



Annual Report

(July 2015-June 2016)

**HYROLOGY DIVISION
DEPARTMENT OF HYDROMET SERVICES
MINISTRY OF ECONOMIC AFFAIRS
THIMPHU: BHUTAN
2016**



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This is an official publication of the Hydrology Division (HD), Department of Hydro-met Services, Ministry of Economic Affairs, and Royal Government of Bhutan.

For inquiries, the reader (s) may contact:

Hydrology Division,
Department of Hydro-met Services,
Ministry of Economic Affairs
Royal Government of Bhutan
Thimphu: Bhutan
Tel No. : 00975-2-323632/322794
Fax. No.:00975-2-323117

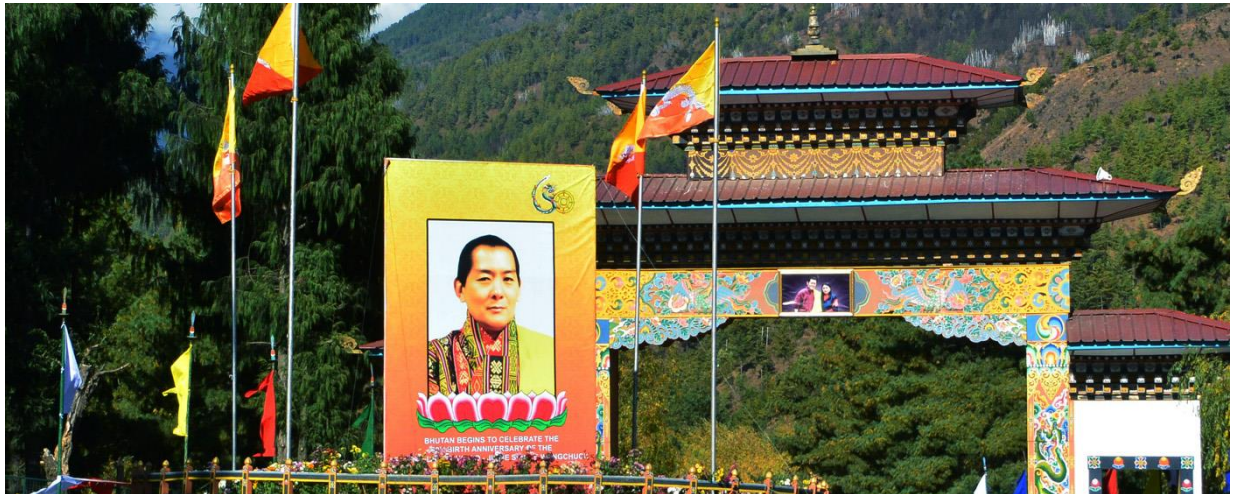
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Department of Hydro-met Services
Ministry of Economic Affairs
Royal Government of Bhutan
Post Box: 207
Thimphu: Bhutan

Photos: Hydrology Division, DHMS Staff



Royal Highness Gyelsay Jigme Namgayl Wangchhuk was born on 5 February 2016



Bhutan Celebrated 50th Birth Anniversary of His Majesty the 4th King Jigme Singye Wangchuck in 2015



Tarina Lakes in the head water of Phochhu basin



Flow measurement by Wading method in Lunana



Automatic Weather Station (AWS) at Tsampa, headwater of Chamkarchhu



Automatic Water level Station (AWLS) at Bjizam on Mangdechhu, Trongsa



ཐུང་པ་མཁའ་མ་གཤིས་བརྟན་དཔུང་ལས་ཁུངས།
བསྐྱར་རྒྱས་ལྷན་ཁག།
DEPARTMENT OF HYDRO-MET SERVICES
MINISTRY OF ECONOMIC AFFAIRS
THIMPHU : BHUTAN



Message

First of all, I would like to congratulate the Hydrology Division, Department of Hydro-met Services, Ministry of Economic Affairs for publishing this first Annual Report for the Fiscal Year 2015-16. The publication is timely as the government has introduced the Government Performance Management System (GPMA) and the Royal Civil Services Commission (RCSC) has started the Performance Management System (PMS) to promote and improve employee effectiveness to achieve the objectives or goals of the organization.

I would like to extend my warmest congratulations to the Staff of the Hydrology Division for their good performance in the fulfillment of their mandated tasks in 2015-2016 and their relentless efforts to enhance their capacity to provide improved flood forecasting and early warning services and to remain focused towards becoming a outstanding national hydro-met service provider.

In 2015-2016, DHMS remained at the forefront of providing valuable weather and flood information. The timely dissemination of relevant information enabled our country to respond better to weather disturbances and helped lessen the loss of lives and damage to properties. Furthermore, the Hydro-met Services worked towards raising the public's level of awareness on the effects of climate change not only to mitigate and reduce disaster risks but also to improve the resiliency of our country particularly on flood and GLOF.

I am confident that Hydro-met Services, fortified with the common desire to better serve our country and people, will continue to move towards the realization of its vision.

Again, my heartfelt Trashi Delek to the Hydrology Division, DHMS in particular and all the staff of the Department in general.

(Karma Tsering)
Director

Acronyms

10 FYP	Tenth Five Year Plan
11 FYP	Eleventh Five Year Plan
ACO	Austrian Coordination Office
ADC	Austrian Development Corporation
AWLS	Automatic Water Level Station
AWS	Automatic Weather Station
DDM	Department of Disaster Management
DGM	Department of Geology and Mines
DGPC	Druk Green Power Corporation
DHMS	Department of Hydro-met Services
DIT	Department of Information Technology
DoLG	Department of Local Governance
EWS	Early Warning System
FWS	Flood Warning Section
GEF	Global Environment Facility
GLOF	Glacier Lake Outburst Flood
GMOG	GLOF EWS Management and Overseeing Group
GoI	Government of India
GWU	GLOF Warning Unit
HD	Hydrology Division
HQ	Head Quarter
ICT	Information Communication Technology
JICA	Japan International Cooperation Agency
IFAS	Integrated Flood Analysis System
LDCF	Least Developed Country Funding
MD	Meteorology Division
MHPA	Mangdechhu Hydropower Project Authority
MoHCA	Ministry of Home and Cultural Affairs
NEC	National Environment Commission
NWFWC	National Weather Flood and Warning Centre
OEM	Original Equipment Manufacturer
PCRD	Planning, Coordination and Research Division
PHPA-I	Punatsangchhu Hydropower Project Authority- I
PHPA-II	Punatsangchhu Hydropower Project Authority- II
RIMES	Regional Integrated Multi-Hazard Early Warning System
R&D	Research and Development
RCSC	Royal Civil Service Commission
RGoB	Royal Government of Bhutan
SOP	Standard Operating Procedure
UNDP	United Nation Development Programmed
WMO	World Meteorological Organization

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Introduction

1 BACKGROUND

Bhutan is located in the eastern Himalayas, between latitudes 26° 45' N to 28° 10' N and longitudes 88°45' E to 92°10' E. It is bordered by the Tibetan plateau of China in the north, the Indian States of Sikkim in the west, West Bengal and Assam in the south, and Arunachal Pradesh in the east, making it unique in terms of its hydro-meteorology. About 20.5% of the total land is covered by perpetual snow and ice, forming the glaciers and glacial lakes.

Variation of climate and its extremes are dependent on the altitude. The great elevation differences and steep sloping terrain predispose the country to various hydro-meteorological hazards. Apart from floods, landslides, wind storms and river erosion, the mountainous region are also quite susceptible to disastrous hazards due to glacial lake outburst floods (GLOFs).

Although it is a relatively small country with maximum north-south distance of 170 km and maximum east-west distance of 300 km, elevations range from 200 to 7,000 meters above sea level within a distance of less than 175 km.

1.1 Climatology and Hydrological Features

Bhutan's climate is strongly influenced by the Indian southwest monsoon, and modulated by the local topography, as one moves from south to north. In general, the climate is characterized by dry winter and wet summer monsoon, and the temporal variations in climate are correspondingly extreme. Thus, while southern Bhutan is generally hot and humid, the high Himalayan Mountains in the northern borders of the country experience severe alpine climate, and are under perpetual snow. Bhutan's climate does vary considerably between the valleys and within the valleys, depending on altitude levels. These features also make the rainfall differ considerably within relatively short distances, due to rain shadow effects. From past records, the mean annual rainfall varies approximately from 2,500 to 5,500 mm in the southern foothills, from 1,000 to 2,500 mm in the inner valleys, and from 500 to 1,000 mm in the northern part of the country.

1.2 River System

Being a landlocked country, Bhutan's water resources are mainly in the form of rivers. There are quite a few lakes, but they are mostly small and are mainly located in the remote high altitude alpine areas. Some of these lakes are glacial lakes, and outburst of these lakes has resulted in flash floods, with damage to lives and property downstream.

Due to the topographic features, the major rivers flow north to south, with their sources in perpetual snow cover, and flowing right down to the tropical zone on the border with India. While most of these rivers originate in Bhutan itself, three rivers have their origin in China. These rivers have steep longitudinal gradients and narrow steep gorge, which occasionally open up and provide broader valleys with small areas of flat land for cultivation. Majority of the valleys are narrow, indicating that water erosion has been the main cause of forming them. Due to the steep longitudinal gradients and the high annual

runoff, these rivers provide significant potential for hydropower development, with an estimated theoretical potential of 30,000 MW (PSMP, 2004).

The existences of distinct rainy and dry seasons are the main reasons for large seasonal variations in river flows. The rivers in Bhutan carry large volumes of flow and, often, also high sediment during the monsoon season. However, the flow is relatively low during the dry season due to the limited rainfall and limited existence of major groundwater reservoirs. Snowmelt from the high altitude alpine areas in the north contributes to the flow at the end of the dry season. Apart from the major north-south flowing rivers, Bhutan has a dense network of small perennial and rain-fed tributaries that flow down the steep slopes and side valleys, often as waterfalls, to join the major rivers.

The planning purpose the country is divided into four major river basins (Figure 1): Amochhu, Wangchhu, Puna-Tsangchhu, and Manas River. They all originate from the high altitude alpine area and from the perpetual snow cover in the north, and flows into the Brahmaputra River in the Indian plains.

The Jaldhaka is small trans-boundary river that that originates from southeastern Sikkim in the eastern Himalayas. The river enters into Bhutan and is joined by Bindu Khola and other small tributaries under Sibsoo Dungkhag, Samtse.

The Amochhu is trans-boundary river that origin in China and flows through the western districts of Ha and Samtse, before it finally drains into the plains of India via Phuntsholling.

The Wangchhu consists of three major tributaries from the three valleys of Thimphu, Paro and Ha. They originate within Bhutan from the glaciers and snow-capped mountains in the north. It flows south to the Indian plains through Chhukha district.

Another major river system is the Punatsangchhu (or Sankosh river), which consists of two major tributaries, Phochhu and Mochhu, that originate from Gasa Dzongkhag. The two rivers join at Punakha Dzong to become Punatshangchu (Sankosh) that flows through Wangdue Phodrang, Tsirang and Sarpang dzongkhags, before flowing to the Indian Plains.

The biggest river basin is the Manas River, which drains almost all of the catchments of the Central and Eastern Bhutan. It consists of four major sub-basins: Mangde Chhu and Chamkhar Chhu (which both originate close to Gangkhar Puensum), Kuri Chhu (which originates from China), and Dangmechhu (which is formed by joining two main tributaries- Kholongchhu that originates from the northern-eastern part of TrashiYangtse and Gongri that originates from China and flows from Aurunacha Pradesh in India to Bhutan). Kurichhu and Gongri are transboundray Rivers that originates from Autonomous region of Tibet, China.

Three minor rivers drain the southeastern corner of the country: Nyera Ama ri, Nonori Chhu, and Jomo Chhu (Dhansari).

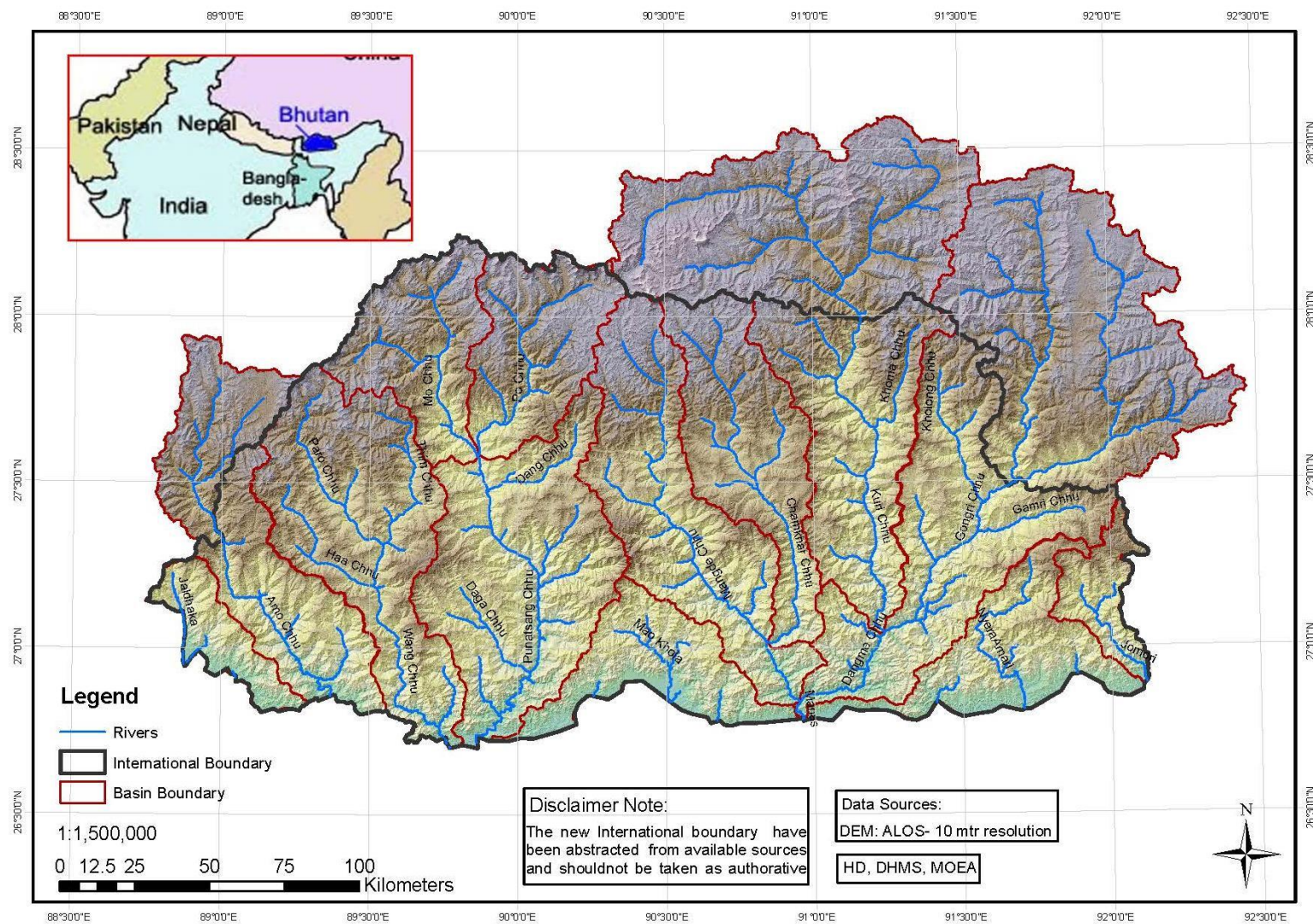


Figure 1:River System and Basins Map of Bhutan

2 DEPARTMENT OF HYDRO-MET SERVICES (DHMS)

The Department of Hydro-met Services (DHMS) under the Ministry of Economic Affairs is the nodal Department responsible for weather, climate and water resources in Bhutan established to fulfill the following vision and mission of the Royal Government of Bhutan. The DHMS was one of the newly created technical departments instituted as a part of restructuring of the Department of Energy in 2011.

2.1 Vision and Mission

Vision

The long-term vision of DHMS is building a nation and its society prepared and responsive to hydro-meteorological threats and opportunities in the pursuit of “Self Reliance and Inclusive Green Socio-economic Development” through provision of decision-support information on weather, climate and water resources.

Mission

- a. Provide weather, water, and climate data forecasts and warnings for the protection of life and property and enhancement of the national economy.
- b. To influence positive results that matter to the public, within severe resource constraints and overcome challenges of building credibility and public trust.

Objectives

- a. To improve and setup Hydrological monitoring network with good national coverage
- b. To improve Flood/GLOF Early Warning Service to minimize loss of lives and properties
- c. To deliver and enhance hydrological and related environmental information & services to the public, government and other users
- d. To set up and improve weather and climate monitoring network with good national Coverage
- e. To improve the delivery of weather, climate & related environmental information & services to the public, government and other users
- f. To implement national integrity and anti-corruption strategy

2.2 Hydrology Division, DHMS

The Hydrology Division (HD) is one of the four technical divisions under the Department of Hydro-met Services (DHMS), Ministry of Economic Affairs mandated with following functions:

- a. Planning and implementation of operational hydrology plans, programs and activities;
- b. Establish new hydrological, flood monitoring/warning stations, and sediment sampling stations;
- c. Operation of national hydrological and flood warning network established in different river basins;
- d. Operate and maintain flood/GLOF Early Warning Systems installed in different river basins;
- e. Operation and maintain sediment network and sediment laboratories facilities;
- f. Maintain and operates communication facilities including hydrological equipment and other electro-mechanical facilities for data acquisition;

- g. Transmit real time data from monitoring field stations to National Flood Monitoring and Command Room (NFMCR) under the National Weather and Flood Warning Centre (NFWFC) for flood forecasting and warning;
- h. Collection of hydrological low flow data from east-west tributaries that are not covered by national hydrological network.
- i. Ad-hoc measurements of rivers and streams based on the request of other agencies and individuals;
- j. Maintain and operate National Hydrological Database (HYDATA) and Sediment Database (SEDAT) for data processing, analysis and archival;
- k. Publication of Hydrological Data Book
- l. Dissemination of hydrological, flood and sediment data and information.
- m. Prepare and provide timely flood forecasting and warning services to mitigate flood related disasters;
- n. Transmit and share flood information to the National Emergency Operation Centre (NEOC) of Department of Disaster Management (DDM), Hydropower Power Generation Companies, and related agencies;
- o. Ensuring timely communication of flood warning data/information to designated contact points in India
- p. Running and maintenance of existing infrastructure and facilities including the construction of new facilities,
- q. Undertake applied research and development in the field of operational hydrology, hydrological modeling, flood forecasting and warning, water resources and impact of climate change etc.
- r. Provide technical backstopping services in preparation of technical specification of hydrological and flood warning equipment, installation, testing and commissioning of stations, flow measurements of river and streams based on the request of other agencies and private individuals;
- s. Coordinate and organize Joint Expert Team (JET) meetings between Royal Government of Bhutan (RGoB) and Government of India (GoI) on a comprehensive scheme for setting up flood forecasting (FF) system on rivers common to India;
- t. Coordinate Joint Group of Experts (JGE) Meeting of Flood Management between Government of India (GoI) and Royal Government of Bhutan (RGoB).
- u. Implement the projects related to operational hydrology, flood forecasting and warning;
- v. Sharing and exchange of hydrological data and products with other countries and regional and international organizations to which Bhutan is signatory through the head of the agency.

2.3 Status of Hydrological and Flood Monitoring Network in Bhutan

The national hydrological and flood monitoring network consists of (as of June 2016):

- a. 16 Principal Hydrological Station equipped with Bank operated cable system with current meter to measure the discharge on North-South Rivers
- b. 9 Secondary Hydrological Station, which use traditional float methods to carryout discharge measurement.
- c. Automatic Water Level Station (AWLS) co-located with the hydrological stations
- d. 15 Sediment Sampling stations and 8 Sediment Laboratories operated in parallel with some of the river gauging stations.
- e. GLOF Early Warning System in the Punakha-Wangdi Valley (10 Real time Automatic AWLS/AWS Station, Basin Control Room (Wangdi) and 18 Warning Sirens,
- f. Rianstorm and GLOF EWS in the Mangdechhu sub-basin (2 Real Time Automatic AWLS/AWS Station, Basin Control Room and 3 Warning Sirens
- g. Rianstorm and GLOF EWS in the Chamkarchhu sub-basin (4 Real Time Automatic AWLS/AWS Station, Basin Control Room and 6 Warning Sirens.

Table 1: Annual Performance Agreement (APA) Targets and Services Delivery of Hydrology Division, DHMS for the FY 2015-16

Sl.No.	Objective	Action	Success Indicator	Unit	Planned (June 2015)	Achievement (July 2016)
1	a. To improve and setup Hydrological monitoring network with good national Coverage	Establish hydrological monitoring network and infrastructures	Number of new Real time hydrological station installed and operational	No.	5	Three AWLS installed on by HD, under MHPA: - Chendbjichhu, - Khagangchhu and - Dhurchhu Installation of other AWL are implemented under the NAPA-II by PCR, DHMS
			Number of existing manual hydrological stations upgraded to real time	No.	5	Two cableway station at Kurje and Sankosh upgraded, Rest AWL are implemented under the NAPA-II by PCR, DHMS
		Sediment network Expanded	Construction of sediment sampling station completed	No.	4	1. Doyagang on Ammochu, 2. Yebes on Mochhu, 3. Dobani on Sankosh, 4. Tingtibi on Mangdechhu, 5. Bijam on Mangdechhu
			Number of sediment lab constructed	No.	4	1. Doyagang on Ammochu, 2. Yebes on Mochhu, 3. Dobani on Sankosh, 4. Tingtibi on Mangdechhu, 5. Bijam on Mangdechhu
		Flood warning network and infrastructures expanded	Number of new site offices constructed	No.	2	Tendering for the Construction of new site office at Panbang on Dangemchhu, Zamthari on Jomori completed, Construction delayed to delayed in fund release from GoI
2	b. To improve Flood/GLOF Early Warning Service to minimize loss of lives and	GLOF Early warning System installed and Operational	Number of river basins covered with GLOF EWS	No.	2	GLOF EWS on Mangdechhu and Chamkharchhu Operational since March 2016.
			Number of Flood Forecasting and Warning Center established	No.	1	1. National Weather and flood Warning Centre (NWFWC), Thimphu, 2. GLOF EWS Control Room Mangdechhu at MHPA Dam colony, 3. GLOF EWS Control Room Chamkharchhu at Kurje
3	c. To deliver and enhance hydrological and related environmental information & services to the public, government and other users	To build and improve hydrological modeling capacity	Number of Hydrological models installed and operational	No.	1	HBV model installed and operational on Mochhu, Mangdechhu and Chamkharchhu IFAS model installed on Chamkharchhu and Wangchhu
		Hydrological datebook and research paper published	Number of data books published	No.	1	Surface Hydrological Data Book of Bhutan (2009-2015) published
			Number of pamphlets, flood advisories, hazard maps, brochures and posters published	No.	5	

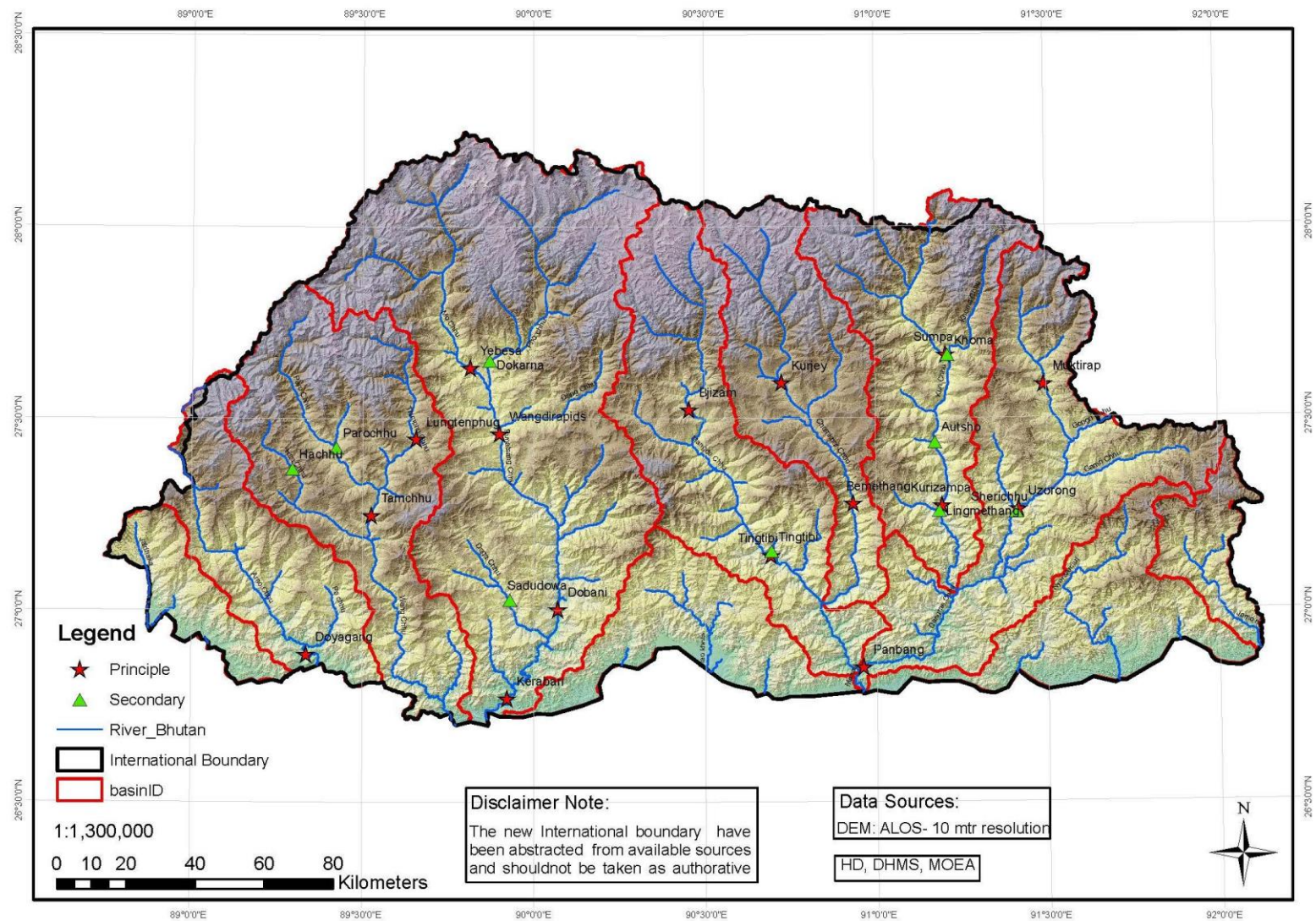


Figure 2: Hydrological Station Map of Bhutan

3 SUMMARY OF FINANCIAL STATEMENT

The summary of the financial statement for the FY 2015-2016

Items	Budget Allocated in millions (Nu.)	Expenditure in millions (Nu.)	Remarks
Capital (RGoB)	3.250	3.250	
Project (PHPA)	1.080	0.904	
Project (MHPA)	16.00	12.486	Some activity spilled over to FY 2016-17
Project (JICA TCP)			Approx. USD 1 million in kind for the Fy 2016-17
Total	20.33	16.64	

Table 2: Detail Budget Break down

Sl.No.	Activity	Approved budget in millions(Nu.)	Expenditure in millions(Nu.)	Remarks
A	RGoB Financing	3.250	3.250	
1	Training - Human Resource Development (Refresher Course)	0.300	0.300	
2	Exp. On Structure – Buildings (Cableway shed at Dobani, Sunkosh)	0.350	0.350	
3	Furniture	0.020	0.020	
4	Computers and Peripherals	0.080	0.080	
5	Plant & Equipt. - Hospital/Lab. Equipment (Sediment)	1.000	1.000	
6	Plant & Equipt.- General Tools, Instrument (Spare parts)	1.500	1.500	
B	PHPA Co-financing	1.080	0.904	
1	Plants & Equipment - General Tools, Instrument	0.200	0.188	
2	Purchase of Vehicle- Bike	0.120	0.112	
3	Professional Services	0.630	0.474	
4	Structure- Buildinging	0.130	0.130	
C	MHPA Co-financing	16.000	12.486	
1	Training - HRD	0.500	0.410	
2	Exp.on Structure-Others	1.600	0.964	
3	Exp.on Structure-Buildings	5.400	5.400	
4	Plants & Equipment - Communication	0.200	0.747	
5	Plants & Equipment - General Tools, Instrument	5.000	1.624	Spilled over to FY 2016-17
6	Furniture	0.100	0.283	
7	Office Equipment	0.100	0.000	
8	Computers and Peripherals	0.600	0.606	
9	Professional Services	2.500	2.452	
	Total	20.330	16.640	

HIGHLIGHTS OF ACCOMPLISHMENTS FOR THE FY 2015-2016

4 HIGHLIGHTS OF ACCOMPLISHMENTS FOR THE FY 2015-16

4.1 Hydrological Monitoring Network with Good National Coverage

4.1.1 Establish Hydrological Monitoring Network and Infrastructures

The modernization and up-gradation of the national hydrological and flood warning network with real time data transmission are being carried out under the NAPA-II project implemented by the DHMS under the LDCF through GEF/UNDP. More than 30 hydrological stations will be modernized under the NAPA-II project. Stations are expected to be operational by the end of 2017.

4.1.1.1 Upgradation of Hydrological Station

To maintain the continuity of hydrological data, the division has undertaken the up-gradation of hydrological stations that are not functional due damaged by flood or river profile changed. Two bank operated cableway station at Dobani on Sankosh river, Tsirang and Kurjey on Chamakharchhu, Bumthang was successfully rehabilitated and upgraded during the FY 2015-16.



Figure 3: The existing cableway at Kurjey, Bumthang raised by 1.7 M to avoid the flooding of the station during the flood.



Figure 4: The shifting of existing cableway at Sankosh, Tsirang

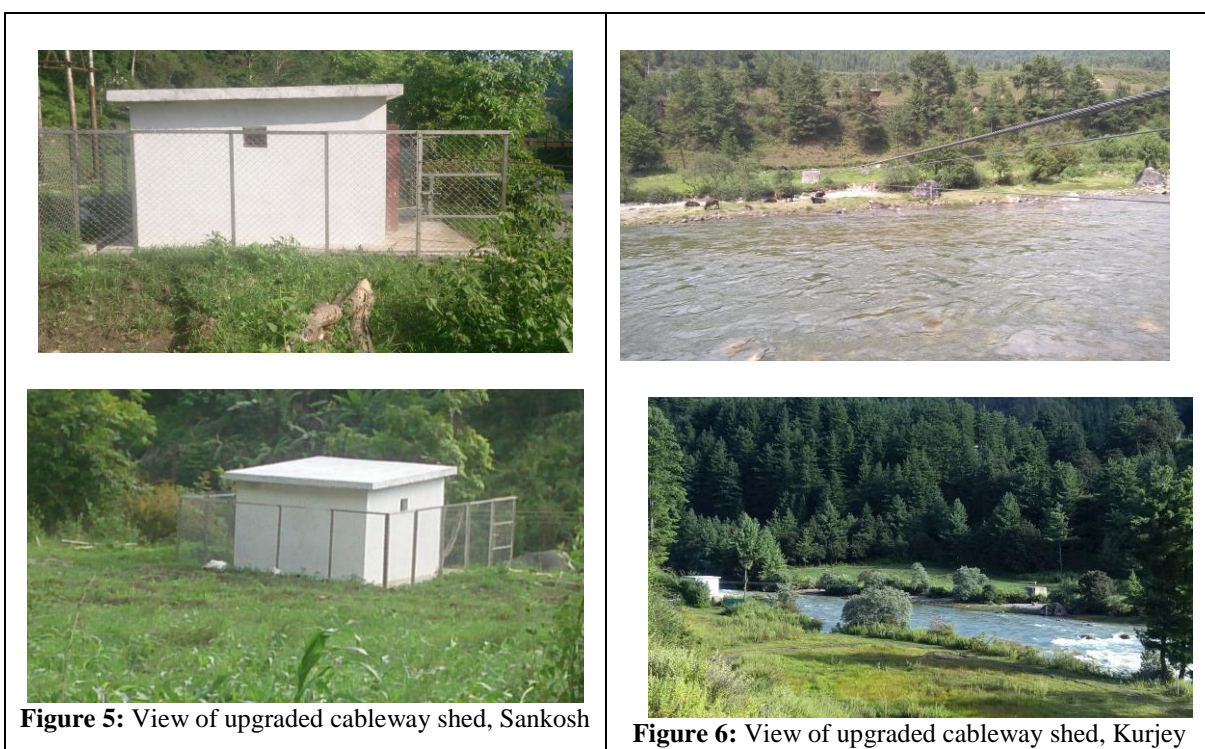


Figure 5: View of upgraded cableway shed, Sankosh

Figure 6: View of upgraded cableway shed, Kurjey

4.1.1.2 New AWLS

Under the MHPA co-financing, three additional Automatic Water Level Station (ALWS) were installed in tributaries of Mangdechhu and Chamkarchhuc basins:

- a. Chendbjichhu at Chendbji
- b. Khagangchhu at Chhumey
- c. Dhurchhu at Dhur



Figure 7: AWLS on Chenbjichhu



Figure 8 : AWLS on Khagangchhu, Geytsa, Bumthang



Figure 9: AWLS on Dhurchhu

4.1.2 Water Quality Monitoring Stations on Wangchhu

The Hydrology Division, DHMS in collaboration with Stroud Water Research Centre (SWRC), USA Team, Water Keeper Alliance (USA) and Clean Bhutan installed three Water Quality Monitoring Stations (WQMS) along Thimchhu/Wangchu at Dodena, Lungtenphug and Damchu. The station is co-located with the Hydrological Stations along the Wangchhu basin. Stroud Water Research Centre (SWRC), USA, donated three WQMS.

Data collected through these stations would provide information to understand the fresh water quality and ecosystem of Thimchhu/Wangchu. Real time of station can be access from this link http://swrcsensors.dreamhosters.com/status_bhutan.php



Figure 10: Photos taken during the WQMS installation.

4.1.3 Sediment Sampling and Laboratories Facilities

There were only 10 Sediment Sampling Stations and only 3 Sediment Laboratory facilities for analysis at the of FY 2014-2015. Sediment data are very important to understand the health of watershed and data are required for planning a design of Sediment Desilting chamber of the Hydropower Plants.

During the FY 2015-16, five (5) new sediment-sampling stations with laboratories facilities were established through RGoB and MHPA funding at the following Site Office.

- a. Bjizam on Mangdechhu, Trongsa under MHPA funding
- b. Tingtibi on Mangdechhu, Zhemgang under RGoB/GOI (FWS) funding
- c. Yebesa on Mochhu, Punakha under RGoB funding
- d. Dobani on Sankosh, Tsirang under RGoB funding
- e. Doyagang on Amochhu, Phuntsholling under RGoB funding

All the site staff were trained for sampling and laboratories analysis. The Sediment laboratories were set up at each site to reduce the cost of transportation of samples from sampling sites to

Laboratory in Thimphu for analysis. This is because a vehicle from HQ, Thimphu has to be deputed for collection of daily collected sediment samples from Thimphu every after 20 days for analysis.



Figure 11: Sediment Lab Facilities at Tingtibi



Figure 12 : Sediment Lab Facilities at Dobani, Sankosh



Figure 13 : Sediment Lab at Bjizam



Figure 14 : Sediment Lab Facilities at Yebesa



Figure 15: Sediment Lab Facilities at Doyagang on Ammochu

4.1.4 Annual Maintenance of Hydrological Network Facilities

Annual maintenance of hydrological and flood/GLOF monitoring network for the FY 2015-16 completed and all the stations operational.



Figure 16: Maintenance work carried out through the country for manual stations

4.2 Flood Warning Network and Infrastructures Expanded

4.2.1 Improve Flood/GLOF Early Warning Services for Preparedness

Flood/GLOF Early warning is one of the major operational services provided by the Hydrology Division, DHMS currently. Flood EWS is one of the non-structural measure that complement with structural measure in flood mitigation. The flood/GLOF EWS measure has gained popularity as the anticipated impacts of climate change are manifested in the occurrence of the extreme hydrological events. With the global warming the glaciers in the head water of Bhutan are melting at an accelerated pace forming large glacier lakes in the high altitude mountain about 4500 m posing threat downstream. The outburst glacier lakes of caused huge impacts such as loss of life and property downstream valleys as more than 70% of Country settlements and infrastructure located along the river valleys. Bhutan has more than 2674 lakes and out of which 25 are identified as potential dangerous lakes (ICIMOD, DGM, 2001).

4.2.2 GLOF EWS along the Punatsangchhu Basin

After the 1994 GLOF on Phochhu, the Royal Government of Bhutan directed the Hydro-met Services to installed GLOF Early Warning System on Phochhu sub-basin. A manual GLOF EWS using the HF wireless communication system was installed by deputing two regular staff at Thanza, Lunana. Later Satellite phone has provided as backup communication.

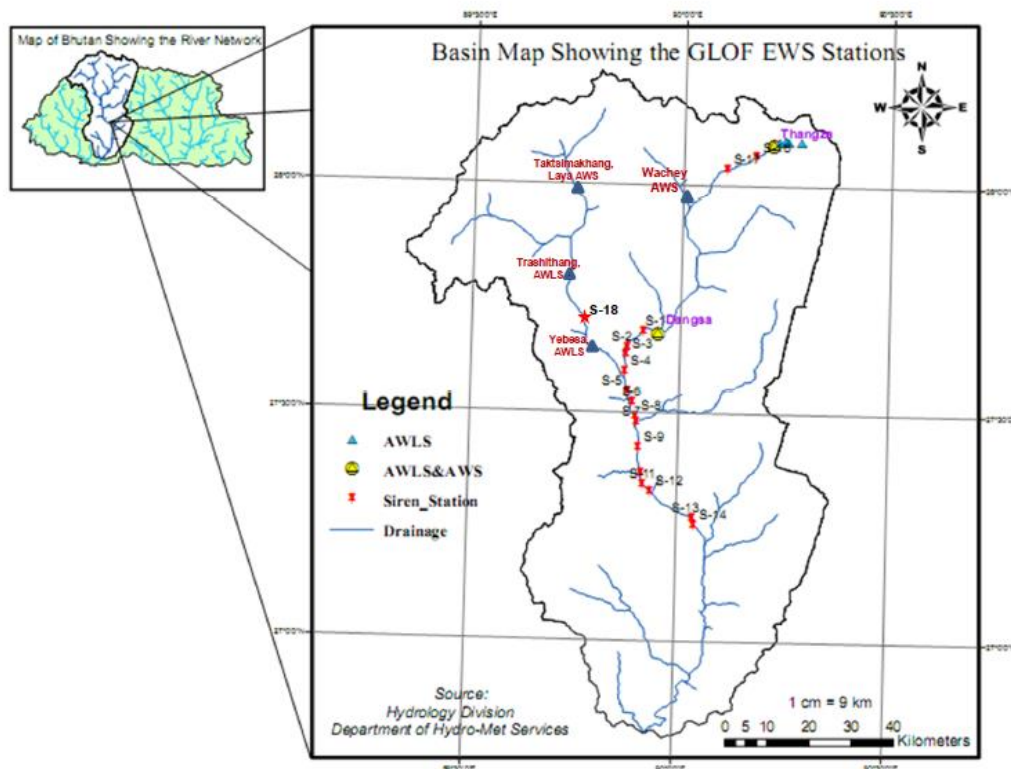


Figure 17: Punatsangchhu Basins Map showing location of GLOF EWS sites

The first GLOF EWS in Bhutan was installed along the Punatsangchhu basin through NAPA-I project funded under the LDCF through GEF/UNDP with co-financing from PHPA-I and II Project (2009-2013). The GLOF EWS along the Phochu was commissioned and operational in 2011. The System was expanded to Mochhu basin later. A EWS system consists of 10 Automatic Real Time Flood Monitoring stations (AWLS), 18 Warning Sirens with 24/7 Control Room operated by Staff at Wangdi Flood Warning Office.

On 28 June 2015, a GLOF occurred due to outburst of the Lemethang Tsho from the head water of Mochhu.

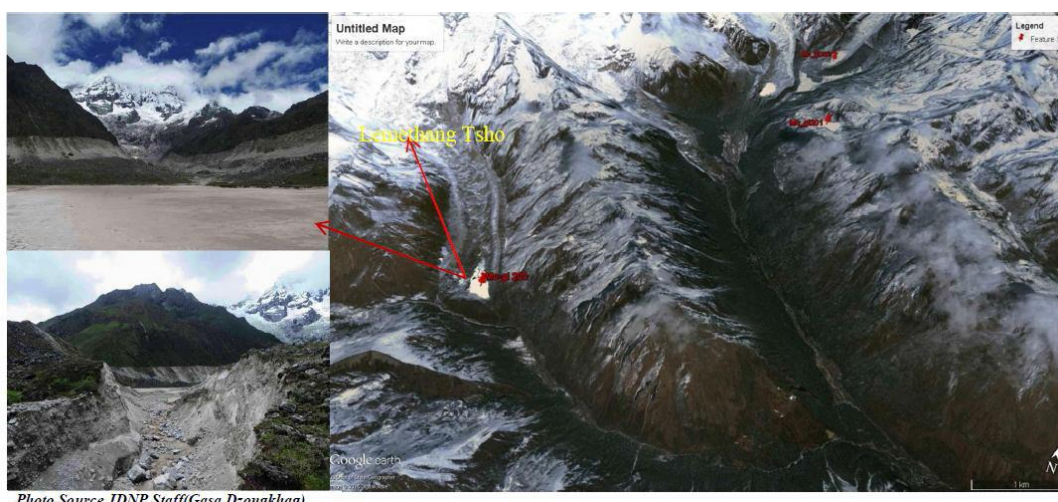


Figure 18: Google map showing Lemethang Lake (Mo-gl200) and lake photos taken by (JDNF Staff) after flood



Figure 19: Lemthang Tsho Before and After GLOF

As per the Standard Operating Procedure (SOP) of the GLOF EWS installed along the Punakha-Wangdue Valley, GLOF Management Oversight Group (GMOG) members of DHMS were informed as soon the flood information was received from MoHCA. MoEA team lead by Tengye Lyonpo, Dasho Secretary and GMOG Members of DHMS monitored the flood situation from DHMS Office and provided guidance to GLOF EWS Control Room located at Wangdue. Warning sirens were activated to evacuate the people to safe areas. As the flood moves downstream Tengye Lyonpo updated flood situation to the Honorable Prime Minister of Bhutan. Information were provided to DDM, Media (BBS and Kuensel) and other stakeholders including local governments and PHPA-I and II. Later Honorable Prime Minister of Bhutan joined MoEA team to monitor the flood.



Figure 20: Tengye Lyonpo updating flood/GLOF situation to the Honorable Prime Minister



Figure 21: Tengye Lyonpo monitoring GLOF situation from DHMS Office

4.2.3 Manual Back up GLOF Early Warning System for Punasatngchhu Basin

The Hydrology Division, DHMS yearly depute two staff to Lunana as back up manual EWS to provide information to downstream in the event of GLOF. This special task was assigned to the

DHMS after 1994 GLOF on Pochhu caused by outbreak of Luggy Tsho. Although Automatic GLOF EWS was installed and operational since 2011, the deputation of staff has been continued by the department as back up to automatic EWS system as well to carry out running and maintenance of GLOF EWS facilities installed in Lunana. The staff are also assigned and is responsible for the physical verification submit weekly report to the Division/Department about the physical status of lakes.

For the FY 2015-16 Mr. Tenzin Dorji and Mr. Sonam Tashi, Hydro-Technicians were deputed on a special duty for a period of one year. The team is expected to back by August 2016 upon arrival of new team to Lunana who are planning their voyage by 23 July 2016.



Figure 22: Mr. Tenzin Dorji and Mr. Sonam Tashi, Hydro-Technicians before their departure to Lunana (July 16, 2015)

During the FY 2014-15, the Hydrology Division, DHMS constructed site single a storied Flood Warning Office at Thanza, Lunana under the Punatsangchhu Hydropower Project Authority (PHPA) co-financing. However, Thanza Flood Warning Office along with communication facilities were completely damaged by windstorm that strike Lunana on 26 December, 2016 and the structure was further damaged by the subsequent windstorm in Lunana.

The structure and facilities of Thanza will be reconstructed and reinstalled during the FY 2016-17.

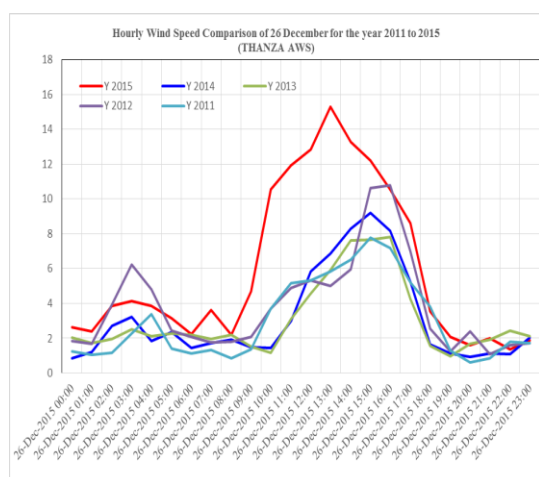


Figure 23: Hourly wind speed comparison Graph (26 December, 2015)



Figure 24: Thanza FWS Office after 26 Dec, 2015 wind storm



Figure 25: Thanza Flood Warning Site Office after the windstorm



Figure 26: Solar panel of HF Communication system

4.2.4 Sharing Flood Information with Indian States of Assam and West Bengal, India

The Flood Warning Section (FWS) under the Hydrology Division, DHMS is responsible for monitoring, operation of Flood Warning Station established in common rivers of Bhutan and India. The FWS is headed by Technical Maintenance Officer (TMO), who is on deputation from the Government of India (GoI). TMO oversee the GoI program of the Flood Warning Section (FWS) under the DHMS. TMO is directly responsible for maintenance of flood warning stations and communicating facilities established, monitoring and sharing of flood and weather information with counterpart Central Water Commission (CWC) offices in the Indian States of Assam and West Bengal.

All the Flood Warning Stations (both Water Level and rainfall) and site office are equipped with HF wireless communication sets and telephone. River water level/flood and weather information are transmitted to Barpeta and Nalbari in Assam, Cooch Behar and Jalpaiguri in West Bengal on near real time basis over HF Wireless Radio and other communication directly from the stations as per the agreed schedule given in table below. Further complied data are daily sent by email to Central Water Commission (CWC) offices to Guwahati (Assam), Jalpaiguri in West Bengal and Office of the Bhutan Investigation Division, CWC based at Phuentsholing, Bhutan.

In line with modernization of hydro-meteorological Stations in Bhutan, FWS has updated all their stations to real time station in the 11 FYP with the objective to transmit real time data to India States of Assam and West Bengal for flood forecasting and warning as well as to the NWFWC, Thimphu

The Government of India (GoI) Program for Flood Forecasting Network on Rivers Common to Indian and Bhutan is jointly administered through a Joint Expert Team (JET) that was established in 1979 with members from both the RGoB and the GOI.

4.2.5 GLOF EWS on Mangdechhu and Chamkharchhu Sub-basin

Under the JICA Technical Cooperation Project “*Capacity Development of GLOF and Rainstorm Flood Forecasting and Warning in the Kingdom of Bhutan*” (2013-2016), has installed two GLOF and Rainstorm Early Warning System along the Mangdechhu and Chamkharchhu sub-basins. The EWS were installed to provide data and information on flood/GLOF in near time to the vulnerable communities along the river valleys and hydropower downstream. The EWS Control

Room at Kurje, Bumthang and MHPA Dam Colony for Mangcehhu are operational from 24/7 with effect from May 2016.

Detail report of the JICA project is given in Annexure.

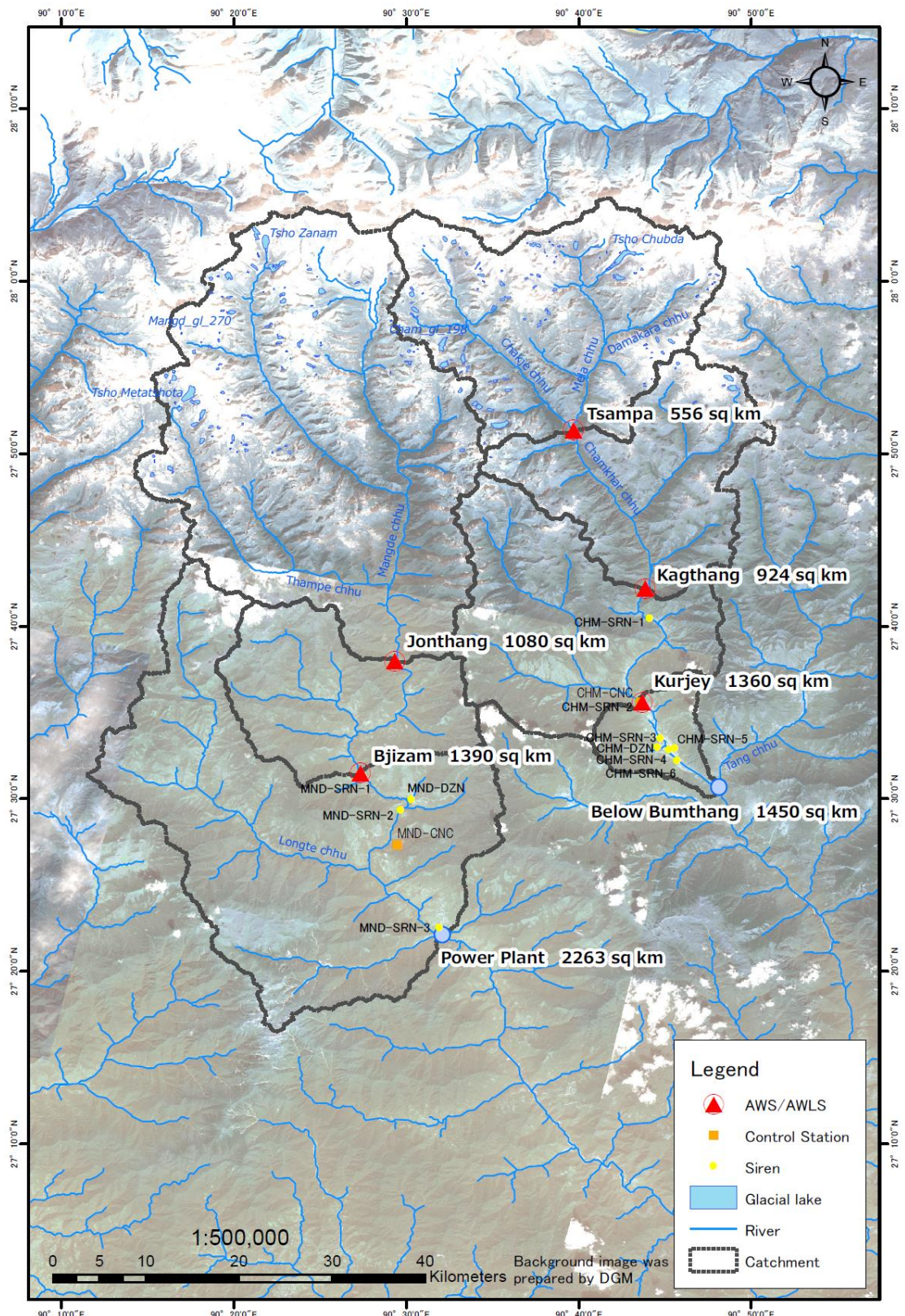


Figure 27: Map Showing the Mangdechhu and Chamkahrchhu Sub-basins

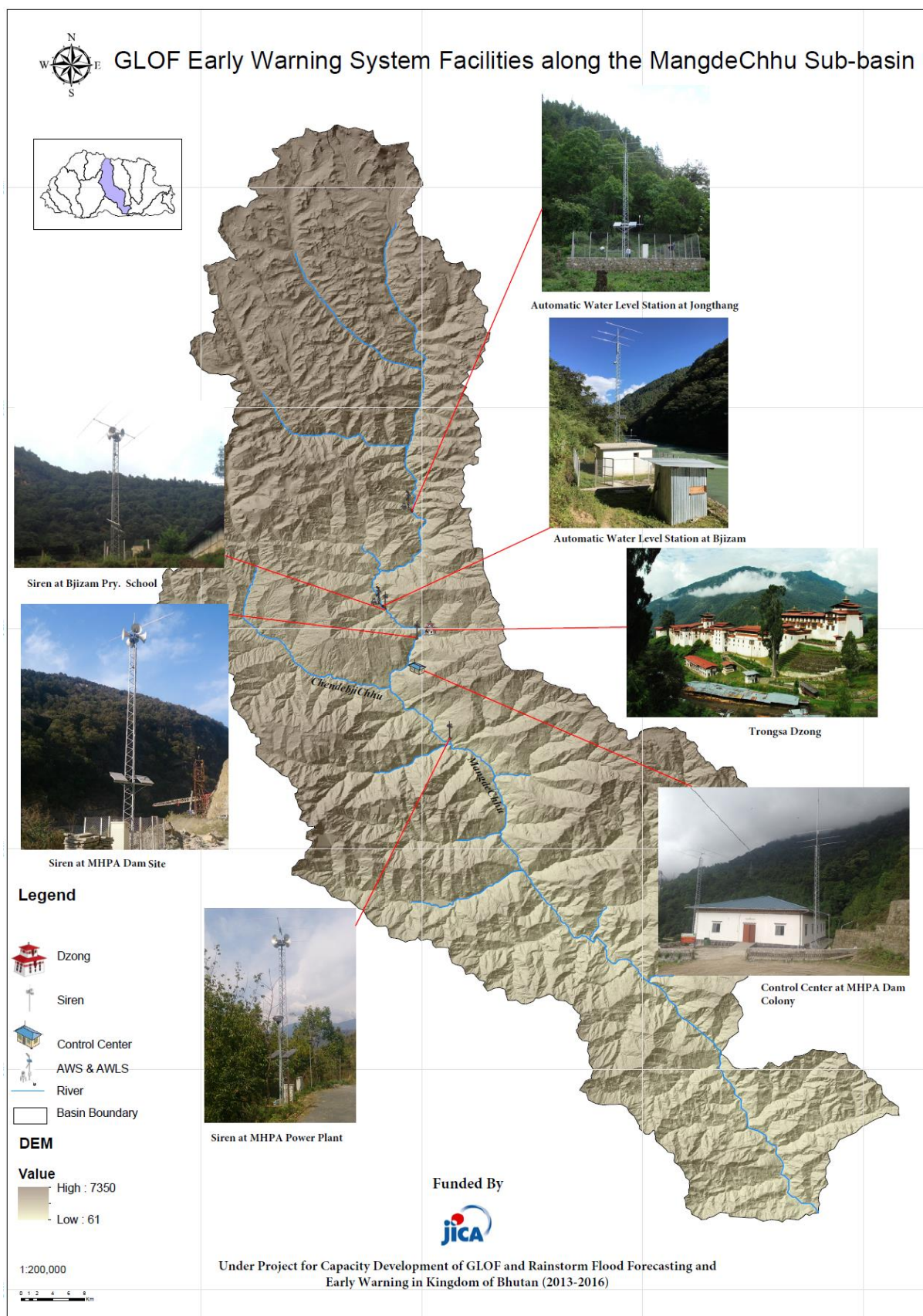


Figure 28: GLOF EWS Facilities along the Mangdechhu Sub-basin

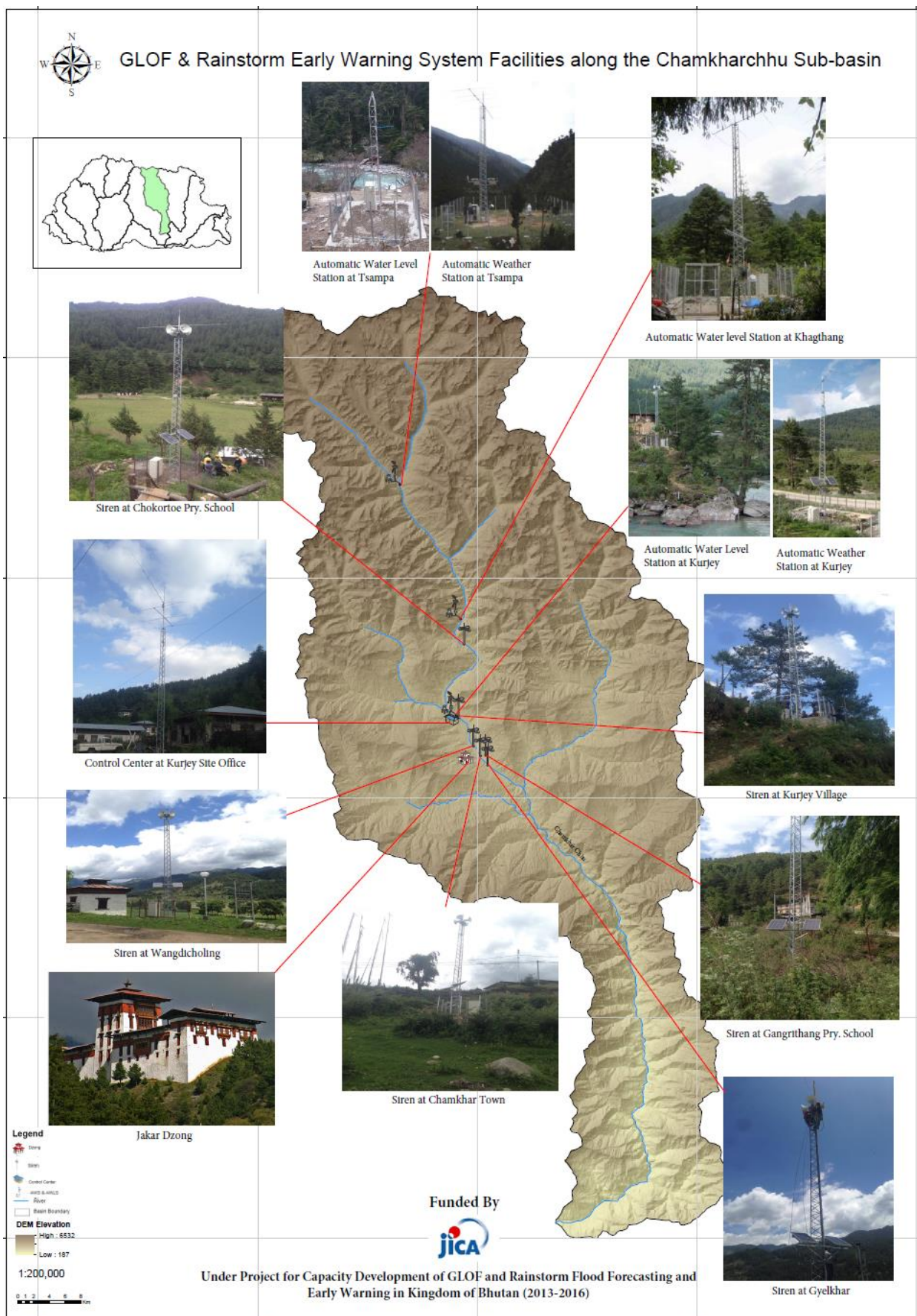


Figure 29: GLOF EWS Facilities along the Chamkharchhu sub-basin

4.2.6 National Weather and Flood Warning Centre (NFWWC)

National Weather and Flood Warning Centre (NFWWC) is the national supervisory and command center for the Department of Hydromet Services for real time monitoring of hydro-meteorological hazards and issue advisory/warnings in Bhutan. NFWWC will be directly link with the National Emergency Operation Centre (NEOC) and hydropower Plants control rooms in future.

The National Weather and Flood Warning Centre (NFWWC) building with ICT facilities of the Department of Hydro-met Services (DHMS), MoEA was inaugurated by the Honorable Tengye Lyonpo Norbu Wangchuk, Ministry of Economic Affairs on 5 November, 2015 commemorating the 60th Birth Anniversary of the His Majesty the Fourth Druk Gylepo Jigme Singye Wangchuck. The NFWWC building was constructed with funding from hydropower sector with top-up from the Mangdechhu Hydropower Project Authority (MHPA). The ICT facilities and software's were provided through JICA and other projects implemented by DHMS.



Figure 30: Inaguration of NFWWC by Tengye Lyonpo Norbu Wangchuk, Ministry of Economic Affairs

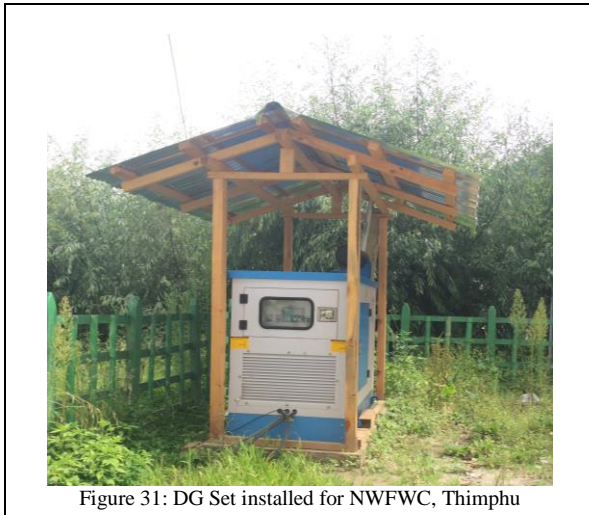
NFWWC has two main operation sub-center or room that operates for 24/7: National Weather Forecasting Room (NWFR) and Flood Monitoring and Command Room (FMCR). The NFWWC is equipped with following facilities to facilitate the weather forecasting and flood warning services.

- ICT Central Server room- established through MHPA funding
- Puntsangchhu GLOF EWS Monitoring facilities
- Mangdechhu and Chamkarchhu Rainstorm and GLOF EWS monitoring facilities;
- Hydrological Real time monitoring facilities
- Hydrological Modeling facilities
- Telephone and HF wireless communication system
- Global Telecommunication System (GTS)

- h. Himawari Caste Satellite receiving Station
- i. Himawari-9 Satellite monitoring and data facilities
- j. WRF modeling facilities
- k. Diesel power generator back up system

4.2.6.1 Installation of Backup Diesel Generator (DG) at Control Rooms

Communication and uninterrupted power supply is the backbone of early warning system. Through the support of JICA, three DG sets were procured and installed for National Weather and Flood Warning Centre (NWFWC), GLOF EWS Control Room Mangdechhu at MHPA Dam Site and GLOF EWS Control Room Chamkarchhu at Kurje, Bumthang in May 2016.



4.3 Delivery of Hydrological and Related Environmental Information & Services

4.3.1 Capacity in Hydrological Modeling for river flow and Flood Forecasting

The capacity of Hydrology Division, DHMS in hydrological modeling was enhanced through NORAD Phase IV project and JICA TCP project. For the FY 2015-16 the following two hydrological models were installed and running in Bhutan.

a. HBV Modeling

HBV is a semi-distributed conceptual model used to calculate river discharge using rainfall, temperature, topography & land Use. A licensed HBV model was developed by Swedish Meteorological and Hydrological Institute (SMHI) and the model is widely used in the Scandinavian countries for flood forecasting.

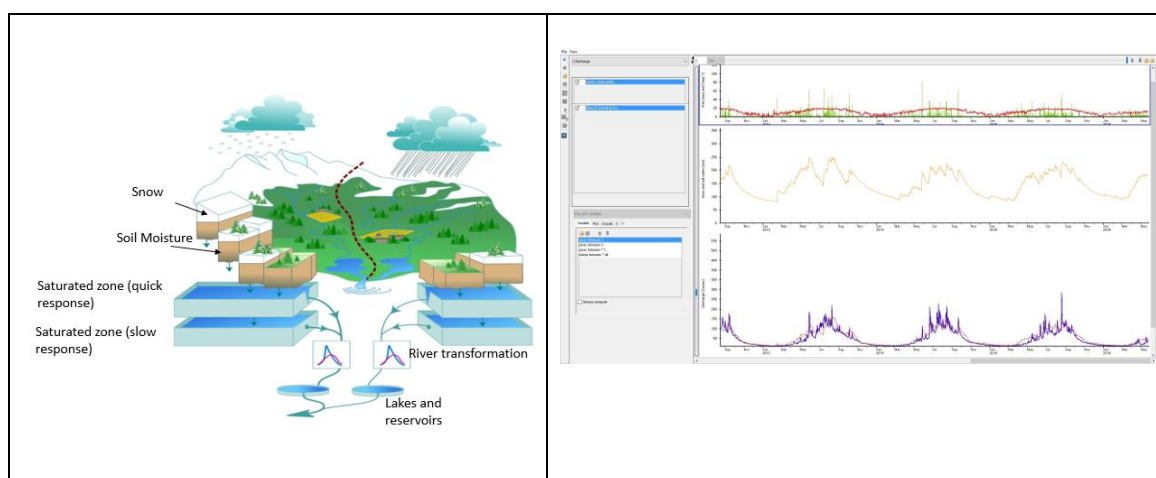


Figure 34: Outputs of HBV Model for Chamkhar Chhu

A HBV licensed hydrological model was procured from the Swedish Meteorological and Hydrological Institute (SMHI) through NORAD-IV supported project. Necessary training for modeling and setting up of model was imparted to DHMS staff by SMHI in Sweden from 16-20 March 2016. At the same time NVE deputed hydrological and IT experts in Bhutan for installation, setting up of model and training. With the technical back stopping from the Norwegian Water Resources (NVE), HBV model were set up on pilot river basin in Bhutan- Mochhu, Mangdechhu and Chamkarchhu basins in Bhutan. Based on the performance, the model will be set up for other river basins in Bhutan. The outputs of the model will be used for inflow forecasting for hydropower plants and flood forecasting.

b. Integrated Flood Analysis System (IFAS) Modeling

An (IFAS) is a distributed hydrological model used to calculate river discharge using rainfall Topography & Land Use. A rainfall-runoff hydrological model was developed by model developed by International Centre of Hazard and Risks Management (ICHARM) and Public Work Research Institute (PWRI) of Japan is testing in Bhutan river basin. A concise flood-runoff analysis system was developed as a toolkit for more effective and efficient flood forecasting in developing countries. The Model can be downloaded free from the <http://www.icharm.pwri.go.jp/research/ifas/>

A model is being tested in Wangchhu and Chamkarchhu basins in Bhutan. More than three batch of Hydrology Division, DHMS staff attended the regional training on IFAS at ICHAM/PWRI at Tsukuba, Japan under the JICA project counterpart training in Japan.

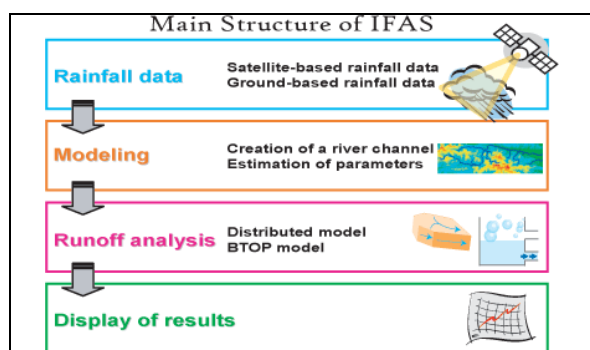


Figure 35: IFAS Model Structure

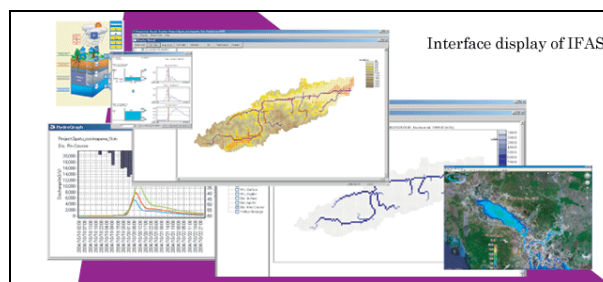


Figure 36: IFAS Model interface Display
Sources: ICHARM/PWRI Web site

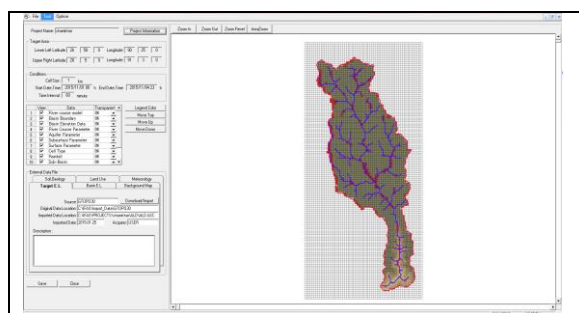


Figure 37: IFAS Model Setup of Chamakharchhu

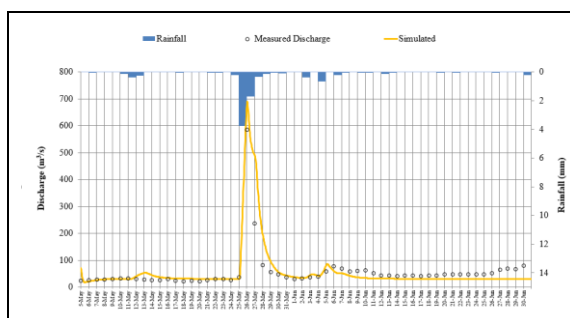


Figure 38: Outputs of IFAS Model for Chamkhar Chhu

4.3.2 Education Awareness of Flood and GLOF Early Warning System

Under the JICA and MHPA supported project, the Hydrology Division, DHMS in collaboration with Department of Disaster Management (DDM), MoHCA and local governments organized number of education and awareness on flood and GLOF EWS.

4.3.2.1 JICA Annual Seminar 2015-19 June 2015

The “Annual Seminar 2015” for the Project *Capacity Development of GLOF and Rainstorm Flood Forecasting and Early Warning in the Kingdom of Bhutan* funded by JICA under TCP was held on 19th June, 2015 at Hotel Phuntsho Pelri, Thimphu, Bhutan. The Seminar was jointly organized by the Department of Hydro-met Services, MoEA in collaboration with JICA Project experts. The main objectives of the seminar were to provide a platform for sharing progress and lessons from the project and also serve as a scientific forum for knowledge exchange and technical cooperation among relevant stakeholders in enhancing our understanding and approaches in managing climate change-induced flood/GLOF risks and vulnerabilities.

All the presentations during the seminar were made by the Bhutanese project counterparts and participant from the College of Science and Technology (CST) under the Royal University of Bhutan (RUB) covering following topics.

- Climate change impact on the Glaciers and Glacial lakes in Bhutan
- Flood/GLOF Early Warning Systems in Bhutan
- Study of Potential GLOF area in Bhutan Himalaya using GIS and Remote Sensing
- Snow and Glacier Monitoring in Bhutan
- GLOF/Flood Hazard Mapping in Bumthang, Chamkharchhu basin
- Disaster Risk Management Administration in Bhutan
- CBDRM Activity in Bumthang, Chamkharchhu basin
- Incorporating Disaster Risk Reduction into Bumthang Urban Development Plan
- Flood Engineering Management in Bhutan



Figure 39: Annual Seminar 2015

The Honorable Tengye Lyonpo, Ministry of Economic Affairs was the Chief Guest. More than 60 participants from counterpart agencies and officials from JICA Bhutan Office including the Member of Parliament (MP) from Trongsa and Bumthang and local governments (Trongsa and Bumthang) attend the seminar.

4.3.2.2 CBDRM

As a part of Community Based Disaster Risk Management (CBDRM) of the Flood/GLOF management, the JICA CBDRM Experts conducted the Flood Evacuation planning workshop with all the vulnerable communities in the Chamkhar valley and Bjizam from 5-30 November, 2016.



Figure 40 CBDRM Activities in Pilot River Basin

4.3.2.3 Mock Drill GLOF EWS Bumthang

DHMS in collaboration with Dzongkhag administration organized the CBDRM activities of the all the vulnerable communities along the Chamkhar Valley and Bjizam in Trongsa. The CBDRM activities were carried out by two JICA CBDRM experts Ms. Lilita and Ms. Kaorus Sasaoka for the period of more than 2 months.

Upon commissioned of GLOF EWS systems in the Mangechhu and Chamkharchhu sub-basins, a mock drill of the GLOF EWS was conducted with the all the vulnerable communities by activation of sirens. The mock drill at Gangrithang Primary school was also attended by the official from JICA Project Terminal Evaluation team lead by Dr. Baba, Dasho Dzongda and officials from Dzongkhag Administration, Department of Disaster Management (DDM), local government, Royal Bhutan Police (RBP) and community's leaders.



Figure 41: Photos from GLOF EWS Mock drill at Gangrithang Pry. School, Bumthang

4.3.2.4 Stakeholder Awareness Workshop with MHPA

Upon installation of GLOF EWS system along the Mangdechhu sub-basin, a day long consultation and awareness workshop was organized at MHPA Dam colony on 3 June 2016 for the MHPA officials. More than 40 officials from the MHPA attended the workshop. The Participants visited the Control Room located the MHPA Dam colony and Siren. MHPA is the primary user of the GLOF EWS installed along the Mangdechhu sub-basin. Two sirens are specifically installed at MHPA Dam and Power house sites. MHPA has also co-financed the GLOF EWS project.



Figure 42: Stakeholder Consultation Workshop with MHPA, Trongsa

4.3.2.5 Stakeholder Consultation Workshop at Trongsa and Bumthang

Stakeholder consultation workshop for formulation of Standard Operating Procedure (SOP) of the GLOF EWS was conducted by JICA Experts and counterpart staff from the Hydrology Division, DHMS in collaboration with the Dzongkhag administration of Trongsa and Bumthang was organized from February 20-25, 2016.

The workshop was attended by the JICA Terminal Evaluation members from Japan.

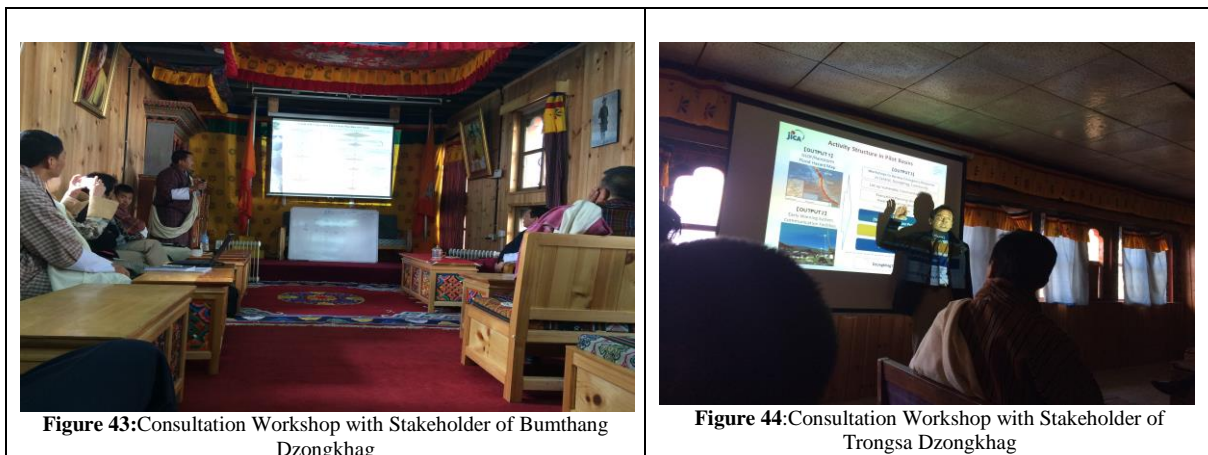


Figure 43: Consultation Workshop with Stakeholder of Bumthang Dzongkhag

Figure 44: Consultation Workshop with Stakeholder of Trongsa Dzongkhag

4.3.2.6 Awareness Workshop at College of Science and Technology (CST)

JICA Experts in collaboration with Department of Hydromet Services organized a presentation workshop on GLOF and disaster risks reduction with students of the College of Science and Technology (CST), Royal Univeristy of Bhutan, Phuntesholing on 26 March 2016.



Figure 45: Education and Awareness Workshop with student and staff of CST, Phuntsholling

4.3.2.7 Final JICA Annual Seminar 2016 - 14 June 2016

The “Annual Seminar 2016” for the Project *Capacity Development of GLOF and Rainstorm Flood Forecasting and Early Warning in the Kingdom of Bhutan* funded by JICA under TCP was held on 14th June, 2016 at Hotel Le Meridian, Thimphu, Bhutan.

The Seminar was jointly organized by the Department of Hydro-met Services, MoEA in collaboration with JICA Project experts. The main objective was to share the project outputs and knowledge among relevant stakeholders in enhancing our understanding and approaches in managing climate change-induced flood/GLOF risks and vulnerabilities.

The opening session was graced by the Honorable Chief Guest Tengye Lyonpo Leki Dorji, Ministry of Economic Affair and Mr. Koji YAMADA, Chief Representative of JICA Bhutan Office and seniors officials from line agencies and international organizations.



Figure 46: Opening remarks by the Honorable Chief Guest Tengye Lyonpo Leki Dorji, Ministry of Economic Affairs and Mr. Koji YAMADA, Chief Representative of JICA Bhutan Office

More than 60 participants from counterpart agencies-Department of Disaster Management (DDM), Department of Geology and Mines (DGM), Department of Engineering Services (DoES), Department of Human Settlement (DHS) under the Ministry of Works and Human Settlement (MoWHS), National Land Commission (NLC), Department of Hydropower and Power Systems (DHPS), National Environment Commission (NEC), Druk Green Power Corporation (DGPC), Mangdechhu Hydropower Project Authority (MHPA), Dzongkhag Administration, Trongsa. Officials from JICA, UNDP, WWF also attended the seminar.

4.3.3 Hydrological Data Book

The first Hydrological Data Book of Bhutan was published in 2009 under DANIDA funding. The Second series of the Hydrological Data Book of Bhutan (2009-2015) was published this year (2016) under the Mangdechhu Hydropower Project (MHPA) co-financing project implemented by the Hydrology Division, DHMS. The Data Book was formally launched by the Hon'ble Tengye Lyonpo Leki Dorji, Minister, Ministry of Economic Affairs during the inaugural session of the “Annual Seminar 2016” for the Project *Capacity Development of GLOF and Rainstorm Flood Forecasting and Early Warning in the Kingdom of Bhutan* held on 14th June, 2016 at Hotel Le Meridian, Thimphu, Bhutan.

The National Hydrological Database has more than 24 years of hydrological time series data of hydrological stations operated by the Hydrology Division, DHMS. The data are currently made free available to line agencies, public and private individual based on the request.



Figure 47: Hydrological Data Book 2016 was jointly launched by His Excellency Lyonpo Leki Dorji, Ministry of Economic Affairs and Mr. Koji YAMADA, Chief Representative, JICA Bhutan Office on June 14, 2016 at Le Meridian, Thimphu

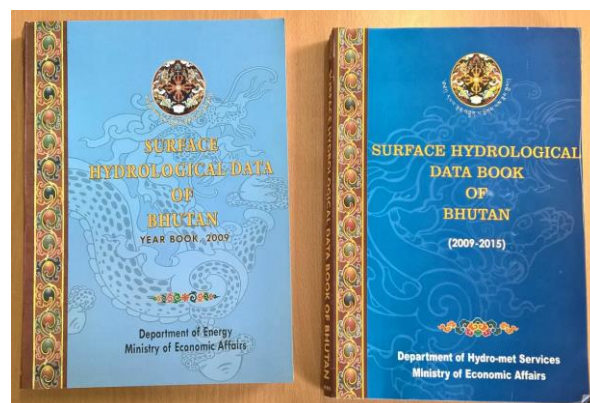
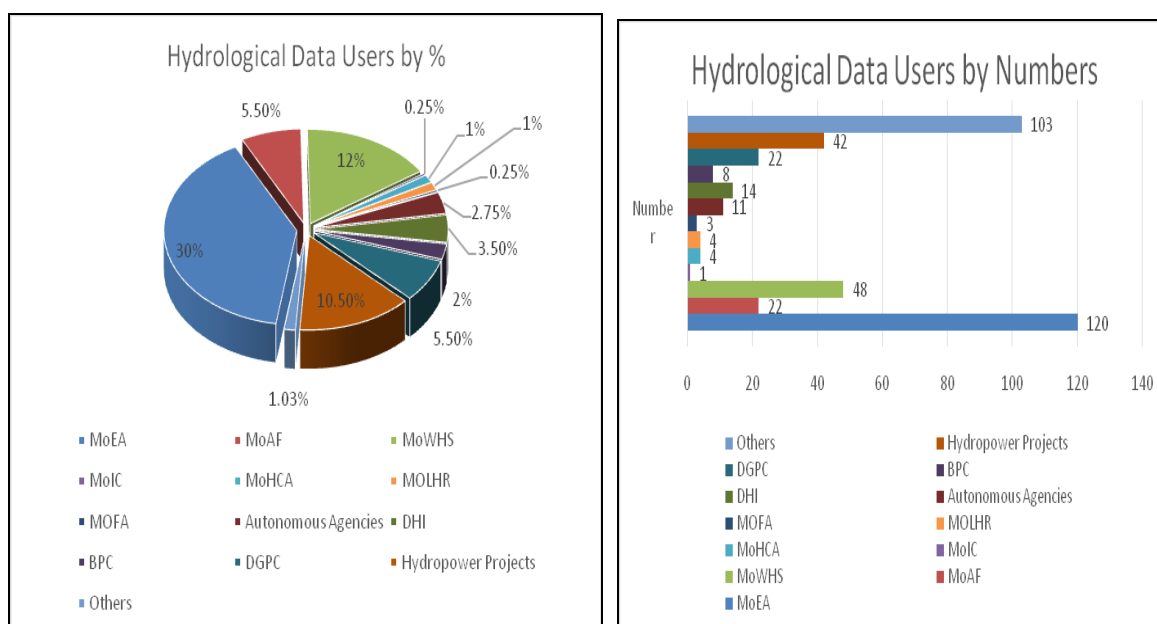


Figure 48: Two Hydrological Data Book Series published by Hydrology Division, DHMS in 2009 and 2016

4.3.4 Dissemination of Hydrological and Sediment Data to Users

Beside the flood and GLOF Early warning products and services, the Hydrology Division (HD) also provides raw and processed hydrological time series data to line agencies, private individuals, academic researchers and students. The main user of hydrological data is hydropower sector (Department of Hydropower and Power Systems and Druk Green Power Corporation (DGPC) and Hydropower Project Authorities.

The main hydrological data users of the FY 2015-16 are given below.



4.3.5 Pamphlets, Brochures, posters, hazard maps published

With the support of JICA TCP and MHPA co-financing project the Hydrology Division, Department of Hydro-met Services formulated and published number of information pamphlets, Brochures, posters and disseminated to public.

- JICA TCP project information Brochure
- Flood Hazard Map of Chamkharchhu valley, Bumthang
- Flood Hazard Map of Bjizam, Trongsa
- Rainstorm and GLOF EWS Brochure
- GLOF EWS Communication of Mangdechhu and Chamkharchu Brochure

4.4 Technical Backstopping Services Provided to Other Divisions of the DHMS

For the FY 2015-16, the Hydrology Division, DHMS has provided technical backstopping services for the implementation of NAPA-II project implemented by the Planning Coordination and Research Division (PCRD) of DHMS in the following activities.

- Staff of Hydrology Division took a lead role in site selection, site verification, tender preparation and awarding and site handover to Contractor of Civil works for the Installation of AWLS and discharge measurements.
- Preparation of Technical specification of Hydrological equipment's (AWLS and Discharge measurements)



Figure 49: Site Selection on after Mangdechhu and Chamkarchhu confluence (January 2015)



Figure 50: AWLS Site Selection at Bemethang on Chamkarchhu, Shingkhari, Zhemgang



Figure 51: Handover of ALWS NAPA-II Site at Tingtibi.

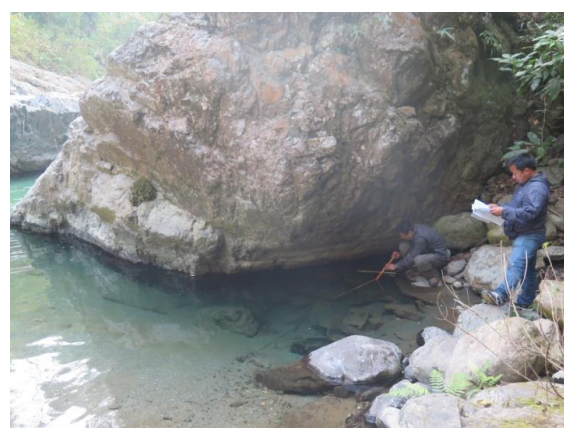


Figure 52: AWLS site at Dewri, Deothang

4.5 Technical Backstopping and Hydrological Services to Other Agencies

For the FY 2015-16, the Hydrology Division provided technical backstopping and other hydrological services to the following public as well as private individuals.

4.5.1 Department of Hydropower and Power System (DHPS), MoEA

DHPS is the focal agency in Bhutan responsible for coordinating, planning and development of hydropower projects in Bhutan. Hydrological data being the primary requirement for planning and designing of hydropower plants, based on the request of DHPS, the Hydrology Division, DHMS provided technical backstopping services for the establishment of Hydrological stations for data collection at their identified hydropower project sites.

For the FY 2015-16, Hydrology Division, DHMS assisted the DHPS for the site survey study, discharge measurement, installation of Hydrological Station at the following sites.

- Piping river



Figure 53: Discharge measurement of Pipingchhu



Figure 54: Hands on training of flow measurement imparted to local staff by Hydrology Division team.

4.5.2 Druk Green Power Corporation (DGPC)

The Hydrology Division assisted the DGPC for the establishment of river gauging stations for the planning and development of Hydropower projects. For the FY 2015-16, the Hydrology Technical team assisted DGPC in installation of the manual river gauging station at the following hydropower sites. Installed work was carried out from December 25 to January 09, 2016.

- Nyera Amari I Hydropower Project Site at Paedung, Thrimshing
- Nyera Amari I & II Hydropower Project Site at Mastshala, Samdrup Jongkhar
- Druk Bindu Small Hydropower Project at Sibsoo under Samtse Dzongkhag



Figure 55: Technician installing river gauge post at Nyera Ama ri



Figure 56: River gauge post at Nyera Ama ri

4.5.3 Tangsibji Hydro Energy Limited (118 MW Nikachhu)

Technical team from the Hydrology Division, DHMS also assisted the Tangsibi Hydropower Project for the installation of water level monitoring station at Dam site, trail race along the Nikachhu/Chendbjichhu.



Figure 57: River Gauge Post being installed at Nikachhu near Bailey Bridge

4.5.4 Druk Holding and Investment (DHI)

Based on the request of DHI, a Hydrology Division (HD) technical team was deputed to carryout site survey for establishment of river gauging station on Pachhu below Drukgyal Dzong. A mini ultrasonic Automatic Water Level Station (AWLS) was installed by the Hydrology Division on Parochhu below the Drukgyal Dzong including the river cross section survey. A real time water level can be view online at www.swrcsensor.dreamhosters.com/status_bhutan-php



Figure 58: Mini Ultrasonic Water Level Sensors installed on Pachhu below Drukgyal Dzong.

CAPACITY BUILDING AND HUMAN RESOURCES DEVELOPMENT (HRD)

5 CAPACITY BUILDING AND HUMAN RESOURCES DEVELOPMENT (HRD)

Being a technical agency, the Department of Hydro-met services continues to develop its manpower resources to provide adequate pool of qualified and well trained professional, technical and administrative personal for effective and efficient delivery of services. With approved fund from RGoB and donors fund projects the Hydrology Division, DHMS for the FY 2015-16 implemented in country and number of ex-country trainings. Further, Hydrology Division personnel got opportunities to attended several international meetings/workshop/seminar/conference related to hydrology, flood, disasters, early warning and climate change impacts organized by regional and international organization. The workshop and seminar provide opportunities and international exposure related to their work.

5.1 In-country Training

To keep up with the pace of modernization of Hydro-Meteorological equipment, the skills and knowledge of our field staffs who dealing with using the equipment in the field on a daily basis needs to be enhanced. Based on the availability of fund, the division always organized workshop and refreshers course of the field technicians and observers from time to time.

5.1.1 Refresher Training Course on Operational Hydrology

For the FY2015-16, a 10 days refresher course on “Operational Hydrology” was conducted at the College of Natural Resources (CNR), Royal University of Bhutan (RuB), Lobesa from January 25 to February 3, 2016. More than 25 Hydro-met Technicians from the sites working the under the Operation and Maintenance Section (OMS) and Flood Warning Section (FWS) attended the training. The lectures and field training were provided the professional staff of Hydrology Division, DHMS covering the following topics.

- a. On Hydrological cycle and the influence of man
- b. Basics of hydraulics: SI Units, properties of fluids, basic mechanics
- c. Hydrostatics: Pressure, pressure measurement, pressure and forces on submerged surfaces
- d. Fluids in motion: Types of flow. Continuity, energy and momentum equations and their applications. Behavior of a real fluid
- e. Precipitation, measurement of precipitation amount and intensity, spatial analysis. Interception and depression storage. Evapotranspiration, Penman approach, actual evapotranspiration. Runoff processes; overland flow, interflow, base flow
- f. Runoff measurement; velocity area methods. Structures; hydraulic principles of weirs and flumes.
- g. Stage and flow measurements
- h. Rating curves and other methods
- i. Sediment sampling and analysis
- j. Communications types and transfer of data from remote stations to Central database
- k. Database management, data processing and
- l. Bhutan Civil Services Rules and Regulation (BCSR), Financial rules and regulations, online processing of security clearance, Audit clearance, Asset Deceleration, and PIT filing and other.

The opening and closing session was attended by the Director, DHMS and Director of College of Natural Resources (CNR), Royal University of Bhutan.



Figure 59: Refresher course on Operation Hydrology



Figure 60: Theory session for Refresher Course



Figure 61: Hands on Training for Survey Equipment and Discharge Measurement



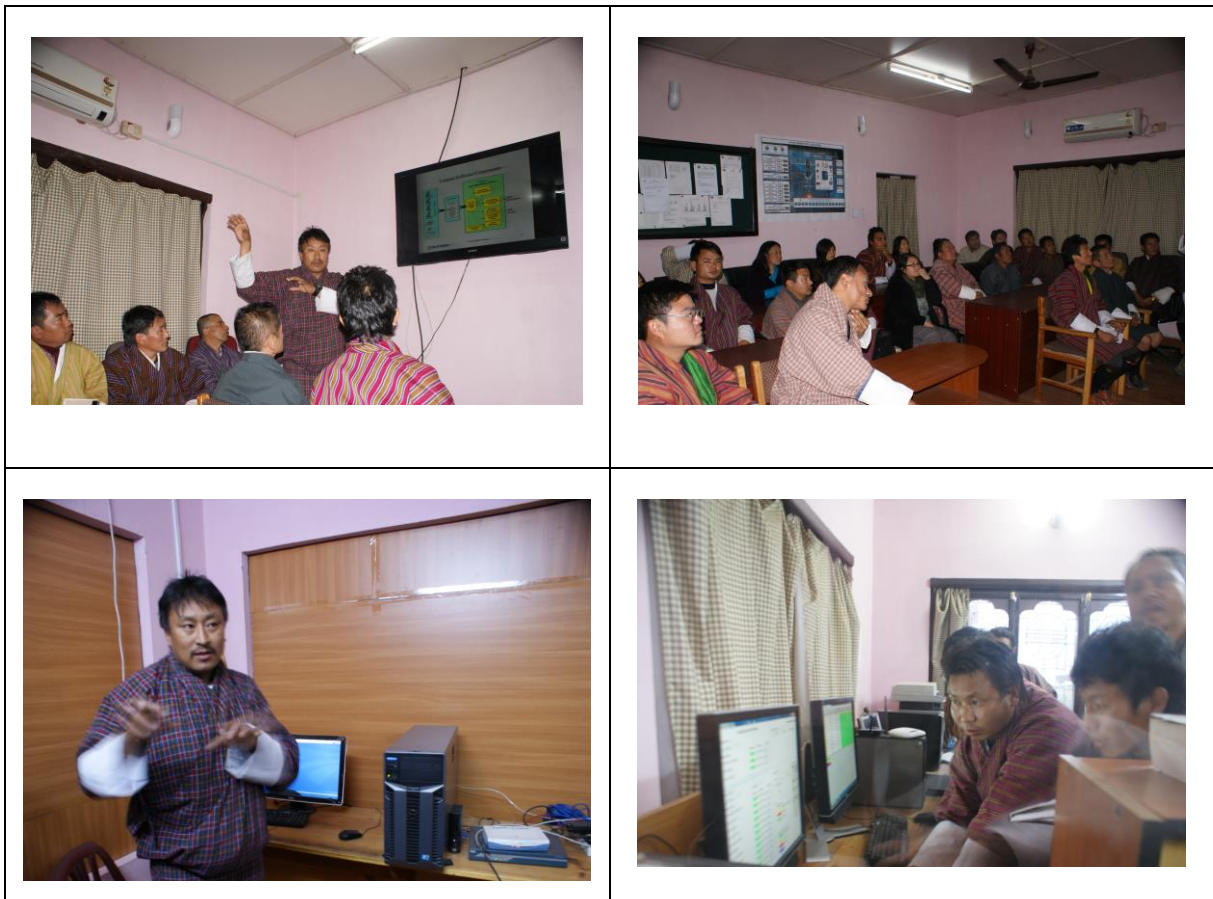
Figure 62: Hands on Training for Sediment Analysis during Refresher Course.



Figure 63: Field Visist to PHPA-I



Figure 64: PHPA-II visit



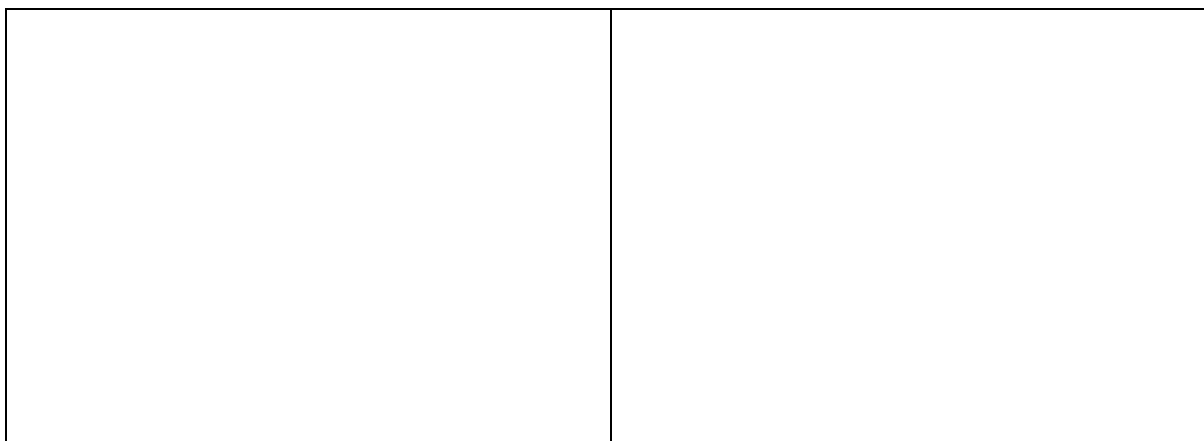


Figure 65: Wangdue GLOF EWS Visit

a. Hands on Training Workshop on HEC_HMS and IFAS

To strengthen the capacity of division for GLOF and Rainstorm Flood Forecasting and Early Warning System in the country, a hands on workshop was organised by the Hydrology Division, DHMS under the guidance of JICA Expert (Dr. Tomoyuki Wada, Hydrologist) to enhance the skills in forecasting of flood and analysis. A hand on training on HEC-HMS and IFAS was conducted at Wangdiphodrang from 23rd to 27th November 2015 for the selected participants of the department.



Figure 66: Participants with Dr. Tomoyuki Wada (Resources Person)

b. Hands on Training Workshop on HEC_RAS and IRIC

The second phase of hydrological modeling workshop focusing on HEC-RAS and IRIC from the preparation of inundation map was organized from 29 March 2016 to 2 April, 2016 in Thimphu. The workshop was conducted under the guidance of JICA Expert (Dr. Tomoyuki Wada, Hydrologist) as resources person.

The participants from the Department of Engineering Services (DoEs), MoWHS also attended the above workshop as from the 5th Flood Hazard Mapping (FHM) Working Group meeting held on 21 March 2016, requested their participation in workshop. It is expected that around 6-8 participants from the collaborating agencies will also attend the above workshop.

c. HBV IHMS Hydrological Forecasting Workshop scheduled from 23-27 May 2016

Based on the special request by the Hydrology Division, DHMS, Norwegian Water Resources and Energy Directorate (NVE) deputed Mr. Stein Beldring, and Mr. Bård Grønbech from NVE

conducted HBV IHMS Hydrological Forecasting Workshop in Bhutan. The 5 days' workshop was held from 23-27 May 2016 at National Weather and Flood Warning Centre (NFWFC), Thimphu. The workshop was attended the by the following officials.

- a. Bikash Pradhan, HD, DHMS
- b. Pema Wangdi, HD, DHMS
- c. Tandin Wangchuk, HD, DHMS
- d. Sangay Tenzin, FWS, HD, DHMS
- e. Pema Wangyel, PCRD, DHMS

During the workshop, NVE experts set up HBV model in Mangdechhu and Chamkharchhu basins and trained Staff in use of model and data processing.

5.2 Ex-country Trainings and Meetings

Through international and bilateral funding program, HD staff got opportunities to attend various trainings, meetings and conferences outside in various countries for the FY 2015-16.

Table 3 :Training/Study Tour attended by HD personnel for the FY 2015-16

Title	Participant Name	Date (Duration)	Venue/ Country	Funding
Technology on River Management, EWS, Weather Observation and local government	a. Mr. Karma Dupchu, Chief, HD, DHMS b. Mr. Pashupati Sharma, EE, Sediment Lab, HD, DHMS c. Mr. Bikash Pradhan, Engineer, OMS, DHMS	May 10 – 21, 2015	JICA Centre/ Japan	JICA
Capacity Development for Flood Risk Management with IFAS	a. Mr. Pema Wangdi, Assistant Engineer, OMD, HD, DHM	July 6 – Aug. 2, 2015	International Centre for Water and Hazard and Risk Management (ICHARM), the Public Works Research Institute (PWRI), Tsukuba, Japan	JICA
International Visitor Leadership Program (IVLP) on “ <i>Water Resources Management in the U.S</i> ”	a. Mr. Karma Dupchu, Chief, HD, DHMS	Sep. 21- Oct. 09, 2015	USA	United States Department of States, USA
Administration on river management, EWS, weather observation and local government	a. Mr. Kuenzang, AE, FWS, HD, DHMS, b. Mr. Tandin Wangchuk, Engineer, OMS, HD, DHMS	Jan.17 – 28, 2016	JICA Centre/Japan	JICA



Figure 67: Technology on River Management, EWS, Weather Observation in Japan under JICA



Figure 68: IFAS Training, Tsukuba, JICA, Japan



Figure 69: IVLP on Water Resources in USA

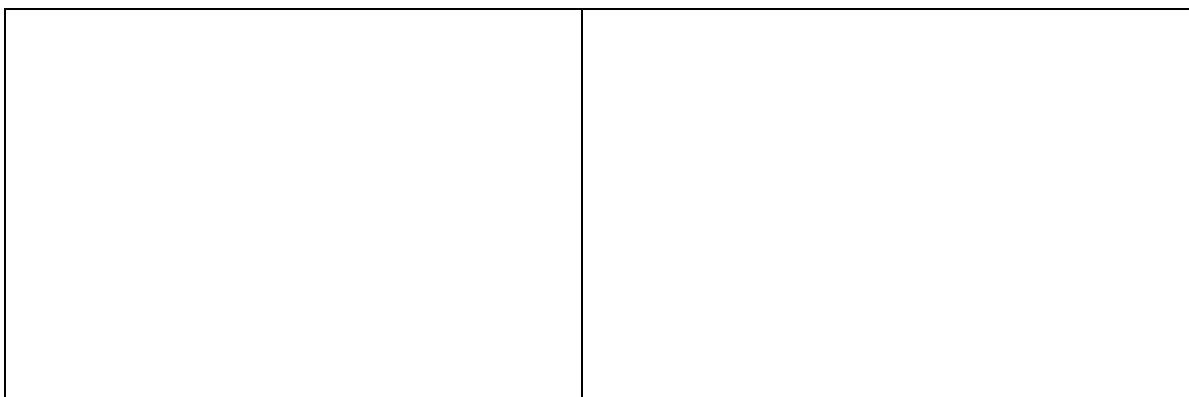


Figure 70: Administration on river management, EWS, weather observation and local government training in Japan under JICA

5.2.1 Meeting and Conference

As per the mandates of DHMS, the officials from the Hydrology Division during the FY 2015-16 attended bilateral, regional and international meetings and conferences related to weather, climates and water resources.

Table 4: Meeting/Conference /Workshop/Seminar attended by HD personnel for the FY 2015-16

Title	Participant Name	Date (Duration)	Venue/ Country	Funding
The First Steering Committee Meeting of South Asia Flash Flood Guidance System (SAsia FFG) Project Meeting	a. Mr. Karma Dupchu, Chief, HD, DHMS b. Mr. Pema Wangdi, AE, HD, DHMS	26-28 Apr. 2016	IMD, New Delhi/India	WMO
Forty-third Session of the IPCC (IPCC-43)	a. Mr. Karma Dupchu, Chief, HD, DHMS- As the Head of RGoB delegation	11 – 13 Apr. 2016	United Nations Environment Programme, United Nations Avenue, Nairobi, Kenya	IPCC
The 6 th meeting of the Joint Group of Experts (JGE) on Flood Management between the Royal Government of Bhutan (RGoB) and the Government of India (GoI)	a. Mr. Karma Tsering, Director, DHMS- Team Leader (RGoB) b. Karma Dupchu, Chief, HD, DHMS- Member Secretary to JGE (RGoB)	17-18 Feb. 2016.	Oberoi Hotel, New Delhi, India	RGoB/GoI
The 4 th Joint Technical Team (JTT) meeting on Flood Management between the Royal Government of Bhutan (RGoB) and the Government of India (GoI)	a. Karma Dupchu, Chief, HD, DHMS- Team Leader JTT (RGoB) b. Phuntsho Namgyal, Chief, PCRD, DHMS- Member Secretary JTT (RGoB)	6-7 Jan 2016	Siliguri, West Bengal, India	RGoB/GoI
Regional Flood Early Warning System Workshop held from, organized by World Bank in collaboration with RIMES,	a. Mr. Karma Tsering, Director, DHMS b. Karma Dupchu, Chief, HD, DHMS	23-27 Nov. 2015	Bangkok , Thailand	RIMES/World Bank
Workshop on HBV Modeling	a. Mr. Sangay Tenzin, AE, FWS, HD b. Mr. Pema Wangdi, AE, OMS, HD, DHMS c. Mr. Bikash Pradhan, Engineer, OMS, HD, DHMS d. Mr. Pema Wangyal, Engineer. PCRD, DHMS	16-20 Mar. 2015	Swedish Meteorological and Hydrological Institute (SMHI), Norrkoping, Sweden	NORAD



Figure 71: Forty-third Session of the IPCC (IPCC-43), Nairobi, Kenya



Figure 72: Workshop on HBV Modeling, Sweden



Figure 73: 31st JET meeting between RGOB and GOI, Paro, Bhutan



Figure 74: 6th Meeting of JGE between RGoB and GOI, New Delhi, India



Figure 75: 4th JTT Meeting between RGoB and GoI, Shiliguri, West Bengal, India



Figure 76: Workshop on HBV Modeling, Sweden

ON GOING PROJECTS

6 ON GOING PROJECTS

The following are ongoing projects directly implemented by the Hydrology Division, DHMS.

6.1 JICA Technical Cooperation Project (TCP)

The JICA Technical Cooperation Project (TCP) “Capacity Development of GLOF and Rainstorm Flood Forecasting and Early Warning System in the Kingdom of Bhutan (2013-2016) is executed by the Department of Hydromet Services and implemented by the Hydrology Division in collaboration with national agencies- Department of Disaster Management (DDM), Department of Geology and Mines (DGM), Department of Engineering Services (DoEs) and Department of Human Settlement (DHS), National Land Commission (NLC) and local governments- Dzongkhag Administration, Trongsa and Bumthang.

The project started in 2013 and all the activities are expected to be completed by August 2016. The following are activities undertaken for the FY 2015-16:

- Installation of the GLOF EWS along the Mangdechhu and Chmkhararchu
- Testing and commissioning of GLOF EWS System along the Mangdechhu and Chamkharchhu sub-basin
- Installation, testing and commissioning of Control Room hardware and software for Mangdechhu and Chamkharchhu sub-basins
- Installation, testing and commission for the National Weather and Flood Warning Centre (NWFWC), Thimphu
- Community Based Disaster Risks Management (CBDRM) activities in the Trongsa and Bumthang in collaboration with Department of Disaster Management (DDM) and local governments.
- Mock Drill of the GLOF EWS system in Bumthang and Trongsa
- Education and Awareness Workshop with local governments, Mangdechhu Hydropower Project Authority and local communities
- Project Annual Seminar
- Project Joint Coordination Committee (JCC) Meeting and signing of the Record of Discussion
- Project Terminal Evacuation by JICA

6.2 Mangdechhu Hydropower Project Authority (MHPA) Co-financing Project (2014-2016)

The project Institutional Strengthen and Setting up of GLOF Early Warning and Rainstorm Flood Forecasting in Mangdechhu and Chamkarchhu Basins is co-financed by the Mangdechhu Hydropower Project Authority (MHPA) Co-financing Project (2014-2016). The project is executed by the Department of Hydromet Services and implemented by the Hydrology Division in collaboration of the Department of Disaster Management (DDM), Ministry of Home and Cultural Affairs.

The following are main activities implemented for the FY 2015-16

- a. Construction of Regional Office (co-financed by MHPA Project)
- b. Setting up of National Weather and Flood Warning Centre (NWFWC), Thimphu
- c. Renovation of Kurjey Hydrological Station (cableway shed)
- d. Site development (Parking) of NWFWC building, Thimphu
- e. Inauguration of NWFWC
- f. Procurement of furniture, ICT and office equipment,
- g. In-country training on Operational Hydrology for Site technicians
- h. In-country workshops on Hydrological Modelling

6.3 Punatsangchhu Hydropower Project Authority (PHPA-I and II) Co-financed Project

The project of GLOF Early Warning System in the Punakha-Wangdi Valley is co-financed by Punatsangchhu Hydropower Project Authority (PHPA-I and II) is executed by the Department of Hydromet Services and implemented by the Hydrology Division and the following are main activities implemented for the FY 2015-16:

- a. Running and Maintenance of GLOF EWS Stations and facilities
- b. Procurement of spareparts for GLOF EWS Stations

6.4 Strengthening of the Energy Sector, Phase-IV: Component 3

The Country Agreement between the Royal Government of Bhutan and the Government of Kingdom of Norway was signed on May 14, 2012 regarding the assistance to the Project ***“Strengthening of the Energy Sector, Phase-IV”***. The project component Area 3. Support to the DHMS for Sustainable Data Provision to Accelerated Hydropower Development and Other Users is being implemented by the Department of Hydro-met Services, Ministry of Economic Affairs.

Area 3 has three main activities:

- a. Data Protocol and Quality.
- b. Hydrological Modelling and
- c. Glacier Mass Balance

Activity a) Data Protocol and Quality and b). Hydrological Modelling is being implemented by the Hydrology Division, DHMS. The following are undertaken for the FY 2015-2016:

- Full version licensed HBV software procured from SMHI, Sweden by NVE and handed over to DHMS.
- 4 Engineers from DHMS attended 5 days training workshop at HVB modeling at Swedish Meteorological and Hydrological Institute (SMHI), Sweden from March 16th to 20th 2015.
- HBV model successfully installed by NVE/DHMS at NFWWC from 6-12 September 2015.
- HBV Model operational is currently running daily for Mochhu sub-basin (Under testing)
- Based on special request of DHMS, NVE deputed Mr. Stein Beldring, and Mr. Bård Grønbech to set up and conducted HBV IHMS Hydrological Forecasting Workshop in Bhutan, 23-27 May 2016
- Model set up for pilot river basin in Mangdechhu and Chamkarchhu basins

Important Events for the FY 2015-16

7 IMPORTANT EVENTS

7.1 Inauguration of National Weather and Flood Warning Centre (NFWWC), Thimphu

The National Weather and Flood Warning Centre (NFWWC) building with ICT facilities of the Department of Hydro-met Services (DHMS), MoEA was inaugurated by the Honorable Tengye Lyonpo Norbu Wangchuk, Ministry of Economic Affairs on November 5, 2015 commemorating the 60th Birth Anniversary of His Majesty the Fourth Druk Gylepo Jigme Singye Wangchuck.



Figure 77 : Inaguration of NFWWC, Thimphu on 5 November, 2016

7.2 JICA President Visited NFWWC

Mr. Shinichi KITAOKA, President of JICA visited the National Weather and Flood Warning Centre (NFWWC) of the Department of Hydro-met Services, Ministry of Economic Affairs (MoEA) on December 24, 2015. The President was accompanied Ms. Yumiko Asakuma, JICA Chief Representative in Bhutan, Mr. Takumi UESHIMA, Chief Secretary and Mr. Katsuo MATSUMOTO, Deputy Director General, South Asia Department from JICA, HQ and Mr. Sho Takano, Representative of JICA Bhutan Office.



Figure 78: President of JICA visit to National Weather and Flood Warning Centre (NFWFC)

7.3 31st Joint Expert Team (JET) Meeting

The 31st Joint Experts Team (JET) meeting between Royal Government of Bhutan (RGoB) and Government of India (GOI) for the Flood Warning Program supported by GoI was held at Paro, Bhutan from 18-19 December, 2015. The JET oversees and review the Flood Warning program supported by GoI. The CWC Chief Engineer of Brahmaputra and Barak Basin Organization (B&BBO), Shillong leads the Indian side on the JET. The Bhutanese side is led by the Director of the Department of Hydro-Meteorological Services (DHMS), Ministry of Economic Affairs with members from other line agencies.



Figure 79: 31st JET meeting held at Paro, Bhutan 18-19 December, 2015.

7.4 6th Meeting of the Joint Group of Experts (JGE) on Flood Management

The 6th meeting of the Joint Group of Experts (JGE) on Flood Management between the Royal Government of Bhutan (RGoB) and the Government of India (GoI) was held at Oberoi Hotel, New Delhi, India from 17-18 February, 2016. The GoI delegation was led by Shri T.S Mehra, Commissioner (B&B Basins), Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD & GR), Government of India (Go) and the RGoB delegation was led by Mr. Karma Tsering, Director, Department of Hydro-met Services (DHMS), Ministry of Economic Affairs. The JGE meeting is held once in a year between RGoB and GoI “to discuss and assess the probable cause and effects of the recurring floods and erosion in the southern foothills of Bhutan and adjoining plains in India and recommend to both Governments, appropriate and mutually acceptable remedial measures”.



Figure 80: 6th JEG meeting in New Delhi, India

7.5 3rd Joint Coordination Committee (JCC) Meeting of the JICA TCP

The 3rd Joint Coordination Committee (JCC) meeting of the project “Capacity Development of GLOF and Rainstorm Flood Forecasting and Warning in the Kingdom of Bhutan (2013-2016)” was held on March 15, 2016 in Thimphu. The meeting was chaired by Mr. Karma Tshering, Director/Chairman of JCC, Department of Hydro-met Services, MoEA. The JICA project Terminal Evaluation Mission was led by Dr. Hitoshi Baba, Senior Advisor/Leader, JICA, Ms. Miki Inaoka, Dy. Assistant Director, Disaster Risk Reduction Team 1, Global Environment Department, JICA, HQ and Ms. Ai Ishitobi, Evaluation Analysis, General Manager, Tekizai Tekisyo, LLC. The Joint Terminal Evaluation Report for the project was presented to the JCC. The project was evaluated based on the five evaluation criteria proposed by OECD-DAC (“Relevance, Effectiveness, Efficiency, Impact, and Sustainability”). The project has delivered all three outputs. In terms of Relevance, Effectiveness, Impact and Sustainability the project was rated as “HIGH” and Efficiency as “Relatively High”. The meeting endorsed the Joint Terminal Evaluation Report jointly conducted by RGoB and JICA.



Figure 81: 3rd JCC meeting, Thimphu

7.6 Annual JICA Project Seminar

The “Annual Seminar 2016” for the Project *Capacity Development of GLOF and Rainstorm Flood Forecasting and Early Warning in the Kingdom of Bhutan* funded by JICA under TCP was held on 14th June, 2016 at Hotel Le Meridien, Thimphu, Bhutan. The Seminar was jointly organized by the Department of Hydro-met Services, MoEA in collaboration with JICA Expert Team to share the final project achievements and knowledge among relevant stakeholders in enhancing our understanding and approaches in managing climate change-induced flood/GLOF risks and vulnerabilities.

The opening session was graced by the Honorable Chief Guest Tengye Lyonpo Leki Dorji, Ministry of Economic Affairs and Mr. Koji YAMADA, Chief Representative of JICA Bhutan Office and senior officials from line agencies and international organizations (UNDP, World Bank etc).



Figure 82: JICA Annual Seminar, Le Meridien, Thimphu

Annexures

8 ANNEXURES

8.1 Annexure-I: List of Hydrological and GLOF EWS Station

Table 5: List of Principal Hydrological Station with AWLS

Sl. No.	Station No:	Station Name	River Basin	Dzongkhag	Latitude	Longitude	Altitude	Catchment area
1	11210045	Doyagang on Ammochhu	Amochhu	Chhukha	26:53:12	89:20:60	354.6	3650.0
2	12800045	Lungtenphug on Wangchhu	Wangchhu	Thimphu	27:26:48	89:39:40	2260.0	663.0
3	12490045	Damchhu on Wangchhu	Wangchhu	Chhukha	27:14:26	89:31:38	1990.0	2520.0
4	13700045	Yebesa on Mochhu + AWLS	Punatsangchhu	Punakha	27:37:59	89:49:03	1230.0	2320.0
5	13490045	Wangdirapids on Phochhu + Mochhu	Punatsangchhu	Wangdi	27:27:45	89:54:11	1190.0	6271.0
6	13320045	Turitar on Sankosh	Punatsangchhu	Tsirang	27:00:21	90:04:36	320.0	8593.0
7	13140045	Kerabari on Sankosh	Punatsangchhu	Dagana	26:46:06	89:55:41	150.0	10355.0
8	14580045	Bjizam on Mangdichhu +AWLS	Manas	Trongsa	27:31:28	90:27:17	1848.0	1390.0
9	14180045	Tingtibi on Mangdiechhu (Downstream)	Manas	Zhemgang	27:08:50	90:41:59	530.0	3320.0
10	15490045	Kurjey on Chamkharchhu +AWLS	Manas	Bumthang	27:35:13	90:44:13	2600.0	1350.0
11	16520045	Sumpa on Kurichhu +AWLS	Manas	Lhuntse	27:39:50	91:12:54	1170.0	
12	15600045	Bemethang on Chamkharchhu	Manas	Zhemgang	27:16:50	90:56:15	1300.0	
13	16200045	Kurizampa on Kurichhu	Manas	Mongar	27:16:26	91:11:37	519.0	8600.0
14	17670045	Muktirap on Kholong Chhu + AWLS	Manas	Trashigang	27:35:16	91:29:40	1640.0	905.0
15	17400045	Uzorong on Gongri	Manas	Tashigang	27:15:38	91:24:30	554.0	8560.0
16	17120045	Pangbang on Dangme chhu + AWLS	Manas	Zhemgang	26:50:30	90:50:30	136.0	20935.0

Table 6: List of Secondary Gauging Stations

Sl.No.	Station No:	Station Name	Basin	Dzongkhag	Latitude	Longitude	Altitude	Catchment area
1	12460045	Hachhu	Wang Chhu	Haa	27:22:16	89:17:08	2700.0	320.0
2	12550045	Parochhu (Bondey)	Wang Chhu	Paro	27:23:12	89:26:03	2220.0	1101.0
3	13810045	Samdingkha on Phochhu	Punatasangchhu	Punakha	27:38:28	89:51:50	1220.0	1284.0
4	14240045	Tingtibi on Dakpichhu	Manas	Zhemgang	26:50:30	90:57:30	580.0	122.0
5	16130045	Lingmethang on Maurichhu	Manas	Monger	27:15:42	91:11:20	565.0	284.0
6	16500045	Sumpa on Khomachhu	Manas	Lhuntse	22:39:34	91:12:46	1145.0	611.0
7	16350045	Autsho on Kurichhu	Manas	Lhuntse	27:25:59	91:10:38	814.0	8453.0
8	17410045	Sherichhu on Sherichhu	Manas	Mongar	27:15:15	91:24:36	542.0	437.0
9	12350073	Chimakoti Dam on Wangchhu	Wangchhu	Chhukha	27:06:34	89:32:02	1820.0	3550.0

Table 7: Automatic Water Level Station (AWLS) and Automatic Weather Station (AWS) for Flood/GLOF Early Warning and Siren

Sl. No.	Station No.	Station Name	Basin	Dzongkhag	Latitude	Longitude	Altitude
A		Flood Warning for Lingkhana Palace					
1		Begen on Thimchhu (Wangchu)	Wangchhu	Thimphu			
B		GLOF EWS for Punatasangchhu basin					
2	13950150	Luggy Tsho Automatic Water Level Station (AWLS)	Punatasangchhu	Gasa	28.07133	90.29600	4485
3	13930150	Thorthormi Automatic Water Level Station (AWLS)	Punatasangchhu	Gasa	28.09795	0.24867	4364
4	13900510	Automatic Water Level Station (AWLS)	Punatasangchhu	Gasa	28.10040	90.24152	4354
5	13870150	Bay Tsho Automatic Water Level Station (AWLS)	Punatasangchhu	Gasa	28.08537	90.21915	4339
6	13850150	Thanza, Lunana on Pochhu (AWLS +AWS)	Punatasangchhu	Gasa	28.08668	90.21322	4120
7	13840150	Tarina-Wachey on Phochhu AWLS+AWS	Punatasangchhu	Gasa	27.99514	89.99145	3570
8	13600150	Dangsa on Pochhu (AWLS + AWS)	Punatasangchhu	Punakha	27.69472	89.94881	1600
9	13790150	Taktsemakhang on Mochhu (AWLS +AWS)	Punatasangchhu	Gasa	28.01884	89.72760	3289
10	13750150	Tashithang on Mochhu (AWLS + Rainfall)	Punatasangchhu	Punakha	27.74564	89.73443	1584
11	13700150	Yebesa on Mochhu (AWLS+ Rainfall)	Punatasangchhu	Punakha	27.63338	89.81485	1240
12		18 Warning Sirens (3 in Lunana, 15 along the Punakha-Wangdi Valley)	Punatasangchhu	Punakha			
C		Rainstrom and GLOF EWS on Mangdechhu basin					
12	14700150	Jongthang on Mangdechhu (AWLS + AWS)	Manas	Trongsa	27.63300	90.48900	2136
13	14580150	Bjizam on Mangdechhu (AWLS+AWS)	Manas	Trongsa	27.52500	90.45600	1866
14		Three Warning Sirens (Bjizam, MHPA Dam and MHPA Power house)	Manas	Trongsa			
D		Rainstrom and GLOF EWS on Chamkharchhu basin					
15	15600150	Tsampa on Chamkharchhu (AWLS)	Manas	Bumthang	27.85600	90.66200	3674
16	15610150	Tsampa on Chamkharchhu (AWS)	Manas	Bumthang	27.86000	90.65900	3708
17	15550150	Kagthang on Chamkharchhu (AWLS+ AWS)	Manas	Bumthang	27.70300	90.73100	2895
18	15480150	Kurjey on Chamkharchhu (AWLS+AWS)	Manas	Bumthang	27.59300	90.72800	2619

Table 8: Flood Warning Station Operated by the Flood Warning Section (FWS) of HD under GoI

Sl. No.	Station No.	Station Name	River Basin	Dzongkhag	Latitude	Longitude	Altitude
A		Water Level Flood Warning Station					
2	11100149	Dorokha on Ammochu (AWLS + Met)	Ammochu	Thimphu	27.01472	89.22208	479.0
3	12350149	Chhukha on Wangchhu (AWLS+ Met)	Wangchhu	Chhukha	27.04989	89.58039	1374.0
4	13300149	Wangdi on Punatsangchhu (AWLS+ Met)	Punatsangchhu	Wangdi	27.47453	89.89447	1211.0
5	13210149	Dubani on Sankosh (AWLS+Met)	Punatsangchhu	Tsirang	27.00992	90.07139	324.0
6	23400149	Sershong on Aiechhu (AWLS+Met)	Punatsangchhu	Sarpang	26.93906	90.51836	301.0
7	14150149	Tingtibi on Mangdechhu (AWLS+Met)	Manas	Zhemgang	27.02714	90.78381	
8	16200149	Kurizampa on Kurichhu (AWLS+Met)	Manas	Mongar	27.27458	91.19486	500.0
9	16510045	Sumpa on Kurichhu (WL)	Manas	Lhuntse	27.66614	91.20594	1170.0
10	17400149	Chazam on Gongri (AWLS+Met)	Manas	Trashigang	27.33694	91.54633	685.0
11	24150149	Pangzam on Neyra Ama Ri (AWLS+AWS at Thrimshing)	Manas	Trashigang	27.10539	91.58903	1136.0
12	25200149	Zamtari on Jomori (AWLS +AWS)	Jomori	S/Jongkhar	27.02283	91.99917	665.0

Sl. No.	Station Name	River Basin	Dzongkhag	Latitude	Longitude	Altitude
B	Met Station					
13	Tendru Met Station (AWS)	Jaldakha	Samtse	27.06616	88.89277	959.0
14	Pungtha	Ammochu	Samtse	27.08326	89.269902	1222.0
15	Gomtu, Pagli, Samtse		Samtse	26.620505	89.18613	275.0
16	Sombekha	Amochhu	Haa	27.166388	89.104166	1841.0
17	Dungna	Ammochu	Chukha	27.034130	89.395436	1493.0
18	Thimphu-Jungzhina at Indian Embassy	Wangchu	Thimphu	27.501944	89.637777	2291.0
19	Dagapela	Punatsangchhu	Dagana	26.934166	89.949722	1277.0
20	Tsirang	Punatsangchhu	Tsirang	27.001944	90.124444	1599.0
21	Kamechhu	Punatsangchhu	Wangdue	27.27250	90.031666	662.0
22	Samdrup Jongkhar	Dungsamri sub-basin	S/Jongkhar	26.798502	91.504338	170.0
23	Deothang	Dungsam-ri Sub-basin	S/Jongkhar	26.8600	91.46333	861.0
24	Tokarong (Narphung)	Dungsam-ri	S/Jongkhar	26.9725	91.533055	1663.0

8.2 Annexure-II: JICA TCP Project Summary

Hydrology Division, DHMS Staff Profile



Karma Dupchu
Chief of the Division
Email: kdupchu@moea.gov.bt
Contact: 323632

Operation and Maintenance Section	Flood Warning Section	Sediment Lab
 <p>Pema Wangdi Designation: AE Email: pemaw@moea.gov.bt Contact: 322794</p>	 <p>Somik Mukherjee Designation: TMO email: TMO@gmail.com Contact: 321924</p>	 <p>Pashupati Sharma Designation: Civil Engineer email: ppsharma547@gmail.com Contact: 17548945</p>
 <p>Bikash Pradhan Designation: Hydrology Officer email: bikashpradhan@moea.gov.bt Contact: 322794</p>	 <p>Kuenzang Designation: A.E-II email: deebum73@yahoo.co.in Contact: 321924</p>	 <p>Renuka Thapa Designation: Technician email: Contact: 17548945</p>
 <p>Tandin Wangchuk Designation: Engineer Email: tandinw35@gmail.com Contact: 322794</p>	 <p>Sangay Tenzin Assistnat Engineer (Civil) email: sangaytenzin@moea.gov.bt Contact: 17711753</p>	 <p>Sonam Zangmo Designation: Technician email: Contact: 17548945</p>
 <p>Ajay Pradhan Designation: Data Assistant email: ajayp122@yahoo.com Contact: 322794</p>	 <p>Kush Rai Designation: Hydro-Met Officer/Engineer(Electrical) email: krai@moea.gov.bt Contact: 17257378</p>	 <p>Jigme Wangdi Designation: Technician</p>
 <p>Manila Designation: Technician Email:</p>	 <p>Phurpa Wangdi Designation: Sr. Hydro-Met Technician email: phubwangdi08@gmail.com</p>	 <p>Ngawang Namgyel Designation: Technician email: bikashpradhan@moea.gov.bt</p>

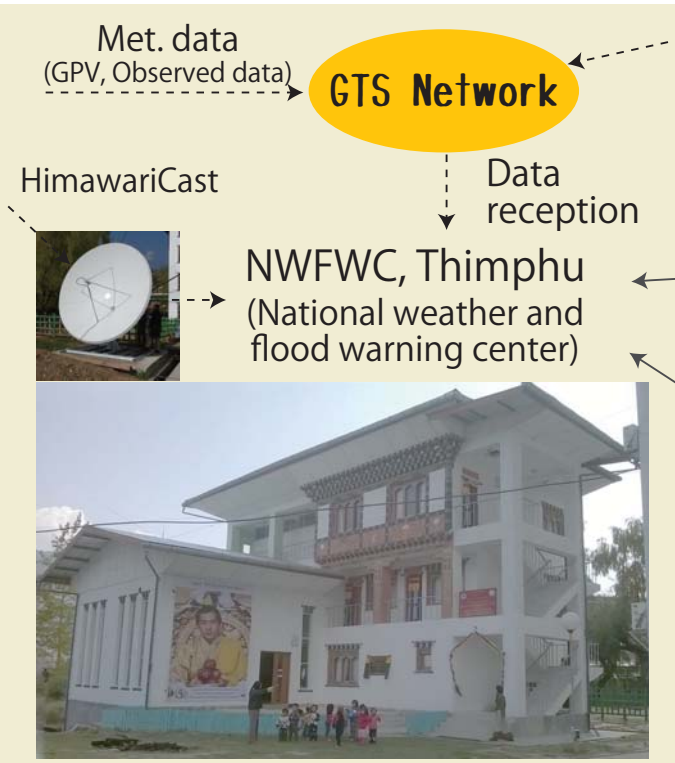
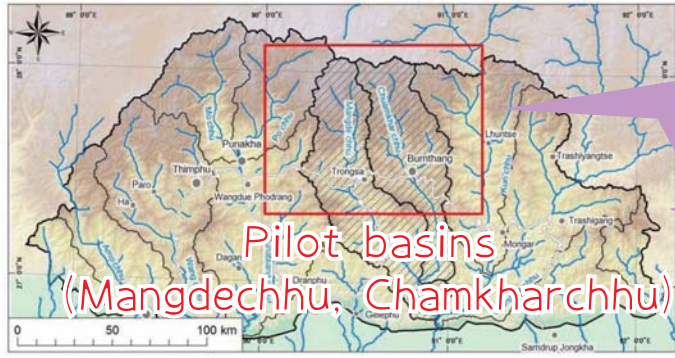
 <p>Kanjur Tenzin Designation: Technician email: bikashpradhan@moea.gov.bt Contact: 322794</p>	 <p>Sujata Designation: Officer/Engineer(Electrical) email: krai@moea.gov.bt Contact: 17257378</p>	 <p>Thinley Gyem Designation: Adm. Assistant email: thinleyg12@gmail.com Contact: 322794</p>
 <p>UgyenTshewang Designation: Technician email: bikashpradhan@moea.gov.bt Contact: 322794</p>	 <p>sujala Designation: Officer/Engineer(Electrical) email: krai@moea.gov.bt Contact: 17257378</p>	 <p>Ugyen Dolma Designation: Officer/Engineer(Electrical) email: krai@moea.gov.bt Contact: 17257378</p>
 <p>PassangGyem Designation: Technician email: bikashpradhan@moea.gov.bt Contact: 322794</p>	 <p>TsheringDorji Designation: Officer/Engineer(Electrical) email: krai@moea.gov.bt Contact: 17257378</p>	

The Project for Capacity Development of GLOF and Rainstorm Flood Forecasting and Early Warning

Sep. 2013 - Sep. 2016
(9 JICA Experts)

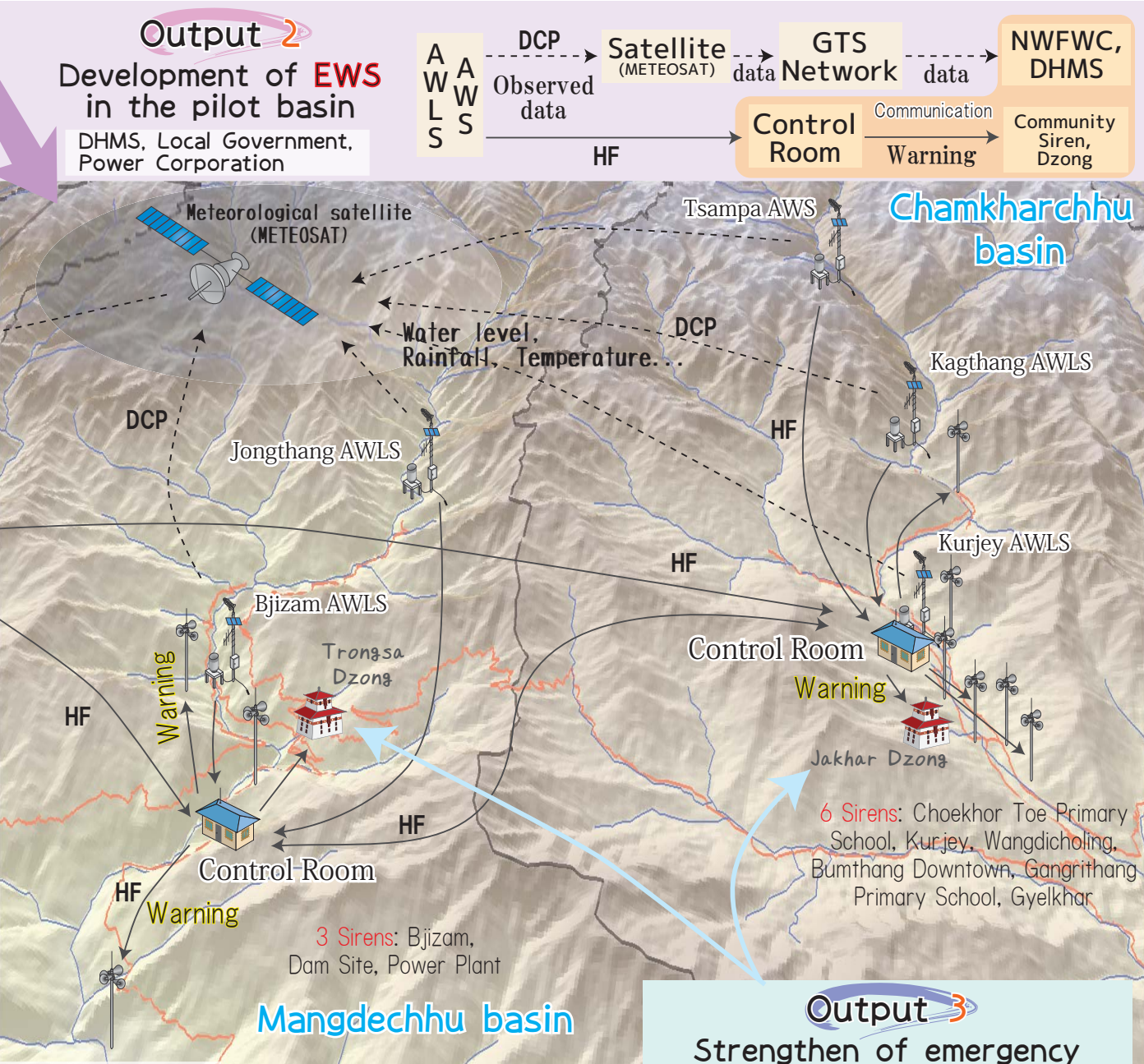


Project Purpose
Capacity of DHMS and relevant stakeholders on emergency response against GLOF and rainstorm flood is enhanced

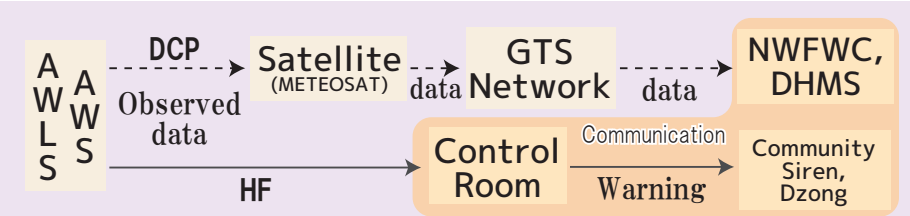


Output 1
Capacity enhancement on disaster response at central level

Weather Forecasting and Warning (GTS etc.) :DHMS
Flood Risk Assessment :DHMS, DoES, DGM
Mainstreaming Disaster Risk Reduction into Development :DDM, DHMS, DHS, NLCS



Output 2
Development of EWS in the pilot basin
DHMS, Local Government, Power Corporation



Mangdechhu basin

3 Sirens: Bjizam, Dam Site, Power Plant

6 Sirens: Choekhor Toe Primary School, Kurjey, Wangdicholing, Bumthang Downtown, Gangrihang Primary School, Gyelkhar

Inter-ministerial Working Groups

Output 3
Strengthen of emergency response in the basin

Community Based Disaster Risk Management: Local Government, Community, DDM, DHMS

International Cooperation Projects: Bhutan & Japan

SATREPS

The Project for Capacity Development of GLOF and
Rainstorm Flood Forecasting and Early Warning

And...?

2009.4

Study on GLOFs (Glacial Lake Outburst Floods) in the Bhutan

Protecting the Land of Happiness from Glacial Lake Outbursts:
A Disaster Resulting from Climate Change

2011.3

2013.9

JICA Project: Capacity Development of GLOF and Rainstorm Flood Forecasting and Early Warning

Flood Early Warning System (EWS) & Global Telecommunication System /
Message Switching System (GTS/MSS, Equipment for Weather Forecasting)
(2013.10 -) :Field Survey & Preparation of Specification Documents

Flood Hazard Map (FHM): FHM Working Group Started
(2014.1 -) FHM Training & Field Survey Started

Mainstreaming Disaster Risk Reduction (MDRR): MDRR Working Group Started
(2014.2 -)

EWS & GTS/MSS: Bidding, Procurement and Shipping of EWS Equipment
(2014.8)

Activities in Communities: Preparation of Evacuation Plan
(2015.3 -)

EWS & GTS/MSS: Installation
(2015.4 -)

EWS & GTS/MSS: National Weather and Flood Warning Center (NWFWC)
(2015.11) Opening Ceremony & Operation Start

Satellite Image Receiver (HimawariCast): Installation
(2016.2)

Activities in Communities: Evacuation Drill
(2016.3)

EWS & GTS/MSS: Trainings on Weather Forecasting
(2016.6) Preparation of Standard Operation Procedure (SOP) for EWS

2016.9

2017-?

Project for Integrated Disaster Management will ...?

Installation of Flood Early Warning System (EWS) for mangdechhu & Chamkharchhu Basin

Field survey & Preparation
of Specification Documents
(2013.10 -)



Bidding, Procurement of
Equipment & Shipping
(2014.8 -)



Installation
(2015.4 -)



Flow of EWS Installation



Installation Complete!
NFWFC Opening Ceremony
& Operation Start
(2015.11)

National Weather and Flood Warning Center (NWFWC)

Operation Start: 2015.11



Back yard:
Satellite image receiver
(HimawariCast)

2nd floor:
Weather forecasting room



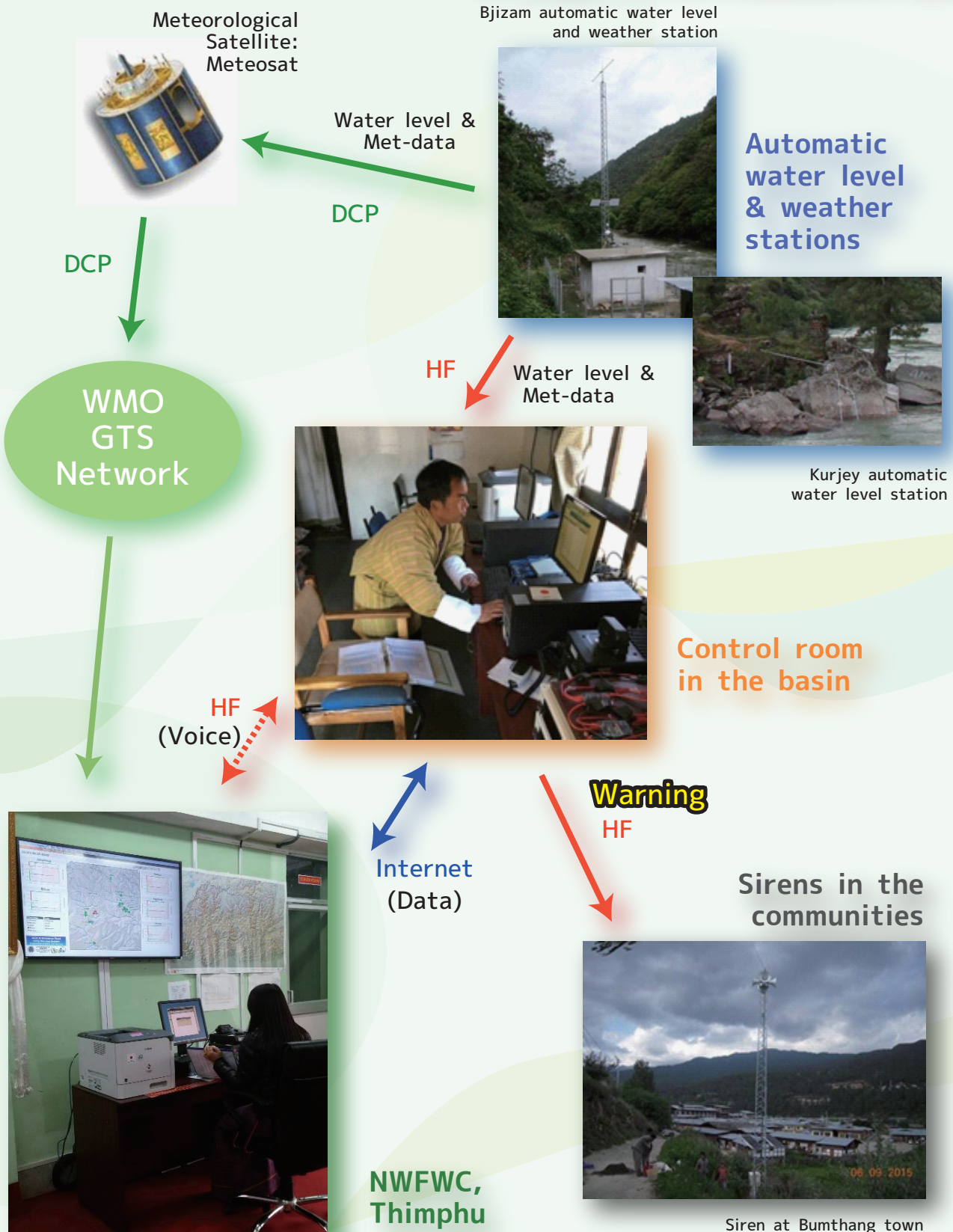
Ground floor: kindergarten



1st floor: flood monitoring &
warning room (left),
emergency meeting room (right)

Outline of Flood Early Warning System (EWS)

Operation Start: 2015.11
in Mangdechhu and Chamkharchhu Basin



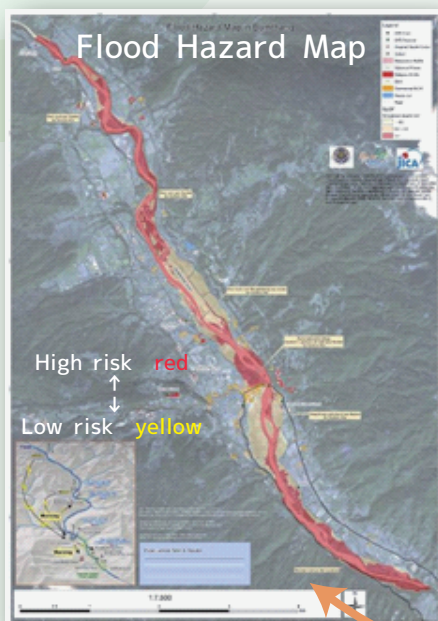
Improvement of Weather Forecast by Utilizing the Numerical Weather Prediction (GPV)

GTS/MSS (Global Telecommunication System / Message Switching System) and satellite image receiver (HimawariCast)



Operation Start: 2016.2

Flood Hazard Map Preparation



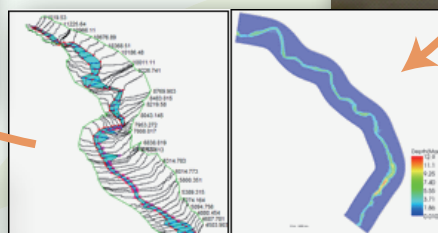
Modeling & Analysis



Field
Survey
OJT
(2014.2 -)



Runoff/flood
analysis
training
(2014.5 -)



Mainstreaming Disaster Risk Reduction Working Group (MDRR W/G)

MDRR W/G Since 2016.2



Main themes of the MDRR W/G are considering risk assessment on development planning, land use improvement, recommendation for organizations and regulations and SOP (Standard Operation Procedure) on emergency situations.

Evacuation planning and drills in Flood Prone Communities

Evacuation Planning (2015.3 -)

Evacuation Drill (2016.3)

Activities were conducted in the flood prone communities and schools in the pilot basin

