed compared to freshwater fisheries. The coastal zone statistics only report on the fishing effort (by boat and gear) for taxable gears which are largely confined to inshore waters. The offshore fishery is largely fished by international fleets of which there are no estimates of effort, catches or revenue collection.

The aquaculture sector is of minor significance to the fishery production of Cambodia. The wild fishery in Cambodia has been so productive that there has been little incentive for development of aquaculture.

The inland fisheries of Cambodia produce an estimated 295,000 – 420,000 tons of fish each year with an estimated value at landing of between US$150 m and US$200 m and a retail value of up to US$500 million. The total volume of seafood harvested is speculated to be 30,000 to 50,000 tons per year, valued at about US$30 million to US$50 million (US$1/kg of seafood on average).

Six million people or 50% of the population of Cambodia are employed full or part time in fisheries. The labor force involved in the marine fishery sector, including fishing, gathering, processing, and marketing and is estimated to be only 10 000 people (10% of the coastal inhabitants).

Needs:

- 1-5 day weather forecasts
- Wind speed and direction
- Wind forecasts including local wind,
- Thunderstorms with gusts
- visibility
- Wave heights
- Water levels
- Historical data for strategy, policy and management planning

3.3 Forest industry

The contribution of forestry, logging and related service activities to the GDP of Cambodia in 2007 was 14 percent (Table 2.1). Parts of the country, particularly the southwest and the north and northeast, are heavily forested, but while in the mid-1960s, 75 per cent of the country was covered in rainforest, a survey in 1993 revealed that this had been reduced to 49 per cent. Logging is a problem in Cambodia and the strong demand for timber and stricter regulations in neighbouring countries mean that its forests continue to be exploited by foreign timber companies. Economic and mining land concessions have put extra pressure on forest resource of Cambodia; this can extend even into protected areas.

About three-fourths of Cambodia was forested in 1970, but by the early 21st century that portion had decreased to roughly half, with Cambodia carrying one of the highest deforestation rates in the world. The provinces bordering Thailand and Vietnam continue to be logged by large companies to whom the government has granted concessions, as well as by smaller entrepreneurs, many of whom do not obtain official permits. Illegal logging is a persistent and serious problem despite efforts to curb it.

Needs:

- Forest-meteorological observation stations
- Near real time data on critical parameters (incl. soil humidity)
- Site specific weather forecasts
- Production of the forest fire index
- Numerical weather forecasting models to produce site specific parameters required to calculate the forest fire index
- Modelling and forecasting of dispersion of smoke
- Estimates of biomass production and its impacts on land use management
- Study in the impact of climate change on the forest sector
- Watershed management and planning

3.4 Water management

Cambodia has a unique hydrological system. The Mekong River and Lake Tonle Sap are connected by the Tonle Sap River which twice a year reverses its direction of flow. From July to the end of October, when the level of the Mekong is high, water flows into the Tonle Sap River, which fills Lake Tonle Sap, thereby increasing the size of the lake from 2,600 km2 to about 10,500 km2 at its maximum. The storage capacity of Lake Tonle Sap is estimated at 72 km3. In October, when the level of the Mekong decreases, the Tonle Sap River reverses its flow, and water flows from Lake Tonle Sap to the Mekong River and thence to the Mekong Delta.

About 86% of Cambodia's territory (156,000 km2) is included in the Mekong River basin, the remaining 14% draining directly towards the Gulf of Thailand.

Water and other related natural resources are essential elements in the interests of every level actors of the Mekong Region as they are the base of the macro- and microeconomics as well as human rights.

The Vision for Water Resources in Cambodia is:

1. Access for all to safe, adequate and affordable drinking water hygiene and sanitation;
2. Freedom for all from the threat of loss of life and livelihood as a result of floods and droughts;
3. Sufficient water where it is needed, to provide for food security, peoples livelihood and economic activity; and
4. A water environment that is unpolluted and support healthy fisheries and aquatic ecosystems.

However, the water management in Cambodia seems to be ecologically unsustainable as there is a growing competition of the resources and the decision-making is characterized by economical and personal interests. These features related to the interest show that water management in Cambodia is planned for the elite rather that the population as a whole.

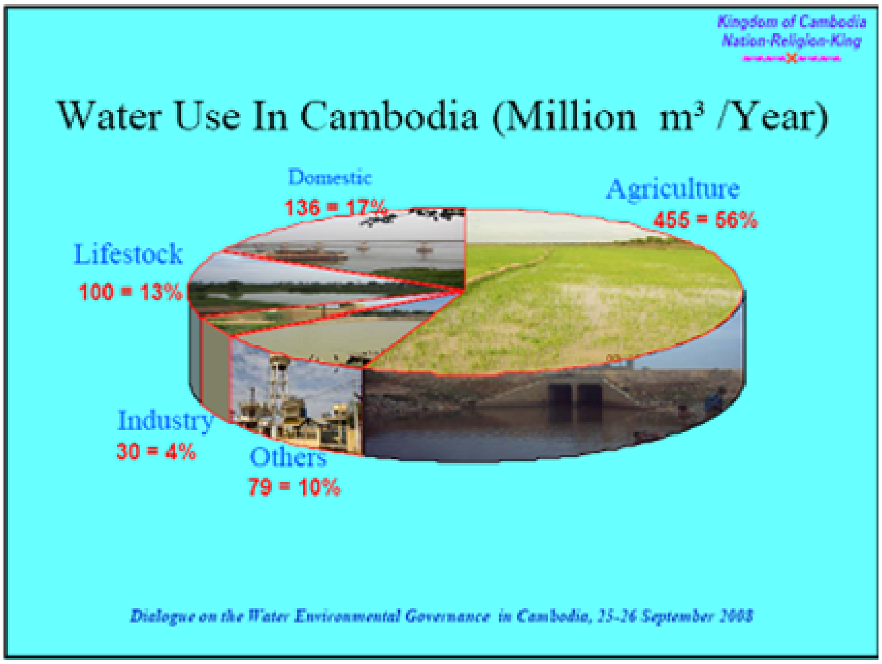


Figure 3.3 Distribution of water utilization in Cambodia

On water utilization of Cambodia, the agriculture sector covers more than half of the total usage of the country (Fig. 3.2). The domestic only consumes 17%, livestock 13% and the industry 4%. The potential water resource of Cambodia is tabulated in Table 3.1.

Table 3.1 Water Resource Potential in Cambodia

Water Resource	Power (MW)	Irrigated Area (ha)
Main Stream	10,800	734,000
Mekong Tributaries	2,727	253,000
Mekong Flooded Area	-	179,000
Tonle Sap Tributaries	306	358,900
Outside Mekong Basin	1,146	142,000
Total	14,979	1,667,300

Source: Dialogue on the Water Environmental Governance in Cambodia, 25-26 September 2008

Institutionally, at the national level, weak legislation in Cambodia impedes clear division of responsibilities and rights. In addition, the interests of the government and local people collide and the mutual trust is low. As a whole, the weak private, social and research sectors and certain significantly strong ministries and political parties distort the configuration for national water management. At the local level there is a growing competition on subsistence, which has already degraded environment but also created organized user communities. At all the regional levels, horizontal cooperation and coordination seem to be minimal and instead the vertical relations between actors and institutions dominate.

There is no data sharing and joint planning even within departments of MOWRAM themselves. The MOWRAM Department of Water Resource Management and Conservation (DWRM&C) developed the National Water Resource Development Plan (as required by the Water Law) and different sub-decrees to implement the Water Law. The Department of Irrigated Agriculture establishes and supervises the national design standard in irrigation/drainage systems development in the country. The Department of Water Supply and Sanitation (DWSS) develops strategy, policy for water supply and sanitation (groundwater and surface water in close cooperation with DWRM&C) and the Department of Engineering (DE) conceives and implements water development and management infrastructure design. These departments have never used or asked for data from DHRW and DOM.

Needs:

- Rainfall observations and forecasts
- Weather advisories particularly for drought & floods
- Seasonal forecast
- Historical water level and flow in each of the national 39 sub-basin;
- Characteristics of river flow and water resource in each of the sub-basin (maximum, average, minimum, environmental flow, water use)

- Current and planned water use in each of the sub-basin
- Water level observations and wave forecasts
- Water availability in each of the sub-basin (groundwater/surface water)
- Water risk and hazard in each of the sub-basin
- Sediment transport and river morphology.
- International and national water transboundary issues such as the MRC procedures for maintenance of minimum flow and reverse flow to the Tonle Sap Great Lake

3.5 Energy

Most of the commercial energy used for power generation, transport, industry, residences, and commercial sectors of Cambodia comes from petroleum. Diesel fuel is the principal source of electricity generation but alternative energy sources, such as hydroelectricity, clean coal, natural gas, solar, and wind power, are being considered to reduce reliance over petroleum products. Gasoline, diesel oil, jet fuel, kerosene, and liquefied petroleum gas (LPG) are all imported from the region.

Since the promulgation of the Electricity Law in 2001 with the view to regulate the power sector the Electricity Authority of Cambodia (EAC) was established as a legal public entity to act as the regulator and arbitrator of power sector business activities. Cambodia's Strategy for the development of electricity supply is to construct transmission lines between major cities in southern and western regions in order to construct large scale power generation plants and to import power from neighboring countries during the construction period of such power plants.

The current electricity supply does not meet the basic demands, where 24-hours supply of electricity is not assured and the quality of electricity is not reliable. According to the Power Development Plan of 2007 of the Kingdom of Cambodia electricity demand is expected to growth rapidly until 2020.

Table 3.2 Power Demand Forecast (MW)

2012	2015	2018	2020
1,062	1,643	2,283	2,770

On the supply side the following construction are planned: Hydropower: 2,241 MW, coal/gas plants 1,335 MW. During the same period 1,889 km of transmission line are built, planned or under construction connecting western and eastern region of the country as well as with Thailand, Vietnam and Lao PDR.

The three main government institutions responsible for energy in Cambodia are listed:

- Ministry of Industry, Mines and Energy (MIME) – responsible for energy planning, policy and management
- Electricity Authority of Cambodia (EAC) – responsible for regulating the electricity industry (www.eac.gov.kh); and
- Electricity du Cambodge (EdC) – government owned power utility responsible for the generation, transmission and distribution of power in nine areas of the country.

Sector needs:

- Thunderstorm/lightning monitoring and forecasting
- More real-time observations on precipitation and water level
- More accurate site specific weather forecasts for estimation of energy consumption and optimization of power production
- More observations and modeling of solar radiation
- Better wind data for assessment in wind energy potential
- 0-24 forecasts for wind power production
- Seasonal forecasts
- National and international cooperation
- Strengthening of existing river monitoring network including their expansion to cover ungauged sub-basins

3.6 Transportation

Cambodia's transportation system was greatly damaged during the war and is inadequately rehabilitated during peacetime. Cambodia received technical assistance and equipment from other countries i.e. France, Germany, Soviet Union, Australia, etc. for the transportation system; roads and railways network.

3.6.1 Land Transportation

Road transport in Cambodia has a total system length of 50,441 km, of which 2,115 km are one digit national, 3,372 km two digit national road, 6,467 km are 4 & 5 digits provincial road, and 38,527 km are rural road. Most rural roads are unpaved, but due to high maintenance cost, under the new government policy, they will be progressively paved.

Road traffic level are generally low though the number of vehicles has grown rapidly during the last decade, the total number of registered vehicles are 1,400, 000 in 2009. Cambodia has one of the highest road traffic dead rate 12.1/100,000 of population, especially mopeds and motocycles of which there were 680,002 in 2009 (IFR 2009). Cambodia also has one of the highest incidences of road accidents in Asia.

Cambodia's rail network is currently being reconstructed as part of the Trans-Asian Railway project. Two rail lines exist, both originating in Phnom Penh with a total of about 641 kilometers of metre gauge single track. A third line is planned to connect Phnom Penh with Vietnam, the last missing link of the planned rail corridor between Singapore and the city of Kunming, China.

The rehabilitation Project is a large and complex project involving the following main track and components and related facilities:

- Rehabilitation or reconstruction of 641 km of main line railway, comprising 385 km on the Northern line and 256 km of the Southern Line;
- Rehabilitation of spur lines to the Green Trade Warehouse complex in the port of Phnom Penh and into Sihanoukville Port;
- Construction of two new freight facilities: a railway container yard located inside Sihanoukville Port and a new freight and maintenance railway yard at Samrong.

The Northern Line was built to carry 15 tons axle load while the Southern Line was built to carry 20 tons axle load. Both lines are being rehabilitated to their respective axle load standards. The Southern Line is being converted from bolted track to continuously welded track. All bridges are being repaired and, where possible, upgraded to 20 tons axles load. Where bridge replacement is required, the new structures will be built for 20 ton axle load. The Government of Cambodia is considering additional upgrading of the northern line to 20 tons axle load to attain a homogenous network and match expected upgrades in Thailand. This would require additional financing.

Southern Line

The 110 km section between Samrong and Tuk Meas opened to traffic in October 2010. Commercial traffic between K-Cement's factory in Tuk Meas and Phnom Penh (3,000 tons per week) started in the same month.

The 146 km section between Touk Meas and Sihanoukville is expected to open traffic in late 2012.

Nothern Line

The 10 km section from Phnom Penh to Samrong was repaired and opened for low speed traffic in October 2010.The section is being upgraded to 20 tons axle load, which is expected to be completed in October 2012 to match opening of traffic to Sihanoukville.

The 21 km section from Samrong to Bat Doeung is rehabilitated and will open for traffic in June 2012.

The 48 km missing link between Poipet and the Thai border is being reconstructed to 20 tons axle load and is nearing completion. The first 42 km to Poipet will be completed in late 2012. Accrual reconnection to the railway network in Thailand depends on reconstruction of the last 6 km track of the border railway line from Aranya Phrathet Station in Thailand. This expected to be completed in 2013 or early 2014.

The 306 km section between Bat Doeung and Poipet is expected to be opened in several phases between 2014 or early 2015.

Spur Lines

The section from Sihanoukville Station into Sihnoukville Port, where the existing post track is being rehabilitated, will open in October 2012.

The section from Phnom Penh to the Green Trade Warehouse complex and Port of Phnom Penh will be upgraded to 20 tons axle load at low speed (15 km/hour). It is expected that this section will open to traffic in 2013.

Freight Facilities

The new container yard in Sihanoukville Port is expected to open in 2014. The timing is determined by the site for the new container yard, which is filled-pond that requires several years to settle before construction can start. In the meantime, existing tracks inside the port will be used for container operations.

The new freight maintenance facility in Samroang is expected to open in 2014, in step with opening of new container yard in Sihnoukville. In the interim, the exiting track in Phnom Penh Station will be used for container operations. The Ministry of Public Works and Transport (MPWT) need hydrometeorological data particularly for constructions of roads and bridges. Normally, the consultants request for these data from the DOM.

Needs:

- Historical data of river flows and water level , wind speed and wind direction for road and water crossing design;
- Historical annual rainfall data;
- Short duration data for water crossing structure, drainage and sewage design;
- Analysis on model results of different scenarios options for road development planning across flood plain;

- Weather forecasts especially during rainy season for road hazard warning
- Mesoscale weather forecasts (convective activities like thunderstorms)
- Rainfall monitoring and forecasts
- Thunderstorm forecast
- Seasonal weather outlook

3.6.2 Water Transportation

Cambodia has extensive inland waterways which were important historically in domestic trade. The Mekong and the Tonle Sap Rivers, their numerous tributaries, provided avenues of considerable length, including 3,700 kilometers navigable all year by craft drawing 0.6 meters and another 282 kilometers navigable to craft drawing 1.8 meters. In some areas, especially along the Mekong-Tonle Sap-Bassac river systems, the villages were completely dependent on waterways for communications. Launches, junks, or barges transport passengers, rice, and other food in the absence of roads and railways.

Cambodia has two major ports, Phnom Penh Port and Sihanoukville Port, also known as Kampong Som, and five minor ones. Phnom Penh, located at the junction of the Bassac, the Mekong, and the Tonle Sap rivers, is the only river port capable of receiving 8,000-ton ships during the wet season and 5,000-ton ships during the dry season. It remains an important port for international commerce as well as for domestic communications.

On merchant marines, there are 626 ships (as of 2008) and 467 of which are foreign owned. These include 41 bulk carrier, 530 cargoes, 3 carriers, 10 chemical tankers, 6 passenger/cargo ships, 15 refrigerated cargoes, 11 petroleum tankers, 1 roll-on/off, and 1 vehicle carrier.

All the domestic ports suffer from insufficient or total absence of supporting infrastructure. There is presently no any reliable data on domestic cargo movements on the river system. In 1994, it was estimated (in depth survey of boat operators) that about 40 to 50,000 tons could constitute the domestic cargo. The absence of reliable figures makes the task of designing and promoting river ports extremely difficult. The shallower Mekong, rather the Bassac River is declared international channel for navigation to Phnom Penh, Kampong Cham and Kratie, restricting vessel size. Small seagoing vessels (up to 4,500 DWT) are able to serve Phnom Penh in Cambodia

Needs for information and services:

- Rainfall and wind observations and forecasts
- Water level monitoring and forecast
- Seasonal forecast (for drought or flood)
- Thunderstorm forecasts
- Severe weather bulletins and typhoon forecast
- Updated river chart (hydrographic atlas)
- Sediment transport and information on river morphology

3.6.3 Air transportation

Cambodia possesses twenty-six airfields, eight airfields had permanent-surface runways. Phnom Penh International Airport is the largest airport. It also serves as the main base for the renascent Cambodian Air Force. Cambodia's second largest airport is Siem Reap International Airport in the major tourist city of Siem Reap. Tourist traffic into Angkor International Airport saw passenger numbers overtake those of Phnom Penh in 2006, the airport now being the country's busiest.

Cambodia also opened a new Soviet-built airfield at Ream, Sihanoukville International Airport in late 1983, which now is increasingly used linking Sihanoukville Siem Reap three flights per week. There is an additional secondary airport in Battambang.

Air Kampuchea was established in 1982 and flew only one route - from Phnom Penh to Ho Chi Minh

City in Viet Nam. In 1984 commercial air service was inaugurated between Phnom Penh and Ha Noi with the arrival at Hanoi International Airport of the Kampuchean Civil Aviation Company's (AKASCHOR) first flight. Since then, there has been regular air service from Phnom Penh to Ha Noi, Vientiane, and Moscow.

The new national airline Cambodia Angkor Air was launched in 2009, with a large financial investment from Vietnam Airlines.

Needs:

- Aerodrome forecasts
- Real time meteorological data, i.e. winds, visibility, upper-air soundings
- Seasonal weather forecasts
- Mesoscale model forecasts
- Severe weather bulletins

3.7 Construction

Construction is an important contributor to the economy of Cambodia. However, it is also vulnerable today due to global financial crisis and highly speculative spending in real estate. The construction sector was estimated to contribute about 7-8 percent a year to the country's GDP.

However, inflation in Cambodia seems to be the challenge to the construction industry, the inflation rate (consumer price) was 4% (est.) in 2010 and 6% (est.) in 2011. The cost of investing in construction has grown rapidly. This price rise has also reduced the capability of investors to finance and finish construction projects. Moreover, even if projects are completed as planned, rising housing costs have the potential to drive buyers out of the market.

Needs:

- Climatological data of meteorological parameters (wind strength & prevailing direction, temperature, rainfall, humidity, etc.) in specific locations for building design and constructions
- Accurate site specific weather forecast (precipitation, wind, temperature, lightning,..): 1 day, nowcasting
- Meteorological measurement based load factors (wind, snow, water,..) for a renewed Regulations for Construction
- Intensities of precipitation for planning of drainage system
- In future: mesoscale and microscale data on solar radiation on inclined surfaces, local wind, temperature chill factor for planning and site purposes of buildings
- Improved customer specified dissemination of information

3.8 Land use and planning

Cambodia faces serious problems concerning land issues and diminishing natural resources. The concession system is a major source of land conflict as concessions deprive some of the local population of the basic resources needed for their livelihood, thus keeping them from achieving long term, sustainable development. This is one of the main reasons behind rural urban migration.

There is uncontrolled growth of settlements in the urban centres of Cambodia, along with insufficient physical and social infrastructure in newly built up areas. Also large scale construction along national roads and along the national borders without considering regional development objectives are only some of the issues in land use and planning that have to deal with. Encroachment of flood plains for urban expansion and agricultural use threatens valuable wetlands resources and increase flood risks to surrounding areas affecting principally poor communities in surrounding suburb.

Legal and institutional frameworks for land management already exist in Cambodia, but implementation seems to be difficult due to structural deficits in the Cambodian Planning system. There are no environmental or ecological planning approaches in planning practice. Furthermore the so called "organic laws", which include the decentralization of planning competences has been passed recently.

Cambodia's total land of 181,035 sq km is comprised of 54.1 % forests, 23.4 % agriculture, 6.8 % wetlands, 15.6 % wood and grasslands and 0.1 % settlements. Cambodian agriculture is predominantly organized on the basis of small farmer communities. Rice production dominates the sector, occupying 90% of cultivated area. While Cambodian soils generally exhibit low to medium soil fertility, the vast flood plains of the Mekong and Tonle Sap provide suitable conditions for extensive areas of rain-fed lowland rice.

Needs:

- Climatological data for specific areas
- Meteorological hazard map
- Historical meteorological data for land use planning
- Hydrological and hydrodynamic capacity for planning of land use zoning

3.9 Tourism

Tourism industry is one of the key players in the growth of Cambodian economy. Over the last five years, the tourism sector has seen steady growth with an average annual growth of 11.32%, with the lowest in 2009 (1.7%) and reaching a peak in 2010 (16%). The number of visitors in 2011 reached 2,881,862 and 1, 756,862 in June 2012, with 32.5 % from neighbouring countries (Viet Nam, Thailand and Lao PDR), 26.4% from Asian countries (Korea, Japan, China) and 48.3% from Western countries.

The major attraction in Cambodia is, of course, the temple complex of Angkor Wat in Siem Reap. This city and province has seen a huge influx of capital with an ensuing hotel building boom. Hotels of varying categories, from 5-star international hotels to simple guesthouses were built. Cambodian tourism industry is to be boosted not only by innovations at Angkor Wat Temple but also to other destinations namely Sihanoukville, Kep, Kampot, Koh Kong and some islands in the Gulf of Thailand and the Eastern region Ratanakiri and Mondulkiri.

Figure 3.4 The main tourist attraction in Cambodia, the Angkor Wat Temple

Needs:
- Weather forecasts tailored for tourist resorts
- Meteorological data for environmental impact and risk assessment and management planning
- Monthly and seasonal forecasts
- Extreme weather phenomena
- River water level, flow, ground water data for integrated watershed management particularly for Stung Siem Reap and Stung Sen river basins.

3.10 Insurance

Insurance industry in Cambodia is still at its development stage, and might be explained by the following fact:

- Sociologically Cambodians and business societies are not fully informed about the insurance system, even though the awareness has been notably improved in recent time;
- Limited local expertise in the field;
- Weak judicial system;
- Limited number of compulsory insurance; and
- Licensing requirement are generally considered high taking into account the size of the market, particularly for micro-insurance business.

The sector is still small but growing. It is managed by the Ministry of Economy and Finance, under the Financial Industry Department and Insurance Division. Regulatory and institutional frameworks have been established in 2000. Currently there are 6 insurance companies operating in the country with a Gross premium of US$20,012,933.64 in 2009 and 24,755,038.27 in 2010, a growth rate of 23.7%. Neither life insurance nor micro-insurance exists yet.

Needs:
- Historical data /climatological normal for risk assessment
- Localized or site specific meteorological data for insurance claims due to weather disturbance
- Meteorological and floods hazard maps

3.11 Health

Like many developing countries, Cambodia faces a range of vulnerabilities and risks, including traditional, modern and emerging health and environmental risks. These risks emanate from unsafe water and inadequate sanitation; unsafe food supplies, especially from street vendors; indoor air pollution and solid fuel use; as well as disease-vector transmission.

In Cambodia, 65% of the total population has sustainable access to an improved water source (80% in urban and 61% in rural areas) and only 28% to improved sanitation (62% in urban and 19% in rural areas) in 2006. Other environmental health hazards include bacteriological contamination of drinking water, the most important health-related concern; arsenic in groundwater, which poses a health threat in seven provinces, exposing around 2.24 million people; indoor and urban air pollution, which is a serious health threat due to almost 98% of the population using biomass fuels for cooking or heating; use of banned pesticides and fertilizers, which has the potential to contaminate food and water; and finally, the serious environmental health impacts from solid and hazardous wastes, including health care waste.

There are around half a million cases of malaria with 5-10,000 deaths per year in Cambodia. Incidence rates vary in different parts of the country. Malaria control is hampered by multiple drug resistance of Plasmodium falciparum, inaccessibility to the major vector, poor security in most malarias areas, and lack of resources. The control strategy emphasises improvement of clinical management and provision of prompt and accurate diagnosis in order to reduce morbidity and to prevent mortality. In addition health information and drug distribution systems are being improved. The use of pyrethroid-treated mosquito nets and health education are being promoted. Particular attention is given to returning refugees as they settle into the country.

Climate is a major driving force behind malaria transmission and climate data are often used to account for the spatial, seasonal and inter-annual variation in malaria transmission.

Needs:

- Data and information on weather related diseases
- Coordination between DOM & Health agencies
- Research study on impacts of weather changes on health
- Flood and drought forecasts
- Seasonal forecast

3.12 Environment

Cambodia has a deteriorating natural environment over the years brought about by a poorly managed pursuit of economic development and a rapidly increasing population. The major environmental issues in Cambodia include illegal logging activities throughout the country, and strip mining for gems in the western region along the border with Thailand and recent mining concession areas. These have resulted in habitat loss and declining biodiversity (in particular, destruction of mangrove swamps threatens natural fisheries, destruction of headwater in some sub-basins); soil erosion; in rural areas, most of the population does not have access to potable water; declining fish stocks because of illegal fishing and over fishing.

With regard to international agreements on environment, Cambodia is a party to a number of the United Nations Conventions: Biodiversity, Climate Change, the Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Marine Life Conservation, Ozone Layer Protection, Ship Pollution, Tropical Timber 94, Wetlands, Whaling. In addition, the Law of the Sea has been signed but not ratified.

3.12.1 Water quality

In Cambodia, the following has been identified as potential causes of deterioration of water quality: a) waste from Residential Areas; b) waste from industries; c) waste from recreation areas; d) waste from agricultural activities; e) pollution from port activities and development; f) pollution from maritime activities; g) pollution from offshore development; h) effects from charcoal production; i) effects from illegal fishing; and j) pollution hotspots

Since 2005, RDI has been conducting ground water surveying activities from province-to-province, collecting samples and analyzing them in our laboratory. Over 7,000 wells have been tested in three priority provinces. Some areas have been found to have unsafe levels of Arsenic, Manganese, Fluoride, and Nitrate which can cause serious impacts to human health. Many areas have high Iron, Turbidity, Hardness, etc. which do not impact human health but may make the water taste and look bad, damage clothes, or cause rice to turn colour when cooked. Groundwater contamination is another risk due to lack of management regulation.

Needs:

- Rainfall and water level monitoring
- Regular rain water sampling analysis to check if polluted/acidic
- Flood forecast
- Development of water quality (surface and groundwater) information system

3.12.2 Air quality

In Cambodia, it is only in Phnom Penh where air quality is monitored regularly. All three monitoring points at Phnom Penh use passive tubes for 24 hours at the roadside and not ambient data; hence, the results obtained do not allow comparison to the WHO guidelines. The data indicate that the average annual levels of NO^2 and SO^2 are within the national standards of 100µg/m^3 for NO^2 and the United States Environmental Protection Agency's (USEPA) standard of 80µg/m^3 for SO^2. Currently, Cambodia has no annual standards for SO^2. Cambodia's national standards for TSP (100 µg/m^3) are not met, and the contributions of mobile emissions and road dust re-suspension are of concern.

Respiratory diseases are among the leading causes of morbidity in Cambodia and PM has been tagged as the potential cause. Vehicle emissions, as well as road dust re-suspension, contribute to increasing amounts of TSP. Despite concerns about the possible impacts of air pollution in Cambodia, currently there is no information about studies that can support this claim.

Needs:

- Upper air observations to enhance the data on meteorological conditions of dispersion
- Dispersion modeling (traffic, industry, forest fires, dumping areas, ..)
- Monitoring network for transboundary transportation of airborne pollutants
- Monitoring of urban air quality
- Mobile monitoring stations
- National database for air quality measurements
- Quality control and traceability of measurements to international standards
- Forecasting and warnings of quality of air
- Dissemination of information to the public
- Environmental databank

3.13 Disaster Risk Reduction

The National Committee for Disaster Management (NCDM) was established by the Royal Government of Cambodia in 1995 not only to provide timely and effective emergency relief to victims of disasters but also to develop preventive measures to reduce loss of lives and property.

NCDM is a Ministerial level Agency, chaired by the Prime Minister that formed to assist the Royal Government in its Mission to lead the Disaster Management in the Kingdom of Cambodia. Its functions and responsibilities are as follows:

1. Manage data of disaster risk and develop report on the disaster situation;
2. Proposal on reserves of resources for Disaster intervention in Emergency Response;
3. Capacity Building and human resource development on disaster management;
4. Coordination in implementation of disaster management policies;
5. Exchange and sharing information;
6. Coordination and mobilization of resources for disaster response;

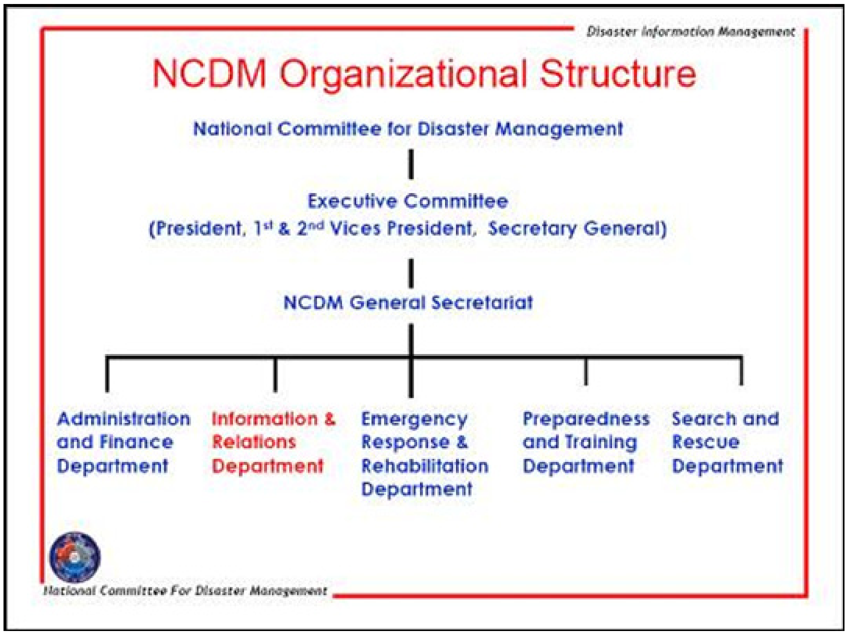


Figure 3.5 Organizational structure of the NCDM

The year 2009 marks a milestone year for Disaster Risk Management in Cambodia. The Strategic National Action Plan for Disaster Risk Reduction (2008-2015) which sets out clear priorities was launched by the Government in March. The field of Disaster Risk Management in Cambodia, however, is also crisscrossed by a host of actors. The field appears uncoordinated and external support fragmented; it remains saturated with reports containing good recommendations that wait to be implemented; and interventions that are yet to make sustainable impact.

Needs:

- Accurate and timely severe weather forecasts
- Hazard maps
- Strong cooperation of NMHS with agencies involved in disaster management
- Real time radar images
- More real time weather and hydrology data and forecast
- Site specific weather forecasts
- Improvements in dispersion modelling of air borne pollutants, especially for accidental cases (gas leaks, industrial malfunctions, etc.) and to make them
- Operational drifting models for oil spills and ship accidents
- Database for the impacts of weather and climate related disasters
- Improved flood forecasts to establish operational model for dispersion for forest fires
- Better information on climate variability
- Outlooks for drought. Forecast on drought and its duration
- Improved and more location specific forecast of precipitation
- Increased number of automatic on-line stations for monitoring of water level
- Water availability forecast

3.14 Military

The Royal Cambodian Armed Forces (RCAF) consists of the Supreme Command Headquarters (SCHQ) located in Phnom Penh, and three distinct forces:

- Royal Cambodian Army
  - 911 Para-Commando Special Forces
- Royal Cambodian Navy
  - Royal Cambodian Marine Corps

- Royal Cambodian Air Force
- Royal Gendarmerie of Cambodia (Military Police)

The RCAF was created in 1993 by the merger of the Cambodian People's Armed Forces and the two non communist resistance armies. At the time, there were also resistance forces opposing the Government comprising the Khmer Rouge and a separate royalist resistance movement (also known as the National United Army or NUA). The armed forces currently operate under the jurisdiction of the Ministry of National Defence.

The Royal Cambodian Army is the largest force with troops stationed in each province of the country. The Royal Cambodian Navy is the second largest force and operates at sea, along the Mekong and Bassac rivers and in the Tonle Sap Lake. The military police force numbers around 7,800 employees and runs parallel to the civilian police force. The military police have posts in every province and municipality across the country. The Royal Cambodian Air Force is the smallest of the three forces and has around 1,000 employees. The air force operates in every province with an airport. The Gendarmarie, or "Military Police", is a para-military unit with about 7,000 soldiers deployed in all provinces. It is headquartered in Phnom Penh, with the unit's chain of command through the Royal Cambodia Armed Force High Command. The Gendarmerie is under the direct supervision of a commander with an equivalent rank to Lieutenant-General. The military police headquarters are in Phnom Penh, and are responsible for monitoring all of the units of Gendarmerie as well as general training.

The Conscription Law of October 2006 requires all males between 18-30 years old to register for an 18-month military service obligation. The available manpower fit for service is: males between the age 16-49: 2,751,618 and females between the age 16-49: 2,835,807 (2010 est.). The Military expenditures of Cambodia is estimated at 3% of GDP (2005 est.)

Needs:

- Weather outlook and improved forecast
- Information and forecast on cloud height
- Upper air observations
- Doppler radar data/images (horizontal and vertical cross sections)
- Good communication link

3.15 Climate change

In Cambodia, the direct impact of climate change may be seen in the change in natural rainfall patterns in the country. Though incidences of flood and drought are common in Cambodia, global warming may increase the country's wet season rainfall and decrease its dry season rainfall in addition to existing great spatial and temporal variability.

As an essentially agrarian country, the Kingdom of Cambodia is highly vulnerable to the impacts of climate change. Cambodia, like other agrarian economies, is especially vulnerable to weather-related disasters as more than 80 percent of its population is subsistence farmers. Adverse impacts include increased in frequencies and magnitude of flood and drought damages, reduction in crop yields, decrease water availability and increase in the number of people exposed to vector and water-borne diseases. Based on data from the past five years, Cambodia's paddy production was destroyed as much as 70 percent by floods, and 20 percent and 10 percent respectively by droughts and diseases.

Results showed that under the high emission scenarios, Dry Season rainfalls will decrease with high probability and Wet Season rainfall may increase but with lower probability than the Dry Season rainfall. This suggests that the onset of rainy season may delay in the future under this emission scenario. Moreover, Wet Season rainfall will decrease until 2025 and then increase again in 2050 and 2080. Similarly, for low emission scenarios, Dry Season rainfall will decrease but with lower probability. However, Wet Season rainfall will increase in 2025 then decreases again in 2050 and 2080.

Available studies indicate the following impacts of climate change on the different sectors in Cambodia:

On Agriculture

The increase in future rainfall variability will have impacts on agriculture production:

- Affect yield variability
- Increase crop production loss due to the increase in frequency and intensity of extreme climate events
- Rice farming system might be exposed to higher flood and drought risks in the future
- Increase frequency of crop pest and diseases outbreak (emergence of new pests and diseases, etc)

On Forestry

- Increased precipitation would increase soil erosion, which in turn would accelerate forest degradation
- Based on studies of neighboring countries, forest productivity and some of species of Cambodia may change and disappear
- Need to further study on the impact of climate change on forest productivity and biodiversity

On Human Health:

- Number of malaria cases is negatively correlated with dry season rainfall, mean annual temperature and percent literate, and positively correlated with wet season rainfall. The Ministry of the Environment estimates that under changing climatic conditions Cambodia may experience increasing incidences of malaria, up 16 percent from its current rate

On Coastal Zone:

- Rising seas will increase the risk of low-lying areas to flood. Koh Kong province will be the most vulnerable to sea level rise
- Coastal erosion will increase
- Saltwater intrusion will increase
- Mangrove ecosystem is the widest area that would be inundated
- Coastal industries and economies, tourism and wildlife habitats would be seriously affected
- A one-meter sea level rise would submerge about 56% of the low lying coastal city of Koh Kong

Natural hazard-induced disasters have upset fragile ecosystems, which in turn have triggered other changes that have consequence in rising poverty and malnutrition of children.

Meanwhile, damage to infrastructure and land has compelled people to relocate, which has caused psychological disorders in many. This illustrates how vulnerable Cambodia is in facing the impact of climate change due to a lack of infrastructure and mechanisms to lessen the effects. With these direct and indirect impacts of climate change, different levels of impacts can be analyzed at the national, community and individual levels.

On the country level, with less agricultural activity and losses due to natural hazard and climate related disasters, Cambodia, which largely depends on the agricultural sector, will experience slow economic growth. In addition, poor and underdeveloped health infrastructure will aggravate the health problems and further burden the government. On the community level, the livelihoods of many will be affected by disasters, which would not only adversely affect homes and properties, agricultural produce and health, but also community collaboration and trust when the economic downturn would lead to more social crimes. On the individual level, people will face with issues such as pollution and access to clean water. Depletion of natural resources and bad economic policies will discourage foreign direct investment, which otherwise provides employment to local people.

Climate Change Management Structure

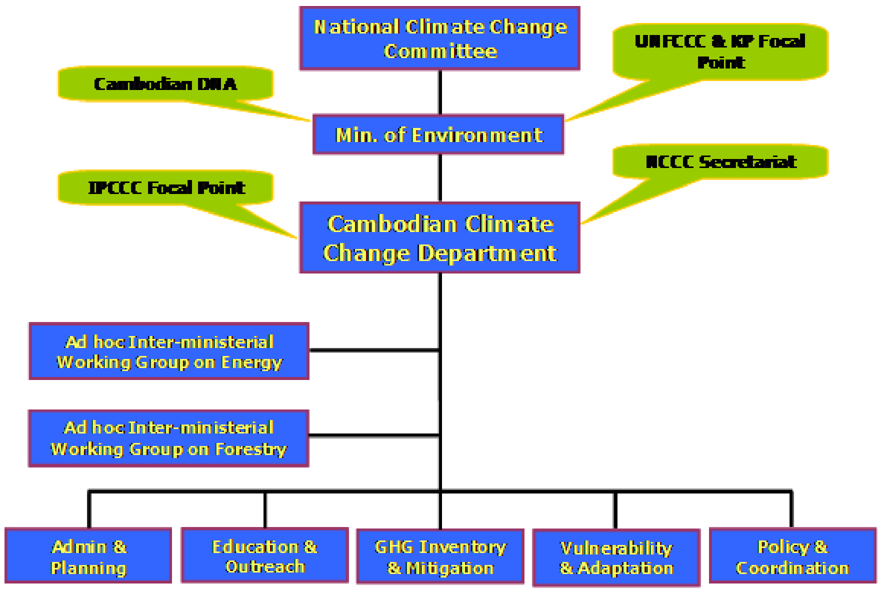


Figure 3.6 Climate management structure in Cambodia

The Second National Communication (SNC) to the UNFCC highlight the following key components: Greenhouse Gas Inventory for 2000, programmes containing measures to facilitate adequate adaptation to climate change, programmes containing measures to mitigate climate change and other priorities (technology transfer, financing, capacity building, awareness raising, research and systematic observation, etc.).

In Cambodia, the Ministry of Environment (MoE) is the National Focal Point for the UNFCCC, the Kyoto Protocol and the IPCC. It also serves as the Cambodia's DNA for CDM projects. The Cambodian Climate Change Office (CCCO) was established within the MoE in June 2003. It was elevated to Department of Climate Change by a Sub-decree dated 14 October 2009. In 1999, MoE had its first ever climate change project to prepare the Initial National Communication to the UNFCCC, the Greenhouse Gases Inventory Adaptation and Mitigation. The National Climate Change Committee (NCCC) was established in April 2006 by a sub-decree. It is a policy-making body comprising representatives from 19 concerned Government ministries and agencies (See structure below). The Prime Minister accepted the position of the Honorary Chair of the NCCC by a sub-decree dated 14 October 2009. The NCCC was mandated to prepare, coordinate and monitor the implementation of policies, strategies, legal instruments, plans and programmes of the Royal Government to address climate change issues.

The National Adaptation Programme of Action to Climate Change (NAPA) was approved in 2006. It consists of 39 'no-regret' adaptation projects in agriculture, water resources, coastal zone and human health. It focuses on measures that have direct impacts on the livelihoods of local people, in particular the poorest. It has a project on "Promoting Climate-Resilience Water Management and Agricultural Practices in Rural Cambodia" being implemented by the Ministry of Agriculture Fisheries and Forestry (MAFF) (US$ 4.1 m, of which US$1.8 m from the LDCF, main counterparts: MAFF and MOWRAM). A proposal on "Vulnerability and Adaptation Program for Climate Change in the Coastal Zone of Cambodia considering Livelihood

Improvement and Ecosystems" is being developed based on NAPA (€ 3.9m, of which €2.2m from EC, €1.2m from LDCF)

National Strategic Development Plan 2006-2010 calls for resource mobilization to implement the NAPA. Historical trends and climate projections has been prepared by the Climate Change Department using the PRECIS model (Figs. 3.6 -3.7).

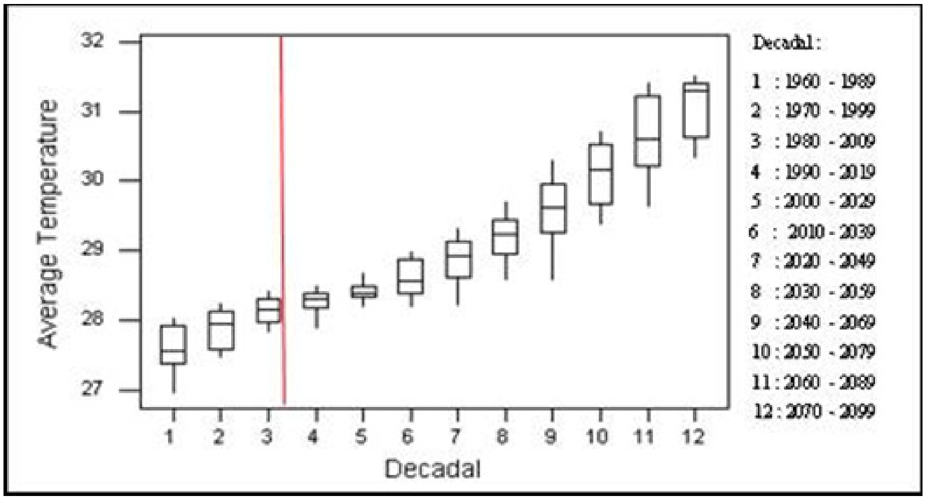


Figure 3.7 Historical and future mean temperature over land area of Cambodia (based on PRECIS)

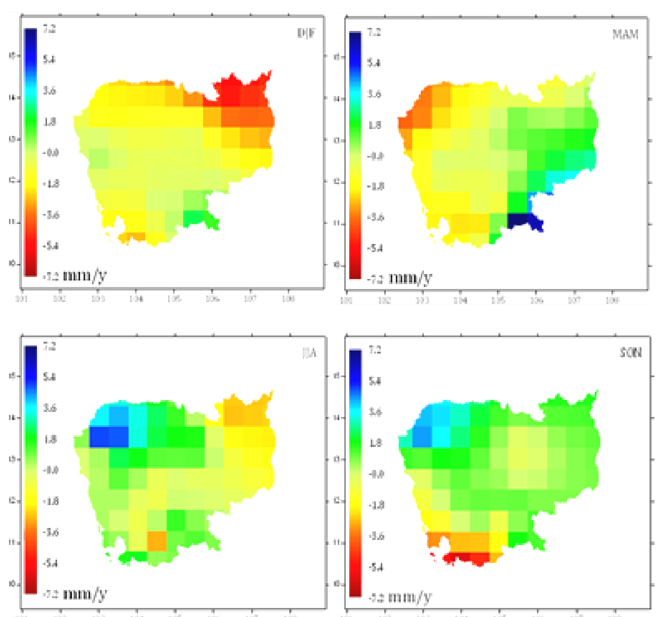


Figure 3.8 Historical change (trend) of seasonal rainfall in Cambodia (1960-2000)

Based on data 1960-2000, Cambodian climate (rainfall and temperature) has already changed, and the future rainfall pattern will continue to change depending on emission scenarios

Needs:

- Vulnerability and risk assessment
- Improvement on data management system
- Climate modelers
- Coordination among agencies related to climate change activities
- Regional cooperation for CC project
- Understanding of the impacts of climate change on different economic sectors
- Downscaling capacity to support local adaptation to climate change

3.16 Media

The Cambodian Media sector is vibrant and largely unregulated. This situation has led to the establishment of numerous radio, television and print media outlets. Many private sector companies have moved into the media sector, which represents a significant change from many years of state-run broadcasting and publishing.

Since emerging from the communist governments of the Khmer Rouge and the Viet Nam-backed People's Republic of Kampuchea regime, the Cambodian media sector has become one of Southeast Asia's liveliest and most free, although a lack of professional journalism training and ethics, and intimidation by both government and private interests limit the Cambodian media's influence.

There are 11 TV stations nationwide, including two relay stations with French, Thai and Vietnamese broadcasts, as well as 12 regional low-power stations (as of 2006). On radio, Cambodia has two AM stations and at least 52 FM stations.

There are over 100 registered newspapers in Cambodia, of which only a handful publish regularly. Perhaps less than 20 of these could be regarded as ‘real’ newspapers, with paid staff and a predictable publishing schedule. The leading Khmer daily newspaper is Rasmei Kampuchea (Light of Kampuchea) Daily, established in 1993, which has a section on arts and culture. Kampuchea Thmei Daily, another broadsheet, has emerged recently as its strongest competitor.

Responsibility for regulation of the media sector in Cambodia is shared between the Ministry of Information and the Ministry of Posts and Telecommunications, with the Minister of the Interior as the ultimate upholder and enforcer of the law. While the duties of these ministries in relation to the media are set out in their respective Decrees and Sub Decrees, there is at present no comprehensive legislation relating to broadcast, print and digital media in Cambodia.

4 THE METEOROLOGICAL AND HYDROLOGICAL SERVICE OF CAMBODIA IN A NUTSHELL

4.1 Brief History

Meteorological observation in Cambodia was established for measurement of climate in 1894. However, meteorological service was not properly established until after independence in 1954. Although there had been some minimal activities before Cambodia had became a member of the World Meteorological Organization (WMO) on November 08, 1955.

In 1964 the meteorological network consisted of 10 synoptic and climatological stations and more than 100 rain gauges across the country. There was the National Forecasting Center at Pochentong International Airport, located at southwest of Phnom Penh. In 1971, WMO had introduced some programs for further strengthening the Cambodia National Meteorological Services (CNMS). The project, funded by the United Nations Development Programme (UNDP) and planned for 1972-1977 was discontinued in 1975 due to political upheavals in Cambodia. Between 1975 and 1979 the CNMS was abandoned, resulting in a complete disruption of entire meteorological network. After 1979, with the assistance of Russia, some services for the aviation purposes have been restored. Since 1982 some out-of-date Russia instruments and about 33 rain gauges were brought in and installed at selected five synoptic stations. However in 1992, all the supports from Russia assistance ended and the Meteorological services had many difficulties.

The Department of Agriculture Hydraulic and Hydro-Meteorology (DAHHM) has become the General Directorate of Irrigation, Meteorology and Hydrology (GDIMH) on September 30, 1996. The GDIMH then became the Ministry of Water Resources and Meteorology (MOWRAM) on November 30, 1998. At the present, all meteorological activities in Cambodia are conducted by the Department of Meteorology (DOM), under the umbrella of MOWRAM.

4.2 Organizations with responsibility for Hydrometeorological and Related Services in Cambodia

Weather services	• Department of Meteorology (DOM) Ministry of Water Resources and Meteorology (MOWRAM)
Climatological and farm weather services	• Department of Meteorology (DOM) • Ministry of Agriculture, Fishery and Forestry (MAFF)
Hydrological services	• Department of Hydrology and River Works • Ministry of Water Resources and Meteorology (MOWRAM)
Hydrological observation network	• Department of Hydrology and River Works • Mekong River Commission
Maritime observations and services	• Department of Meteorology (DOM)
Meteorological services for aviation	• Department of Meteorology (DOM)
Environmental research	
Air quality monitoring	• Ministry of Environment
Water quality monitoring	• Ministry of Environment • DHRW of MOWRAM

4.3 General Information

Name of Organization: Department of Meteorology (DOM)
Ministry of Water Resources and Meteorology (MOWRAM)
Office Address: M.V. Preah Monivong, Phnom Penh, CAMBODIA
Contact Numbers: Tel.: (855)-16-756389 Fax: (855) 23-727446,
Contact person for this study: MR. OUM RYNA
Email address: rynaoum@yahoo.com
Office hours: 0800H to 1700H
Weather service hours and office hours at synoptic stations: 0000 to 2400 (24/7/365)

Legal framework:

DOM is the agency under the Ministry of Water Resources and Meteorology with the following mandates:

- Install and manage the weather monitoring network throughout Cambodia;
- Monitoring weather condition happening in the region;
- Issue the weather forecast and provide warning on weather condition to relevant ministry and public via media; and
- International and regional cooperation in data information sharing, researches and training.

The Department of Hydrology and River Works (DHRW) which is also under the umbrella of MOWRAM is in charge of all hydrological activities in Cambodia. DHRW consists of 5 offices: Administration Office, Research and Flood Fore-casting Office, Water Quality Analysis Office, Hydrological Works Office, and River Bank Protection Office. DHRW has the followingfunctions:

- Strategic of installing hydrology stations on the main water courses in order to serve water resources sector development and management;
- Short, medium and long term strategic plan on river bank protectionerosion control, sediment and morphology monitoring ;
- To establish hydrological and groundwater observation/ monitoring stations to collect data to assess national water resource potential for use in national economic development and environmental management ;
- To implement water level, discharge and sediment transport at each major rivers in the national 39 river basins including the Mekong-Tonle Sap-Bassac river systems and transboundary rivers;
- To collect, analyse and monitor water quality at key hydrological stations and sub-river basins including transboundary rivers ;
- To develop capacity in analytical hydrology at sub-basin level supporting integrated resource evaluation, development and management ;
- To provide short, medium and long term forecast for water availability at each sub-catchment for planning and management ; and
- To disseminate hydrological information through regular publication of primary data, near real time data, flood/drought hazards maps using geographical information system .

4.4 Evaluation criterion

Concerning the duties and responsibilities of DOM, it has special relationships and responsibilities with several ministries and state bodies.

- Ministry of Environment
- Ministry of Agriculture Forestry and Fishery,
- National Committee for Management (NCDM)
- Ministry of Public Works and Transport
- Ministry of Labor and Social Welfare
- Ministry of Industry, Mines and Energy
- Cambodian Red Cross
- Cambodia National Mekong Committee
- Ministry of Land Management Urban and Construction

4.5 Annual report

DOM does not publish an annual report.

4.6 Organizational structure

The organizational structure of DOM is illustrated in Figure 4.1. It is headed by a Director who reports directly to the Minister. In line with its responsibilities, DOM organizational structure is divided into 6 main offices namely: Administrative Office, Observation Office, Equipment Office, Forecasts and Researches Office, Climate Office and Hydrometeorological Office. The Hydrometeorological Office is in charge of the 21 provincial stations all over Cambodia.

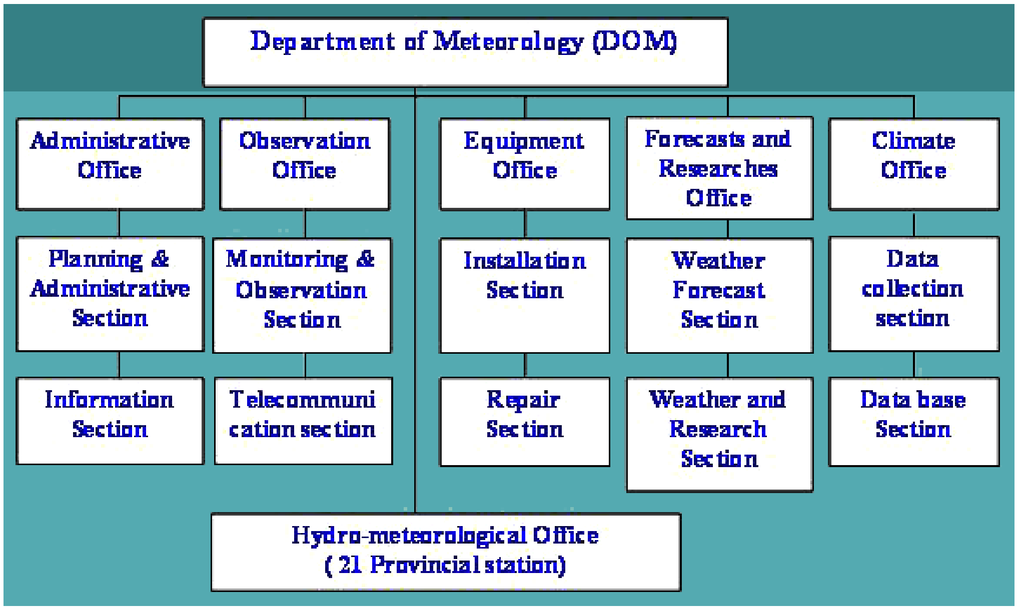


Figure 4.1 New Organizational Structure of DOM

4.7 Regional centres and offices

As shown in the organizational structure, DOM maintains 21 hydro-meteorological stations all over Cambodia, one synoptic station per province. These stations are equipped with meteorological instruments which include twelve AWS and 200 raingauges most of which are old many are not in working condition. After observation, the data are transmitted to the headquarters in Phnom Penh via telephone or SSB.

4.8 Budget and Accounting system

The financial requirements for the operation of DOM and its accounting are being managed by the Administrative section of the Ministry of Water Resources and Meteorology.

4.9 Human resources

DOM employs a total of 44 staff at the Headquarters in Phnom Penh distributed in the 5 offices: Administration = 5, Observation = 10, Research and Forecasting = 9, Climate = 9, and Equipment Management = 9. There are 34 males and 10 females. On the staff's educational attainment, four (4) are Master's Degree holders, five (5) engineers, and 35 technicians. All the Master's Degree holders obtained their diploma from Russian universities through scholarship grants and the engineers and Bachelor Degree holders from Belgium, Vietnam, Russia and Cambodia.

Inherited from past management problems most staff lacks of professional practical experience. Field and offices procedures established during the early days of the establishment of the DOM have been badly eroded. It has been observed that the DOM staffs do not have a strong sense of responsibility towards work. DOM needs to hone the skills of its human resources through the conduct of specialized and highly technical training courses to keep abreast with the fast pace of technology. However, the current salary level paid by DOM and lack of proper training programme do not support these objectives. The government should find ways to address this through awarding of incentives such as scholarship grants, free medical services, low-cost housing and other benefits. Networking with local and international institutions is one of the possible solutions to this.

The DOM still does not have its human resources development plan, which might take some five to ten years to have effect since there are no universities or engineering school in the country offering Earth Science, Geography, Meteorology and Hydrology. Sending Undergraduates for Postgraduate training abroad still faces many difficulties including lack of budget, English proficiency as well as low acceptance of candidates by universities abroad.

4.10 Training programmes

The DOM conducts seminars and short training courses on meteorological observation but not on a regular basis. Most of the staff availed foreign funded fellowships and trainings outside the country.

4.11 Premises

The DOM transferred to its new building in Phnom Penh in March 2010. It occupies the ground floor of the three storey building equipped with computer facilities (Fig. 5.3) donated by JICA for weather forecasting. The ground floor includes a small conference room for group meetings. The DHRW is also housed at the second level of the new building.

Figure 4.2 Headquarters building of DOM and DHRW

Figure 4.3 Computer facility of the DOM

4.12 Visibility of DOM

DOM releases the weather forecast to public trough TV, Radio and News papers. The public telephone, facsimile and e-mail are also utilized in the delivery of weather/flood forecasts and Tropical Cyclone Warnings to public. The forecast messages are regularly sent to the Ministry Water Resources and Meteorology. In case of extreme natural disaster, urgent warnings and advisories are reported to and announced by the Prime Minister on TV. National and Municipal Radio Stations are frequently broadcasting in many programs every day. DOM needs to enhance its relationship to the media

4.13 International memberships and networking

Cambodia, through DOM is a member of the World Meteorological Organization with the Minister of the MOWRAM as the Permanent Representative. Cambodia is also a member of the Typhoon Committee and the Mekong River Commission, International Association of Hydrologists (IAH) and IAHS of UNESCO.

4.14 Cooperation with other users of hydro-meteorological services in Cambodia

There is a need for DOM to enhance its linkages with other government agencies like, the Ministry of Public Works and Transport, Ministry of Environment, Ministry of Industry, Mines and Energy, Ministry of Agriculture, Forestry and Fishery (MAFF), National Committee for Disaster Management, Cambodia Red Cross, etc. Protocols on sharing and transfer of hydrometeorological data and information should be established. Collaborative projects (seminars/workshops) and IEC campaigns among the ministries/agencies should be undertaken to improve hydrometeorological services.

5 CURRENT SERVICES OF DOM

5.1 Weather services

The increasing frequency and intensity of extreme weather events such as floods and drought have caught the attention of the general public on the importance of weather services being provided by NMHSs. Advance forecasts of El Niño/La Niña, warnings for approaching tropical cyclone and heavy rains enable all sectors and the communities to plan their activities and the people to prepare to reduce or avoid damages from these natural hazards. Of all the sectors, the agriculture and transportation industries particularly shipping and aviation are the major beneficiaries of these weather services.

The DOM is the technical department directly under the Ministry of Water Resources and Meteorology mandated to issue weather forecasts and provide warning on weather condition to relevant ministries and public. It provides short, medium and long range weather forecasts and issues Tropical Cyclone Warnings to inform the public of impending hazards.

When there is a tropical cyclone activity in the vicinity of Indochina Peninsula, DOM conducts non-stop monitoring 24 hours a day. Typhoon forecasting is made through subjective analysis of weather maps and weather reports of surrounding countries including weather forecasts for marine issued by the Royal Observatory of Hong Kong. DOM continuously monitors its meteorological observation network, satellite images, and weather charts for tracking of the cyclone.

5.1.1 Forecasts and Tropical Cyclone Warnings Dissemination

Tropical Cyclone forecast Methodology:
The forecast methodologies used are:

- The procedure is based on the method delivered by Dvorak technique.
- Analysis surface observation by using compass method to determine pressure center of Tropical Cyclone.
- The use of Japan's MTSAT imageries of tropical cyclones, has improved the operational work of DOM in analysing and determination of the cyclone's eye and rainfall.
- Pressure falling method: the use of pressure changes can be especially helpful in short range forecasting.

DOM also utilizes NWP products from the following foreign forecasting centers:

- Typhoon forecast from RSMC (JMA) and products from Hong Kong Observatory
- FNMOC WXMAP, one week forecast with time interval every 6 hours
- ADPC–RIMES: DOM receives through e-mail daily advisory from the Regional Integrated Multi – Hazards Early Warning System for the Asia Pacific Region which has been developed under the agreement between WMO and ADPC

The numerical products analysed include Mean Sea Level pressure (MSLP) chart, Upper air Charts of 850, 500 and 200 hPa (analysis and forecasts for 24, 48, 72 and 96 hrs) and 6 hourly forecast rainfall up to 72 hrs.

Sample of Thunderstorm Warnings/ Weather Forecast:

Warning issued by DOM at: 10:00 am
Weather condition expected:

- Heavy rain with speed winds 10-15 mps at certain areas.
- Light rain with thunders over Cambodia. Inhabitants within these above mentioned areas are advised to be aware of damages which may be caused by flash flood and flood.
- Please follow next warning for the necessary actions to be taken

Tropical Cyclone Warnings Dissemination

The Public telephone, Facsimile and E-Mail are used for delivering the weather and flood forecasts and Tropical Cyclone Warnings to government and private sectors. DOM directly reports the message to MOWRAM and releases the message to public through TV, radio and news papers. In case of urgent warning, DOM provides an announcement to MOWRAM, and then MOWRAM reports to the Prime Minister. The Minister of MOWRAM and/or the Director of DOM makes live announcement of warnings on television and broadcasted over radio stations. At the same time DOM send the warning to NCDM and mass media. The dissemination of weather bulletins to public and private sectors is shown in Figure 5.1.

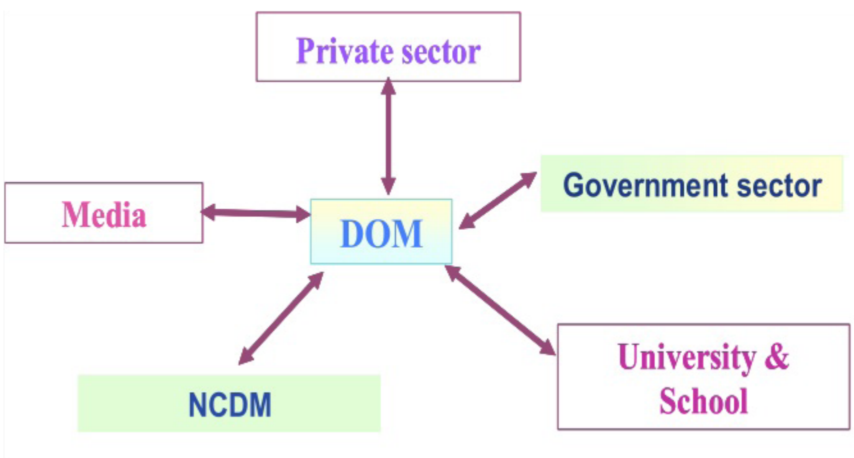


Figure 5.1 Dissemination of Weather Bulletins and warnings

To improve Forecasts and Tropical Cyclone Warnings Dissemination, the DOM and DHRW need to:

- Upgrade meteorological instruments
- Prepare a manual for tropical cyclone forecasting and warning system
- Motivate the DOM staff to work efficiently
- Upgrade communications facilities
- Build capacity of DOM staff through trainings
- Collaborate more closely between DOM and DHRW to improve and expand flood/drought forecasting

5.2 Early Warning System

For Tropical Cyclones:

When a Tropical Cyclone (TC) with storm wind of 20 - 25 knots (10 – 12.5 mps) is approaching Lao and Viet Nam, DOM issues a 24- hour forecast.

For floods:

Using river forecasting model for Cambodia, DHRW provides 1-3 day water level and flood forecast at 7 stations along Mekong, Bassac and Tonle Sap River. From the result of the model Flood Bulletins are issued indicating the forecast water levels and warnings for floods are shown on sign boards for the public to see (Figure 5.2).

Figure 5.2 Flood warnings and bulletin from Flood forecast model by the DHRW.

Kingdom of Cambodia
Nation Religion King

Ministry of Water Resources and Meteorology
Department of Hydrology and River Works

Flood Forecast Bulletin

Satation Name/ Province	Observed WL(m)	Differenc WL(m)	Alarm Stage(m)	Flooded Stage(m)	Rainfall (mm)	Forecasted water levels (m)		
	07/07/05				[illegible]	08/07/05	09/07/05	10/07/05
Stung Treng	6.50	-0.06	10.70		n	6.46	6.37	6.26
Kg. Pong	nd	#VALUE!	nd		n	nd	nd	nd
Kaing Chem	nd	#VALUE!	1.66		n	-1.00	-1.00	-1.00
Porng Teuk	nd	#VALUE!	1.78		n	-1.00	-1.00	-1.00
Onlong Svay	nd	#VALUE!	1.82		n	-1.00	-1.00	-1.00
O Rey	nd	#VALUE!	3.75		n	-1.00	-1.00	-1.00
O Trel	nd	#VALUE!	1.78		n	-1.00	-1.00	-1.00
Kaing Tacher	nd	#VALUE!	2.60		n	-1.00	-1.00	-1.00
Thela Borivath	nd	#VALUE!	1.72		n	-1.00	-1.00	-1.00
Veal Khsach	nd	#VALUE!	1.97		n	-1.00	-1.00	-1.00
Kratie	15.04	+0.14	22.00		n	14.86	14.81	14.74
Ta Thoung	nd	#VALUE!	4.53		n	-1.00	-1.00	-1.00
Bosleav Leu	nd	#VALUE!	2.86		n	-1.00	-1.00	-1.00

(Source: Saravuth, 2005)

In Figure 5.3, the warning procedure is presented. Values of Warning Levels and Flooding Levels at different stations are indicated. There are three categories of warnings based on the observed level and the forecast level. The first two categories indicate that the water level already exceeded the warning levels prescribed so the people living near the river should be ready for the floods especially on the 2nd warning when the water level is very close to the flooding level. The 3rd warning is called Flood Alarming which means that the observed and forecast water levels already exceeded the flooding level and people along the riverbanks should evacuate.

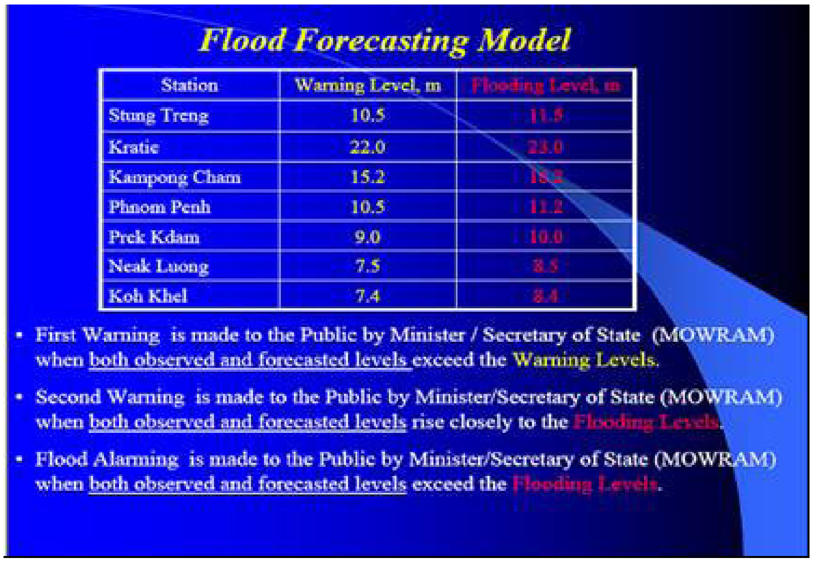


Figure 5.3 Flood warning procedures based on observed and forecast water levels

In addition to the daily weather forecasts, the DOM is providing warnings to different hydrometeorological hazards like thunderstorms, drought, and flash floods in coordination with the Department of Hydrology and River Works.

5.3 Climatological services

For climatological computations and statistics such as mean daily, monthly or annual values of weather parameters, DOM use the Excel of Microsoft Windows Climate Prediction Tools (CPT), NSL and GrADS. It does not run climatological models for trends and climate impacts assessment.

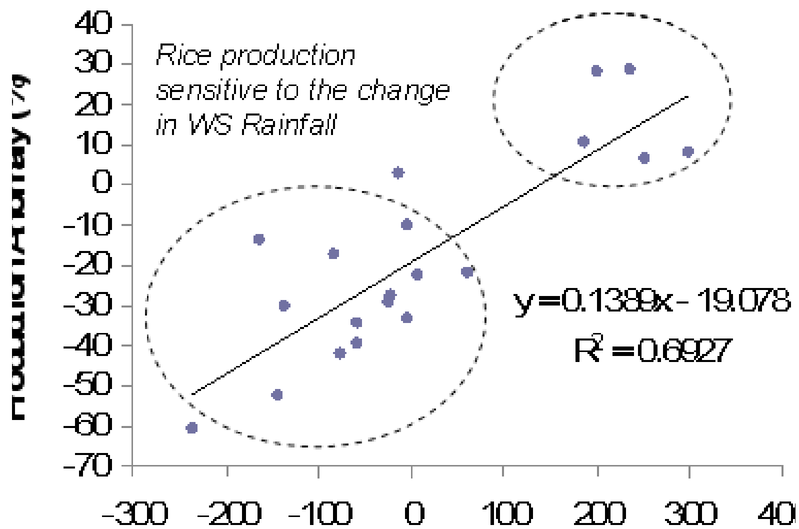
DOM has a Climate Office composed of Data Collection Section and Data-base Section. The Climate Office is housed at DOM Headquarter in Phnom Penh with 9 personnel engaged in climatological services. All requests for weather and climatological data are being attended by the Office. The data-base of observed data collected is not yet fully organized.

The DOM would need to:

- Utilize climate models and tools like CLICOM, INSTAT, etc.
- Organize a good data-base system
- Digitize weather charts
- Produce climate risk maps
- Ensure quality control of data with frequent instrument calibration and rigorous implementation of field and office procedures
- Disseminate the information in E-format

5.4 Agrometeorological services

Agrometeorological services are being handled by the Ministry of Agriculture, Fishery and Forestry (MAFF). DOM and DHRW provide hydrometeorological data in addition to the rainfall data from the MAFF rainfall stations. Based on seasonal forecasts (onset of rainy season, drought or flood) and tropical cyclone warnings, the agriculturists advise the farmers on what variety of crop and the proper time to plant or harvest. For rice production, it is very sensitive to change in wet season rainfall as shown in Figure 5.4; hence, advance information on rainfall forecast is important. Advance planning of planting activity is made based on long range forecast i.e. forecast of El Niño/La Niña. Agrometeorological data helps to improve knowledge on climatic resource supporting crop diversification and intensification.



(Souce:Ponlok,2010)

Figure 5.4 Relationship of rice production and wet season rainfall anomaly

For fisheries, seasonal forecasts, water level monitoring, flood pulse and temperature are also important for aquaculture and inland fish production.

The needs to strengthen the services are:

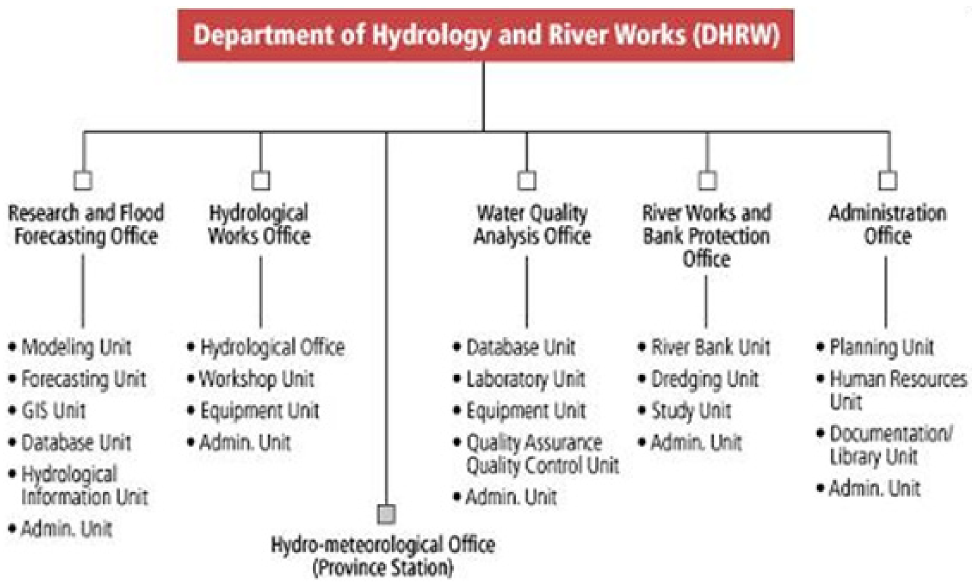
- DOM to conduct seminars/trainings on agrometeorology involving MAFF staff
- Enhance communication/coordination/linkage between DOM and MAFF
- Improve quality of data and accuracy of forecasts
- Introduce Climate Field Schools to Cambodian farmers
- Upgrade existing synoptic stations with additional instrument to meet needs for agrometeorology

5.5 Hydrological services

The DHRW which is also under the MOWRAM is responsible for providing hydrological services in Cambodia. Its functions and duties include:

- Manage the hydrological information, forecast, and provide information in advance of floods and water shortages.
- Develop necessary projects and hydrological stations at designated water areas in order to serve the water resources development;
- Develop the short, medium, and long term plans for erosion, sedimentation, and river bank protection and management;
- Monitor the hydrological flow regime both surface and ground water by establishment of hydrological stations, as well as collecting and analyzing data for the related sectors;
- Measure and evaluate water level, discharge, sedimentation and other related tasks;
- Monitor water quality at the hydrological stations at the designated water areas, which have been installed along the Mekong River, Tonle Sap Great Lake and their tributaries;
- Improve knowledge of hydrological phenomena, by hydrological modeling, hydrological calculation to access surface and ground water potential;

Figure 5.5 Organizational structure of the Department of Hydrology and River Works



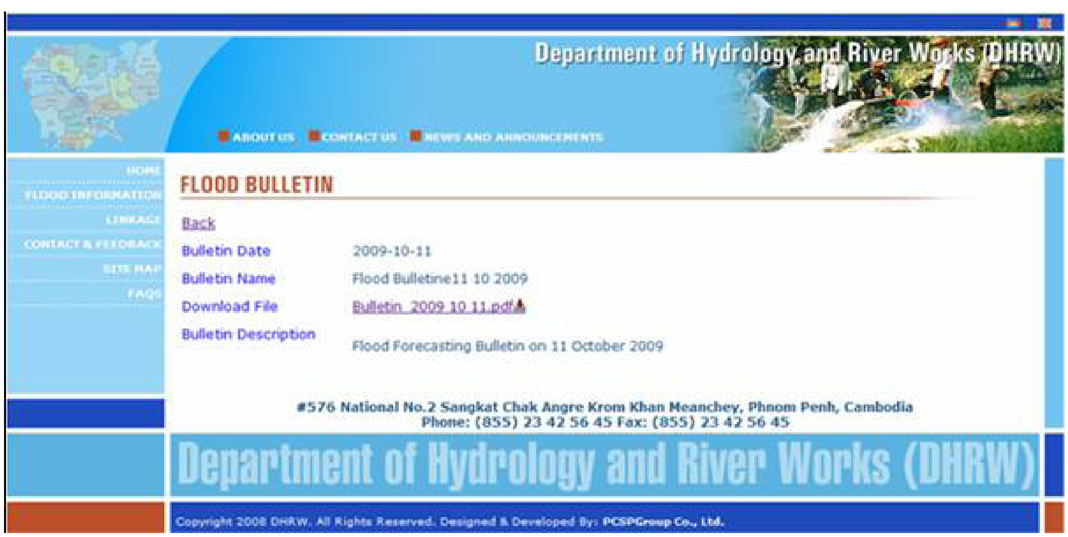


Figure 5.6 DHRW website where hydrological information and flood bulletin are posted

The DHRW maintains a website where it posts hydrological data and information i.e. water level forecasts, flood bulletin etc. for public to see.

5.6 Marine services

DOM does not provide marine services but hydrological information for waterways along the Mekong River are provided by the BHRW. With hydrological network expansion to the coastal areas, tidal stations will be established at some important ports.

5.7 Environmental services

5.7.1 Water quality

As one of its functions, DHRW monitors water quality at key hydrological stations, along the Mekong River, Tonle Sap Great Lake and their tributaries. A number of line ministries are involved in defining and implementing drinking water quality standard namely: Ministry of Health (MOH), Ministry of Industry Mine and Energy (MIME) and the Ministry of Rural Development (MRD). The MOH defines the water quality for human health, the MIME for industrial water supply and sanitation and the MRD for rural water supply and sanitation.

5.7.2 Air quality

As regards to air quality, the Department of Air Pollution Control of the MoE is responsible agency. DOM only provides information on atmospheric condition and meteorological parameters such as winds and temperature.

5.8 UV radiation: None

5.9 Climate Change related services

The Climate Change Department of the MoE undertake studies and provides climate change related services in Cambodia. The Greenhouse Gas inventory was completed in year 2000. Climate change adaptation, mitigation and vulnerability assessment projects are being undertaken under the UNDP Climate Change Programme.

Historical trends and climate projections have been prepared by the Climate Change Department using the PRECIS model. Climatological data of rainfall and temperature from the DOM are used in the climate trends and projections.

5.10 R&D based Expert Services

The DOM staff at present are not involved in any research activities.

5.11 Information services

The DOM used to have a website (dom@camnet.com.kh) but due to some internal problems, it was terminated. Creation of new website is being planned. At this time, information services of the DOM are through radio, TV and newspaper. A brochure on the profile of DOM is available; however, it needs to be updated.

CAMBODIA'S NETWORK OF OBSERVING STATIONS

6

In Cambodia, the DOM only operates and maintains surface observation network. It does not have upper-air stations, marine buoy, the weather radar was installed at the compound of the MOWRAM and put into operation recently but still facing calibration and effective operation due to lack of experienced meteorologist.

6.1 Meteorological stations

The DOM meteorological observing network is composed of 21 Synoptic stations distributed in every province of Cambodia (Figure 6.1). Out of these stations, 8 are automatic weather stations (AWS) and 13 stations are manuals by the conventional analogue system. All AWS were installed between 2001 and 2003 and all of them ceased functioning after 1 to 2 years of operation due to lack of maintenance and insufficient training as well lack of operation funds. Almost all instruments of manual stations are obsolete.

Figure 6.1 Meteorological network of stations in Cambodia

6.2 Climatological stations

Climatological observations are incorporated in all synoptic stations of the DOM.

6.3 Rainfall stations

The DOM has 200 rainfall stations all over Cambodia. The raingauges are being manned by staff from provincial offices and others by part-time observers. Their status is uncertain and need complete review including network expansion to attain acceptable coverage density.

6.4 Hydrological stations

Cambodia has a total of 80 manual and 12 automated hydrological stations manned by the DHRW. At present, only 50 of the manual stations are operational. The distribution of the stations is shown in Figure 6.2. There are still 28 ungauged sub-basins in the country including coastal areas. Many of the existing stations need review especially areas around the Tonle Sap Great Lake to be able to represent better water resources of each of the sub-basins.

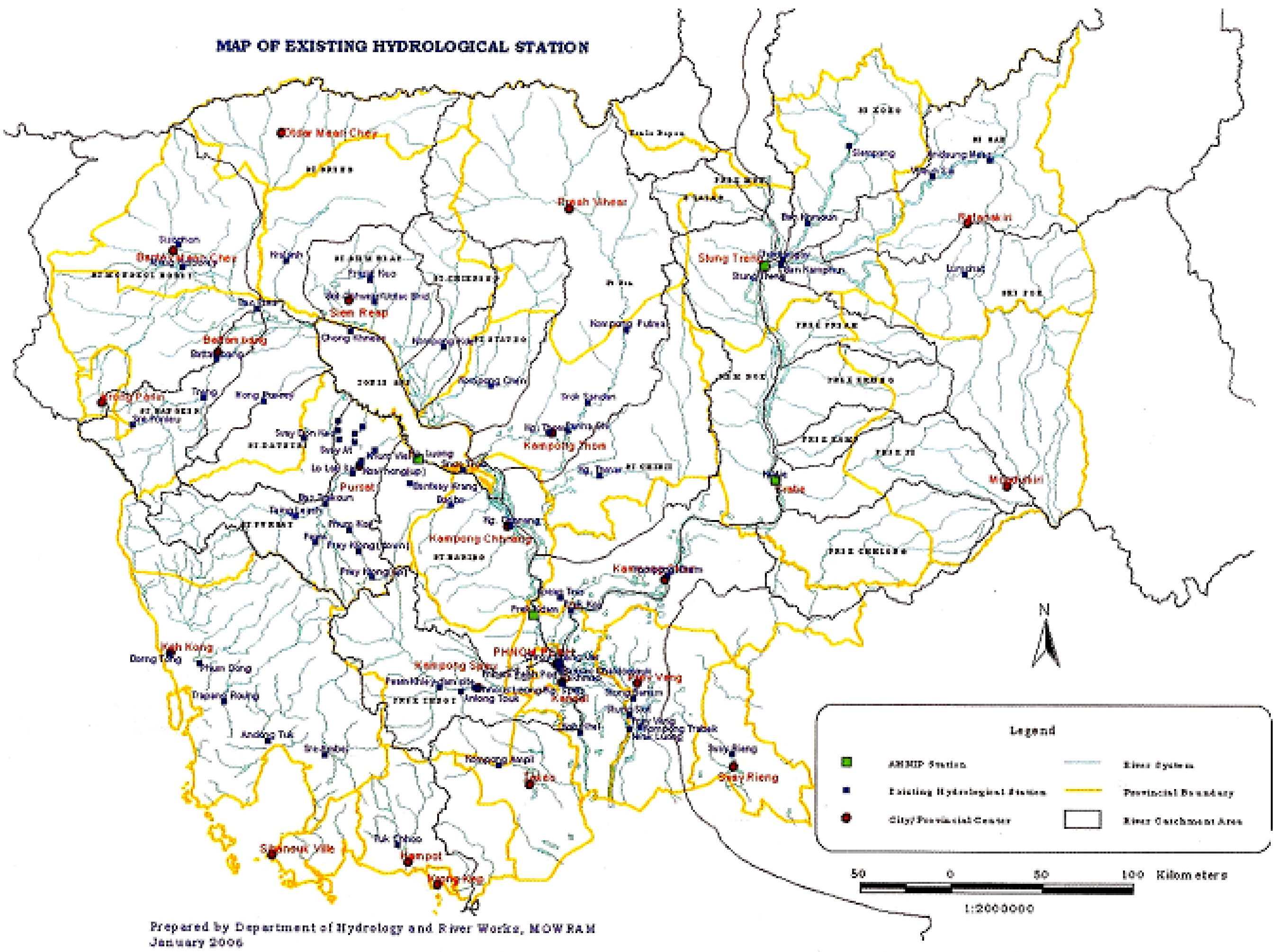


Figure 6.2 Locations of hydrological stations in Cambodia

6.5 Agrometeorological observations

DOM does not operate an agrometeorological stations, the MAFF is in charge of agrometeorological stations; some of the synoptic stations could be upgraded to be an agrometeorological, this needs only a coordination effort.

6.6 Marine observations

No marine observations

6.7 Air quality observations

Air quality monitoring is being undertaken by the Department of Air Pollution Control under MoE.

6.8 Water quality observations

The DHRW operates the water quality monitoring network in Cambodia. The 20 stations are situated along the Mekong River and the Tonle Sap tributaries illustrated in Figure 6.3.

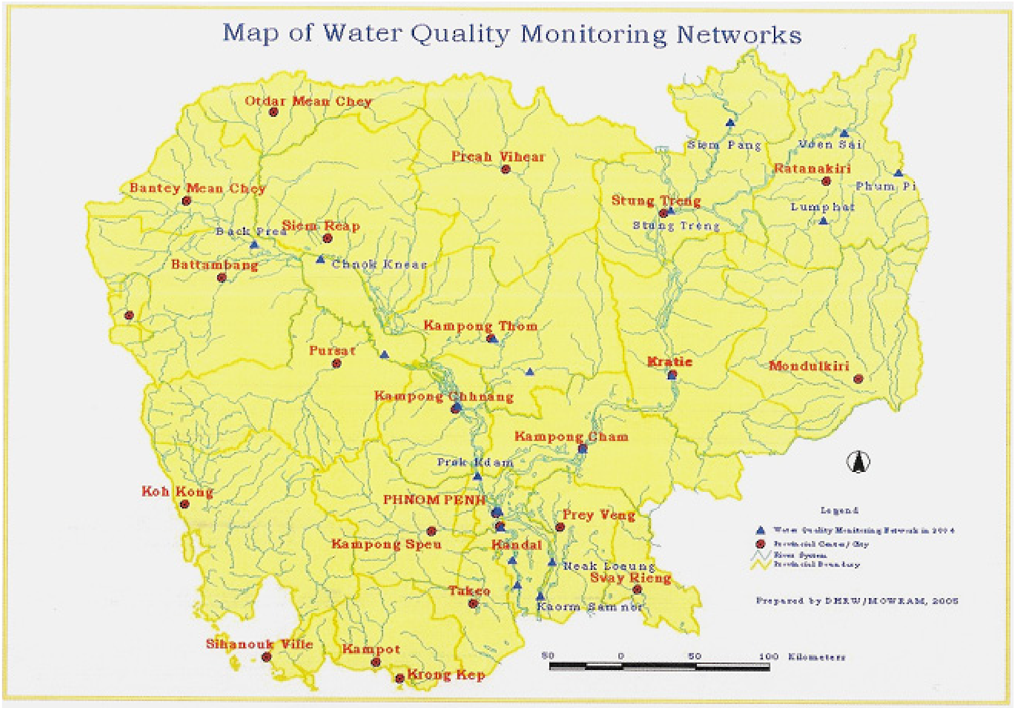


Figure 6.3 Location of water quality monitoring stations in Cambodia

6.9 Lightning

Lightning detector could be of use to assist weather radar in detecting rainstorm activities: None

6.10 Satellite

Under the JICA Project on Urgent Rehabilitation and Improvement of Civil Aviation Meteorology in Cambodia, MTSAT satellite was installed in June 2008 at the then DOM headquarter in Pochentong. Training of DOM staff on MTSAT operation and application was conducted by the JICA experts (Figure 6.4).

Figure 6.4 Training on MTSAT operation by JICA at Pochentong

When the DOM transferred to its new building in March 2010, the operation of the satellite was temporarily stopped. Later in June 2010, the satellite disc as shown in Figure 6.5 was already in the site, waiting for the JICA team for reinstallation. Finally the MTSAT was re-installed in the new DOM building on July 22, 2010. They are now still facing difficulties with its operation (outdated system).

Figure 6.5 The MTSAT satellite disc to be reinstalled at the rooftop of the new building.

7 MAINTENANCE, CALIBRATION AND MANUFACTURING OF MEASUREMENT SYSTEMS

7.1 Meteorological observations

Maintenance and calibration of the meteorological instruments is being done by the Repair of Equipment Section of the DOM or in cooperation with manufacturer. In the new location the DOM does not have space for instrument storage, calibration and maintenance room as well as manufacturing facilities. Furthermore the DOM does not have any car for field operation.

7.2 Hydrological observations

Maintenance and calibration of hydrological instruments is undertaken by the Equipment Unit of the Hydrological Works Office of the BHRW. Similar to the DOM, the DHRW does not have appropriate equipment store room, equipment maintenance and manufacturing facilities, so it is not possible to keep tract of equipment inventories and status. The four terrain vehicles of the DHRW are obsolete.

7.3 Environmental observations

For water quality monitoring, the Equipment Unit of the Water Quality Analysis Office of the DHRW is responsible for the maintenance and calibration of the instruments. The WQ laboratory cooperates with the Hydrological Works section for water quality sampling activities.

8 NUMERICAL WEATHER PREDICTION (NWP)

The DOM does not run any numerical weather prediction models for weather forecasting. NWP products from international forecasting centers i.e. ECMWMF, RSMC (JMA), Hong Kong Observatory, Viet Nam, the Regional Integrated Multi-hazard Early warning System (RIMES) are utilized by DOM for severe weather monitoring and forecasting in Cambodia. Verification on the performance of these models should be done so as to determine the level of accuracy of forecast or limits of confidence on their applicability.

8.1 Operational models

For floods, the Regional Flood Management and Mitigation Center (FFMMC) of the Mekong River Commission utilized the Decision Support Frameworks (DSF) which involves three models: SWAT hydrological model, IQQM, URBS, for river flow and ISIS for hydrodynamics. Regression Model is used for flood forecasting. The DHRW uses only regression model for a three days forecast of water level at seven stations along the Mekong-Tonle Sap- Bassac rivers during wet season.

SWAT (Soil Water Assessment Tool) is a river basin scale developed to quantify the impact of land management practices in large, complex watersheds. It is composed of the following components: weather, surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, crop growth and irrigation, groundwater flow, reach routing, nutrient and pesticide loading, water transfer.

IQQM stands for Integrated Quality and Quantity Model. It has been developed to assess the impacts of different management strategies on all water users. The models have been developed to simulate the major hydrological processes in river valleys, along with relevant management rules, and have been calibrated to match observed reservoir levels, diversions and flows over the calibration periods. The models are set up in such a way as to reproduce average long term behaviour of the river system for planning purposes.

ISIS is a hydrodynamic model whose function is for the calculation the inundated area (flood depth and duration).

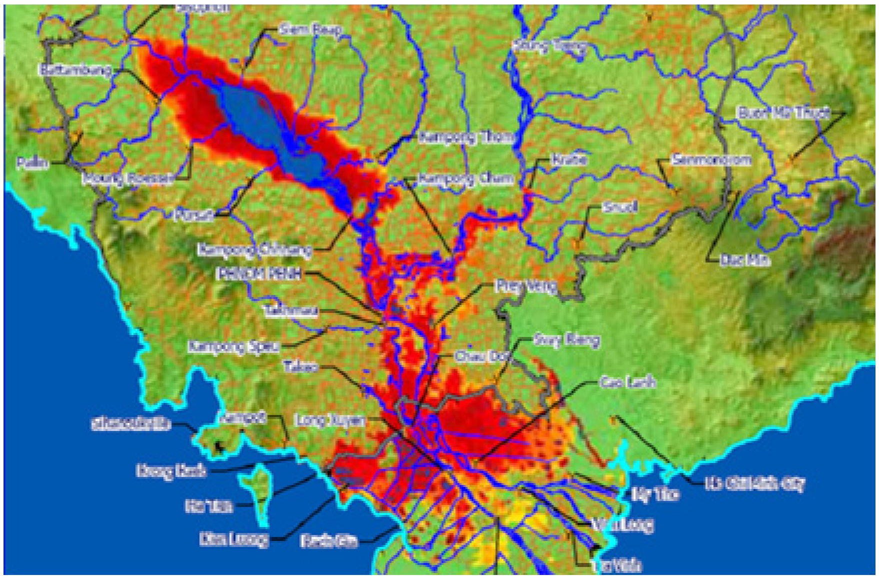


Figure 8.1 DSF output showing the status of the river system in Cambodia

8.2 Verification of NWPs

URBS, Unified River Basin Simulator (URBS) hydrologic model was developed by Seqwater and Terry Malone in Australia. It is a composite of rainfall runoff model together with a runoff routing model. The model was developed in 1992 and since then has been widely used in Australia. The model has been introduced to MRC region for flood forecasting in mid 2000.

For testing and calibration of the DSF hydrological models, regression analysis and the Flash Flood Guidance (FFG) developed by Hydraulic River Commission in USA are used.

9 INFORMATION, COMMUNICATION AND TECHNOLOGY

9.1 Communication facilities

The communication facilities of DMH are summarized in Table 9.1.

Table 9.1 Communication facilities for transmission, reception and exchange of data and products.
RD = to receive data/observations, RI = to receive information/products, SD = to send data/ observation,
SI = to send information/products, RW = to receive warnings, SW = to send warnings.

	RD	RI	SD	SI	RW	SW	Remarks
Telephone	X	X					
Mobile Phone	X	X					
Telefax	X	X	X	X		X	
Dedicated Leased Lines	X	X	X	X	X		
UHF radio transceiver							
High frequency/Single side band radio	X	X	X				
HF Radio Email							
Aeronautical Fixed Telecommunication Network							
Very Small Aperture Terminal							
Data Collection Platforms used to transmit data from AWSs							
Global Telecommunication system (WMO-GTS)	X	X	X		X		
MTSAT Satellite system		X					
Other satellite systems							
Internet	X	X	X	X			
Email	X	X	X	X			
Post/mail							
Print media							
TV –national				X		X	
TV-commercial							
Radio				X		X	
Bulletins							

At national level:

Data transmission from the provincial stations is manually operated using HF single side band radio, public telephone, and Fax (Figure 9.1) then the data are compiled into the prepared format for transmission to the GTS link.

Figure 9.1Communication facility for domestic stations

International level:

DOM in Phnom Penh has been reconnected to Bangkok through GTS since June 14, 2010. It now receives and transmits meteorological data for international use.

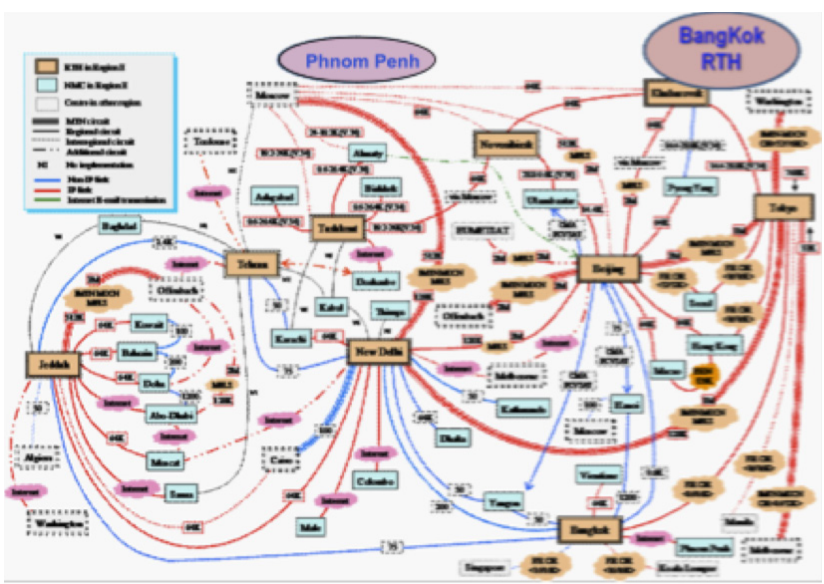


Figure 9.2 Regional telecommunication network for Region II (Asia)

9.2 Data management

The observed data at the synoptic stations are reported to the Phnom Penh headquarter through SSB radio or telephone twice daily to be used in the weather forecast preparation. The data at the synoptic stations are also sent to Department of Meteorology headquarters in paper form several months after observation time for collection and future reference. These data are digitized or encoded into a data base.

Data Handling

- Data transmission and data collection from different sources
- Decoding of observations and plotting on weather maps
- Analysis , briefing and forecasts

Quality monitoring of collected data

DOM does not conduct real-time quality control monitoring on logical checking for manned stations. A non real-time quality control system or checking is done during the encoding of collecteddata.

9.3 IT infrastructure

The DOM network has two internet connections, one for public IP for GTS Broadband (ADSL), with speed of 128/256 kbps.

9.4 IT Personnel

There are five IT personnel recruited and have been trained in France but how MOWRAM will retain them remains a problem.

9.5 Needs to improve communication system and data management

DOM needs the following to improve its communication system and data management:

- automation for real-time data
- increase data density
- develop the data base system and data management
- upgrade disk storage and backup system
- upgrade the devices and system
- entering historical data into electronic database
- upgrade of safety systems
- development of data QC systems
- upgrade the existing data management system
- promote common real-time and other use of all hydro-meteorological and environmental data, user friendly system
- upgrade the IT infrastructure, both hardware and software

NATIONAL AND INTERNATIONAL COOPERATION AND DATA SHARING

10

10.1 National

Meteorological and climatological data and information are provided to the public in hardcopy upon request. Most common users are those from agriculture, energy, education, transportation and environmental sectors.

On the national level, there is a need for DOM to strengthen its interaction or linkages with both public and private agencies. It is high time for them to go out of their shell and explore the opportunity to collaborate with other agencies that needs meteorological information and services like those mentioned above. They should collaborate with NDCM and the Media in Information Education and Communication campaign for public awareness on natural disasters; with MAFF on agrometeorological crop weather modelling and other activities for farmers and fishermen, with power sectors for wind energy utilization and many others.

It has been observed that DOM works independently at present, even coordination with DHRW is very poor. It only looks up to MOWRAM for support and guidance.

10.2 International

Cambodia is reconnected with WMO-GTS: to RTH Bangkok; FTP, TCP/IP protocol since June 14, 2010. They are now receiving meteorological data from other countries and sending SYNOP reports to WMO through GTS.

11 RECENT DEVELOPMENT PLANS PROPOSED BY CAMBODIA

After the disaster brought about by Typhoon Ketsana in October 2009 in Cambodia, international organizations have offered support/assistance for the recovery of the country. Through the assistance of the World Bank, the Cambodia Post Disaster Needs Assessment (PDNA) was conducted in November 2009 and completed in March 2010 (Figure 11.1). This was conducted to ascertain the extent of the damage and loss caused by TY Ketsana.

The PDNA estimated the total damage and loss to be US$132M. The World Bank in cooperation with ESCAP and UN ECLAC prioritized the project "Damage and Loss Assessment (DaLA) for Economic and Social Cost of Recovery & Reconstruction of Cambodia". of these projects are summarized in Tables 11.1 and 11.2.

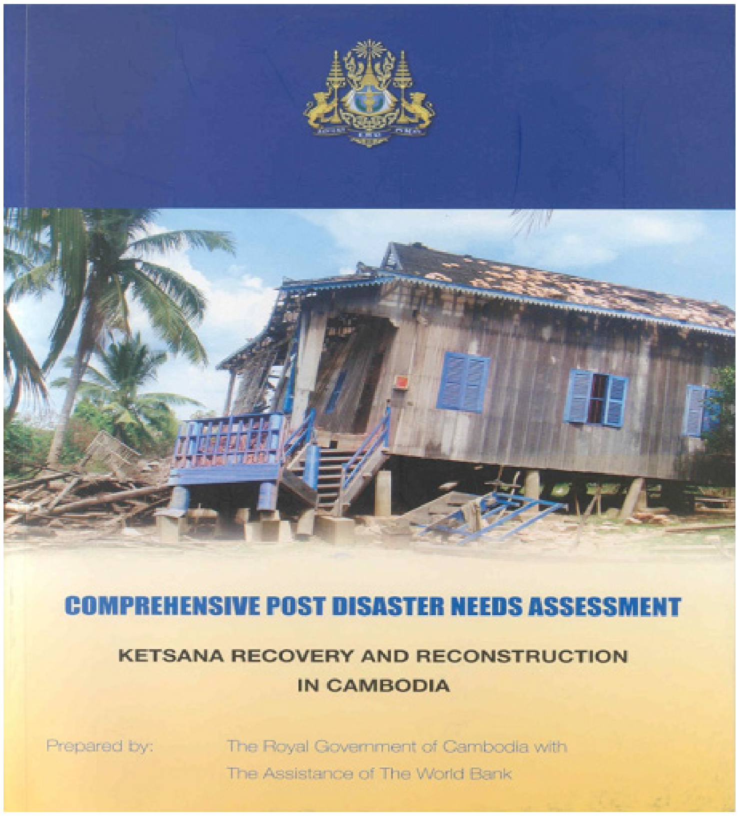


Figure 11.1 Cambodia Post Disaster Needs Assessment Report prepared through the assistance of the World Bank

Table 11.1 Recovery and Reconstruction Needs of Cambodia after TY Ketsana

Summary of Needs				
Sector and Subsectors	Recovery Needs, US$			
	Short Term	Medium Term	Long Term	Total
Infrastructure	**7.114.206**	**13.406.626**	**85.960.511**	**106.481.343**
Transport	5.124.206	9.264.626	76.360.511	90.749.343
Water Supply and Sanitation	-	500.000	4.250.000	4.750.000
Water Management and Irrigation	1.690.000	2.792.000	3.500.000	7.982.000
Energy	300.000	850.000	1.850.000	3.000.000
Social Sectors	**14.075.690**	**2.648.500**	**2.480.000**	**19.204.190**
Housing and Shelter	12.089.000	2.087.800	-	14.176.800
Health	86.690	560.700	2.480.000	3.127.390
Education	1.900.000	-	-	1.900.000
Productive Sectors	**5.960.000**	**12.800.000**	**41.200.000**	**59.960.000**
Agriculture, Livestock and Fisheries	5.000.000	10.000.000	35.000.000	50.000.000
Industry & Commerce	960.000	2.800.000	6.200.000	9.960.000
Cross-Cutting Sector	**196.085**	**2.396.000**	**2.803.600**	**5.395.685**
Environment	181.000	2.232.400	2.803.600	5.217.000
Public Administration	15.085	163.600	-	178.685
TOTAL	**27.345.981**	**31.251.126**	**132.444.111**	**191.041.218**
Disaster Management				8.937.000

Table 11.2 Recovery framework and tentative donor commitment

Summary of Recovery Framework					
Priority Sector and Subsectors	Planned Development Partner Commitment	Recovery Needs, US$			
		Short Term	Medium Term	Long Term	Total
Infrastructure					
Transport	RGC, P.R China, ADB, WB	5.124.206	9.264.626	76.360.511	90.749.343
Urban Roads		563.798	346.912	-	910.710
National Roads		621.680	163.943	15.496.500	16.282.123
Provincial Roads		135.729	1.071.290	13.366.750	14.573.769
Rural Roads	WB	3.803.000	7.682.480	47.497.261	58.982.741
Water Management and Irrigation	MOWRAM, ADB, WB	1.690.000	2.792.000	3.500.000	7.982.000
Water Management		-	1.100.000	1.500.000	2.600.000
Irrigation	ADB	1.690.000	1.692.000	1.500.000	4.882.000
Capacity Building		-	-	500.000	500.000
Social Sectors					
Housing and Shelter	RGC, ADB	12.089.000	2.087.800	-	14.176.800
Repair damaged houses		11.980.000	-	-	11.980.000
Temporary shelter and basic support		109.000	-	-	109.000
Reconstruction of completely destroyed houses		-	1.237.800	-	1.237.800
Design standard review/compliance		-	350.000	-	350.000
Education	RGC, ADB, WB, INGOs	1.900.000		-	1.900.000
Replace buildings that are too badly damaged to repair	WB	1.500.000	-	-	1.500.000
Repair of buildings which are unsuitable for teaching		200.000	-	-	200.000
Furniture, Equipment and Education materials		200.000	-	-	200.000
MoEYS Maintenance program for Schools		TBD	TBD	TBD	-
Productive Sectors					
Agriculture, Livestock and Fisheries	RGC, DPs, INGOs	5-10 million	10-20 million	35-45 million	50-75 million
Priority 1: Food, fertilizer, seeds		TBD	TBD	TBD	TBD
Priority 2: Cash for work, seeds, replenish emergency stock		TBD	TBD	TBD	TBD
Priority 3: Capacity building and policy support		TBD	TBD	TBD	TBD
Industry & Commerce	RGC, Private Sector, WB	960.000	2.800.000	6.200.000	9.960.000
Reparation and replacement of damaged machinery and equipment	WB	960.000	-	-	960.000
Upgrade machinery and equipment to make it disaster-resilient		-	2.000.000	5.000.000	7.000.000
Regulatory framework		-	500.000	700.000	1.200.000
Small industru and agirbusiness recovery	WB				
Raise awareness of entrepreneurs		-	300.000	500.000	800.000
Disaster Management					8.937.000

Source: PDNA Report (2010)

The assistance being provided through these projects is generally for recovery of the different sectors of the society. For disaster management, US$8.937M is necessary; however nothing is specifically mentioned about the rehabilitation of the Department of Meteorology. It is important to strengthen the capacity of the DOM as a warning agency for preparedness to reduce damages from these natural disasters. Prevention is better than cure hence it is better to invest on forewarning or preventive measures to reduce if not avoid the damages.

From 2002 to 2007, US Office of Foreign Disaster Assistance (OFDA) provided funding to the American Red Cross to develop a community-based disaster preparedness capacity within the Cambodian Red Cross. The program included support for the establishment of a preparedness unit called Community Based Flood Early Warning System (CBFEWS) where community volunteers are trained to read and transmit rainfall data to the Red Cross Central Office then to DHRW to be used for flood forecasting. Villagers were provided with cell phones, flood markers and flood information boards, as well as training as observers to take wet-season water level measurements at 14 Villages in Leuk Dek and Peam Ro Districts, in Prey Veng Province, bordering Viet Nam. The processed data in the form of flood forecast or bulletin are sent back to the community for warning. The project also involved vulnerability assessment as well as the implementation of flood preparedness measures in flood-prone communities. In 2009, GTZ reactivated the CBFEWS in two districts operating only during flood season.

The major concern of DOM is to strengthen its services through the following:

- Improvement of forecasting capacity through advance studies and trainings
- Improvement of severe weather monitoring capability, especially for typhoon when it approaches Indochina Peninsula
- Improvement of precision of rainfall monitoring
- Establishment of real-time data transmission system
- Installation of Automatic Weather Station,
- Request to WMO establish Sub - Regional Forecast Support Center to provide Severe Weather guidance to Southeast Asia
- Strengthening of with regional and international organization in term of disaster prevention and mitigation.
- Medium to long term human resource development plan

SUMMARY 12

Due to its weak institutional set up and lack of technical skill of its staff, the DOM lacks the capacity to provide timely and accurate forecasts (Table 12.1) that are required by the various agencies (Table 12.2).

Table 12.1 Issues, institutional capacities, gaps and needs of DOM and DHRW

Issues	Institutional Capacities	Gaps & Needs
Data products	Synoptic data, climate data, satellite data,	• Replace/upgrade instruments • Regular maintenance and calibration needed • Computerized and quality controlled database needed • Reliable communication for data transmission and dissemination
Hazard analysis to support risk assessment	No available expert on disaster mitigation	• Lacks experts to undertake hazard analysis & risk assessment • No digitized hazard maps
Forecasts and warnings	Cambodian cities daily weather forecast, water level data and flood forecast	• Radar & upper-air data • Improve on accuracy and timeliness • Lacks special/specific forecasts for marine/shipping, farming, mining, • No thunderstorm forecast & warning • Train forecasters on NWP interpretation & analysis
EWS expertise and advisory service	Only have a total of 44 staff with 4 MSc graduates & 5 engineers	Lacks qualified staff to provide EWS expertise and advisory service
Cooperation with other technical agencies	National level : • NCDM • MAFF • MoE • Cambodian Red Cross • Local/provincial governments • International level : • WMO • ASEAN's SCMG • GTZ Germany • RIMES • JICA Japan • JMA Japan • DHRW	• Weak cooperation/linkage and partnership with MAFF, MoE, etc. • Need to strengthen/establish linkage/partnerships w/local & international agencies • Need to collaborate with other agencies in conduct IEC & seminars on natural hazards, technology transfer especially on telecommunication
Dissemination mechanisms Principles	Online, Printed, Multimedia	• Improve dissemination mechanism • Develop own website • Establish protocols/SOPs
Means	Telephone, cellular phone, facsimile, SSB, internet (e-mail/website), television, radio, newspaper	Reliable telecommunication system, i.e. VSAT
Communication and media	State and private TVs, radios, newspapers, internet website, mobile phone providers	Establish good partnership with the media & mobile phone providers

Table 12.2 Meteorological and hydrological data, products and services required by secto	
SECTOR	NEEDS
Agriculture	• Seasonal weather outlook • More site specific long time historical hydro-meteorological data for planning • Better and more site specific short term and medium term (1-5 days), and long term weather forecasts • Data and forecasts on evapotranspiration, temperature • Data on humidity, wind speed & direction, rainfall • Monthly, yearly, normal values of met-hydro parameters • Crop specific forecasts • Fast communication link of DAFF with DOM for data transport • Strong coordination with DAFF & other agencies • Access of met-hydro data from regional centers • Historical data for land resources planning
Fisheries	• 1-5 day weather forecasts • Wind speed and direction • Wind forecasts including local wind, • Thunderstorms with gusts • visibility • Wave heights • Water levels • Historical data for the development of strategy, policy and plans
Forestry	• Forest-meteorological observation stations • Near real time data on critical parameters (incl. soil humidity) • Site specific weather forecasts • Production of the forest fire index • Numerical weather forecasting models to produce site specific parameters required to calculate the forest fire index • Modelling and forecasting of dispersion of smoke • Estimates of biomass production and its impacts on land use management • Study in the impact of climate change on the forest sector • Watershed management and planning
Water Resources	• Rainfall observations and forecasts • Weather advisories particularly for drought & floods • Seasonal forecast • Historical water level and flow in each of the national 39 sub-basin; • Characteristics of river flow and water resource in each of the sub-basin (maximum, average, minimum, environmental flow, water use) • Current and planned water use in each of the sub-basin • Water level observations and wave forecasts • Water availability in each of the sub-basin (groundwater/surface water) • Water risk and hazard in each of the sub-basin • Sediment transport and river morphology • International trans-boundary water obligations such as the MRC procedures for maintenance of minimum flow and reverse flow to the Tonle Sap Great Lake
Energy	• Thunderstorm/lightning monitoring and forecasting • More real-time observations on precipitation and water level • More accurate site specific weather forecasts for estimation of energy consumption and optimization of power production

Energy	• More observations and modeling of solar radiation • Better wind data for assessment in wind energy potential • 0-24 forecasts for wind power production • Seasonal forecasts • National and international cooperation • Strengthening of existing river monitoring network including their expansion to cover ungauged sub-basins
Transportation	• Historical data of river flows and water level, wind speed and wind direction for road and water crossing design; • Historical annual rainfall data; • Short duration data for water crossing structure, drainage and sewage design; • Analysis on model results of different scenarios options for road development planning across flood plain; • Weather forecasts especially during rainy season for road hazard warning • Mesoscale weather forecasts (convective activities like thunderstorms) • Rainfall and wind observations and forecasts • Water level monitoring and forecast • Thunderstorm forecast • Seasonal weather outlook • Severe weather bulletins and typhoon forecast • Updated river chart (hydrographic atlas) • Sediment transport and information on river morphology • Aerodrome forecasts
Construction	• Climatological data of meteorological parameters (wind strength & prevailing direction, temperature, rainfall, humidity, etc.) • Accurate site specific weather forecast (precipitation, wind, temperature, lightning,..): 1 day, nowcasting • Meteorological measurement based load factors (wind, snow, water,..) • Intensities of precipitation • Mesoscale and microscale data on solar radiation on inclined surfaces, local wind, temperature chill factor for planning and site purposes of buildings
Tourism	• Weather forecasts tailored for tourist resorts • Meteorological data for environmental impact and risk assessment and management planning • Monthly and seasonal forecasts • Extreme weather phenomena • River water level, flow, ground water data for integrated watershed management particularly for Stung Siem Reap and Stung Sen river basins.
Disaster risk management	• Accurate and timely severe weather forecasts • Hazard maps • Strong cooperation of NMHS with agencies involved in disaster management • Real time radar images • More real time weather and hydrology data and forecast • Site specific weather forecasts • Improvements in dispersion modelling of air borne pollutants, especially for accidental cases (gas leaks, industrial malfunctions, etc.) • Database for the impacts of weather and climate related disasters • Improved flood forecasts to establish operational model for dispersion for forest fires • Outlooks for drought. Forecast on drought and its duration • Improved and more location specific forecast of precipitation • Increased number of automatic on-line stations for monitoring of water level • Water availability forecast

The following table summarizes the rating of different activities and services of the DOM:

Table 12.3 Evaluation of level of different skills of DOM
5= excellent, 4= good, 3= moderate, 2= poor, 1= very bad

	Score	Remarks
Forecasts and services for disaster reduction	3	Lack of on-line real-time data; no weather forecasting model
Data sharing / GTS 4 Networking to Asian hydromet organizations	2	Has been disconnected to GTS for some time. DOM was reconnected on June 14, 201
International cooperation	3	Has a good relationship with international agencies
Weather forecast	3	Prepares daily weather forecasts
Number of WF products/d	2	Partially manual production system
NWP	0	Does not run NWP model
Hydrological forecast	4	BHRW use flood forecasting model
Agrometeorological serv.	-	Being provided by other agency (MAFF)
Automated processing and visualization	-	Not available
Climate Change	3	Staff of 10 related to this issue
Support of R&D to main lines	0	No R&D activity at the moment
Surface synop. network	2	Low number of on-line stations
Upper-air data	0	No upper-air station
Radar data	3	Coverage of network, no composite pictures
Lightning detection	0	No equipment
Hydrol. Obs. network	2	No automatic stations
Environmental obs.	0	Done by other agency (MoE)
Maintenance and calibration	2	Done by equipment unit
Communication system	2	Low number of real-time and on-line stations
Data management	2	Has to prepare a database system
Webpage	0	No website at the moment
Human resources	2	Staff are not seriously responsible
Level of education of staff	2	DOM has no PhD degree holder
Training programme	2	Limited training for staff
Competitiveness on labour market	2	- Low salary level; out dated headquarters + good visibility on TV
Management	3	New organization under production
Organization	3	Need to strengthen
Competitiveness	2	Need to improve
Public visibility	2	No website
Public appreciation	2	No public feedback mechanism
Customer orientation	2	There is a need for IEC
Cooperation with media	2	Need to establish strong relationship with media
Foreseen possibilities for sustainable development	3	Active mobilization of international financing
Total score	60	

RECOMMENDATIONS TO STRENGTHEN THE HYDROMETEOROLOGICAL SERVICES 13

Based on the assessment of the current status of DOM, there is a big gap to fill to meet the requirements for hydrometeorological services. First and foremost is the human resource. It has been observed that the DOM staffs do not have a strong sense of responsibility to work. Many do not report to work on time; others just come and go as they wish. The salary rate of government employees is not competitive with the private companies. The government should find ways to address this through award of incentives such as scholarship grants, free medical services, low-cost housing projects and other benefits. Another issue on human resources is the lack of trained personnel to do the technical jobs hence, capacity building is necessary. The second major concern is on physical resource. DOM compared to other Asian countries is way far behind in terms of technical equipment/instruments and facilities.

To be able to fill the gaps and meet the requirements of good hydrometeorological service, the following recommendations are made:

1) Adequate networks to monitor hydrometeorological parameters
   - Upgrade or modernize DOM stations / instruments together with data communication network (domestic links):
     - automation of raingauge stations;
     - automation of synoptic stations;
   - Establish stations for upper air sounding facilities, with training of professional staff
   - Improve precision in rainfall monitoring;
   - Upgrade surface main station a by introducing automatic weather station (AWS); convert manual (analogue) instruments to digital;
   - Automate the hydrological stations (water level gage, rain gage);
   - Increase the number of on-line hydro-meteorological stations;
   - Improve the quality of observations, equipment maintenance, automatic quality control and data management;
   - Enhance Severe Weather monitoring and forecasting capability, especially for typhoon when it approaches Indochina Peninsula;

2) Robust communication system for data transmission, disseminate of forecasts and sharing of information
   - Upgrade communication from HF to GSM from field stations to HQ;
   - Establish tools (hardware & software) for climatological applications with training of professional staff;
   - Establish visualization display system;
   - Facilitate exchange of real time rainfall data observation during passage of Typhoon.

- Integrated decision and information system to forecast severe hydrometeorological and environmental events;

3) High speed computing system for data assimilation and ensemble forecasting
   - Promote IT-supported data collection, smooth and user friendly data management of all data, and automated manufacturing of products; The data collected from the automatic stations could be based on GPRS system in order to reduce communication costs;

4) Human resources
   - Capacitate the DOM staff through advance studies and technical training of the professional and sub-professional staff;
   - Activate the R&D arm to produce studies that would be useful for operational forecasting, the DOM and DHRW need to be restructured and given financial autonomy in planning and implementation of their own programmes

5) More interaction with users of weather and climate information
   - Strengthen its collaboration with local and national agencies particularly those involved in disaster management and environmental issues like climate change;
   - Plan activities in cooperation with stakeholders and end-users to promote collection, sharing and use of data, extending their use to meet local, regional and international demand;
   - Promote the role of DOM as the focal point for Early Warning System;
   - Raise the visibility of DOM, through collaborative projects with the media i.e. IEC campaign; and
   - Improve cooperation and data sharing with agriculture, energy, transportation, road sector and other sectors providing hydro-meteorological and environmental data;
   - Promote cooperation and data sharing with neighboring countries particularly radar, upper-air and other meteorological data;
   - Request WMO to establish Sub-Regional Forecast Support Center that provides Severe Weather guidance to Southeast Asian country;
   - Strengthen collaboration with regional and international organization in term of disaster prevention and mitigation;

The DOM and DHRW must start to plan for their medium to long term human resources development. Both departments need to reorganize their space needs to be able to manage their assets.

DHRW and DOM must be decentralized to a number of hydromet centers in different locations of the country.

PROJECT PROPOSAL 14

Based on the assessment of the DOM, there are needs to be addressed to strengthen the basic weather services in Cambodia. Strategies include upgrading of meteorological instruments and equipment; improvement of network density of monitoring stations, establishment of a good real-time communication system, activation of research and development studies for the advancement of the operational activities of the agency and capacity building of its personnel. The weather forecasting is ineffective unless it is used for flood/drought forecasting, in collaboration with the DHRW and the MRC's Regional Flood Management and Mitigation Centre (RFMMC). Flood/drought forecasting must expand far beyond current covering areas of only mainstream to cover also tributaries to serve the real need of the people for their day to day planning and concerned economic sectors to adapt their plan accordingly.

To allow appropriate time for DOM and DHRW to develop and strengthen their institutional and human resources capacity, a medium to long term plan must be carefully considered since past experiences have shown that main causes of equipment failures were inadequate training, poor management, lack of staff's motivation and lack of learning environment in both departments. There are very significant professional generation gaps of some twenty years and shortage of qualified staffs at all level including lack of leadership. Another critical issue is that the MOWRAM is not able to retain qualified staffs due to its centralized system, lack of appropriate staff's policy and managers in key departments. To bring a significant change, it might need up to 20 years divided into two phases.

The first ten years will be an adjustment plan that could be subdivided into two periods of five years each. The first five years would be to focus on the restructuration planning of the DOM and DHRW in line with the Policy and Institutional Reform and Capacity Development in Water Sector of the MOWRAM. In parallel with the medium to long term planning process which will include institutional capacity building, human resource development will be planned and implemented under the plan. Capacity strengthening of existing staffs will be progressively made to support effective operation of invested equipment namely the Doppler radar system, the installation and put into operation of (i) the 10 set of semi-automatic weather stations provided by ADPC in 2009, (ii) the review and installation of 800 manual rainfall stations with near real time data transmission, (iii) the initiation of the flood/drought forecasting in major tributaries by DHRW and (iv) the training plan for professional hydrologists and meteorologists including the reestablishment and restructuring of the DOM and DHRW human resources.

Similarly the DHRW shall re-establish its medium to long term plan to maintain existing stations and related infrastructure; to review the status of exiting stations and expand the network to cover ungauged sub-basins; to expand activities towards operational hydrology rather than sticking to hydrometry, as usual. The expected outcome of the first phase of the DHRW would be to begin the integration of the national water resource planning and management into their annual plan. This includes the provision of regular water resource status (annual) of all 39 sub-basins in the country, initiating a support programme for water law and related sub-decrees development, implementation and the programme for flood/drought, river monitoring in each of the sub-basins and initiating the application of the integration of the radar data and synoptic data into the day to day water resource management including the downscaling of potential impact of climate change for use in development of policy and strategy for climate change adaptation.

During this first five years phase, both departments will require adequate logistics supply for their field works and facilities for their need handling and management of technical equipments (store rooms, calibration maintenance facilities), appropriate physical space for new installation (upper air stations, new standard synoptic stations, training centres etc. (DOM within the new site of synoptic stations), and the DHRW in the compound of the MRC.

Building on the success of the first phase, in the second five years period, both departments should work more closely together while strengthening their business relationship with potential data users. The second 10 years period is the full business development period which at the end, both departments will be fully financed by the government and their own generated incomes.

Early in the second 10 years period, it is envisaged that five Hydromet Centers will be established (Kratie, Kampong Thom, Pursat, Sihanoukville and Prey Veng).

The following 5-year project proposal is based on the requirements for disaster reduction and management of DOM services in Cambodia.

14.1 International cooperation

As a least developed country (LDC) recovering from war, the DOM will be most benefited by the enhancement of international cooperation and networking.

Activities: International cooperation, attendance/participation at meetings & conferences
Budget: US$200,000

14.2 Telecom, IT and Data management

Taking into account the JICA proposal (Table 14.2), the estimated budget for 5 years is as follows:

	Telecom	IT Center	Data Management
Hardware + software	600,000	150,000	610,000
Consultation & training		50,000	100,000
Storage 30 TB			125,000
Additional staff		25,000*	
TOTAL	600,000***	225,000	835,000

* Shall be shouldered by DOM.

***The communication network will be upgraded from HF to GSM. This will involve telecommunication system of about 400 field stations to headquarters.

14.3 Meteorological observation network

There is a need to rehabilitate the stations particularly the meteorological instruments. The activities include: provision of the 24 Automatic Weather Stations (AWS), proposed by JICA, installation of manual and rehabilitation of existing raingauges and installation of the 10 semi-automatic weather stations.

The cost of 800 manual raingauges and telephone is estimated at US$424,000, operation cost US$ 96,000 per year for near real time rainfall data collection.
Budget: US$ 6,719,810

14.4 Hydrological stations (under DHRW, MOWRAM)

Repair/upgrade, relocate of exiting 50 hydrological/stream gauging stations and expand to cover 28 ungauged sub-basins. Hydrological network investment cost would be US$660,000 with operation cost of US$430,000/year.
Budget: US$ 660,000

14.5 Environmental stations

Under the Department of Environment, this will be addressed by the projects on Greenhouse Gas emissions of the Climate Change program of the NAPA.

14.6 Remote sensing network

Upper air soundings

At present, Cambodia has not a single upper-air station. Based on their requirement, there should be 4 upper-air stations all over the country. However, due to its present financial capacity, and human resources, DOM can not operate 4 upper-air stations. Hence only 1 upper-air station is proposed. The equipment including installation is about US$ 445,000 with operating expenses of US$1.0Million (1 observation/day, US$200,000/year) and sounding technician salary of US$3,600/year.

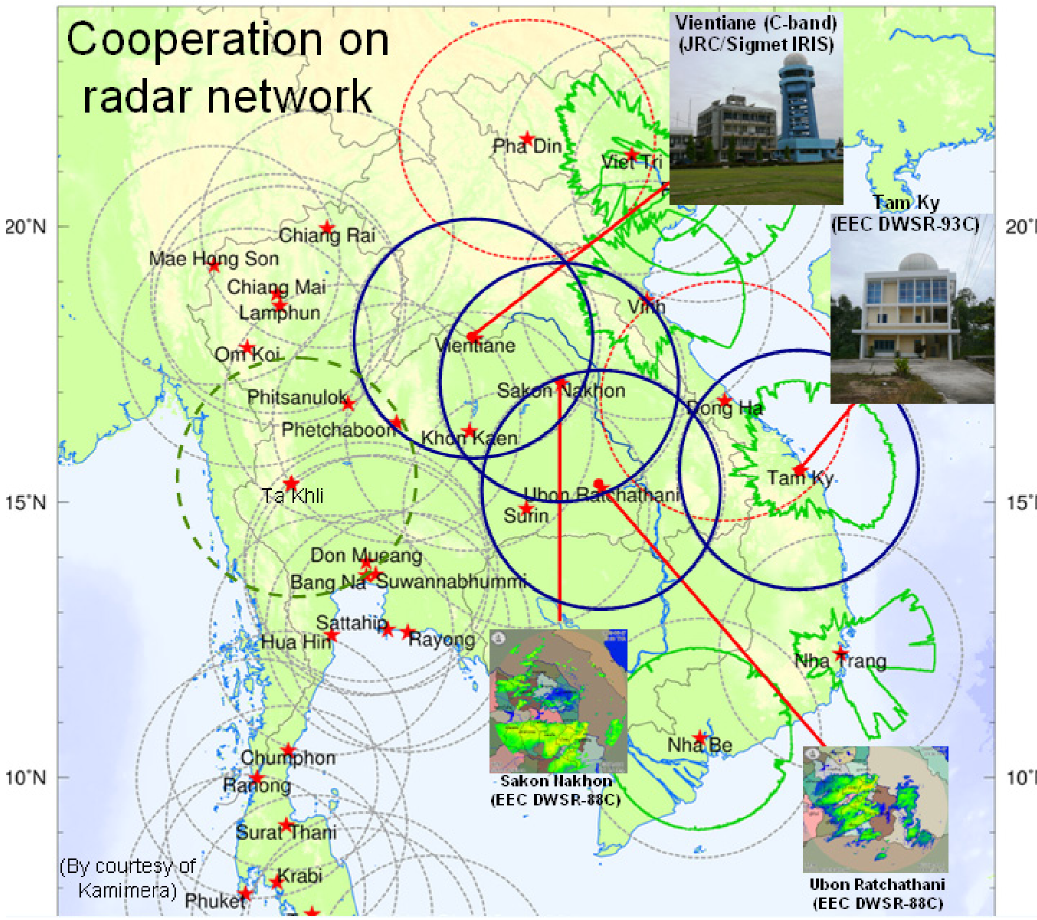
Budget: US$1.445Million
(Operating expenses during the 5 years is covered by project)
The salary of technician should be shouldered by DOM.

Radar

The Doppler radar has been installed at the MOWRAM Headquarter but still facing technical capacity to fully operate the installation including human resources and softwares.

A very interesting cooperative research on mitigation of water disasters is being conducted by the Graduate School of Science in Kyoto University. Data analysis will use remote and in-situ observation from a network of radars covering countries in Asia as input to downscaled meteorological numerical model. The research will analyze rainfall from monsoon disturbances and tropical depressions in South-East Asia in order to better understand extreme weather phenomena and increase lead-time to predict extreme weather. The study will require a composite of radars (blue circles) which include those in Vientiane, Tam Ky (Viet Nam) and Sakon Nakhon and Ubon Ratchathani (Thailand), however there is quite difficulty in obtaining radar data from Thailand.

Figure 14.1 Existing network of weather radars in Indochina



Source: Takehiko Satomura, Graduate School of Science, Kyoto University

Figure 14.1 shows the existing network of radar in Indochina and surrounding regions (except China). In its NHMS modernization plan, Viet Nam envisions to establish nine (9) more radars in addition to the existing six (6) radars to come up with 15 radars that will cover the whole country. And the NHMS of Viet Nam is willing to share its data to Lao PDR and Cambodia.

Satellite receiving station

Acquire one (1) additional satellite receiving facility, Fengyun Cast from China
Budget: US$135,000

14.7 Visualization display system

As an aide to forecasters in weather prediction, a visualization display system i.e. SYNERGIE is a necessity. This would facilitate fast and proper analysis of weather charts and NWP products to meet the growing demands of the different sectors of society.
Budget: US$400,000

Website Development

DOM has no existing website at present. To enhance its visibility, a website showcasing its services should be developed.
Budget: US$50,000

14.8 Lightning detection system

As per report of NDCM, the number of deaths due to lightning has been increasing for the past year. At present, Cambodia has no lightning detector so there is also a need to put up about 3 lightning stations but these can be integrated in the network of AWS.
Budget: US$10,500

14.9 Climate change

Conduct studies on climate change including seminars in cooperation with Ministry of Environment and Ministry of Agriculture, Forestry and Fishery.
Budget: US$100,000

14.10 Training

Additional assistance is also required for the development of forecasting system through support for human resources development. This will include training of personnel on climate change, numerical modelling, disaster management, etc. Trainings on IT, equipment operations and maintenance, they are incorporated in the budget for IT, telecom and data management.
Budget: US$ 100,000

In addition, two professional training programmes are proposed: 1) postgraduates/master degrees (to seek scholarships), 2) Bachelor degree at ITC, which requires additional lecturers in Hydrology and Meteorology; Technician in Hydrology and Meteorology (CL3 at ITC) and Technician CL4 at a vocational school. The training will not only target the need of the DHRW and DOM but also the universities and the media. It is proposed to train for the next ten years:

- Hydrologists: Msc/Post graduates (13), Bachelor (16) Technician CL3(65), Technician CL4 (40).
- Meteorologist: Msc/Post graduates (14) Bachelor (21), Technician CL3 (40), Technician CL4 (48)

Estimated cost: US$ 2,500,000.

The summary of proposed activities and corresponding budgetary requirements as stand alone organization is listed in Table 14.1 with Column A a “Stand alone “ system and Column B with regional cooperation.

Table 14.1 Distribution of the costs of a 5 year project in the case all the investments are done in the first year		
CAMBODIA	A (USD)	B (USD)
International cooperation of experts	200,000	100,000
Communication systems		
• Hardware + software	600,000	600,000
IT Center		
• Hardware	150,000	150,000
• Consulting	50,000	50,000
• IT staff (by DOM)	Salary by DOM: 25,000	
Data management		
• Hardware and installation	610,000	610,000
• Storage 30 TB	125,000	125,000
• Consultation and training	100,000	50,000
Meteorological observation network		
• 24 Automatic Weather Stations and training	6,309,590	6,309,590
• Installation of manual and rehabilitation of existing raingauges	400,000	400,000
• Installation of 10 Semi-automatic weather stations	10,220	10,220
Hydrological observation network		
• Automatic hydrological stations	550,000	550,000
• Upgraded and expansion of new stations	110,000	110,000
Remote sensing network		
• Upper air observations	445,000	445,000
• Sounding technicians	Salary by DOM: 20,000	
• Upper-air operation and maintenance (5 years)	1,000,000	1,000,000
• New weather radars (including towers)	6,200,000	2,050,000
• Radar technicians	Salary by DOM: 20,000	
• Lightning detection	10,500	10,500
• Satellite receiving station	135,000	135,000
Calibration and maintenance	100,000	75,000
Forecasting and manufacturing tools		
• Visualization system	400,000	400,000
• Training	20,000	10,000
• Staff to promote 24/7/365	Salary by DOM: 40,000	
Capacity Building		
• Training and capacity building for staff	100,000	50,000
• Formal training of professional staffs	2,500,000	2,500,000
Research and development		
• Impacts of climate change	100,000	50,000
• Socio economic impacts	100,000	50,000
• National seminar on socio-economic benefits	100,000	100,000
• End-user seminar	75,000	20,000
Website	50,000	30,000
Project management		
• Consultant	200,000	100,000
• Local project coordinator	100,000	100,000
Total	20,850,310	16,190,310

Table 14.2: JICA Proposal for the provision of 24 Automatic Weather Station (AWS)
For the Improvement of Meteorological Observation in Cambodia

Summary:

1. Installation of the 24 AWS	US$ 2,877,020.00
2. Domestic Telecommunication Systems	US$ 369,020.00
3. Upgrading the GTS Information Systems	US$ 530,090.00
4. Improvement of weather forecasting tools	US$ 296,470.00
5. Community Warning Facility	US$ 190,820.00
6. Domestic Data Gathering and Distribution Systems	US$ 1,327,730.00
7. Calibration System for Meteorological measuring equipment and networks	US$ 450,990.00
8. Vehicles for maintenance on site AWS stations	US$ 167,500.00
9. Digitizing historical meteorological data of Cambodia	US$ 99,950.00
GRAND TOTAL	US$ 6,309,590

Detailed proposal:

1) Installation of the 24 AWS

Classification	Item	Cost (US$)
Facilities(1)	Observatory shed (building)	30,000.00
	Sensor pole & Foundation base	17,330.00
	Sub-total	47,330.00
Equipment(2)	Weather Sensors	28,960.00
	AWS data logger	9,900.00
	Solar Power Supply System	24,520.00
	Communication devices	1,440.00
	Accessories & Spare parts	5,460.00
	Sub-total	70,280.00
Soft (Non-physical) components(3)	Training course for operations	30,000.00
	Training course for maintenance	20,000.00
	Sub-total	50,000.00
Design/Supervision(4)		4,380.00
Total 1	(1)+(2)x 24 sites + (3)+(4)	2,877,020.00

2) Domestic Telecommunication Systems

Classification	Item	Cost (US$)
Facilities	Antenna towers (30m)	133,300.00
	Foundation base	26,670.00
	Sub-total	159,970.00
Equipment	Radio-wave telemetry system	28,800.00
	Microwave communications	126,140.00
	GPRS communication devices	3,200.00
	DCP satellite communications	8,030.00
	Accessories & Spare parts	16,610.00
	Sub-total	182,780.00
Soft (Non-physical) components	Training course for operation	3,650.00
	Training course for maintenance	5,480.00
	Sub-total	9,130.00
Design/Supervision		17,140.00
Total 2		369,020.00

3) Upgrading the GTS Information Systems

Classification	Item	Cost (US$)
Equipment	Message Switching Systems	240,000.00
	Upgrading software for TDCF	160,000.00
	Connection with 2nd RTH	48,000.00
	Communication equipment	9,600.00
	AC power backup system (UPS)	8,000.00
	Accessories & Spare parts	25,750.00
	Sub-total	491,350.00
Soft (Non-physical) components	Training course for operation	14,740.00
	Training course for maintenance	9,830.00
	Sub-total	24,570.00
Design/Supervision		14,170.00
Total 3		530,090.00

4) Improvement of weather forecasting tools

Classification	Item	Cost (US$)
Equipment	AWS data processing software	96,000.00
	Visualization software	80,000.00
	Radar ingesting software	64,000.00
	Forecasting support tool	42,350.00
	Sub-total	282,350.00
Soft (Non-physical) components	Training course for operations	8,470.00
	Understanding theory	5,650.00
	Sub-total	14,120.00
Design/Supervision		0
Total 4		296,470.00

5) Community Warning Facility

Classification	Item	Cost (US$)
Facilities	Equipment shed (building)	50,000.00
	10m Pipe mast & Foundation base	20,000.00
	Sub-total	70,000.00
Equipment	Telemetric instrument	18,780.00
	PA amp & loud speaker system	16,800.00
	Solar power supply system	49,040.00
	RF Communication devices	14,400.00
	Accessories & Spare parts	9,910.00
	Sub-total	108,930.00
Soft (Non-physical) components	Training course for operation	3,270.00
	Training course for maintenance	2,170.00
	Sub-total	5,440.00
Design/Supervision		6,450.00
Total 5		190,820.00

6) Domestic Data Gathering and Distribution Systems

Classification	Item	Cost (US$)
Facilities	TV & radio studio in DOM office	100,000.00
	Engine generator facility	5,000.00
	Sub-total	105,000.00
Equipment	Domestic MSS systems	192,000.00
	AWS data collection software	80,000.00
	TV & Radio broadcasting system	640,000.00
	AC power backup system (UPS)	48,000.00
	Engine power generator (30kVA)	61,100.00
	Accessories & Spare parts	94,120.00
	Sub-total	1,115,220.00
Soft (Non-physical) components	Training course for operation	33,450.00
	Training course for maintenance	22,300.00
	Sub-total	55,750.00
Design/Supervision		51,760.00
Total 6		1,327,730.00

7)Calibration System for Meteorological measuring equipment and networks

Classification	Item	Cost (US$)
Facilities	A wind tunnel facility	50,000.00
	Calibration workshop	50,000.00
	Sub-total	100,000.00
Equipment	Accuracy reference standards	224,030.00
	Measuring instruments	48,000.00
	Network maintenance equipment	15,960.00
	Maintenance tools	4,800.00
	Machine tools	2,400.00
	Accessories & Spare parts	23,900.00
	Sub-total	319,090.00
Soft (Non-physical) components	Training course for operation	9,570.00
	Training course for maintenance	6,380,00
	Sub-total	15,950.00
Design/Supervision		15,950.00
Total 7		450,990.00

8) Vehicles for maintenance on site AWS stations

Classification	Item	Cost (US$)
Equipment	Four-wheel drive cars	30,000.00
	Machine tools	500.00
	Accessories & Spare parts	3,000.00
	Sub-total	33,500.00
Total 8	For 5 sites	167,500.00

9) Digitizing historical meteorological data of Cambodia

Classification	Item	Cost (US$)
Equipment	Operational computers	19,200.00
	Database and editing software	56,020.00
	Network equipment	8,030.00
	AC power backup system (UPS)	5,220.00
	Accessories & Spare parts	3,130.00
	Sub-total	91,600.00
Soft (Non-physical) components	Training course for operation	2,750.00
	Sub-total	2,750.00
Design/Supervision		5,600.00
Total 9		99,950.00

Annex 1

People met during the Mission

No	Name	Organization	Telephone	E-mail
1	H.E. PEOU SAMY	NCDM Secretary General	(855) 23 885920	caccdm@yahoo.com
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3	Mr. OUM RYNA	DOM	(855) 16 756389	rynaoum@yahoo.com
4	Ms. BIN CHANN MONY	DOM	(855) 12 500270	mony_130164@yahoo.com
5	Mr. YIN SAVUTH	DHRW	(855) 11 974322	savuthyin@yahoo.com
6	Mr. MA NORITH	NCDM Director	(855) 77 2204729	ma_norith@hotmail.com
7	Mr. UY KAMAL	MOE	(855) 12 283 956	kamaluy@yahoo.com
8	Mr. VASIM SORYA	MPWT, Director General	(855) 12 900 735	tranplan@camnet.com.kh
9	Dr. KAO SOCHIVI	Fisheries Adm. MAFF	(855) 23 220417	Kaosochivi2007@yahoo.com
10	Mr. Prak Cheatho -	MAFF, Dep. Gen. Director	(855) 17 881 8886	
11	Ms. U SURITA	MAFF	(856) 23 725 1289	u.sirita@gmail.com
12	Mr. MUCH CHHUN HORN	MIME, Director	(856-20) 5702533	chhunhorn@yahoo.com
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Appendices - Tables

Table 1 Number of weather and climate-related disasters in Cambodia, 2005-2009

	2005	2006	2007	2008	2009	Total
Flood	1	2	1	-	0	4
Storm	0	0	0	-	2	2
Drought	1	0	0	-	0	1
TOTAL	2	2	1	-	2	7

Source of data: EM-DAT: The OFDA/CRED International Disaster Database

Table 2 Number of weather and climate-related deaths in Cambodia, 2005-2009

	2005	2006	2007	2008	2009	Total
Flood	16	5	2	-	-	23
Storm	-	-	-	-	19	19
Drought	-	-	-	-	-	-
TOTAL	16	5	2	0	19	42

Source of data: EM-DAT: The OFDA/CRED International Disaster Database

Table 3 Actual socio-economic damages due to weather and climate-related disasters in Cambodia, 2005-2029 (million US dollars)

	2005	2006	2007	2008	2009	Total
Flood	-	-	1	-	-	1
Storm	-	-	-	-	-	-
Drought	-	-	-	-	-	-
TOTAL	-	-	1	-	-	1

Source of data: EM-DAT: The OFDA/CRED International Disaster Database

Table 4 Summary of damages caused by natural disasters, Cambodia 2000-2009

Sector: Social

Type of Damage	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Provinces-cities affected	28	26	19	6	11	5	23	21	13	44
Districts affected	131	84	76	7	-	-	-	-	-	73
Communes affected	883	595	420				-	-	-	336
Families affected	750618	324995	698653		344356	71517	71870	16108	-	48787
People affected	3448629	1549976	3487304		1377424	317689	-	80273	-	48787
Families evacuated	84717	-	-				-	-	-	6210
People evacuated	318884	-	14356				549	595	841	11308

Households damaged	7641	2251	35			32	642	1112	835	1861
Households destroyed	347	62	29			4	17	50	106	188
People dead	873	-	-				57	6	45	184
People injured	989	911	129				-	-	6	10
Schools affected	-	-	2				-	-	-	-
Schools destroyed	6620	-	-				-	-	-	-
Classrooms affected	158	-	-				-	-	-	-
Health Centers affected	-	45	7				-	-	-	-

Unit: Number

Sector: Agriculture

Type of Damage	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Rice crops affected	616749	348162	-		247393		-	20936	18150	111290
Rice crops destroyed	374107	204105	107705			1300	10678	24449	1626	2621
Subsidiary crops affected	51272	11537	-				-	-	-	3026
Subsidiary crops destroyed	47461	8250	-			200	813	-	-	-
Buffalo-cow	2309	306	78				-	87	13	860
Pigs	1619	650	1690				-	186	-	1754

Unit: Hectares

Sector: Infrastructure

Type of Damage	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Irrigation systems & water channels affected (No)	-	-	-				39	-	-	102
Drainage pipes damaged (No)	19	44	-				-	-	-	-
Bridge damaged	-	175	-				24	-	-	-
Pumps & latrines damaged (No)	17371	-	-				-	-	-	-
National and provincial road affected (km)	907	39000	35				-	-	-	-
National and provincial road damaged (km)	-	-	12				70234 (m)	34,056 (m)	-	167
Rural roads affected / destroyed (km)	1300	7937	-				-	-	-	313
Rail road damaged (km)	34	-	-				-	-	-	-
Out of 115 spots of bridges damaged (No)	3024	-	-				-	-	-	-

Table 5 The main qualitative benefits and impacts of meteorological and hydrological information services in general level

Sector/ Industry	Main Benefits and Impacts
Road traffic	Accident reduction, savings in material and working times (road maintenance)
Railway traffic	On-time arrivals (time-value), savings in passenger and working times (railway maintenance)
Maritime industry	Reduction of accidents and environmental damages, fuel savings, more efficient rescue operations
Aviation	Reduction of accidents and emissions; savings in fuel, passenger times, materials and working times (airport maintenance)
Construction production	Possibility to eliminate serious construction problems beforehand (risk controlling system)
Energy production	Prediction of power demands, power failure reduction, savings in material and working times (maintenance) energy savings
Air quality monitoring and warnings	Reducing adverse health impacts; saving human lives in possible environmental accidents (evacuations)
Flood protection	Savings in human lives and material damages, more efficient rescue operations
Agriculture production	Plant protection, crop dusting, right timing of harvesting

Source: Hautala et al. 2008