STANDARD OPERATING PROCEDURE (SOP)
FOR
GLOF EARLY WARNING SYSTEM
PUNAKHA-WANGDUE VALLEY

(Version 3.00, March 2021)

NATIONAL CENTER FOR HYDROLOGY AND METEOROLOGY
ROYAL GOVERNMENT OF BHUTAN
THIMPHU: BHUTAN
MARCH 2021

Disclaimer

The GLOF EWS installed on Phochu and expanded on Mochhu sub-basins under the Punatsangchhu basin is the first system of its kind in the region and hence experiences and problems encountered on early warning systems are limited. It is therefore imperative that the Standard Operation Procedure (SOP), the GLOF Operation Flow Chart, Alarm/Alert and other assigned parameters are continuously assessed, evaluated and the changes/modifications are incorporated from time to time.

Further, the remoteness of the sites in Lunana and Laya regions, harsh weather conditions, inaccessibility during winter months and limited technical knowledge of staff posted at Thanza Site Office can pose a significant challenge to attend to emergency inspection and maintenance in a timely manner.

The readers are reminded that this SOP is valid only for the present GLOF-EWS installed along the Punakha-Wangdue valley and may not be transferred to other similar systems verbatim.

Foreword

The National Disaster Management Authority (NDMA) of Bhutan in pursuant to the section 108 of the Disaster Management Act of Bhutan (2013), designated NCHM as the Hydro-met EWS provider within the country. Timely dissemination of early warning can help society better prepare for disasters created by GLOF/floods and could help in reducing the loss of lives, livelihood and productive assets. Therefore, an automated GLOF Early Warning System was installed along the Punakha-Wangdue valley by the National Center for Hydrology and Meteorology (NCHM) to provide real time early warning services under the National Adaptation Program Action (NAPA-I) in 2008-2013.

This revised Standard Operating Procedure (SOP) for the GLOF EWS provides a standard working tool for the operators, managers and other stakeholders engaged during the time of GLOF events. The primary users of this SOP will be the line agencies, who collect or review and manage information pertaining to GLOF EWS.

I am very happy that this revised SOP (Version 3, March 2021) for the GLOF EWS installed in the Punakha-Wangdue valley is being updated and published by the Center. The SOP will be useful in providing guidance for an effective operation and maintenance of GLOF EWS installed, as well as timely dissemination of warning information to the relevant line agencies and communities. I commend the NCHM for bringing out this SOP as it is vital for the smooth operation of the EWS and is critical to avoid any miscommunication.

(Karma Dupchu)
Director
National Center for Hydrology and Meteorology

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
CSD	Cryosphere Services Division
DDM	Department of Disaster Management
DGM	Department of Geology and Mines
DGPC	Druk Green Power Corporation
DIT	Department of Information Technology
DoLG	Department of Local Governance
EWS	Early Warning System
FMCR	Flood Monitoring and Command Room
FWS	Flood Warning Section
GEF	Global Environment Facility
GLOF	Glacier Lake Outburst Flood
GLOF EWS	GLOF Early Warning System
GMOG	GLOF EWS Management and Overseeing Group
GoI	Government of India
HOID	Hydro-met Operation and Infrastructure Division
HWRSD	Hydrology and Water Resources Services Division
HQ	Head Quarter
ICT	Information Communication Technology
LDCF	Least Developed Country Funding
WCSD	Weather and Climate Services Division
MoHCA	Ministry of Home and Cultural Affairs
NAPA-I	National Adaptation Program of Action -I
NDMA	National Disaster Management Authority
NEC	National Environment Commission
NEOC	National Emergency Operation Center
NCHM	National Center for Hydrology and Meteorology
NWFWC	National Weather and Flood Warning Centre
OEM	Original Equipment Manufacturer
PHPA-I	Punatsangchhu Hydropower Project Authority- I
PHPA-II	Punatsangchhu Hydropower Project Authority- II
POI	Point of Interest
R&D	Research and Development
RCSC	Royal Civil Service Commission
RGoB	Royal Government of Bhutan
SOP	Standard Operating Procedure
UNDP	United Nation Development Programmed
USA	United State of America
WMO	World Meteorological Organization

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GLOF EWS Standard Operating Procedure

1 Introduction

1.1 Background

To cope with flood disasters, such as flash flood, Glacier Lake Outburst Flood (GLOF) and riverine flood, efforts are made traditionally to protect the people by keeping the flood away from people by means of structural measures. Through the experience of several decades, it is recognized that the measure to keep people away from the flood should also be considered. At present the latter measure becomes more important to mitigate flood damages under the conditions of limited financial resources.

In order to realize the flood damage reduction by keeping the people away from the flood, it is essential to disseminate timely, adequate and reliable information to the people regarding the flood with enough lead-time for actions against such approaching threats. The flood monitoring and warning is expected to play an important role in this regard.

On October 7, 1994, a Glacial Lake Outburst Flood (GLOF) occurred on Lake Luggy in Lunana, sending a flood wave down the Phochhu and Punatsangchhu that claimed 22 human lives and caused massive property damages and loss of livestock and agriculture land. Although major flooding had occurred in the past, the 1994 GLOF was the catalyst for the need to establish an early warning system (EWS) giving downstream inhabitants time to evacuate and emergency response to prepare for the situation.

To provide services on flood monitoring and warnings to the vulnerable communities and infrastructure downstream in the Punakha-Wangdue Valley, the National Center for Hydrology and Meteorology (NCHM) installed automatic GLOF Early Warning System (GLOF EWS) in the Punakha-Wangdue Valley through the financial support from LDCF through GEF/UNDP under the project **"Reducing Climate Change-Induced Risks and Vulnerabilities from Glacier Lake Outburst Flood in the Punakha-Wangdue and Chamkhar Valleys"** with co-financing from the Punatsangchhu Hydropower Project Authority (PHPA-I and PHPA-II) and Austria Development Cooperation (ADC).

GLOF EWS system was established on Phochhu sub-basin under the Punatsangchhu Basin in 2011. Later in 2013 the warning system was expanded to Mochhu sub-basin covering whole Punatsangchhu basin.

1.2 River System

The Punatsangchu River basin is one of the largest basins in Bhutan, covering an approximate area of 13,263 sq. km encompassing the two sub-basins of Phochhu and Mochhu River (**Figure 1**). The basin area extends to following Dzongkhags: Gasa, Punakha, Wangdue, Tsirang and Dangna entering into Indian Plain of West Bengal before joining Brahamaputra River. Its course in Bhutan has a length of about 250 km (Pradhan, 2008). The catchment area upstream of the principal gauging station at Wangdue rapids is about 6271.00 km^2**.** The principal tributaries of the Punatsangchhu River are Phochhu and Mochhu, which join at Punakha to form the main Punatsangchhu river.

Flood Disaster: There were historical GLOFs incidents in the basin. The last extreme GLOF event in the Phochhu sub-basin occurred on 7th October 1994 that resulted in loss of lives, and destroyed livelihood and properties downstream.

1.3 Profile of GLOF Early Warning System

The GLOF EWS installed along the Punakha-Wangdue valley consists of 10 Remote Automatic Water Level Stations (AWLS) and Automatic Weather Stations (AWS) and 18 Sirens to warn vulnerable communities along the river valley downstream. Iridium satellite communication is used to transmit data from remote stations to control room for monitoring and detection of GLOF in real time, and linked to a network of sirens that are activated in the event of eminent GLOF threats. Control Room operators monitor the latest data from the 28 stations using customized software by M/s Sutron Corporation, USA.

The schematic diagram showing location of monitoring stations and sirens of GLOF EWS installed along the Punakha-Wangdue Valley is shown in **Figure 1, Table 1 and Table 2.**

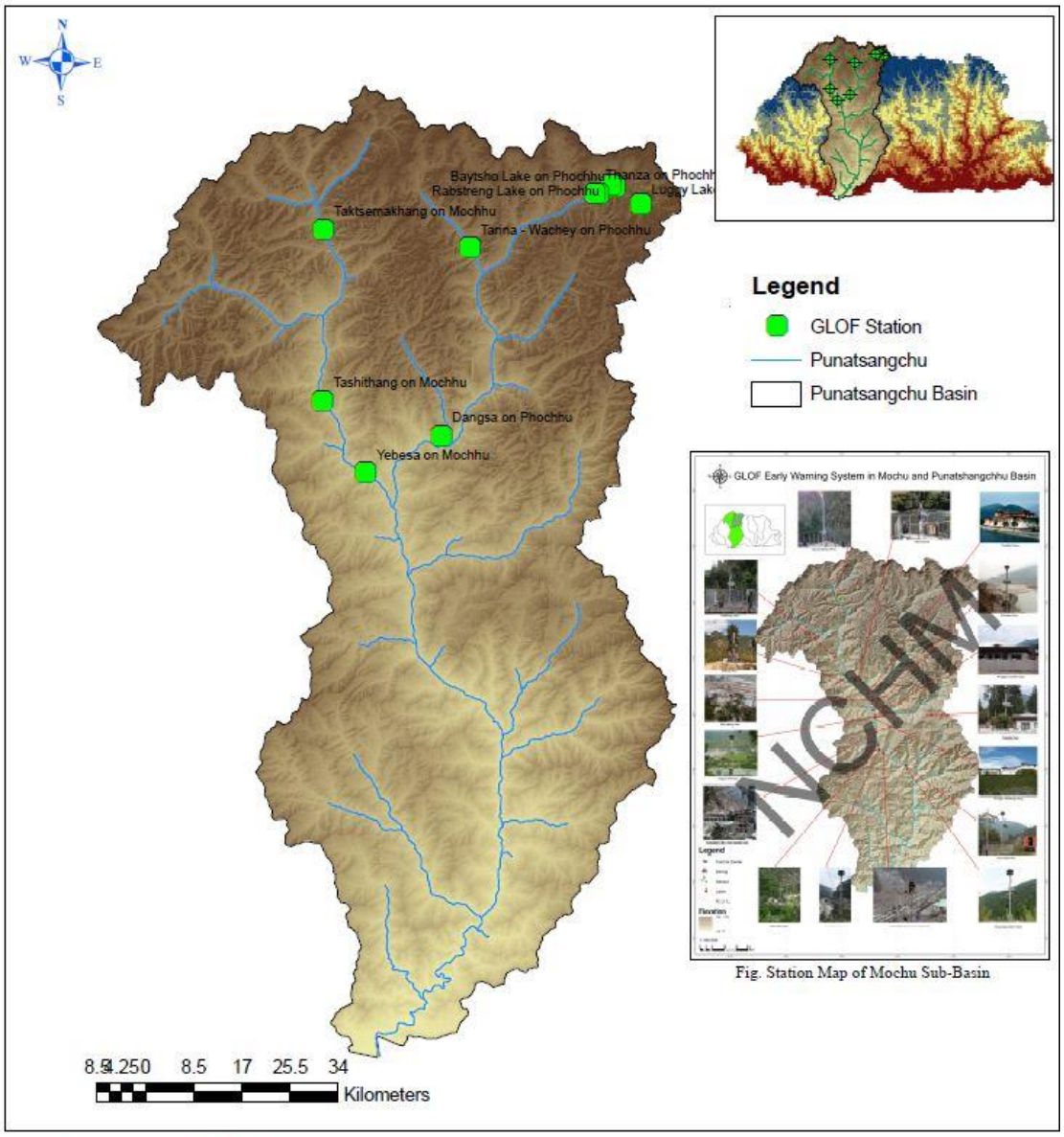

Fig. Station Map of Mochu Sub-Basin

Punatsangchu Basin

Yebesa on Mochhu
Luggy Lake on Phochhu
Thorthomi Lake on Phochhu
Rabstreng Lake on Phochhu
Baytsho Lake on Phochhu
Thanza on Phochhu
Dangsa on Phochhu
Tarina - Wachey on Phochhu
Taktsemakhang on Mochhu
Tashithang on Mochhu

Note: There are also several siren stations along the river in the basin

Figure 1: Punatsangchhu Basins Map showing location of GLOF EWS sites

Table 1:List of AWS/AWLS station and location of sirens in Punatsangchu GLOF EWS

Sl. No	**Location name**
A.	**Remote Monitoring Stations (Sensors) on Phochhu Sub-basin**
1	Luggy Tsho AWLS
2	Thorthormi AWLS
3	Rapstreng AWLS
4	Bay Tsho AWLS
5	Thanza AWLS + AWS
6	Tarina-Wachey AWLS + AWS
7	Dangsa AWLS + AWS. Located above Tame Damchu village.
B.	**Remote Monitoring Stations (Sensors) on Mochhu Sub-basin**
8	Taktsemakhang (Below Laya) AWLS + AWS
9	Tashithang AWLS + Rain-Gauge
10	Yebesa AWLS + Rain-Gauge
C. **Sirens in Punakha-Wangdue Valley- Lower Region**	
Siren No.	**Location**
S-1	Wolathang Community School
S-2	Samdingkha Area (Near Jibjokha Village)
S-3	Khowajara Area (on hill above feeder road to Samdingkha near chorten)
S-4	Punakha Dzong Area (Above long Suspension bridge and cremation ground)
S-5	Kuruthang Area Punakha (above Khuruthang town)
S-6	Samthang Area above Samthang VIT.
S-7	GLOF EWS Control Room, Flood Warning Office, Wangdue
S-8	Above Dragon Nest Resort (Near Community school)
S-9	Punatsangchhu I – Project Dam Site
S-10	Basochhu at Mazafall (above Wangdue – Tsirang High-way)
S-11	Rurichhu Basochhu Power House(above high way overlooking Basachu-II Powerhouse)
S-12	Punatsangchhu I – Power House (near the bridge on right bank of Punatshangchhu)
S-13	Kamichhu Suspension Bridge (in front of Gup's office)
S-14	Punatsangchhu II – Power House (50 meter above high way)
Sirens in Upper Region in Lunana	
S-15	Thanza & Tenchey Villages
S-16	Tshojo Village
S-17	Lhedhi Village
Siren along Mochhu	
S-18	Wakuna under Kabjisa Gewog, Punakha
Note: ***S*** *– Siren Station;* ***AWS*** *– Automatic Weather Station;* ***AWLS*** *– Automatic Water Level Station.*	

For the operation of the system 18 warning sirens are divided into three groups as given below.

Table 2: Grouping of sirens based on the region

Upper Region LUNANA	Lower Region PHOCHU	Lower Region MOCHU
S-15		
S-16		
S-17		
	S-1	
	S-2	
	S-3	
	S-4	S-4
	S-5	S-5
	S-6	S-6
	S-7	S-7
	S-8	S-8
	S-9	S-9
	S-10	S-10
	S-11	S-11
	S-12	S-12
	S-13	S-13
	S-14	S-14
		S-18

1.4 The Standard Operation Manual

In order to organize, operate and maintain the system properly, the SOP Manual of GLOF EWS was formulated and revised. The SOP is guided by the basic principles and concepts of GLOF warning procedures and consists of logical steps to be followed by all responsible staff for monitoring, detection and issuance of warning.

2 Objective of GLOF Monitoring and Warning

GLOF EWS is a service extended to the public by NCHM as a part of civil contingencies to help prepare, respond and recover from GLOF events.

The main objective is to provide adequate, reliable and timely GLOF warnings to safeguard life and property downstream.

2.1 Activities for GLOF EWS

Activities required for the GLOF EWS are generally divided into three parts as follows:

a) Monitoring to detect flood-causing phenomena such as heavy rainfall, rise in water level in the upstream tributaries and lakes.

b) Dissemination of GLOF information and warning to the people in the flood-prone areas with enough lead time to take preventive/protective actions against impending flood.

c) Inform and update the GLOF status to the government focal agencies in the emergency command structure such as Department of Disaster Management (DDM), MoHCA, concerned Dzongkhags and relevant Agencies in the event of GLOF.

2.2 Lead Time for Flood Warning

Time duration from the detection of flood-causing phenomenon to the occurrence of flood at the point of interest (POI) is called gross lead time, while the time available for the people to take preventive/protective actions is called net lead time or simply lead time. The lead time is worked out from the gross lead time deducting the time spent for the preparation of flood forecasting and warning activities. In other words, the lead time is the time period from the dissemination of flood warning to the occurrence of the flood.

In order to secure longer lead time, two measures can be implemented, namely, (a) to extend gross lead time in detecting remote flood-causing phenomenon and (b) to shorten time required for forecast preparation and warning.

In order to ensure that information is transmitted without unnecessary delays during such time and events following measures are adopted for the GLOF EWS installed in Punatsangchhu:

a) Real-time monitoring of GLOF by automatic sensors and communication using satellite telemetry networks and

b) Immediate dissemination of warning by activation of sirens and other land based communication facilities.

In order to increase the lead time for the Punatsangchhu GLOF EWS, flood/GLOF detection sensors (water level sensors) have been installed in the Lakes in Lunanaas well as downstream at ***Thanza (***common outlet confluence of all the four lakes of Lunana) to confirm occurrence of lake breach. Additional automatic water level sensors and weather stations have been installed further downstream at ***Wachey*** (Tarina sub-basin) and ***Dangsa***, above Tame Damchhu Village under the Punakha Dzongkhag to detect GLOF from Tarina area and flood from other tributaries of Phochhu river.

For the Phochhu sub-basin, Lunana sensors are located about 100 km from Punakha and Dangsa sensor location is about 22 km upstream from Punakha Dzong. The 1994 flood took approximately 7 hours to reach Punakha as per Austro-Bhutanese back-calculation of the event (Brauner et. al., 2003) and also from eye witness report. Therefore, once the flood is detected by the sensors at Lunana, the approximate time available for alerting and evacuation of people as result of the EWS along the Punakha-Wangdue valley will be around 5-7 hours.

Similarly, Taktsemakhang (below Laya) Automatic Water Level Monitoring Station (AWLS) on Mochhu sub-basin is located about 70.00 km upstream of Punakha Dzong. Once the flood/GLOF is detected by Taktsemakhang sensor the approximate time available for alerting and initiating emergencies response will be approximately 3-4 hours till Punakha Dzong.

However, to accurately determine the flood lead time is often a tricky issue as flow of flood water will depend on number of factors and scenarios such as the volume of flood water released from the lakes (either full or partial breach of glacier lakes), formation of artificial dams along the river course, amount of debris etc.

2.3 Remote Stations and Warning Water Levels

There are 7 Automatic Water Level Station (AWLS) installed along the Phochhu sub-basin and three (3) AWLS on Mochhu Sub-basin. All the water level monitoring sensors are connected by telemetry network to the Control Room located at the Flood Warning Office, Wangdue. Out of 10 AWLS, 4 stations have additional Automatic Weather Station (AWS) installed (i.e. Thanza, Wachey, Dangsa on Phochhu and Taktsemakhang on Mochhu). For

the respective water level stations, Alert and Alarm levels are specified to indicate magnitude or seriousness of the impending flood.

Table 3: ALERT and ALARM Criteria

Monitoring Station	Alert Stage	Alarm Stage	Alarm Rate of Change
A. Phochhu Sub-basin			
Luggy (channel)	Above 7.8 meter	Above 10.0 meter	Above 1.0 meter in 15 min interval
Thorthormi (Lake)	Above 7.5 meter	Below 5.0 meter	Above 1.0 meter in 15 min interval
Rapstreng (lake)	Above 7.4 meter	Below 5.0 meter	Above 1.0 meter in 15 min interval
Bay Tsho (lake)	Above 7.4 meter	Below 5.0 meter	Above 1.0 meter in 15 min interval
Thanza (channel)	Above 7.7 meter	Above 8.7 meter	Above 1.0 meter in 15 min interval
Tarina-Wachey (Channel)	Above 7.5 meter	Above 8.5 meter	Above 1.0 meter in 15 min interval
Dangsa (channel)	Above 6.5 meter	Above 7.5 meter	Above 1.0 meter in 15 min interval
B. Mochhu Sub-basin			
Taktsemkhang, below Laya	Above 5.5 meter	Above 8.5 meter	Above 1.0 meter in 15 min interval
Tashithang	Above 8.5 meter	Above 10.5 meter	Above 1.0 meter in 15 min interval
Yebesa	Above 5.0 meter	Above 7.0 meter	Above 1.0 meter in 15 min interval

Note: Above thresholds are subject to change depending on physical changes in monitoring site

ALERT: When water level reaches alert level there will be an alert message at Control Room to alert or put staff at Control room in the state of readiness and will monitor the flood more vigorously. The water level will be updated and turns yellow on control room display. The icon on the GLOF website map will also turn yellow. No sirens will be activated

ALARM: When water level from any of the four lakes on Phochhu headwater reaches alarm level, the three (3) sirens (No. S-15, S-16 and S-17) in the upper Lunana region will be activated automatically after 15 minutes, the other sirens in the lower region of the Punakha-Wangdue Valley (No.S-1 to S-14) will remain deactivated. Only when water level at Thanza, Wachey and Dangsa remote stations reaches at Alarm level, the sirens in the lower region can be activated.

When water level of any of the three stations on Mochhu reaches Alarm level, only sirens (S-4 to 14 and S-18) will be activated. The Alarm water level will get updated in the control room display with icon will turning red and there will be audible alarm sound with pop-up message in the monitor. Simultaneously, icon in the GLOF web site will also turn red.

3 Management and Operation of GLOF Monitoring and Warning

The GLOF monitoring and warning services are provided by the NCHM.

3.1 GLOF Management and Oversight Group (GMOG)

Considering that operation and management of GLOF EWS requires chain of commands and decision making processes especially in the event of emergencies. The GLOF Management and Oversight Group (GMOG) is established within the NCHM. Need for GMOG was felt as GLOF EWS is complex that requires the services of other professional outside the division such as ICT. The members of GMOG will consist of:

a) Director, NCHM - Chairman
b) Chief, Hydrology and Water Resources Services Division, NCHM- Member
c) Chief, Hydromet Operation and Infrastructure Division, NCHM- Member

d) Chief, Weather and Climate Services Division, NCHM- Member,
e) Chief, Cryosphere Services Division, NCHM- Member
f) Head/Engineer, Forecasting and Warning Section, HWRSD, NCHM- Member Secretary

3.1.1 Roles and Responsibilities of GMOG

a) The GMOG will generally meet bi-annually or on any emergency related to GLOF/flood;
b) The GMOG will strive to improve the methods, procedures and techniques in hydrological (flood) monitoring and warning;
c) The GMOG will inform and update the Governing Board of NCHM and other line agencies on the status and developments in the event of GLOF.
d) The GMOG will conduct briefings for media and other interested parties on floods and other hydrological hazards, if required.

3.2 National Center for Hydrology and Meteorology

Some of the specific roles and responsibilities of Director/Chairman of GMOG:

a) Director of NCHM as the Chairman of GMOG will oversee and provide policy guidance for the operations of the flood/GLOF EWS, public information and education on flood/GLOF, and post-flood investigation with concerned agencies.
b) Facilitate and authorize procurement of spare-parts during emergencies for timely repair and maintenance of GLOF EWS and associated facilities installed.

3.3 Hydrology and Water Resources Services Division

Some of the specific roles and responsibilities of Chief of HWRSD:

a) To coordinate and monitor operations of the flood/GLOF EWS installed,
b) To coordinate and liaise with the Department of Disaster Management (DDM), Department of Geology and Mines (DGM), and other inter-agencies and local governments through Director, NCHM.

3.4 Flood Monitoring and Command Room (FMCR), NWFWC

The Flood Monitoring and Command Room (FMCR), NWFWC of NCHM is directly responsible to monitor the GLOF EWS with dedicated personnel in the Control Room 24/7 on shift basis. The members of FMCR will consist of:

a) Engineer/Hydrology Officer, Forecasting and Warning Section (FWS), HWRSD, NCHM- Head
b) Hydro-met Officer, HWRSD, NCHM - Member
c) Engineer (Civil), HOID, NCHM - Member
d) ICT officer, NCHM - Member
e) Control Room Operators/Technicians - Operators

3.4.1 Roles and Responsibilities of FMCR

The following are the responsibilities of FMCR:

a) The FMCR is answerable to the GMOG for the operation, management and maintenance of the GLOF-EWS installed.
b) Oversee the functions of GLOF EWS Control Room, Wangdue and Thanza FWS, Lunana.
c) Propose budget for operation and maintenance of GLOF EWS installed.

d) Coordinate to conduct preventive and corrective maintenance of the telemetry and telecommunication equipment of the GLOF EWS, Control room and regular inspection of sirens and remote sensors stations as per maintenance schedule.
e) To maintain safe custody of spare parts of GLOF EWS as well as inventory of equipment installed.
f) To collaborate/cooperate with local communities and other matter related to GLOF and other related activities.
g) Any other functions as and when directed by Division/Center/GMOG

3.5 GLOF EWS Control Room, Wangdue

The Control Room for GLOF EWS located at the Wangdue, Flood Warning Site Office and shall be manned by duty personnel for 24/7. The Control Room's overall duties and responsibilities shall be implemented under the direction/supervision of In-charge of Control Room, Wangdue in close consultation with Engineer in-charge of FMCR and HOID.

3.5.1 Roles and Responsibilities of GLOF EWS Control Room, Wangdue

The GLOF EWS Control Room at Wangdue shall perform the following functions:

a) To monitor and operate GLOF EWS network installed.
b) To operate and maintain Control Room facilities such ICT equipment, power supplies, internet connection, servers, etc.
c) To monitor and check the following as per the GLOF EWS Operating Manuals.
   - Retrieving Environmental Data from all GLOF EWS remote monitoring and siren stations.
   - Decoding and Storing Data in database;
   - Activating Sirens in alarm conditions.
   - Displaying map of GLOF EWS monitoring Sites and Sirens.
   - Monitoring status of health of the GLOF EWS.
d) In the event of GLOF, Control room will carry out the monitoring/coordination activities, inform relevant agencies and activate/deactivate the sirens as per the ***GLOF EWS Operation Flow Chart*** given in **Annexure-I/Annexure II.**
e) In the event of earthquake, Control Room will directly communicate with Thanza FWS Office, Lunana to check the lakes status and report to HQ.
f) To collaborate/cooperate with local government/communities related to GLOF in consultation with FMCR.
g) To communicate with the local government/community, providing information support in the event of false alarm, if any.
h) To carryout emergency maintenance and replacement of equipment under the guidance of FMCR and HOID;
i) To maintain safe custody of spare parts of GLOF EWS as well as inventory of equipment installed at Punakha-Wangdue valley.
j) Regular inspection of sirens and remote sensors station in the Punakha-Wangdue valley as per the direction of FMCR.
k) Maintain log book of all the GLOF EWS facilities (AWLS/AWS and Sirens) in lower region.
l) Any other functions as and when directed by Division/Center.

3.6 Flood Warning Office at Thanza, Lunana

The Flood Warning Office at Thanza, Lunana shall operate as back up for the Automatic GLOF EWS.

3.6.1 Roles and Responsibilities of Flood Warning Office, Thanza

The primary functions of Thanza Flood Warning Office, Lunana are:

a) Physical monitoring of glacial lakes and outflow in and around Lunana areas and transmit information to Control Room, Wangdue through wireless/mobile/satellite phone.
b) Physical monitoring of water level at Thanza (common confluence for all four lakes) and transmit information over wireless to Wangdue and Sunkosh Dobani Flood Waning Office of the Flood Warning Section, HOID, NCHM as per the schedule below.

Table 4: Thanza Wireless Transmission Schedule

Gauge Reading Time (hours)	Wireless Schedule (hours)
0200	0230
0500	0530
0900	0930
1200	1230
1500	1530
1800	1830
2100	2130
2400	0030

c) To carryout minor maintenance of GLOF EWS system components and communication facilities in Lunana area including three sirens as per the guidance of FMCR.
d) Regular inspection of sirens and remote sensors stations in Lunana area as per the schedule.
e) To collaborate/cooperate with local communities related to GLOF.
f) To communicate with the local communities, providing information support in the event of false alarm.
g) Immediate transmission of information, during emergency due to outburst of glacier lakes, to Wangdue Control Room and FMCR, Thimphu, HQ or Sunkosh Dubani.
h) To maintain safe custody of spare parts of GLOF EWS as well as inventory of equipment installed at Lunana region.
i) During the event of earthquake, monitor and report status of lakes to Wangdue Control Room and FMCR, NCHM, HQ.
j) Maintain log book of all the GLOF EWS facilities (AWLS/AWS and Sirens) in upper region of Lunana area.
k) Any other functions as and when directed by Wangdi Control Room and FMCR, NCHM.

4 Repair and Maintenance of GLOF EWS Facilities

The repair and maintenance is aimed to have stable operation of the system for a reasonably longer lifetime. The main objectives of this activity are:

a) Detection of weaknesses, potential malfunctions, abnormalities, etc.,
b) Calibration of the gauges/equipment; and
c) Correction of defects and restoration of systems function.

The continuous operation of the GLOF EWS real-time data transmission system depends on effective safeguard against malfunctions and breakdowns that in turns totally relies on

preventive maintenance. In general, systems failure is prevented through periodic check-ups in addition to restoration of systems function by repair and servicing.

4.1 Maintenance and Inspection Service

The maintenance inspection services shall be carried out as follow;

a) **The Daily Inspection** performed by the Control Room engineer/technician is primarily to check the stability of the data transmitted by remote monitoring stations as well as by the Siren stations. Where the voltage/signal levels are found to have varied from the specified standards, corrective procedures are performed to rectify the anomaly as per the GLOF EWS Control Centre and Field Station Manuals.

b) **The Quarterly Inspection** carried out by the maintenance team, NCHM is in general for the remote monitoring stations and sirens in the lower Punakha-Wangdue valley, to assess the operational condition and performance of the telemetry equipment including the activity mentioned in item (a). Where necessary, corrective measures are carried out to restore the functional operation of the equipment and stability of the signals. The inspection requires extensive on-site examination and testing.

c) **The Annual Inspection** is usually performed before the onset of the rainy season where emphasis is given to the assessment and testing of the operational condition of the whole system.

d) **The Emergency Inspection** is carried out when a sudden system malfunction occurs and when the abnormality tends to seriously affect the monitoring operation, such as during flood. Such emergency inspection must be carried out immediately and shall be reported by the Control Room personnel to FMCR, NCHM and further to GMOG if, necessary. The primary concerns during the emergency inspection are: (a) the determination of the cause of any abnormality or malfunction; and (b) the initiation of corrective or remedial procedures to restore the system to normal operation. The inspections of the GLOF EWS will be as per the schedule given in the **Table 5**.

Table 5: GLOF EWS inspection schedules

<table>
<tr><th rowspan="2">Months</th><th>Daily Inspection</th><th>Quarterly Inspection</th><th>Annual Inspection</th><th>Emergency Inspection</th></tr>
<tr><th>FMCR - Thimphu and Control Room Wangdue</th><th>Control Room and Thanza Station</th><th>Maintenance Team in coordination with Control Room and Thanza Station</th><th>Maintenance Team in coordination with Control Room and Thanza Station</th></tr>
<tr><td>January
February
March</td><td rowspan="4">On all days</td><td>X</td><td>X
(For lower region in the Punakha-Wangdue Valley)</td><td rowspan="4">Any time as and when required</td></tr>
<tr><td>April
May
June</td><td>X</td><td></td></tr>
<tr><td>July
August
September</td><td>X</td><td>X
(For upper region in Lunana area)</td></tr>
<tr><td>October
November
December</td><td>X</td><td></td></tr>
</table>

4.2 Maintenance Toolkits

It is necessary that there are sufficient sets of tools and test equipment in stock and readily available for the use of the maintenance team at all times. The Center will ensure that the Control room and maintenance team are sufficiently and properly equipped with the appropriate tools and equipment.

4.3 Spare Parts for Maintenance

All the necessary spare parts may be stored at Wangdue Control Room for easy access and timely repair of equipment. The Center shall ensure that there are sufficient stock of spare parts for all times. Center shall incorporate the purchase of equipment in the annual budgeting plan.

5 Monitoring & Dissemination of Warnings

Although the monitoring and operation of flood warning is a continuous program throughout the year, the monitoring activities will be more vigorous during the summer seasons. The dissemination of GLOF early warning information will be done by:

5.1 Activation of Sirens

5.1.1 Phochu Sub-basin

The sirens will be activated only when water levels in the Remote Monitoring Stations on Phochhu reaches at **ALARM LEVEL** as detailed in the **Table Annexure-III**. If there is a GLOF from any of the 4 (four) lakes in Lunana, 3 Sirens in the Lunana region will be activated automatically after 15 minutes. There will be a popup message with audible alarm in the Control Room but will not activate the 14 Sirens (S-1 to S-14) located in the Punakha-Wangdue valley.

As soon as GLOF is detected by sensors at Thanza and water level reaches the **ALARM LEVEL**, there will be an **ALARM** in the Control Room and the Control Center Operator shall follow the following steps:

a) Operators shall immediately contact Thanza Station at Lunana and confirm the GLOF. If GLOF is confirmed by Thanza Staff, Sirens (S-1 to S-14) are activated.

b) Simultaneously, Operators will inform FMCR, NCHM for information and further directives. Officer Incharge/Engineer, FMCR after receiving information from Control Room will inform at least two of the members of GMOG of the situation for follow up action.

c) For the smooth operation of GLOF EWS installed, Control Operator will always refer ***GLOF EWS Operation Flow Chart*** given in the **Annexure-I.**

5.1.2 Mochhu Sub-basin

The sirens will be activated only when water levels in the Remote Monitoring Stations on Mochhu reaches at **ALARM LEVEL** as detailed in the **Table Annexure-IV**.

As soon as flood/GLOF is detected by sensors at Taktsemakhang, Laya and water level reaches the **ALARM LEVEL**, there will be an **ALARM** in the Control Room, the Operators shall follow the following steps:

a) Operators shall contact Taktsemakhang Station at Laya and get Flood/GLOF confirmation.

b) Operators will inform FMCR, NCHM for directives. Officer Incharge/Engineer, of FMCR shall inform at least two of the members of GMOG for decision and directive.

c) For the smooth operation of GLOF EWS installed, Control operator will always refer ***GLOF EWS Operation Flow Chart*** given in the **Annexure-II.**

5.1.3 False Alarm

Considering that most of the sensors installed in the glacier lakes in Lunana area are located above 4500 masl, occurrence of sensors jammed by icing were observed during the winter when temperatures drops well below freezing point. Icing of sensors often causes false rise in water level above alert and alarm level defined for each monitoring station that may trigger activation of sirens. The system is designed in such a way that Control Operator at Control Room can stop automatic activation of sirens.

However, false alarm (Activation of Sirens) may occur under un-expected circumstances due to instrument failure or absence of personnel in the GLOF EWS Control Room, Wangdue. In the event of false alarm, sirens may activate only 2 to 3 cycles, where in the real flood situation sirens will be activated at least for 12 cycles (interval of 5 minutes off/on). In the meantime Operator at Control Room, Wangdue can switch off sirens and will notify DDM and Disaster Focal Person of Local Government, hydro-power projects downstream on nature of such false alarms.

5.2 Control Room and FMCR Shift Duty Operation

The Control Room and FMCR, NCHM will be in operational 24/7 on shift duty system. The in-charge of FMCR and Control Room shall be responsible for preparing an appropriate Monitoring Duty Schedule and shall be shared with the officer in-charge of FMCR.

The schedule/roaster shall indicate the general assignment of the operations personnel.

a) The schedule shall include the maximum number of personnel that may possibly be required during any shift.
b) Generally duty schedule/roaster shall be prepared for shift operation as,
    i. Shift-I operates from 6 a.m. to 2 p.m.
    ii. Shift-II operates from 2 p.m. to 10 p.m.
    iii. Shift-III operates from 10 p.m. to 6 a.m.

    However, In-charge Control Room may prepare duty roster based on manpower availability and other considerations.
c) As all the site staff has been posted considering their choices also in addition to the requirements of office, gender, age, health and family considerations are generally not to be given weightage while preparing the Duty Schedule/roaster in the bigger interest of public service.
d) The swapping of scheduled duties shall be allowed on mutual consent of the concerned parties.
e) During the emergency or in the event of disaster, all the site staff posted at Wangdue has to be present till the emergency is called off.
f) In case of emergency leave applications, the in-charge of the FMCR and Control Room shall ensure unhindered performance of the above mentioned duties, even if it involves performing additional duty by the remaining staff. Duty roaster must then be amended following the procedures mentioned above.
g) Copies of the duty roaster shall be shared with Chief of HWRSD and Chief of HOID.

5.3 Dissemination of Information to Stakeholders

5.3.1 Wangdue Control Room

After activation of sirens, Control Room staff at Wangdue, will further disseminate/inform the following offices:

a) GLOF Focal Person/Director General, Department of Disaster Management (DDM), Ministry of Home and Cultural Affairs or National Emergency Operation Centre (NEOC)
b) Dzongkhag Disaster Focal Person, Dasho Dzongda, Dzongkhag Administration Gasa, Punakha, Wangdue, or Dzongkhag Emergency Operation Centre
c) Focal person from Hydropower Plants (PHPA-I, PHPA-II and Basochu (DGPC).

General information flow scheme for the GLOF Warning is shown in **Figure 2**.

During an EVENT OF GLOF, the Control Room will only PROVIDE the flood occurrence information via phone or other available communication (automatic dial-up or notification via SMS, MMS, e-mails), all other updated information will be provided by GMOG, NCHM.

Dissemination of GLOF occurrence (and other related information packages) by Control Room shall be properly recorded in the operations log book. Each entry should indicate: (a) name of the person transmitting; (b) time transmitted; (c) the name of the recipient or person receiving on the behalf the recipient and (e) time received.

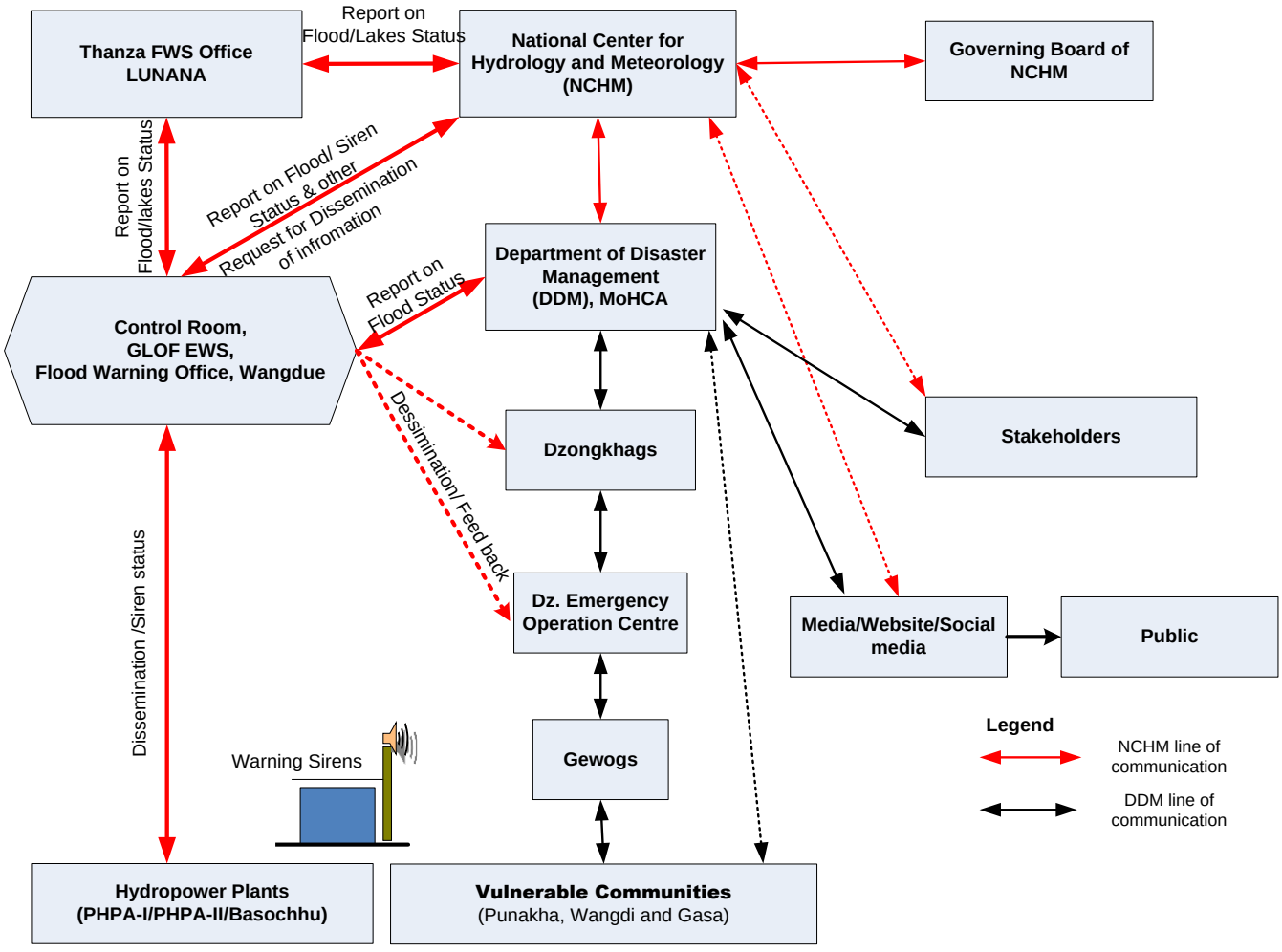

Figure 2: Information Dissemination Flow Chart

5.3.2 GLOF Management and Oversight Group (GMOG)

Upon receipt of information of GLOF from FMCR and Control room, all the members of GMOG shall convene at National Weather and Flood Warning Centre (NWFWC) immediately for an emergency meeting till the GLOF threat recedes. At the same time the Chairman/Offtg. of GMOG shall inform the Chairman of Governing Board of NCHM of the emergency.

The GMOG will carry out the following functions in the event of a GLOF emergency:

a) Continuously monitor and interact with the Control room at Wangdue and Thanza Station and provide technical and advisory support.

b) Provide update information on GLOF to Department of Disaster Management (DDM) and other lines agencies including Media. The requesting broadcast media is given priority due to their capability to disseminate information to the public almost immediately.

c) Call in requests for GLOF event information shall be attended. Any questions and inquiries on technical matters shall be referred to the Engineer or any competent member of the FMCR or GMOG.

d) Walk-in requests and/or inquiry concerning flood/GLOF event shall be attended.

e) Dissemination of any updated information shall be properly recorded. Each entry should indicate: (a) the name of the recipient; (b) person receiving for the recipient; (c) time transmitted; (d) time received; and, (e) person transmitting.

f) Flood/GLOF warnings should also be uploaded on the Center's website and social medias as soon as possible.

6 Education and Awareness

The Center shall conduct public/stakeholders education and awareness on the GLOF EWS regularly in coordination with the Department of Disaster Management.

Annexure –I: GLOF EWS Operation Flow Chart Phochhu Sub-Basin

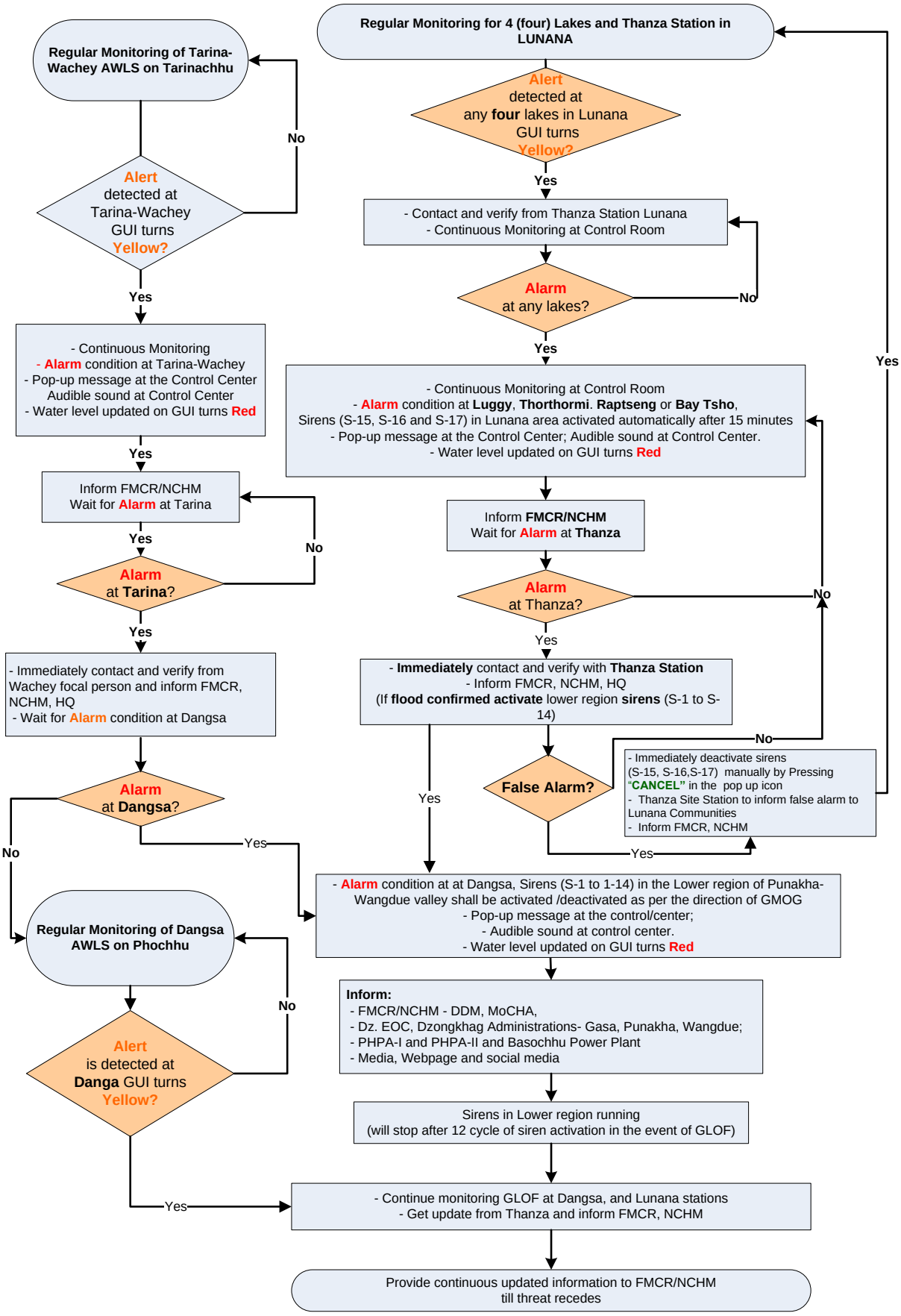

Figure 3: GLOF EWS Operation Flow Chart Phochhu Sub-Basin

Annexure –II: GLOF EWS Operation Flow Chart Mochhu Sub-Basin

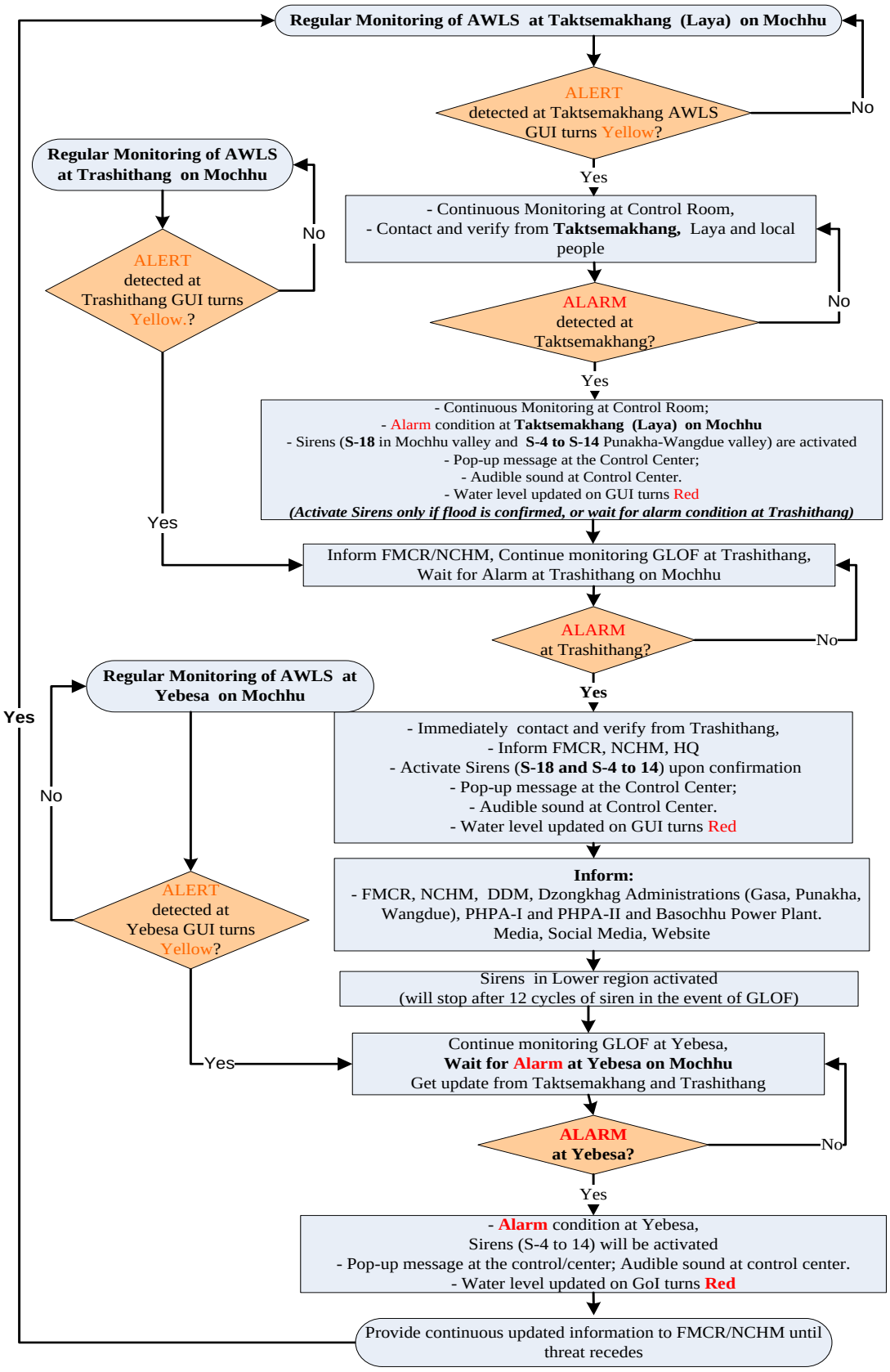

Figure 4: GLOF EWS Operation Flow Chart Mochhu Sub-Basin

Annexure- III: Table showing ALERT and ALARM Conditions and Operation for Phochhu Sub-Basin

Sl.No.	Alert and Alarm	Control System response or What happens?	Operator Choices
1	Alert at any of the 7 GLOF monitoring stations (4 Lakes + Thanza, Tarina/Wachey and Dangsa)	- Water level on the water level status panel of the siren control GUI is updated with current value and turns yellow. - Icon on the map of the website turns yellow. - The detail of the Alert can be viewed in the Bhutan Alarms link of the website. - SMS or email is sent to Control Operators and other Decision Making Personnel.	➢ Continue monitoring data; ➢ Contact Thanza and get update or status ➢ Immediately inform FMCR, NCHM
2	Alarm at Luggy, Thorthormi, Rapstreng or Bay Tsho	- Message pops up at the control center indicating which station is in alarm and what threshold was exceeded. - An audible sound is played at the control center. - Water level on the water level status panel of the siren control GUI is updated with current value and turns Red. - Icon on the map of the website turns red. - SMS or email is sent to Control Operators and other Decision Making Personnel.	➢ **PROCEED** (If pressed Proceed and confirmed the activation) • Sirens **S-15, S-16**, and **S-17** (Lunana region) activated. • Sirens **S-1 to S-14** and **S-18** (Punakha-Wangdue Valley) remains deactivated. ➢ **CANCEL** • Sirens **S-15, S-16**, and **S-17** (Lunana region) deactivated. • No operator response • After 15 minutes of inaction, the upper Sirens S-15, S-16, and S-17 will ring automatically. ***The Operator can turn off Sirens S-15, S-16, and S-17 manually from Control Room***.
3	Alarm at Thanza	- Message pops up at the control center indicating which station is in alarm and what threshold was exceeded. - An audible sound is played at the control center. - Water level on the water level status panel of the siren control GUI is updated with current value and turns red. - Icon on the map of the website turns red. - SMS or email is sent to Control Operators and other Decision Making Personnel.	➢ **PROCEED** • Sirens **S-15, S-16** and **S-17** (Lunana region) are activated. • Sirens **S-1** to **S-14 (**Punakha-Wangdue Valley) are activated. ➢ **CANCEL** • Deactivate Siren **S-15, S-16**, and **S-17** • Sirens **S-1 to S-14** and **S-18** (Punakha-Wangdue Valley) remains deactivated ➢ No operator response: Audible sound continues to be played at the control center. ***The Operator can turn off Sirens S-1 to S-14 or S-15 to S-17 manually from Control Room***

4	Alarm at Tarina/Wachey	- Message pops up at the control center indicating which station is in alarm and what threshold was exceeded. - An audible sound is played at the control center. - Water level on the water level status panel of the siren control GUI is updated with current value and turns red. - Icon on the map of the website turns red. - SMS or email is sent to Control Operators and other Decision Making Personnel.	➢ **PROCEED** • Siren lower region **S-1 to S-14** are activated. ➢ **CANCEL** • Sirens **S-1 to S-14** remain deactivated ➢ No operator response: Audible sound continues to be played at the control center. ***The Operator can turn off Sirens S-1 to S-14 manually from Control Room***
5	Alarm at Dangsa	- Message pops up at the control center indicating which station is in alarm and what threshold was exceeded. - An audible sound is played at the control center. - Water level on the water level status panel of the siren control GUI is updated with current value and turns red. - Icon on the map of the website turns red. - SMS or email is sent to Control Operators and other Decision Making Personnel.	➢ **PROCEED** The lower sirens S-1 thru S-14 are activated. ➢ **CANCEL** - Does not activate S-1 thru S-14 ➢ No operator response - The audible sound continues to be played at the control center. ***The Operator can turn off Sirens S-1 to S-14 manually from Control Room***

Annexure- IV: Table showing Alert and Alarm Conditions and Operation for Mochhu Sub-Basin

Sl.No.	Alert and Alarm	Control System response or What happens?	Operator Choices
1	Alert at any of the 3 AWLS on Mochhu (Taktsemakhang, Trashithang and Yebesa Hydrological Station)	• Water level updated on the GUI and turns yellow; • Icon on map of the website turns yellow; • Detail can be viewed in Bhutan Alarms on website	➢ Continue monitoring data; ➢ Get updates from Taktsemakhang, Trashithang and Yebesa. ➢ Inform FMCR, NCHM
3	Alarm at Thaktsemakhang, Laya	- Message pops up at the control room indicating alarm stations and what threshold was exceeded. - An audible sound is played at the control center. - Water level panel of siren control GUI is updated with current value and turns red. - Icon on the map of the website turns red. - SMS or email is sent to Control Operators and other Decision Making Personnel.	➢ **PROCEED** • Sirens **S-4 to S-14 and S-18** are activated. ➢ **CANCEL** • Sirens **S-4 to S-14 and S-18** remains deactivated ➢ **No operator response** • The audible sound continues to be played at the control center. ***The Operator can turn off S-4 to S-14 and S-18 manually from Control Room***
4	Alarm at Tashithang	- Message pops up at the control center indicating which station is in alarm and what threshold was exceeded. - An audible sound is played at the control center. - Water level on the water level status panel of the siren control GUI is updated with current value and turns red. - Icon on the map of the website turns red. - SMS or email is sent to Control Operators and other Decision Making Personnel.	➢ **PROCEED** - The lower sirens **S-4 to S-14 and S-18** are activated. ➢ **CANCEL** - Does not activate any sirens **S-4 to S-14 and S-18** - No operator response - The audible sound continues to be played at the control center. ***The Operator can turn off S-4 to S-14 and S-18 manually from Control Room***
5	Alarm at Yebesa	- Message pops up at the control center indicating which station is in alarm and what threshold was exceeded. - An audible sound is played at the control center. - Water level on the water level status panel of the siren control GUI is updated with current value and turns red. - Icon on the map of the website turns red. - SMS or email is sent to Control Operators and other Decision Making Personnel.	➢ **PROCEED** - The lower sirens **S-4 to S-14** are activated. ➢ **CANCEL** - Does not activate any sirens **S-4 to S-14** - No operator response - The audible sound continues to be played at the control center. ***The Operator can turn off S-4 to S-14 manually from Control Room.***

Annexure –V: Contact Detail- Central Agencies

Sl. No.	Agency	Contact Person Name	Telephone	Mobile No.	E-mail
1	Department of Disaster Management, (DDM), MoHCA	Mr. Jigme Thinlye Namgyal Director General	02-327098	17600584	jtnamgyal@ddm.gov.bt
		Pema Singye (RRD Chief)	02-321792	17118690	psingye@ddm.gov.bt
		Thinley Norbu (RPRD Chief)	02-321004	17333084	thinleyn@ddm.gov.bt
		Yang Dorji (PRD Chief)	02-327319	17650223	yangdorji@ddm.gov.bt
2	Department of Geology and Mines, Ministry of Economic Affairs	Choiten Wangchuk Director General	02-323349		choitenw@moea.gov.bt
		Dr. Dowchu Drukpa Chief Seismologist Earthquake and Geophysics Division	02- 323096		ddrukpa@moea.gov.bt
3	National Center for Hydrology and Meteorology Thimphu	Mr. Karma Dupchu, Director	02-382820	17629918	kdupchu@nchm.gov.bt
		Mr. Tayba Buddha Tamang, HWRSD Chief	02-323632	17666639	tbtamang@nchm.gov.bt
		All Chief of NCHM			hod@nchm.gov.bt
		TMO, FWS, GOI	02-322025	17609540	tmofws@gmail.com
		Mr. Sangay Tenzin, Engineer	02-323117	17711753	sangaytenzin@nchm.gov.bt
		Flood Monitoring Command Room, NWFWC, Thimphu	02-338442	17128052	fmcr@nchm.gov.bt
4	GLOF Early Warning Control Centre, Flood Warning Office Wangdue	Mr. Purna Kumar Poudel Incharge	02-481369	17669575	glofewswangdue@gmail.com
		Mr. Sangay Tshering		17693263	
		Dawa Yamchen		17617030	
		Sonam Tashi		17773801	
		Pempa Dorji		17979381	
		Tshering Choden		17994926	
		Phachey Dampa Singye		17354351	
		BB Gurung (Wangdirapid)		17670419	
5	Flood Warning Station, Thanza, Lunana, Gasa	In-Charge	008821679110636 (Satellite Phone)	17616065	

Annexure –VI: Contact Detail - Dzongkhags/Other

Sl. No.	Agency	Contact Person	Phone No.	Mobile No.	e-mail
1	Dzongkhag Administration, Gasa	Dasho Dzongda (Dasho Rinzin Penjore)	02-688102	16288100	rpenjore@gasa.gov.bt
		Dzongrab (Mr. Dorji Gyeltshen)		17115772	dgyeltshen@gasa.gov.bt
	Dzongkhag Disaster Management Officer Person, Gasa	Mr. Tshering Wangchuk Ms. Deki Yangzom		17605489 17450700	tsheringwangchuk@gasa.gov.bt dekiyangzom@gasa.gov.bt
2	Dzongkhag Administration, Punakha	Dasho Dzongda (Dasho Karma Dukpa)	02 584110	17644023	kdrukpa@punakha.gov.bt
		Dzongrab (Mr. Ugyen Tshering)	02 584117	17114588	utshering@ounakha.gov.bt
	Dzongkhag Disaster Management Officer Person, Punakha	Mr. Tshewang Phuntsho	02 584549	77637312	tphuntsho@punakha.gov.bt
3	Dzongkhag Administration, Wangdue	Dasho Dzongda (Dasho Sonam Jamtsho)	02 491273	17110553	sjamtsho@wangduephodrang.gov.bt
	Dzongkhag Administration, Punakha	Dzongrab (Mr. Tshewang Namgyel)	02 481408	17122404	tnamgyel@wangduephodrang.gov.bt
	Dzongkhag Disaster Management Officer Person, Wangdue	Mr. Sonam Wangchuk	02 481686	17491489/ 77259307	somchuksonam558@gmail.com
4	Punatsangchhu Hydropower Project Authority (PHPA-I)	Mr. Karma Tshewang, JMD	02 471576	17775454	ktshewang@phpa1.gov.bt
		Captain Wangchuk Hexzo, Chief (Adm)		17116039	kamjon2010@gmail.com
		Captain Kelden Drukpa, CSO		17161965	dycsophpa@gmail.com
	Punatsangchhu Hydropower Project Authority (PHPA-II)	Mr. Chundi Dorjii, Chief (Adm)	02 471587	17645259	chiefadm@phap2.gov.bt
		Major Kinley Namgay, CSO	02 471638	17172574	cso@phap2.gov.bt
		Mr. Jigme Nidub, Dy. Chief Environmental Officer	02 471583	17620848	dy.eo@phpa2.gov.bt
5	Basochhu Power Plant, Rurichhu	Mr. Dechen Dorji, Head Operation & Maintenance Division	02 471021/ 02-471026	1729983	d.dorji133@drukgreen.bt
6	Bhutan Broadcasting Services (BBS)- Dzongkha Radio/TV News Editor	Mr. Sonam Wangdi		17615612	editorondesk@gmail.com
		Mr. Tandin Phuntsho		17630179	tandinphuntsho@bbs.com.bt