



**STANDARD OPERATING PROCEDURE  
FOR  
HYDROMET OPERATIONS AND INFRASTRUCTURE DIVISION**

**National Center for Hydrology and Meteorology  
Royal Government of Bhutan  
2020**





**STANDARD OPERATING PROCEDURE  
FOR  
CRYOSPHERE SERVICES DIVISION**

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## **Acronyms**

APT: Annual Performance Target

AWLS: Automatic Water Level Station

AWS: Automatic Weather Station

BCAA: Bhutan Civil Aviation Authority

CIM: Cryosphere Information & Management

CMSS: Cryosphere Monitoring & Survey Section

CSD: Cryosphere Services Division

DEM: Digital Elevation Model

dGPS: differential Global Positioning System

FYP: Five Year Plan

GLOF: Glacial Lake Outburst Flood

HOID: Hydro-Met Operation and Infrastructure Division

NCHM: National Center for Hydrology and Meteorology

RBA: Royal Bhutan Army

SBD: Standard Bidding Document

SOP: Standard Operating Procedure

SWE: Snow Water Equivalent

UAS: Unmanned Aircraft System

## **01. Title**

Standard Operating Procedure for Cryosphere Services Division.

## **02. Objective**

To actively engage CSD officials in line with Division's mandate and functions.

## **03. Effective**

1 July 2020.

## **04. Mandate of CSD**

The Cryosphere Services Division (CSD) is mandated to study and monitor cryosphere (snow, glaciers, glacial lakes) and its associated risks and impacts on the lives and properties in the downstream in relation to water resource and associated hazards

## **05. Functions of CSD**

- a. Prepare plans and programs related to cryosphere (snow, glaciers, glacier lakes) monitoring
- b. Time series monitoring of glaciers, glacier lakes and snow cover.
- c. Operation of snow and glacier monitoring networks in coordination with other divisions of the Center
- d. Maintain National Cryosphere Database (Snow and Glacier Hub)
- e. Assess risk associated with Glacial Lake Outburst Flood (GLOF) and melt contribution from glacier and snow to the surface runoff;
- f. Coordinate with national agencies related to snow and glacier monitoring and data collection
- g. Foster collaboration with regional and international institutions/agencies involved in the field of cryosphere research.
- h. Establish linkages with regional and international institutions involved in snow and glacier related activities for knowledge /data sharing
- i. Provide professional and technical services to the Center/other agencies on conceptual and methodological aspects of cryosphere monitoring and related studies



**Fig. 1. Organogram of CSD**

**06. SOP for Cryosphere Monitoring & Survey Section (CMSS)**

**Functions of CMS:**

- Establish and operate benchmark glacier monitoring stations for status of glaciers (mass balance, terminus activity, glacier surface activity, glacier dynamics including flow velocity and ice thickness) using conventional stake nets, Unmanned Aircraft System, Ice-Radar and geodetic methods.
- Establish and operate research based/time bound snow monitoring stations.
- Preparing glacier inventory and regular updating.
- Conduct research on melt contribution to surface runoff from snow and glacier.
- Plan and implement research activities on glaciers and snow monitoring.

<b>06.01 Annual Glacier Mass Balance measurement.</b>			
<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Output/Result</b>
a) Plan glacier fieldwork as per targeted activities, approved-budget and schedule.	2 months	Field team	<ul style="list-style-type: none"> <li>➤ Desk studies carried out.</li> <li>➤ Logistics (ponies, testing &amp; calibration of field equipment) arranged.</li> <li>➤ Approval such as special route permit and UAS operation clearance as per BCAA regulations (if applicable) sought.</li> <li>➤ Budget mobilized.</li> <li>➤ Helpers or field assistants arranged (if applicable).</li> </ul>

b) Conduct glacier field work.	1-2 months	Field team	<ul style="list-style-type: none"> <li>➤ Stake data collected.</li> <li>➤ Replaced/rectified stake(s).</li> <li>OR/and</li> <li>➤ Necessary data collected through geodetic survey carried out.</li> <li>➤ UAS survey as per flight plan carried out.</li> <li>➤ Snow pit measurement (depth, density, snow water equivalent and grain-size) carried out.</li> <li>➤ Repeat photographs taken from identified point.</li> <li>➤ Ice-radar survey carried on selected glacier if applicable. Discharge measurement conducted (if applicable).</li> <li>➤ Maintenance/data retrieval from AWS &amp; AWLSs.</li> </ul>
b) Data analysis.	1 month	Field team	<p>Analyzed and processed:</p> <ul style="list-style-type: none"> <li>● Stake data.</li> <li>● Geodetic data.</li> <li>● Ice-radar data.</li> <li>● Snow data (SWE).</li> <li>● UAS data.</li> <li>● Discharge data.</li> <li>● Repeat photographs.</li> <li>● AWS and AWLS data.</li> </ul>
d) Report submission.	2 months	Field team	<ul style="list-style-type: none"> <li>● Standard/comprehensive scientific report generated and submitted.</li> </ul>
d) Data archival.	1 week (after report submission)	Field team and data focal.	Field data (both Raw and processed including stake, dGPS, photos, discharge etc.) submitted to data focal for official archival.

**06.02 Establishment of automatic climate & snow monitoring stations. \*\*\***

<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Output/Result</b>
a) Prepare technical comparative statement of technical specifications and present it to management for finalization.	1-2 Months (depending on number of parameter/sensors listed)		Technical specification prepared and submitted to concerned Division.
b) Prepare estimates and process technical sanction from Center's Technical Committee.	1 Month		<i>The document comprising estimates of the work, technical specifications and implementation method should be presented to Center's technical committee.</i>
c) Prepare standard bidding document (SBD), float tender.	1-2month		<i>One month should be kept by default for inviting open tender.</i>
d) Evaluate tender (work) as per PRR and SBD norms	1-2 Month		<i>Time frame will be governed by complexity of preset evaluation criterion and number of prospective bidders</i>
e) Award work, monitor, test and take over work accordingly.	Letter of intent=10 Days Signing of Contract awarding=5 Days.		<i>Site handing taking and monitoring will depend on the duration of contract and location of site/destination.</i>

**06.03 Conduct research on melt contribution to surface runoff from snow and glacier.**

<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Output/Result</b>
a) Compilation of time series data.	1-2 months	Melt modelling focal	➤ Acquired and downloaded satellite-data/observed-data (observed-discharge, rainfall, temperature,



			humidity, solar radiation and other meteorological parameters).
b) Analyse and process data.	1-2 months	Melt modelling focal	➤ Analyzed and Processed product of a).
c) Set-up and run melt model	1 month	Melt modelling focal	➤ Results on contribution of glacier/snow melt to surface runoff estimated.
d) Report submission.	1 month	Melt modelling focal	➤ Standard/comprehensive scientific report generated and submitted
d) Data archival.	1 week (after report submission)	Melt modelling focal and data focal	All data (both Raw and processed) submitted to data focal for official archival.

#### ***06.04 Preparing glacier inventory and regular updating***

<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Output/Result</b>
a) Data acquisition	2 weeks	Glacier mapping team	➤ Satellite imageries acquired/downloaded.
b) Process satellite imageries	1 month	Glacier mapping team	➤ Refined imageries produced for further analysis. <ul style="list-style-type: none"> <li>● Atmospheric correction.</li> <li>● Ortho-rectification.</li> <li>● Shadow removal.</li> <li>● Filtering clouds.</li> <li>● Generating geotiff.</li> </ul>
c) Glacier mapping	2 months	Glacier mapping team	➤ Glacier boundary digitized.
d) Data analysis	1 month	Glacier mapping team	➤ Analyzed glacier maps through the following steps. <ul style="list-style-type: none"> <li>● Set criterion for area threshold.</li> <li>● Assign glacier attributes.</li> </ul>

			<ul style="list-style-type: none"> <li>● Compare the results (area, number) with existing inventories.</li> <li>● Accuracy assessment.</li> </ul>
e) Report submission.	1 month	Glacier mapping team	➤ Standard/comprehensive scientific report generated and submitted.
f) Data archival.	1 week (after report submission)	Glacier mapping team and data focal.	➤ All data (both Raw and processed) submitted to data focal for official archival.

**\*\*\* will be carried out in collaboration with HOID**

## **07. SOP for Cryosphere Hazard Assessment & Prediction Section (CHAPS)**

### ***Functions of CHAP:***

- Carry out Time Series Monitoring of glacial lakes, asses associated risk and recommend appropriate mitigation/adaptation measures for implementation.
- Coordinate with national line agencies pertaining to snow and glacier hazards and risk assessment
- Preparing and updating of GLOF hazard/vulnerability maps in selected basins in collaboration with other divisions in the Center and related agencies.
- Plan and carry out research activities pertaining to GLOF and related Hazard
- Preparing and regular updating of Glacial Lake Inventory and list of potentially dangerous glacial lakes (PGDL) in the country.

<b><i>07.01 Time series monitoring of glacial lakes.</i></b>			
<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Result/Remarks</b>
a) Plan fieldwork as per target activities, budget and schedule.	1-2 months	Field team	<ul style="list-style-type: none"> <li>➤ Desk studies carried out.</li> <li>➤ Logistics (ponies, testing &amp; calibration of field equipment) arranged.</li> <li>➤ Special route permit as per RBA regulations arranged.</li> <li>➤ Budget mobilized.</li> </ul>
b) Conduct lake survey.	1-2 months	Field team	➤ Assessed glacial lake(s)

			<p>through:</p> <ul style="list-style-type: none"> <li>● Bathymetry (depth, area, and volume) survey.</li> <li>● Shoreline of lake mapped using GPS.</li> <li>● End-moraine characteristics (slope, grain-size distribution, slope-stability, and dead-ice-distribution) study.</li> <li>● Study of surrounding morphology (lateral moraines/ slopes and feeding glaciers).</li> <li>● Discharge measurement at outlet.</li> </ul>
c) Analyze and process data	1 month	Field team	<p>➤ Processed field-data:</p> <ul style="list-style-type: none"> <li>● Bathymetry data.</li> <li>● Geotechnical parameters.</li> <li>● Discharge data.</li> </ul>
d) Submission of scientific report	2 months	Field team	<p>➤ Standard/comprehensive scientific report submitted.</p>
e) Data archival.	1 week	Field team and data focal.	<p>➤ All data (both Raw and processed) submitted to data focal for official archival.</p>
<b><i>07.02 Prepare Glacial lakes inventory &amp; Potentially Dangerous Glacial Lakes.</i></b>			
<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Output/Result</b>
a) Data acquisition	2 weeks	Glacial lake mapping team	<p>➤ Satellite imageries acquired/downloaded.</p>
b) Process satellite imageries	1 month	Glacier mapping team	<p>➤ Refined imageries produced for further analysis.</p> <ul style="list-style-type: none"> <li>● Atmospheric correction.</li> <li>● Ortho-rectification.</li> <li>● Shadow removal.</li> <li>● Filtering clouds.</li> <li>● Generating geo-tiff.</li> </ul>

c) Glacial lake mapping	1 months	Glacial lake mapping team	➤ Glacial lake boundary digitized.
d) Data analysis	1-2 month	Glacial lake mapping team	➤ Analyzed glacial lakes through the following steps. <ul style="list-style-type: none"> <li>● Assign glacial lake attributes.</li> <li>● Set criterion for PDGL.</li> <li>● Review existing PDGL and identify new PDGL.</li> <li>● Compare the results (area, number) with existing inventories.</li> <li>● Accuracy assessment.</li> </ul>
e) Report submission.	1 month	Glacial lake mapping team	➤ Standard/comprehensive scientific report generated and submitted.
f) Data archival.	1 week (after report submission)	Glacial lake mapping team and data focal	All data (both Raw and processed) submitted to data focal for official archival.

***07.03 Preparing and updating of GLOF hazard maps in selected basins in collaboration with other divisions and related agencies.***

<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Output/Result</b>
a) Plan fieldwork as per target activities, budget and schedule.	1 month	GLOF hazard mapping team	➤ Desk studies carried out. ➤ Logistics (ponies, testing & calibration of field equipment) arranged. ➤ Special route permit as per RBA regulations arranged. ➤ Budget mobilized.
b) Data acquisition	3 weeks	GLOF hazard mapping team	➤ High resolution satellite imageries and DEM acquired and prepared.

c)Field work	1-2 months	GLOF hazard mapping team	<ul style="list-style-type: none"> <li>➤ Hazard assessment in the targeted basin through: <ul style="list-style-type: none"> <li>● Bathymetry survey of targeted lake(s) conducted.</li> <li>● Shoreline of lake (s) mapped using GPS.</li> <li>● Geotechnical data of moraine dams collected.</li> <li>● River cross section data collected.</li> </ul> </li> </ul>
d)Set up and run hydro-dynamic model	3 months	GLOF hazard mapping team	<ul style="list-style-type: none"> <li>➤ GLOF hazard map produced.</li> </ul>
e) Submission of scientific report	2 months	GLOF hazard mapping team	<ul style="list-style-type: none"> <li>➤ Scientific report submitted.</li> </ul>
f) Data archival.	1 week (after report submission)	GLOF hazard mapping team and data focal.	<ul style="list-style-type: none"> <li>➤ All data (both Raw and processed) submitted to data focal for official archival.</li> </ul>

## 08. SOP for Cryosphere Information & Management Section (CIMS)

### *Functions of CIM:*

- Compile and archive up to date cryosphere data.
- Maintaining updated inventories on snow, glacier, and glacial Lake and make timely publication.
- Compilation and archiving of reports, data and publications related to cryosphere.
- Data ingestion and operation of Cryosphere Information Hub-linked with NCHM web-server.
- Data processing and analysis to generate reliable information (long term goal).
- Provide cryosphere data and information for end users.

***08.01 Compile reports, data(field), satellite imageries in Cryosphere Information Hub and Maintain data repository systematically.***

<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Outcome/result</b>
a) Compile Cryosphere data including stake data, snow-field data, dGPS-data, field-photographs, discharge measurement-data etc into database and maintain backup on regular basis.	Every end of field season	Data focal in collaboration with field team	➤ Archived digital data.
b) Compile publications, article, scientific paper and scientific reports related to snow and glaciers in Bhutan.	As and when required	Data focal	➤ Archived digital information (publication, article, scientific report, etc.)

***08.03 Data ingestion and operation of Cryosphere Information Hub-linked with NCHM web-server***

<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Output/Result</b>
a) Ingest data and information (publication/scientific report) related cryosphere in Bhutan using web interfaces(geonet/NCHM-database) disseminate through media (CIH)	As and when required	Data focal	Metadata prepared for each data(publication/article/report) and disseminated through website
b) Record snow across the country <ul style="list-style-type: none"> <li>● Snow depth</li> <li>● SWE</li> <li>● Density</li> <li>● Snow incidence</li> </ul>	Daily	Data focal	➤ Maintained up to date record.
c)Generate Snow cover map	Seasonally	Data focal	➤ Generated snow cover maps from available satellite imageries.

***08.04 Provide cryosphere data and information for end users.***

<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Output/Result</b>
a) Render cryospheric data to	As and	Data focal	➤ Data provided based on

user(s) upon instruction from Division head on Data request.	when required		Data sharing guidelines of the Center.
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### 09. SOP for Common Services under the Division.

#### **09.01 Planning, organizing meetings, submitting proposals for Divisional fiscal year Budget, Five Year Plan(s), APT, and update status on Budget.**

Action	Time Frame	Operator	Outcome/result
a) Prepare budget proposal in coordination with Division upon instruction from the management.	1-2 weeks	Budget focal	<ul style="list-style-type: none"> <li>➤ Proposed budget for the Division through: <ul style="list-style-type: none"> <li>● Activity description.</li> <li>● Period of performance.</li> <li>● Estimation of cost.</li> <li>● Justification and write up.</li> </ul> </li> </ul>
b) Report budget balance statement, prepare mid-term budget report and submit as per the template.	1-2 weeks	Budget focal in collaboration with accounts section.	<ul style="list-style-type: none"> <li>➤ Submitted budget utilization report, mid-term report and appropriated depending on the need of the Division.</li> </ul>
c) Prepare APT in coordination with Head and NCHM APT focal for CSD and keep track of division activities in line with APT.	1-2 weeks	APT focal	<ul style="list-style-type: none"> <li>➤ APT submitted</li> </ul>
d) Prepare and update (planned) five year plan activities pertaining to the Division .	2-3 weeks	FYP focal	<ul style="list-style-type: none"> <li>➤ Updated Division timely to keep Divisional activities on track with FYP.</li> </ul>

#### **09.02 Maintenance of CSD stocks, scientific equipment and goods under CSD**

Actions of CMS	Time Frame	Operator	Output/Result
a) Maintain stock ledger for consumable & fixed assets for delivered stocks and issue	Routine work	Store in-charge	<ul style="list-style-type: none"> <li>➤ Stock ledger and good receipt note maintained up to date.</li> </ul>

good receipt notes for further payments(s).			
b) Maintain inventory for CSD equipment, gear, survey tools and machineries.	Routine work	Store in-charge	➤ Maintained inventories up to date.
c) Issue requested equipment with proper handing-taking upon approval for hiring of equipment.	As and when required	Store in-charge	➤ Equipment issued with proper hand-taking.
d) Check and charge rechargeable batteries (9V& 12 V) of walki-talki, satellite phone, Drone, Ice-radar, field note-book and additional.	Regularly	Assigned officer	➤ Kept batteries healthy.
<b>09.05 Ad-hoc services</b>			
<b>Actions of CMS</b>	<b>Time Frame</b>	<b>Operator</b>	<b>Output/Result</b>
a) Bathymetry services <ul style="list-style-type: none"> <li>● Field preparation</li> <li>● Field work</li> <li>● Data analysis</li> <li>● Report writing</li> </ul>	The report will be delivered within a month of field work completion.	Assigned team	➤ Bathymetry report submitted including: <ul style="list-style-type: none"> <li>● Depth.</li> <li>● Bottom topography.</li> <li>● Volume.</li> <li>● Shoreline.</li> </ul> <i>Note*: Result shall be based on client's specific request.</i>
b) Aerial mapping using UAS	The report will be delivered within a month of field work completion.	Assigned team	➤ Aerial mapping report including: <ul style="list-style-type: none"> <li>● Aerial photographs</li> <li>● Georeferenced aerial photographs.</li> <li>● High resolution DEM.</li> <li>● Topographical map.</li> </ul> <i>Note*: Result to be based on client's specific request</i>





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