Bhutan Glacial Lake Inventory (BGLI) 2021

Cryosphere Services Division
National Center for Hydrology and Meteorology
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CRYOSPHERE SERVICES DIVISION
NATIONAL CENTER FOR HYDROLOGY AND METEOROLOGY,
ROYAL GOVERNMENT OF BHUTAN

The Cryosphere Services Division on behalf of National Centre for Hydrology and Meteorology has produced this work on Bhutan Glacial Lake Inventory 2021.

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FOREWORD

The first inventory of glacial lakes in Bhutan was published by ICIMOD in 2001. All references regarding the information on glacial lakes in Bhutan are being made to this inventory till date. Glacial lakes are also an important source of freshwater and act as a flow regulator for major river systems in the country. However, with climate change some of these lakes have become more of a source of natural disaster such as Glacial Lake Outburst Flood (GLOF). The magnitude of devastation of such GLOFs can be verified from the recent event in Uttarakhand, India. Bhutan has experienced a number of GLOFs in the past and the one which occurred in 1994 along Puna Tsang Chu basin is a testimony of our vulnerability to such natural hazards.

National Center for Hydrology and Meteorology (NCHM) as a scientific and technical autonomous agency was created bringing in all related fields under one umbrella. At present the center is mandated to conduct research and provide scientific services through dissemination of information in the field of weather, climate, hydrology and cryosphere to all the end users. The earlier publication on the inventory of glacial lakes in Bhutan is almost two decades old. Therefore, it has become necessary to update the information on glacial lakes in the country considering the long gap and advancement in remote sensing and GIS techniques whereby satellite imageries of better spatial and temporal resolutions are available. Glacial lakes being dynamic in nature, various changes have taken place in course of time.

We are happy to officially release the scientific report on Bhutan Glacial Lake Inventory 2021 (BGLI,2021). The information in the report is generated using the latest available high resolution satellite images which are analyzed with appropriate geoinformatics tools. The findings in this report provides a general idea on the current status of the glacial lakes in Bhutan which was achieved through extensive data analysis. We hope that the information in this report will serve the intended purpose of providing a clear picture on the status of existing glacial lakes in the country.

Karma Dupchu
DIRECTOR

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The Center would like to thank ICIMOD and SATREP for providing their earlier data set and other related information, which made the task easier for the team.

The Center remains grateful to European Space Agency (ESA) and NASAs Earth system Data and Information System for making the sentinel and SRTM DEM data freely available.

We would also like to acknowledge the contribution made by Mr.Sonam Wangcuk through valuable comments, who was a PhD student at the Department of Geography, University of Zurich, Switzerland. Lastly, we would like to extend our gratitude to UNDP Bhutan for the kind financial support for printing of this report.

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Executive Summary

Glacial lakes are common features in mountainous areas formed as a result of glacial activities. Once formed these glacial lakes grow in size in course of time, turn into huge moraine dammed lakes with a potential to outburst and cause catastrophic damages to the lives and properties of people living in the downstream area. Because of the impact of climate change, glaciers around the world have experienced accelerated melting resulting in an increasing number of glacial lakes over the past few decades. Apart from posing risk to communities and infrastructures in the downstream valleys, these lakes also serve as storage for fresh water and help in regulation of flows in the streams and rivers, which are vital for sustaining lives and maintaining ecosystems. Therefore, an updated inventory on glacial lakes in the country can serve as a primary source of information for any scientific studies as well as basis for various socio-economic developmental planning in the country.

There are very few inventories published on glacial lakes in Bhutan so far. The first inventory on glacial lakes in Bhutan was published by International Center for Integrated Mountain Development (ICIMOD) in 2001 and later in 2011, an updated inventory of glacial lakes was published through the project titled "Science and Technology Research partnership for Sustainable Development (SATREPS) implemented under the assistance of JICA. The present report on the glacial lake inventory, which is the most recent updated inventory, is an indigenous product published by the National Center for Hydrology and Meteorology using the latest and more refined satellite images and Remote Sensing techniques.

In total there are 567 glacial lakes identified covering an area 55.04±0.055 km^2 within the four river basins of Bhutan. Glacial lakes in Bhutan account for 19.03% of the total numbers of water bodies and 0.14% of total land area of Bhutan.

Introduction

Due to the impact of climate change, glaciers in high mountain regions are experiencing accelerated retreat rate. Moreover, glaciers in Eastern Himalaya receive much higher summer precipitation (Hoy, Katel, Thapa, Dendup, & Matschullat, 2016) compared to the western Himalaya. This type of summer accumulating glaciers in Bhutan has a more negative mass balance (AGETA et al., 2001) resulting in higher recession rate. This response of glaciers to changes in global and regional climate leads to formation of new glacial lakes. Extension and expansion of lakes on the south facing glaciers were found to be in the range of 35-70 m yr^{-1} and < 0.04km^2 $year^{-1}$ respectively, while those lakes in northern range were found to be 10-40m $year^{-1}$ and <0.03km^2 (FUJITA et al., 2012) for the lakes of Bhutan during the late 1960s to early 2000. South facing glaciers are experiencing higher rates of retreat compared to north facing glaciers (Ageta et al., 2000). This difference in growth rate of lakes in the north and south facing aspect are attributed to different glacier velocity (Fischer, Kääb, Huggel, & Noetzli, 2006). It has been reported that glacial lakes in Bhutan Himalaya were formed wherever the glacier surface inclination is less than 2° (Reynolds, 2000) while others found that lakes developed wherever there is low slope and surface velocity of glaciers is less than 10 ma^{-1} (Quincey et al., 2007). Surface lowering rate for Thorthomi and Luggye glaciers are 0-3m a^{-1} and 5 m a^{-1} respectively in 2002-2004 (Ukita et al., 2011). However surface lowering for Jichu Dramo Glacier, a small debris free glacier from 2003-2010 was found to be 3-4 m a^{-1}. All these active glacier activities result in formation of new lakes, expansion of existing supra glacial ponds and increase in water level in the proglacial lakes. Some earlier records of areal expansion of glacial lakes compiled through topographic map and satellite image by (Ageta et al., 2012; Fujita & Ageta, 2000; Komori, 2008) has shown that formation of small lakes in ablation part of the glaciers which later coalesce to form larger lakes.

Those glacial lakes which were formed are either dammed by moraine walls or ice from the tributary glaciers. Due to various factors such as increase in hydrostatic pressure from accumulation of water from excessive melting of glaciers or external factors such as earthquake, avalanches and rock/landslides, these lakes outburst causing catastrophic floods in the downstream called Glacial Lake Outburst Floods (GLOFs). Bhutan had experienced a total of 21 GLOFs in the past and only 6 cases were reported in literature while remaining 15 was detected using field survey data based on Corona KH-4A, Hexagon KH9-9, Landsat 7/ETM+, and ALOS PRISM satellite imageries (FUJITA et al., 2012). There are still numerous moraine dammed lakes identified with potential of causing GLOF in the future (Samjwal Ratna Bajracharya, Mool, & Shrestha, 2007). Besides associating with disaster of GLOFs, these glacial lakes are also known to serve as water reservoirs and natural regulators. Therefore it is imperative to have a regularly updated inventory of glacial lakes in the country which can provide vital information for decision makers and planners to plan any developmental activities in the country. The first inventory which was officially published on the glacial lakes in Bhutan was by the International Center for Integrated Mountain Development (ICIMOD) in 2001. This publication had served as all official references regarding glacial lakes in Bhutan till date.

Rationale

The inventory of glaciers and glacial lakes published by ICIMOD in 2001 is being used for all official referencing purposes so far for glacial lakes in Bhutan. Although there were few other inventories of glacial lakes in Bhutan published by individual researchers and institutes but those are focused either on regional coverage or on specific research purpose. The only official country focused inventory on glacial lakes published by ICIMOD is about two decades old. Considering the dynamic nature of glaciers and glacial lakes under the influence of the impact of climate change, a need was felt to have an updated and country focused inventory of glacial lakes in Bhutan, which can be used for all official referencing hereafter. The present inventory has been prepared to meet this objective using the most recent high quality base materials and techniques.

Data set

The inventories compiled earlier were based on topographic maps of 1950s and 1960s, Landsat Thematic mapper (TM/ETM+) (Mool et al., 2001), ALOS data (10m) and Shuttle Radar Topography Mission (SRTM) Digital Elevation Models (DEM) (Ukita et al., 2011). The Landsat Thematic Mapper (TM) sensor was decommissioned in 2012 after 27 years of its service. Sentinel-2 was launched on 23rd June 2015 and it operates with Multispectral Instrument (MSI). Sentinel imagery has been made freely available to the users through the European Space Agency (ESA) Copernicus Open Access Hub (https://scihub.copernicus.eu/) with improved spatial (10m) and temporal resolution. For this inventory considering both resources and technical capacity, Sentinel images from the year 2018 were used. Fourteen Scenes of Sentinel-2 images covering the whole of Bhutan with the least cloud and snow cover and minimum shadow effect were selected. The details of the images are given in Table 1.

Table 1: Detail of sentinel-2 MSI scenes used for glacial mapping

#	Image ID	Sensor	Sensing date
1	*COPERNICUS/S2/20181101T043929_20181101T044117_T45RYL*	*MSI, Level-1C*	*01/11/2018*
2	*COPERNICUS/S2/20180917T043701_20180917T044308_T46RBR*	*MSI, Level-1C*	*17-09-2018*
3	*COPERNICUS/S2/20180929T042659_20180929T043512_T46RBS*	*MSI, Level-1C*	*20-09-2018*
4	*COPERNICUS/S2/20180922T043659_20180922T044344_T45RYM*	*MSI, Level-1C*	*22-09-2018*
5	*COPERNICUS/S2/20181108T042959_20181108T043611_T46RCR*	*MSI, Level-1C*	*08-11-2018*
6	*COPERNICUS/S2/20180907T043701_20180907T044447_T46RBS*	*MSI, Level-1C*	*07-09-2018*
7	*COPERNICUS/S2/20181123T043101_20181123T043857_T46RBR*	*MSI, Level-1C*	*23-11-2018*
8	*COPERNICUS/S2/20181009T042659_20181009T044031_T46RCS*	*MSI, Level-1C*	*09-10-2018*
9	*COPERNICUS/S2/20180917T043701_20180917T044308_T45RXL*	*MSI, Level-1C*	*17-09-2018*
10	*COPERNICUS/S2/20181101T043929_20181101T044117_T45RYK*	*MSI, Level-1C*	*01-11-2018*
11	*COPERNICUS/S2/20180102T043149_20180102T043943_T46RBQ*	*MSI, Level-1C*	*02-01-2018*
12	*COPERNICUS/S2/20181123T043101_20181123T043857_T46RCQ*	*MSI, Level-1C*	*23-11-2018*

13	*COPERNICUS/S2/20181101T043929_20181101T044117_T45RXK*	*MSI, Level-1C*	*01-11-2018*
14	*COPERNICUS/S2/20181213T043151_20181213T043713_T46RDQ*	*MSI, Level-1C*	*13-12-2018*

Since there were some difficulties found associated with differentiating glacial lakes from shadows formed by the surrounding mountains, terrain analysis was carried out using SRTM DEM. The SRTM DEM was obtained from NASAs Earth system Data and Information System (https://reverb.echo.nasa.gov/). Previously SRTM DEM (SRTM Version 3.0 Global (90m)) data for regions outside the USA were available at 90m resolution, however in 2015 SRTM version 3.0 (SRTMV3) with 30m resolution was made available for the Asian region. The 30m resolution SRTM DEM was used to extract relief of the mountain topography in the present work.

Information from the earlier inventories published by ICIMOD and SATREP project were used for change detection. The location and the physical features of the lakes mapped were further validated using Google Earth image using Universal Transverse Mercator projection (UTM zone 45N and 46N in world Geodetic System 1984 ellipsoidal elevation WGS84).

Sentinel-1, Synthetic Aperture Radar (SAR) imageries were used to automatically delineate water bodies for this current work. Freely available, Sentinel 1 SAR images of 2018 covering the whole country were compiled as shown in Table 2. The Sentinel-1 mission comprises a constellation of two polar-orbiting satellites (Sentinel 1A and Sentinel 1B), operating day and night performing C-band synthetic aperture radar imaging, enabling them to acquire imagery regardless of the weather. Sentinel-1A was launched on 3 April 2014 and Sentinel-1B was launched on 25 April 2016. The S-1 satellites both have a temporal resolution of 12 days, allowing image acquisition every 6 days (Copernicus. 2018b).

Table 2: Detail of Sentinel 1 SAR C-band images used for glacial mapping

#	Image ID	Sensor	Sensing date
1	*COPERNICUS/S1_GRD/S1A_IW_GRDH_1SDV_20180501T120524_20180501T120549_021711_02573C_AD8E*	*SAR C-band*	*01/05/2018*
2	*COPERNICUS/S1_GRD/S1A_IW_GRDH_1SDV_20180508T115708_20180508T115733_021813_025A6C_5AD8*	*SAR C-band*	*08/05/2018*
3	*COPERNICUS/S1_GRD/S1A_IW_GRDH_1SDV_20180501T120459_20180501T120524_021711_02573C_BCC1*	*SAR C-band*	*01/05/2018*

Methodology

The delineation of water bodies using sentinel images (sentinel 1 and sentinel 2) can be carried out using automatic and semi automatic techniques. Using and depending fully on the automatic technique to map water bodies (lakes) has various drawbacks and glitches as the process is entirely left to the RS software used. On the other hand the semi automatic technique is a method in which minor issues and problems faced in the automatic process is minimized with expert (human) intervention by rectifying the mistakes committed by the software. Therefore, in the current work on the preparation of this inventory on glacial lake, semi automatic technique was used which is shown in figure 1.

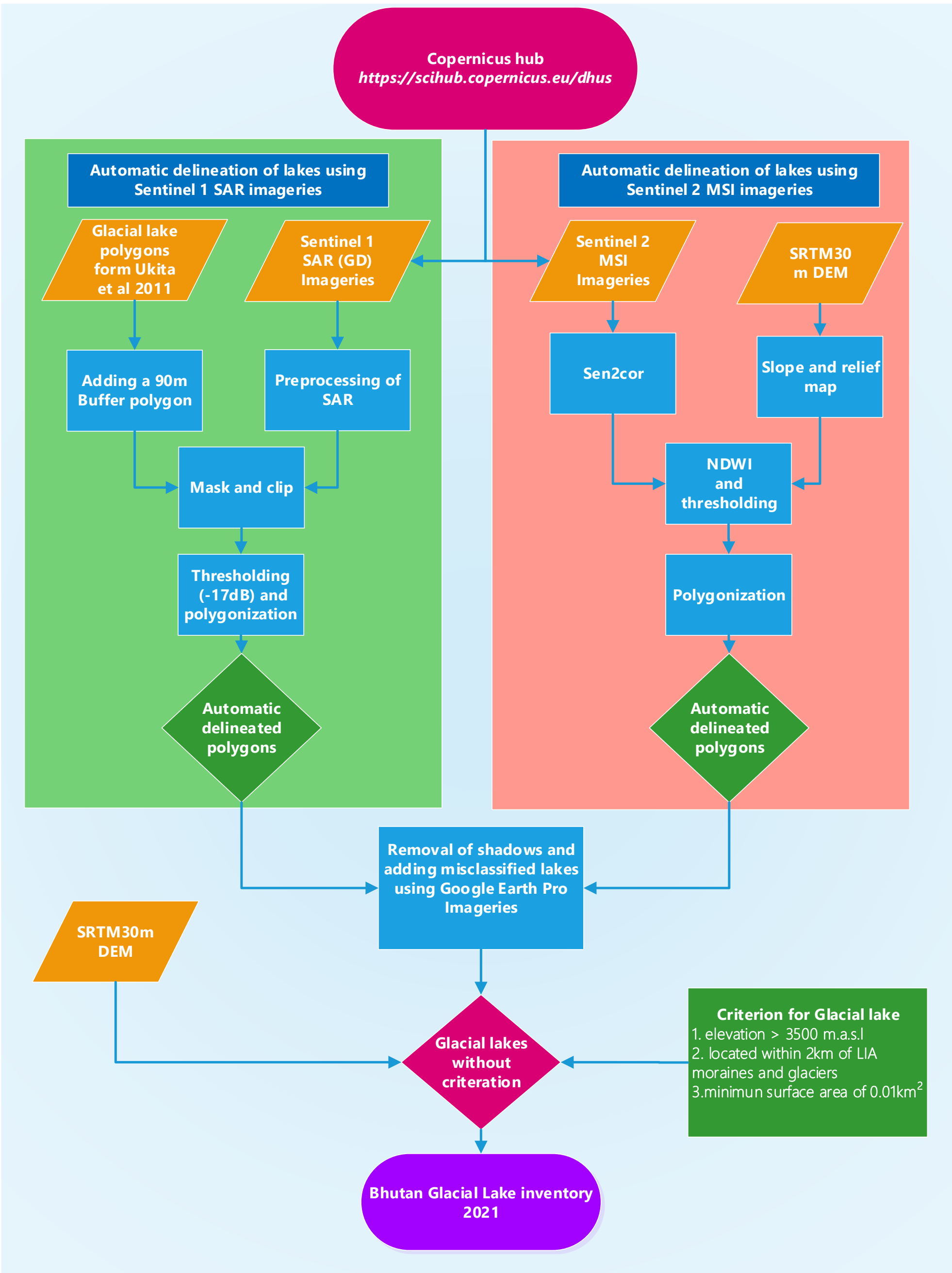


Figure 1: Workflow for semi-automatic delineation of glacial lake using both Sentinel 1 (SAR) images and Sentinel-2 MSI.

The stepwise approach along with detailed methods are presented in the following section:

- Automatic delineation of all water bodies visible on SAR imagery.
- Automatic delineation of lakes using NDWI index using sentinel-2 imageries.
- Overlapping both the automatic delineated polygons (sentinel 1 and 2) in Google Earth and manual removal of shadows and miss-classified lakes.
- Applying the criteria for lakes to be considered as glacial lakes.

Automatic Delineation of water bodies from SAR Imagery using Image segmentation processes

Image segmentation is the process or technique of partitioning a digital image into several sets of pixels. This segmentation process is the fundamental step for image analysis, object representation, visualization and other image processing tasks that is applied in various fields of applications. The main purpose of image segmentation is to simplify and/or change the respective image sample into an easily analysed image. Thresholding is a simple but most effective technique in segmentation. It is based on classifying image pixels into objects and backgrounds depending on the relation between the grey level value of the pixels and the threshold. For our study, we went with the Otsu method of thresholding with local thresholding for which a threshold value is assigned to each intensity pixel to determine whether it is a water-body pixel or non-waterbody pixel using the backscattering intensity of the image. The detailed procedures are as follows:
Pre-processing of SAR imageries

The downloaded images of Sentinel 1 (SAR) were fed into the Sentinel Application Platform (SNAP) for analysis and processing. Sentinel 1 (SAR) carries a single C-Band synthetic aperture radar instrument operating at a centre frequency of 5.405 GHz. The passive sensor is effective to carry out image capturing even during adverse weather conditions.
A set of Sentinel 1 SAR data from April to June 2018 (summer duration) were downloaded from Copernicus Hub. The processing of Sentinel 1 SAR data involves selecting a region of interest in imagery, radiometric calibration[1], geocoding[2], co-registration, and backscatter calculations which are operated using the Sentinel-1 Toolbox (S1TBX) in SNAP application to derive the sigma naught (σ_o) (radar backscattering) products, which represents the normalized radar echoes from distributed ground targets (Wangchuk, Bolch, & Zawadzki, 2019). The unscaled intensity (σ_o) image is then converted to decibel (dB) using the following expression (σ_{dB}) (Small 2011).

$$\boldsymbol{\sigma dB = 10\log10(\sigma 0)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(1)}$$

After the calibration, the images are geo-orthorectified and geocoded using the SRTM1 DEM (30 m) via Range Doppler Terrain Correction (RDTC) and SAR simulation Terrain

[1] A number of factors, such as atmospheric absorption, scattering, sensor-target-illumination geometry, sensor calibration, influences spectral data acquired by satellite sensors and image data processing procedures, which tend to change through time therefore, it is necessary to carry out **radiometric correction** to rectify these errors.

[2] **Geocoding** is the process where it converts address into spatial data and associates the exact geographical coordinates for that address. It is used in geographical information systems to help find the coordinates of a place or address.

Correction. The final product generated as a geotiff file with a pixel resolution of 10 m are exported to GIS analysis tools (ArcGIS) for further analysis.

Threshold determination and lake mapping.

To determine a threshold to segregate a water-body pixel from non-water body pixel in Sentinel 1 images, sets of Lake Polygon from (Ukita et al., 2011) are overlaid on sentinel 1 image (SAR) and a buffer of 90 m was introduced around the polygon. This was carried out to generate a bimodal histogram from which a desired threshold value is taken to delineate lake and non- lake pixel as shown in Fig. 2 (Y. Li et al., 2016; Wangchuk et al., 2019).

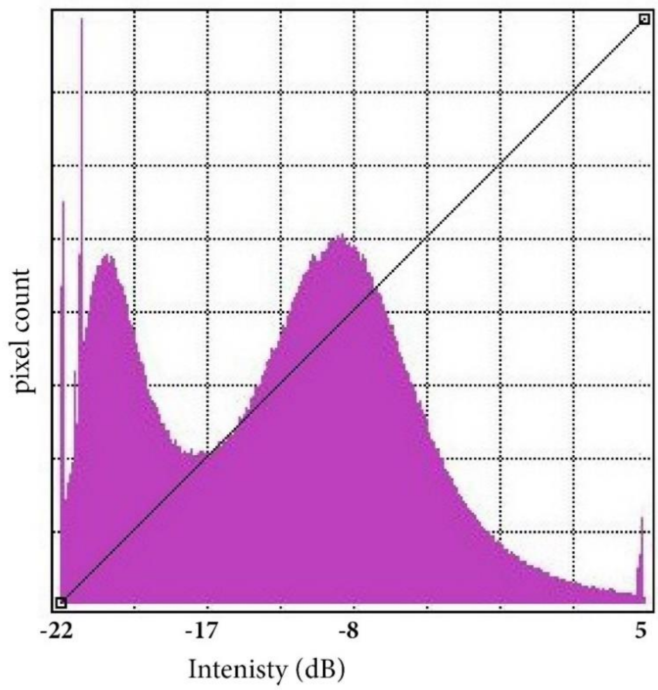


Figure 2: Bimodal Histogram of water and non-water pixel

For the present work a backscatter value of -17(dB) revealed much accurate delineation between water and non-water pixels. This threshold was determined using the bimodal histogram from the backscattering intensity following (Wangchuk et al., 2019). Using a raster calculator the backscattered intensity pixel values greater than -17dB were classified as non-water and pixel values less than -17dB as water bodies as shown in figure 2.

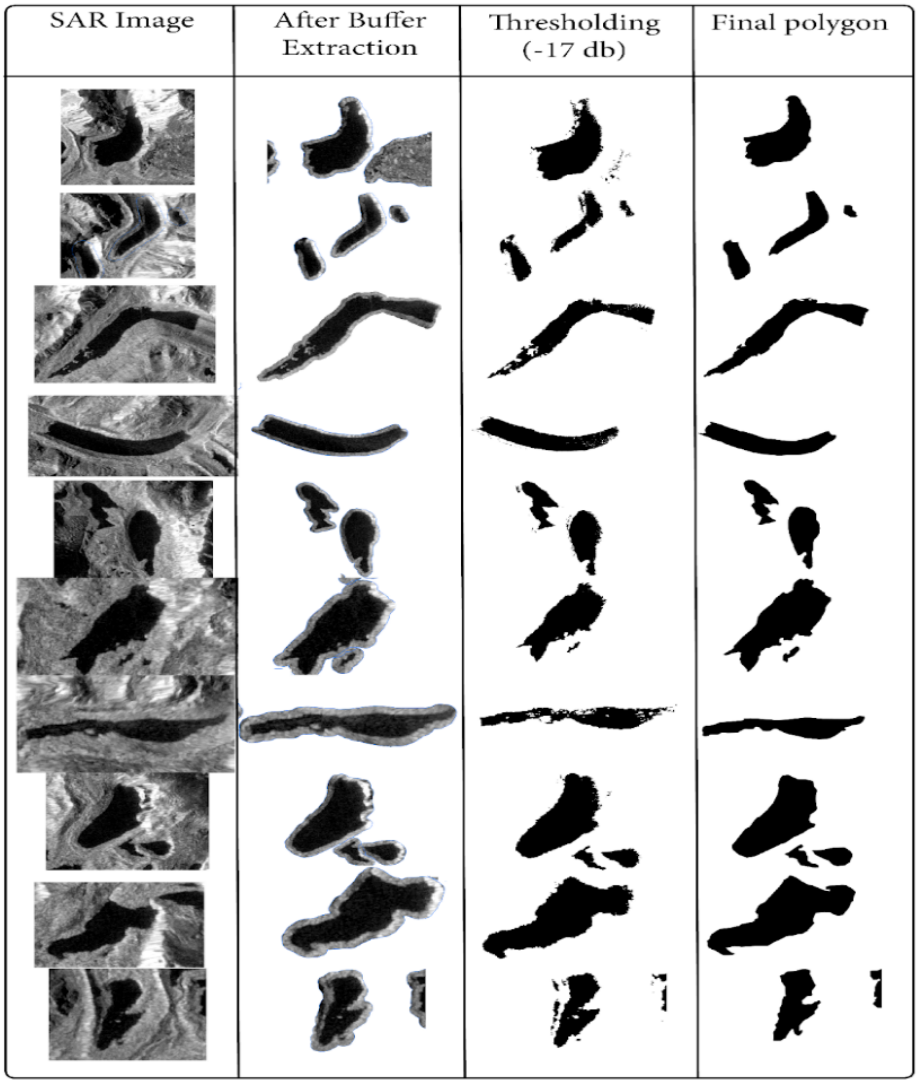


Figure 3: Automated mapping of Glacial lake in SAR image using threshold value (-17dB).

A mask was generated using the threshold containing all the water body pixel values and was polygonised to get an automatic generated lake polygon. The outcome of this approach is as shown in figure 3. This approach eliminates all the non-water pixels, however the newly formed lakes that are not present in the (Ukita et al., 2011) were not included; hence, we had to go for an additional method of automatic delineation from Sentinel 2 Images, which was used as a supplement to validate the automatically delineated lake polygons from Sentinel 1 SAR imagery.

Automatic delineation using NDWI (Sentinel 2 MSI)

The downloaded Sentinel 2 image was fed to the Sentinel Application Platform (SNAP) for further analysis. This image initially is composed of 13 spectral Channels (*Table.3*) of different spatial resolution (Band 2, 3, 4, 8 =10 m, Band 5, 6, 7, 8a, 11, 12 =20 m, and Band 1, 9, 10 = 60 m) (Yang et al., 2017). The bands 5, 6, 7, 8a, 11, 12, 1, 9, 10, were resampled to 10 m resolution in the SNAP tool. These images obtained are visualized in false color composite (band 8, 4 and 3, corresponding to red, green and blue respectively) (*Figure 4*). Here the delineation of water bodies is carried out using Normalized Difference Water Index (NDWI) as defined by McFeeters (McFEETERS, 1996)in which this normalized ratio between green and near Infrared (NIR) spectral bands enhances the water features and suppresses other surrounding ground features. The formula is defined as follows:

$$\mathbf{NDWI} = (\varrho\mathrm{Green} - \varrho\mathrm{NIR}) / (\varrho\mathrm{Green} + \varrho\mathrm{NIR}) \qquad \text{-------- (2)}$$

Where ϱGreen and ϱNIR are Bottom of Atmosphere (BOA) reflectance for green and NIR bands, respectively. Glacial lakes being dynamic in nature, their physical form keeps on changing with an increased rate of melting from feeding glaciers and deposition of suspended silt into the lakes. This makes the lakes show different spectral characteristics and makes it even more difficult to segregate glacial lakes with one single NDWI value (Huang et al., 2011).

To delineate glacial lakes distinctly we have incorporated more than one threshold value in this case. Further to assist this approach of mapping from surrounding features, terrain analysis through SRTM DEM data is used. SRTM DEMv3 is used to compute slope and shaded relief to map the glacial lakes located in mountain and cloud cover areas. Surface gradient less than 10° (Quincey et al., 2007)and shaded relief values higher than 0.25 (J. Li & Sheng, 2012) was used in our method to define a glacial lake.

Table 3: Detail of spectral bands of Sentinel-2 with central wavelength (µm) and spectral resolution (m) used for glacial lake mapping.

Band	Band Number	Central Wavelength (µm)	Resolution
Coastal aerosol	*Band 1*	*0.443*	*60*
Blue	*Band 2*	*0.49*	*10*
Green	*Band 3*	*0.56*	*10*
Red	*Band 4*	*0.665*	*10*
Vegetation Red Edge	*Band 5*	*0.705*	*20*
Vegetation Red Edge	*Band 6*	*0.74*	*20*
Vegetation Red Edge	*Band 7*	*0.783*	*20*
Near Infrared (NIR)	*Band 8*	*0.842*	*10*
Vegetation Red Edge	*Band 8A*	*0.865*	*20*
Water Vapour	*Band 9*	*0.945*	*60*
SWIR-Cirrus	*Band 10*	*1.375*	*60*
Short Wave Infrared (SWIR)	*Band 11*	*1.61*	*20*
Short Wave Infrared (SWIR)	*Band 12*	*2.19*	*20*

Through this method of mapping all glacial lakes formed by glacier melt and located on the glacier surface are included. This method has also taken into consideration the glacial lakes located in lowland formed by paleo-glaciation. However, it excludes englacial and subglacial lakes that are not captured in optical satellite images. The figure 3 shows the NDWI mask generation where white pixels are water bodies and the black pixels as non-water bodies.

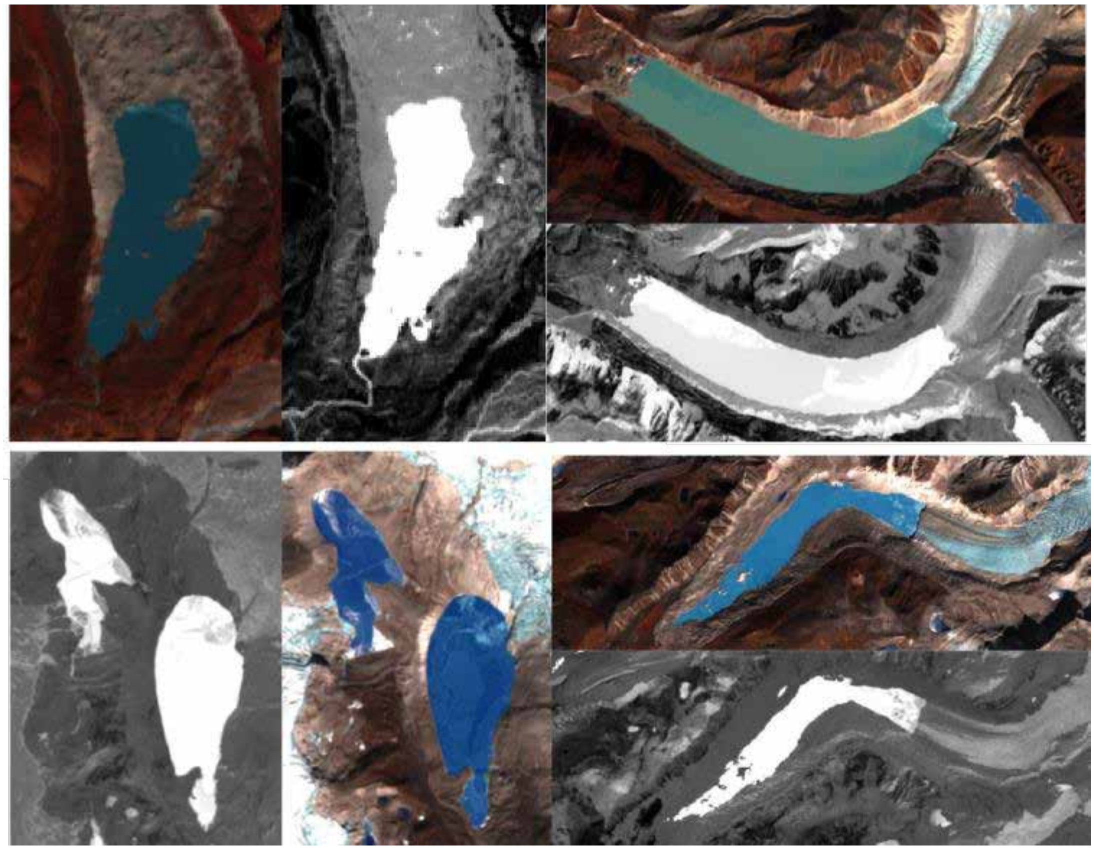


Figure 4: Glacial lake classification using NDWI overlaid on Sentinel-2 false Color composite.

Removing shadow and miss-classified lakes

The two automatically generated lake polygons (using step 1 and step above) are then converted to .kmz file format and overlaid on Google Earth Images, which has a better image resolution to be considered as base map. The misclassified lake polygons which were shadows, bare land and rocks but classified as water bodies in the above steps were then manually removed (*Fig.5*) using google earth images as base reference. Similarly, water bodies that were misclassified as non-water pixels were also added using the latest available image of that area from Google earth. The final lake polygons were then converted from kmz file to shape file for further processing.

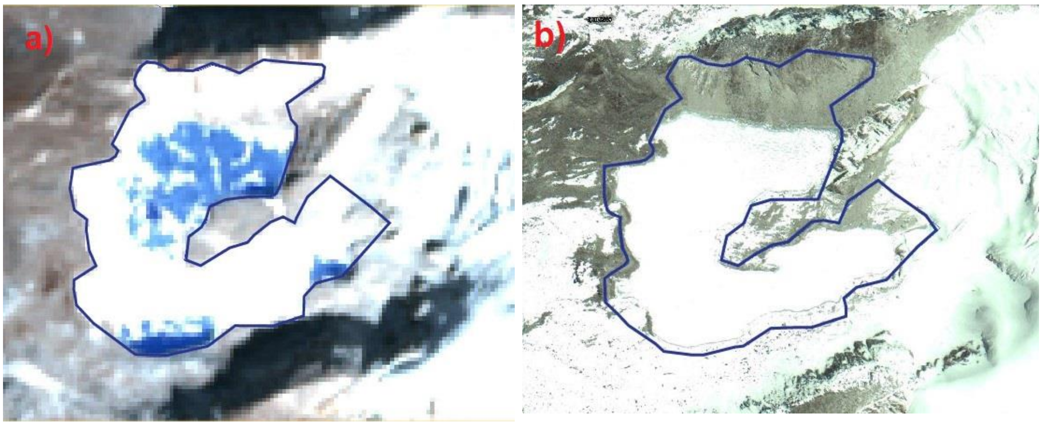


Figure 5: 5a) Mis-classified Glacial Lake in Sentinel-2 image. 5b) validated the glacier polygon

Glacial lake attributes

Once glacial lake polygons are generated, attributes are generated in ArcGIS in accordance with the protocol set by Global Land Ice Measurement from Space (GLIMS) community (Racoviteanu, Paul, Raup, Khalsa, & Armstrong, 2009). Other glacial lake attributes such as area, elevation, range and type are generated in a similar manner to that of Bhutan Glacier Inventory (NCHM, 2018). Assigning of Glacier lakes ID was carried out in line with guidelines from World Glacier Inventory (WGI) guidelines (Cogley, 2009; Paul et al., 2009).

A brief description on the convention for assigning of the glacial lake attributes is given in the following section and for ease of comparison the method used for mapping of glacial lakes adopted by ICIMOD (Mool et al., 2001) was followed.

Numbering of glacial lakes:
The numbering of the lakes starts from the outlet of the major stream and proceeds clockwise round the basin.

Longitude and latitude:
Reference longitude and latitude were designated for the approximate center of the glacial lakes.

Area:
The area of the glacial lakes are determined from the attribute table after digitization and smoothing of the lake polygons from sentinel 1 SAR images cross checked and verified with Sentinel-2 and Google Earth images.

Altitude:
The altitude was registered by the water surface level of the lakes in m.a.s.l.

Local names:
Wherever the lake has local names it has been attributed.

Glacial Lake Criteria

Area Threshold

Different researchers in preparing inventory of glacial lakes used various area thresholds. Some of the researchers used an area threshold of >0.01km^2 to define a glacial lake (Ukita et al., 2011) whereas others used >0.0045km^2 (J. Li and Y Sheng, 2012). There are some inventories where the area threshold was not even included as criteria for defining a glacial lake (Mool et al, 2001). In the present work while preparing this inventory for glacial lakes in Bhutan an area threshold of >0.01km^2 was taken similar to Ukita et al, 2011.

Elevation Threshold

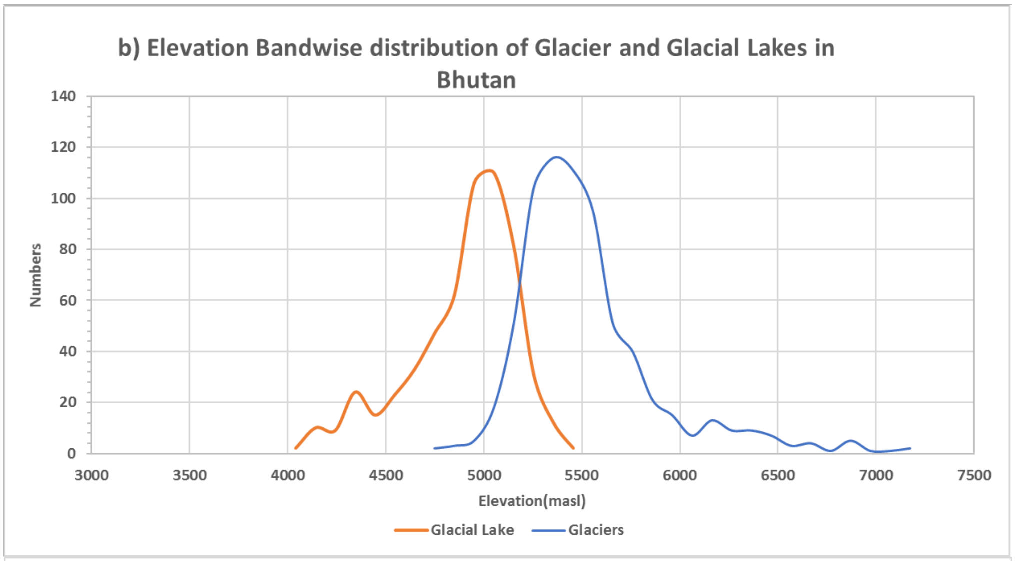
Since not all lowland water bodies are fed by glaciers and formed by glacial activities, this report has excluded low-lying water bodies from the list of glacial lakes. Referring to glacier distribution in Bhutan (NCHM, 2018) and in compliance to earlier published scientific reports (Ukita et al., 2011), elevation threshold of 3500m.a.s.l. was set.

LIA Proximity

In the inventory of glacial lakes in Bhutan published by ICIMOD in 2001, all water bodies lying above 3500 m.a.s.l were considered as glacial lakes irrespective of proximity to the glacier or glacial features formed during Little Ice Age (LIA) and the source feeding the lakes. An additional criteria for defining a glacial lake from the perspective of source feeding the lake has been considered in this inventory. Adopting this criteria, all water bodies (lakes) located between LIA moraine and glacier snout and/or lying within a proximity of 2 km downstream from the LIA moraine (Ukita et al., 2011) were confirmed to be fed by meltwater from the glaciers located in the upstream. Therefore, all those water bodies (lakes) have been considered as glacial lakes in the present inventory.

Hypsometry

An analysis to have clear picture on the glacial lake distribution pattern in different elevation band was carried out. Based on the hypsometry generated it is observed that all glacial lakes in Bhutan are located within the elevation range between 4062 m.a.s.l to 5507 m.a.s.l. (Fig.6a,Blue). It is also clear from the figure 6a that numbers of larger glacial lakes are mostly found in elevation band of 4750 m.a.s.l to 5200 m.a.s.l. This pattern of glacial lakes distribution is mainly due to the presence of higher number of glaciers within or above this elevation band that feeds the glacial lakes (Fig.6b). Even in the recently published Glacier Inventory of Bhutan (NCHM, 2018) shows that the larger glaciers are located in this elevation range. The hypsometry pattern from the present inventory correlates well with that of the one from SATREPS project (Fig.6a)



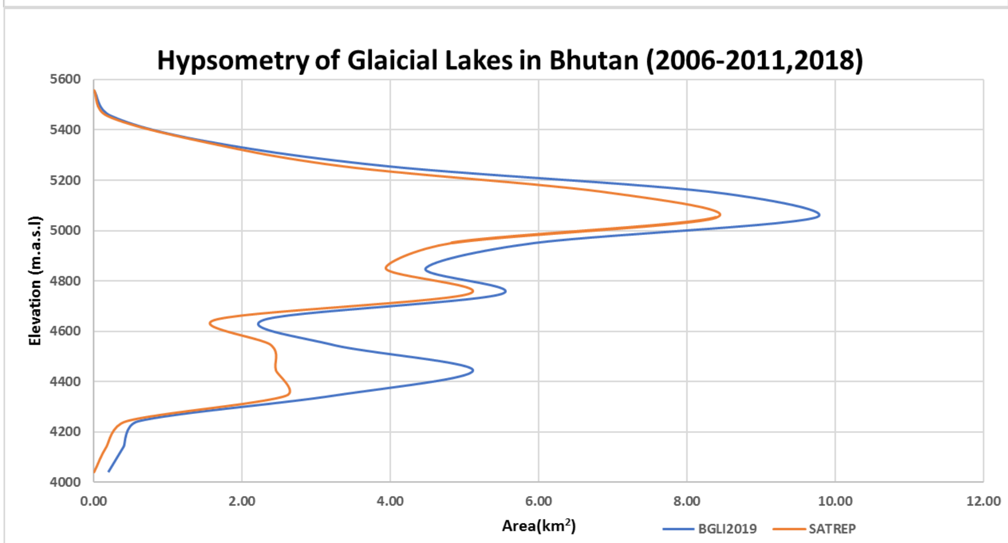


Figure 6: a) Hypsometry of Glacial lake b) Elevation Band wise Distribution of Glacier and Glacial lakes in Bhutan

Glacial Lake Classification

Different researchers such as ICIMOD, GAMDAM and individual researchers have proposed different schemes of lakes classification. Primarily, most of them are classified based on dam type and the process of lakes formation. For the purpose of this current study, the lakes were classified using the classification scheme of ICIMOD based on types of damming materials and process of formation.

Glacial lakes can be classified into the following broad categories:

1. Moraine-dammed lakes [M].
2. Ice-dammed lakes [I].
3. Erosion lakes [E].

Moraine- dammed lakes [M]

These types of lakes are dammed by moraine following glacial retreat. There are many types under moraine-dammed lakes and they are:

- End-Moraine dammed lakes[M(e)]- lakes dammed by end moraines
- Lateral moraine dammed lakes [M (l)] - lakes dammed by lateral moraines (in the tributary valley, trunk valley, or between the lateral moraine) i.e. away from the former glacial path.

Ice-dammed lakes [I]

Ice-dammed lakes formed at the side of the valley, when the main advancing glacier meets with adjoining tributary glaciers. This type of glacial lake is said to have less risk of GLOF compared to Moraine-dammed lakes.

Erosion lakes [E]

These are the lakes formed after glacier retreat and detached from mother glacier

Accuracy Assessment

Despite remote sensing techniques gaining popularity as a method to map glacial lakes in recent times, this method also has a certain degree of uncertainty. In order to minimize such uncertainties at source, data such as sentinel 1 and sentinel 2 imageries, the best quality imagery available were selected. Source data imageries with least cloud and surrounding shadows were filtered in Google Earth Engine Environment (GEE). Automated glacial lake outlines from NDWI and SAR threshold were validated by overlaying on Google Earth imageries and earlier available glacial lake inventory data. In some earlier works for preparation of glacial lake inventory in the Hindu Kush Himalayan (HKH) region, the accuracy of glacial lake mapping has been computed using Root Mean Square Error (RMSE) approach (Samjawal et al., 2020) using the following equation.

$$Root\ mean\ square\ Error\ (RMSE) = \sqrt{\frac{\Sigma_{i=1}^{n}\ (A-a)^2}{n}}$$

Where 'A' is an area of glacial lake mapped by GPS in the field, and 'a' is the area of glacial lake polygon mapped from satellite imageries. The root mean square error of 0.055km^2 has been calculated from this four set of glacial lake polygons that has been verified from field visit.

However, in absence of field based data, RMSE in their work was computed with area of the lake polygon and buffer area induced around the lake. Validation through field based data to compute the RMSE was recommended to have a realistic error value. A field based data approach to compute RMSE was adopted for glacial lake inventory of Bhutan prepared under SATREPS project (Ukita et al., 2011) with a single GPS based area data from a glacial lake. In this study, areas of four glacial lakes (*Figure.7*) measured based on GPS measurement in different field seasons were used to compute RMSE. These field data were used for validation of remotely mapped glacial lake boundaries. However, some glacial lakes show significant variation in terms of area (*figure 7d*). This is mainly due to seasonal fluctuation of lake water level since the GPS measurement and satellite images are from different seasons.

Following the above method to compute error margins in the present work in updating the inventory of glacial lakes in Bhutan, the RMSE was found to be ±0.055 Km^2

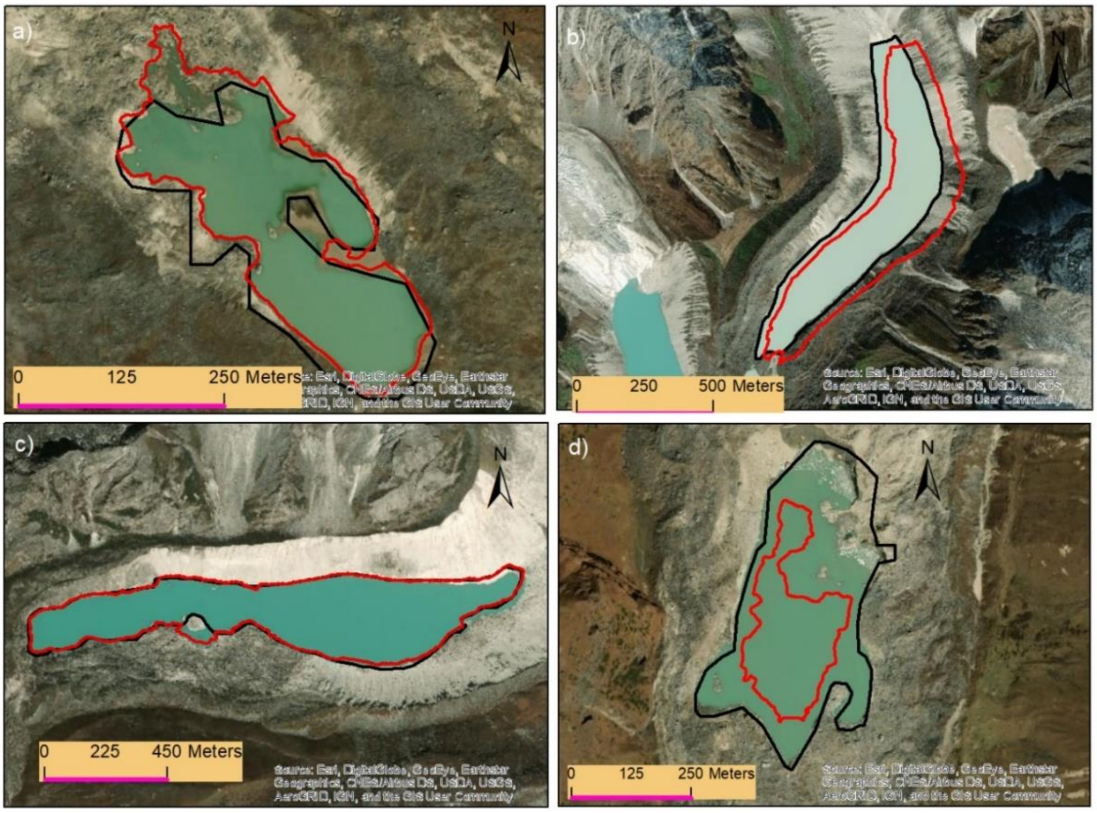


Figure 7 : Lake outlines (Red: GPS field data and Black: Mapped through semi-automated methods). 7a and 7d: Lake outlines (Red) of Lhaluphu Gom Tsho and Karma Lake in the headwaters of Paa Chhu obtained during May 2019 field survey, using Trimble R-10 2 GNSS receiver. 7c: Lake Outline (Red) of Wachay Lake, obtained using the same Trimble R10 2 in the headwater of Pho Chhu sub basin in October 2019. 7b: Lake outline of Tarina Lake II (Red) obtained in September 2016 using Promark GNSS receiver in the headwater of western part of Pho Chhu. All of the images above are overlaid on the base map of ArcGIS by Esri

Basin wise Distribution

Figure 8 shows the summary of the basin wise distribution both in term of area and number of the glacial lakes in Bhutan. The detail information's are as follows:

Wang Chhu Basin

Wang Chhu basin is in the western most part of Bhutan formed by Pa Chhu, Haa Chhu and Thim Chhu sub basins. These basins consist of 13 glacial lakes. The glacial lakes of these regions are in stable condition with end moraine M (e) dam glacial lakes dominant in numbers. Among 24 previously identified potentially dangerous glacial lakes in Bhutan, this basin consists of only one PDGL under Pa Chhu sub basin. Most glacial lakes in this region are smaller, ranging from 4332m a.s.l to 5022m a.s.l .

Punatsang Chhu Basin

Punatsang Chhu basin consists of three major sub basins namely Pho Chhu, Mo Chhu and Dang Chhu. Pho Chhu in east and Mo Chhu from west are the major tributaries of PunatsangChhu converging near Punakha Dzong. These two big sub basins have the highest number of glaciers (NCHM, 2018) and glacial lakes than any other major river basins.

Mo Chhu Sub basin

Mo Chhu is the western branch of Punatsang chhu, consisting of two tributaries one originating from Masang Gang region in East and the other from Gangchen Tag region in the west. This sub basin consists of 66 glacial lakes covering an area of 4.25 km^2. Erosional glacial lakes are more common, ranging from 4163 m a.s.l until 5295 m,a.s.l. The largest glacial lake in this sub basin is Mo_gl 57 covering an area of 0.355km^2 located at latitude of 27.982N and longitude of 89.896 E at an altitude of 5144 m a.s.l.

Pho Chhu Sub basin

Pho Chhu sub basin also has two major tributaries, one originating from Tarina region in the west and one from Lunana region in east. This sub basin consists of 157 glacial lakes covering an area of 20.98 km^2. Major number of previously identified potentially dangerous glacial lakes are located in this region. Some of them located in eastern part of Pho Chhu are Tarina Glacial lakes one and two noted as Pho_gl 32 and Pho_gl 33 respectively .While eastern part of Pho Chhu consists of PDGL namely Luggye Tsho (Pho_gl 77), Thorthomi Tsho (Pho_gl 76), and Raphstrang Tsho (Pho_gl 75). Earlier studies show that these lakes possess risk to the downstream settlement. A detailed explanation of the expansion of glacier lakes in Bhutan Himalaya can be seen in this report (Ageta et al., 2012, 2000; Komori, 2008) .Luggye Tsho have breached in 1994 (Watanbe & Rothacher, 1996) causing loss of life and damage to infrastructure downstream of this basin. Studies show that lakes in this area are advancing over time. Several research (Ageta et al., 2012, 2000; Bajracharya, Maharjan, & Shrestha, 2014; Mool et al., 2001; Shackleton, 2007) has been conducted on glacial lakes in this area and has been recommended for constant supervision of lakes status in this area.

Manas Basin

The Manas Basin is the eastern basin consists of Mangde Chhu sub basin, Chamkhar Chhu sub basin, Kuri Chhu sub basin, and Drangme Chhu Sub-basin.

Mangde Chhu Sub basin

The Mangde Chhu sub basin is western most part of Manas basin flowing through the gorges of Trongsa valley. This basin comprises of 130 glacial lakes covering a total area of 11.86 km^2. This sub basin consists of 3 Potentially Dangerous Glacial lakes as per (NCHM, 2018). Few glacial lakes in this basin were studied for GLOF issues by (FUJITA et al., 2012) in the Zanam area including the largest glacial lakes in this area, Metatshota Glacial lakes (Mang_gl 10).

Chamkhar Chhu Sub basin

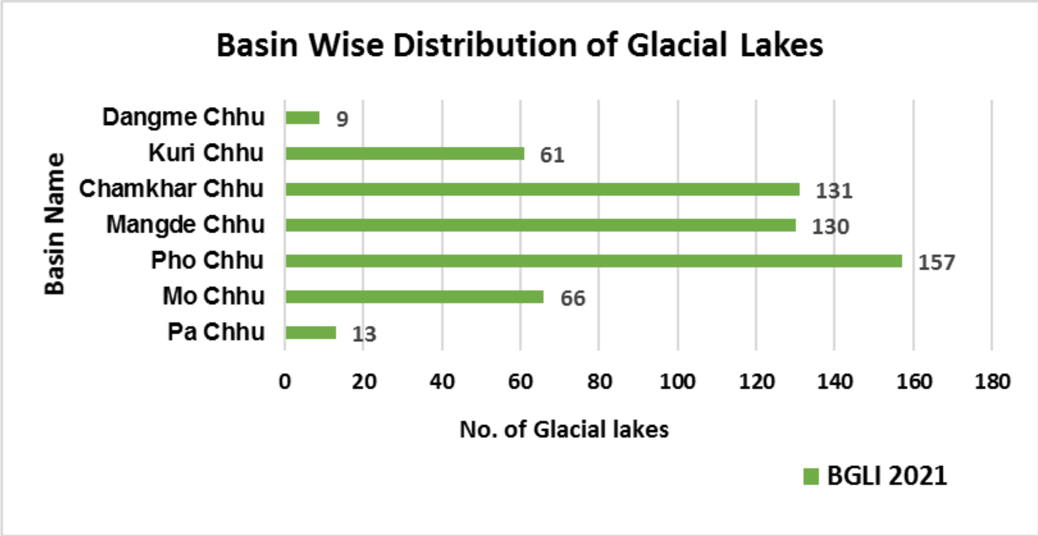
Chamkhar Chhu sub basin in total has 131 glacial lakes. Largest of all the glacial lakes is Cham_gl 89, having a surface area of 1.528 km^2. Studies by (Mool et al., 2001) have reported to have four PDGL, while new report on PDGL, NCHM, 2018 has reported just two in this sub basin. One of the largest glacial lakes named Churapokto Tsho (EL.4870 m, 28°01.3'N, and 90° 42.4'E) by the Geological Survey of Bhutan (1999) and Chubda Tsho by Karma et al (1999) .This lakes has been first studied during expedition in August 1999, September 2002 and in 2018. However, assessment of Chubda Tsho suggested that the glacial lake is in stable condition with less risk from GLOF issue. In 2018 a team from the National center from Hydrology and Meteorology has carried out a detailed bathymetry survey on these same lakes.

Kuri Chhu sub basin

One of the largest sub basins originating from the northern part of Bhutan as a transboundary river has 61 glacial lakes covering an area of 5.01km^2. The lakes in these areas range from an elevation of 4062m a.s.l to 5070m a.s.l. The largest of all lakes is Kuri_gl 23 with an area of 0.83 km^2 at 4754m a.s.l. This basin consists of one PDGL attributed as Kuri_gl 40 with an area of 0.15 km^2. Though effort has been made to validate this glacial lake but the study site here is inaccessible.

Drangme Chhu sub basin

The eastern most sub basin of Bhutan flowing through Trashigang Dzongkhag. This sub basin has a total of 9 glacial lakes covering an area of 0.77 km^2. The largest lake in this region is located at an elevation of 4432m a.s.l attributed as Drang_gl 1 in this inventory. Moraine dammed lakes are more dominant in numbers followed by erosion lakes. This sub-basin does not have any potentially dangerous glacial lakes. Glacial lakes of this region ranges from 4432m a.s.l to 4761m a.s.l.



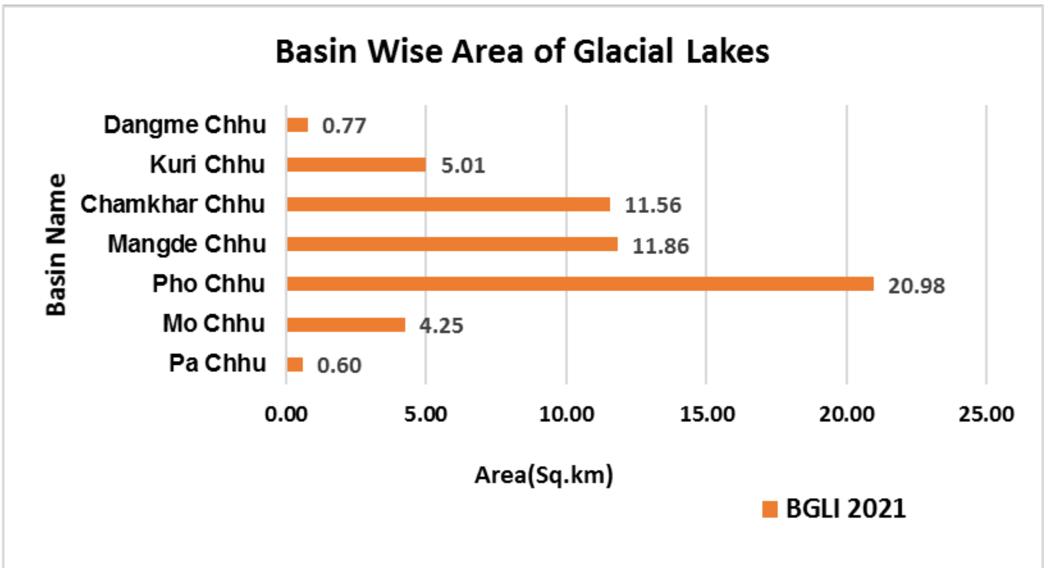


Figure 8: 8a) Basin wise area distribution and 8b) Basin wise Distribution of glacial lake distribution in Bhutan.

Comparison with Earlier Inventory

The product from the present work was compared with earlier inventories of ICIMOD and SATREP project. This is mainly to see the changes that has taken place on the lakes in course of time. The details of the comparisons in terms of glacial lake numbers and area coverage is shown in table.4.

Table 4: Comparison of number and change in glacial lakes between ICIMOD, SATREP and BGLI.

	BGIL	ICIMOD 2001	SATREP
Number	567	2674	461
Area (km^2)	55.04	106.8	43.95

Overall, the glacial lakes of Bhutan show very little change over time. However, automated mapping using Synthetic Aperture Radar (SAR) on potentially dangerous glacial lakes (Wangchuk et al., 2019) shows that some of the lakes like Lugge Tsho and Thorthormi Tsho have variability in their area over the time and season. While some glacial lakes like Lemthang Tsho have already breached (Gurung et al., 2017) and many more unaccounted (Ageta et al., 2012). These are the few causes of change in glacial lake area and numbers over time.

Result

Since glacial lake formation is a continuous and dynamic process, regular and timely updates on glacial lake information is very important. A total number of 2979 water bodies (lakes) were mapped in the course of preparation of this inventory. After applying different sets of criteria to define a glacial lake, 567 water bodies were found to fulfil all sets of criteria and are classified as glacial lakes. Total area covered by the glacial lakes in Bhutan is 55.04 ± 0.055 km^2 which is just 0.14% of land area of the country. Among the river basins, Pho Chhu sub basin has the highest number of glacial lakes (157 lakes) and basin with least number of glacial lakes is Dangme Chhu sub-basin (9 lakes). Among the major river basins of Bhutan, Amo chhu basin does not have any glacial lake in its headwater. Most glacial lakes in Bhutan are erosional type of glacial lakes followed by moraine dammed and least is Ice dammed lakes. The overall distribution of glacial lake is shown in Fig.9.

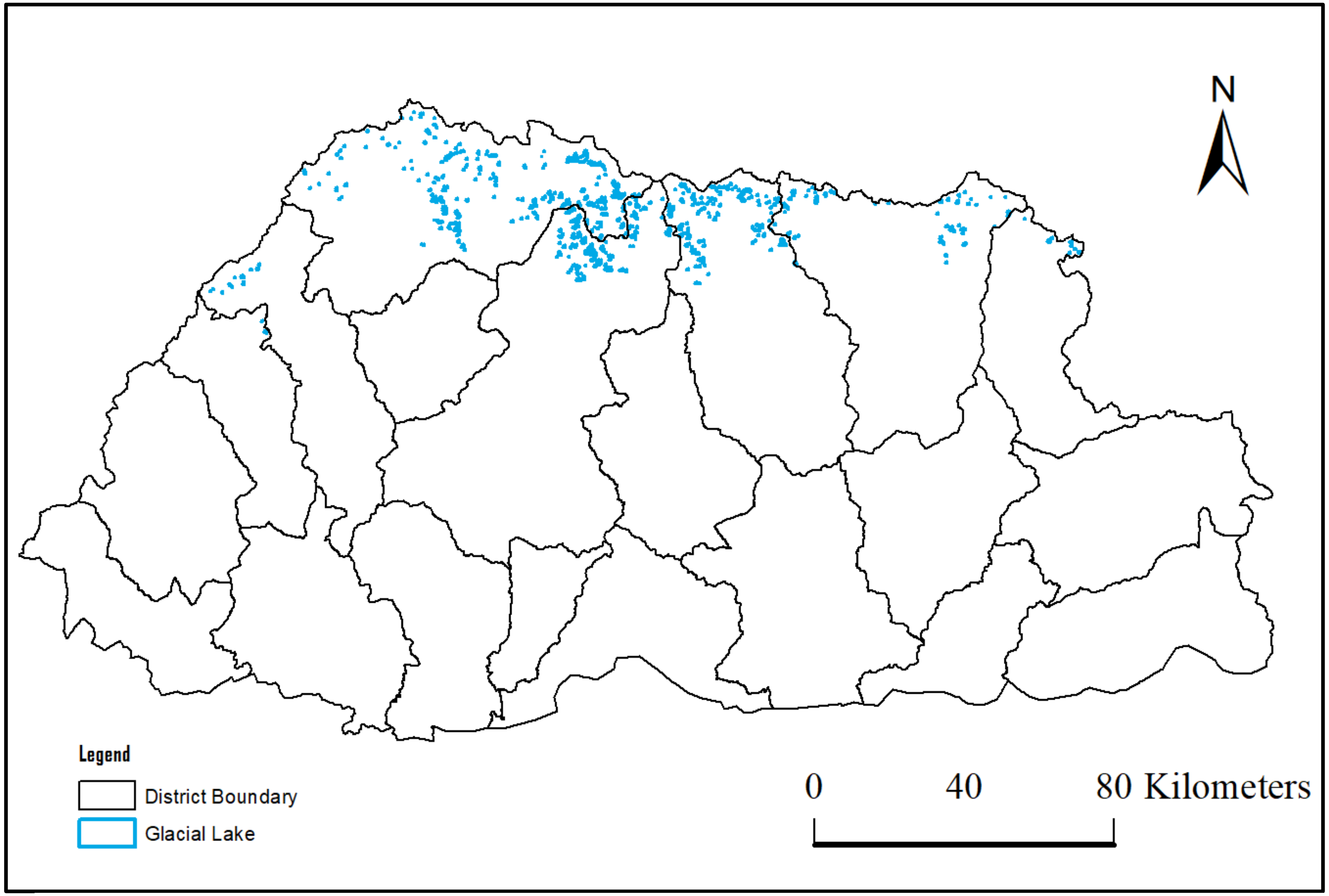


Figure 9: Distribution of Glacial Lakes in Bhutan (outline increased to make lake distinct)

Discussion

In comparison with the earlier inventories published by ICIMOD and SATREPS project, there is an inconsistency in the number of glacier lakes and areas covered by them. The present inventory has 567 glacial lakes which is 2107 less than the ICIMOD inventory. Similarly, the area covered by the glacial lakes in the present inventory is less by 51.76 Km^2. The huge disparity in number of glacial lakes and area coverage between the two inventories can be attributed to the inclusion of additional criteria such as area threshold and proximity from LIA moraines for defining a glacial lake in the present work. The other reason can be the different data set used as base materials where ICIMOD inventory was prepared using LANDSAT TM (30m resolution) and topographical maps (1:50,000) prepared in 1960s and 1970s whereas the present inventory was prepared using more finer resolution base materials such as sentinel images and google earth.

The number of glacial lakes and area coverage when compared to the inventory from SATREPS project are more by 106 and 11.09 Km^2 respectively. This difference might have been caused mainly due to different data sets used as base materials for mapping the glacial lakes. Also the increase in both the number and area of the glacial lakes in the current work can be attributed to the expansion of the glacial lakes over time.

From the hypsometry, it has been observed that glacial lakes with larger area are mostly found in the elevation band of 5000m.a.s.l to 5200 m.a.s.l. When the same analysis was carried out on glacier distribution, a similar pattern was obtained. Therefore, it can be concluded that presence of larger glacial lakes in this elevation band is attributed to presence of large numbers of glaciers with close proximity and feeding the glacial lakes directly.

Conclusion

The following are the conclusions drawn from the present work on the preparation of glacial lake inventory in Bhutan.

- There are 567 glacial lakes covering a total area of 55.04 $\pm$.0.055 $km^{2.}$ identified from the present work which accounts to 0.14% of the total land area of Bhutan.
- All glacial lakes in Bhutan falls between 4062 m.a.s.l to 5507 m.a.s.l. elevation with larger glacial lakes located between the elevation band of 5000 m.a.s.l to 5200 m.a.s.l.
- In comparison with the earlier published inventories, there are variations in number as well as area coverage which can be attributed to inclusion of additional criteria to define a glacial lake in the present work. Different base materials with differing resolution and techniques used are also some factors which might have contributed to such disparity in numbers and area coverage.
- Since glacial lakes are dynamic in nature, the inventory needs to be updated regularly with better base materials as and when they become available. This is to cope and cater to the demand from growing end users for better and more reliable information.

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Appendix

SI No	BGLI_ID	GLIMS_ID	Basin	Latitude	Longitude	Elevation	Area(km^2)	Lake_type	Local_Name
CHAMKHAR CHHU SUB BASIN									
1	Cham_gl 30	G090508E27973N	Chamkhar Chhu	27.973	90.508	5102	0.25690	E	
2	Cham_gl 77	G090625E28035N	Chamkhar Chhu	28.035	90.625	5177	0.29231	E	
3	Cham_gl 108	G090780E27972N	Chamkhar Chhu	27.972	90.780	5174	0.01071	E	
4	Cham_gl 35	G090505E27993N	Chamkhar Chhu	27.993	90.505	5211	0.08040	E	
5	Cham_gl 29	G090505E27969N	Chamkhar Chhu	27.969	90.505	5071	0.01440	E	
6	Cham_gl 27	G090510E27966N	Chamkhar Chhu	27.966	90.510	5060	0.02542	E	
7	Cham_gl 20	G090555E27925N	Chamkhar Chhu	27.925	90.555	4775	0.27764	E	
8	Cham_gl 22	G090557E27937N	Chamkhar Chhu	27.937	90.557	4757	0.02038	E	
9	Cham_gl 36	G090540E28003N	Chamkhar Chhu	28.003	90.540	4707	0.25930	I(s)	
10	Cham_gl 37	G090543E28021N	Chamkhar Chhu	28.021	90.543	4841	0.03538	M(l)	
11	Cham_gl 39	G090537E28041N	Chamkhar Chhu	28.041	90.537	5003	0.17746	E	
12	Cham_gl 41	G090546E28038N	Chamkhar Chhu	28.038	90.546	4994	0.17227	E	
13	Cham_gl 42	G090552E28032N	Chamkhar Chhu	28.032	90.552	5160	0.02523	E	

14	Cham_gl 43	G090558E28027N	Chamkhar Chhu	28.027	90.558	5123	0.07568	E	
15	Cham_gl 44	G090573E28020N	Chamkhar Chhu	28.020	90.573	5209	0.01407	E	
16	Cham_gl 45	G090570E28017N	Chamkhar Chhu	28.017	90.570	5168	0.05332	M(l)	
17	Cham_gl 47	G090568E28013N	Chamkhar Chhu	28.013	90.568	5165	0.02892	M(l)	
18	Cham_gl 48	G090571E28012N	Chamkhar Chhu	28.012	90.571	5175	0.03201	E	
19	Cham_gl 50	G090572E28006N	Chamkhar Chhu	28.006	90.572	5155	0.13649	E	
20	Cham_gl 52	G090569E27993N	Chamkhar Chhu	27.993	90.569	5208	0.01646	M(l)	
21	Cham_gl 54	G090583E27974N	Chamkhar Chhu	27.974	90.583	4963	0.10257	E	
22	Cham_gl 61	G090593E27983N	Chamkhar Chhu	27.983	90.593	5028	0.11681	E	
23	Cham_gl 62	G090599E27984N	Chamkhar Chhu	27.984	90.599	5029	0.07489	E	
24	Cham_gl 71	G090592E28010N	Chamkhar Chhu	28.010	90.592	5152	0.02481	E	
25	Cham_gl 69	G090621E28008N	Chamkhar Chhu	28.008	90.621	5154	0.06955	E	
26	Cham_gl 68	G090616E28003N	Chamkhar Chhu	28.003	90.616	5240	0.03368	E	
27	Cham_gl 67	G090628E28005N	Chamkhar Chhu	28.005	90.628	5068	0.08172	E	
28	Cham_gl 55	G090614E27964N	Chamkhar Chhu	27.964	90.614	4952	0.03908	E	
29	Cham_gl 59	G090635E27973N	Chamkhar Chhu	27.973	90.635	5024	0.03260	E	
30	Cham_gl 58	G090638E27970N	Chamkhar Chhu	27.970	90.638	5020	0.07440	E	
31	Cham_gl 56	G090628E27958N	Chamkhar Chhu	27.958	90.628	4914	0.08700	E	
32	Cham_gl 57	G090630E27962N	Chamkhar Chhu	27.962	90.630	4927	0.01866	E	
33	Cham_gl 66	G090644E27992N	Chamkhar Chhu	27.992	90.644	4850	0.07545	E	

34	Cham_gl 78	G090617E28037N	Chamkhar Chhu	28.037	90.617	5179	0.01816	E	
35	Cham_gl 80	G090642E28035N	Chamkhar Chhu	28.035	90.642	5039	0.02535	E	
36	Cham_gl 79	G090636E28034N	Chamkhar Chhu	28.034	90.636	5196	0.01802	E	
37	Cham_gl 75	G090636E28024N	Chamkhar Chhu	28.024	90.636	5149	0.01109	E	
38	Cham_gl 74	G090639E28025N	Chamkhar Chhu	28.025	90.639	5127	0.01381	E	
39	Cham_gl 73	G090645E28024N	Chamkhar Chhu	28.024	90.645	5064	0.01196	E	
40	Cham_gl 72	G090643E28019N	Chamkhar Chhu	28.019	90.643	5187	0.02637	M(e)	
41	Cham_gl 81	G090648E28034N	Chamkhar Chhu	28.034	90.648	5008	0.02695	E	
42	Cham_gl 82	G090652E28034N	Chamkhar Chhu	28.034	90.652	5009	0.01873	E	
43	Cham_gl 83	G090654E28037N	Chamkhar Chhu	28.037	90.654	5127	0.01902	E	
44	Cham_gl 84	G090664E28035N	Chamkhar Chhu	28.035	90.664	4717	0.30688	M(l)	
45	Cham_gl 85	G090672E28043N	Chamkhar Chhu	28.043	90.672	4960	0.08270	M(e)	
46	Cham_gl 86	G090676E28031N	Chamkhar Chhu	28.031	90.676	4784	0.01655	E	
47	Cham_gl 87	G090684E28034N	Chamkhar Chhu	28.034	90.684	4797	0.05291	E	
48	Cham_gl 88	G090694E28028N	Chamkhar Chhu	28.028	90.694	5038	0.02177	E	
49	Cham_gl 89	G090709E28022N	Chamkhar Chhu	28.022	90.709	4882	1.52848	E	Chubdra Tsho
50	Cham_gl 95	G090744E28016N	Chamkhar Chhu	28.016	90.744	5120	0.03028	E	
51	Cham_gl 93	G090728E28012N	Chamkhar Chhu	28.012	90.728	5162	0.04634	E	
52	Cham_gl 92	G090721E28008N	Chamkhar Chhu	28.008	90.721	5086	0.03733	E	

53	Cham_gl 90	G090700E28006N	Chamkhar Chhu	28.006	90.700	4903	0.01975	E	
54	Cham_gl 91	G090705E28004N	Chamkhar Chhu	28.004	90.705	4927	0.30699	E	
55	Cham_gl 97	G090749E27993N	Chamkhar Chhu	27.993	90.749	5012	0.07452	E	
56	Cham_gl 109	G090775E27953N	Chamkhar Chhu	27.953	90.775	5161	0.01824	E	
57	Cham_gl 116	G090748E27931N	Chamkhar Chhu	27.931	90.748	4988	0.06619	E	
58	Cham_gl 33	G090505E27988N	Chamkhar Chhu	27.988	90.505	5199	0.18500	E	
59	Cham_gl 31	G090505E27979N	Chamkhar Chhu	27.979	90.505	5147	0.03799	E	
60	Cham_gl 23	G090535E27939N	Chamkhar Chhu	27.939	90.535	5037	0.59613	E	Phudung Tsho
61	Cham_gl 24	G090541E27944N	Chamkhar Chhu	27.944	90.541	5041	0.01101	E	
62	Cham_gl 21	G090556E27934N	Chamkhar Chhu	27.934	90.556	4769	0.01685	E	
63	Cham_gl 38	G090520E28029N	Chamkhar Chhu	28.029	90.520	4866	0.01637	I(s)	
64	Cham_gl 70	G090610E28011N	Chamkhar Chhu	28.011	90.610	5275	0.01479	I(s)	
65	Cham_gl 76	G090634E28029N	Chamkhar Chhu	28.029	90.634	5153	0.02822	E	
66	Cham_gl 98	G090767E28012N	Chamkhar Chhu	28.012	90.767	5084	0.01956	E	
67	Cham_gl 99	G090769E27997N	Chamkhar Chhu	27.997	90.769	4844	0.01816	E	
68	Cham_gl 100	G090776E27999N	Chamkhar Chhu	27.999	90.776	4870	0.02749	E	
69	Cham_gl 106	G090791E27993N	Chamkhar Chhu	27.993	90.791	5086	0.03425	E	
70	Cham_gl 9	G090581E27876N	Chamkhar Chhu	27.876	90.581	4610	0.15370	E	
71	Cham_gl 8	G090590E27862N	Chamkhar Chhu	27.862	90.590	4771	0.76723	M(e)	

72	Cham_gl 7	G090596E27855N	Chamkhar Chhu	27.855	90.596	4936	0.05078	M(e)	
73	Cham_gl 4	G090576E27844N	Chamkhar Chhu	27.844	90.576	4987	0.03118	E	
74	Cham_gl 6	G090601E27846N	Chamkhar Chhu	27.846	90.601	4953	0.02994	E	
75	Cham_gl 3	G090610E27825N	Chamkhar Chhu	27.825	90.610	4466	0.02158	E	
76	Cham_gl 15	G090596E27906N	Chamkhar Chhu	27.906	90.596	4575	0.07079	M(l)	
77	Cham_gl 13	G090599E27895N	Chamkhar Chhu	27.895	90.599	4635	0.11707	M(l)	
78	Cham_gl 1	G090585E27803N	Chamkhar Chhu	27.803	90.585	4649	0.09464	E	
79	Cham_gl 2	G090577E27805N	Chamkhar Chhu	27.805	90.577	4710	0.08815	E	
80	Cham_gl 121	G090737E27906N	Chamkhar Chhu	27.906	90.737	5024	0.01458	E	
81	Cham_gl 123	G090731E27899N	Chamkhar Chhu	27.899	90.731	4859	0.01626	E	
82	Cham_gl 128	G090817E27897N	Chamkhar Chhu	27.897	90.817	4713	0.43758	M(l)	
83	Cham_gl 130	G090844E27852N	Chamkhar Chhu	27.852	90.844	4685	0.04391	M(l)	
84	Cham_gl 129	G090846E27855N	Chamkhar Chhu	27.855	90.846	4668	0.03057	M(e)	
85	Cham_gl 131	G090848E27848N	Chamkhar Chhu	27.848	90.848	4742	0.10601	M(l)	
86	Cham_gl 124	G090779E27883N	Chamkhar Chhu	27.883	90.779	4571	0.04295	E	
87	Cham_gl 114	G090738E27931N	Chamkhar Chhu	27.931	90.738	5143	0.01222	E	
88	Cham_gl 111	G090743E27944N	Chamkhar Chhu	27.944	90.743	4848	0.10688	E	
89	Cham_gl 112	G090731E27939N	Chamkhar Chhu	27.939	90.731	5020	0.03402	E	
90	Cham_gl 96	G090747E28001N	Chamkhar Chhu	28.001	90.747	5060	0.01752	E	
91	Cham_gl 113	G090733E27935N	Chamkhar Chhu	27.935	90.733	5064	0.01207	E	

92	Cham_gl 119	G090763E27921N	Chamkhar Chhu	27.921	90.763	4956	0.07823	E	
93	Cham_gl 120	G090760E27916N	Chamkhar Chhu	27.916	90.760	4882	0.01728	E	
94	Cham_gl 107	G090781E27986N	Chamkhar Chhu	27.986	90.781	5064	0.06575	E	
95	Cham_gl 110	G090756E27942N	Chamkhar Chhu	27.942	90.756	5034	0.16680	M(e)	
96	Cham_gl 118	G090746E27919N	Chamkhar Chhu	27.919	90.746	5185	0.01145	E	
97	Cham_gl 122	G090730E27901N	Chamkhar Chhu	27.901	90.730	4859	0.01356	E	
98	Cham_gl 117	G090758E27936N	Chamkhar Chhu	27.936	90.758	5134	0.01713	E	
99	Cham_gl 101	G090793E28007N	Chamkhar Chhu	28.007	90.793	5069	0.03399	M(l)	
100	Cham_gl 103	G090801E28006N	Chamkhar Chhu	28.006	90.801	5077	0.05397	E	
101	Cham_gl 126	G090807E27899N	Chamkhar Chhu	27.899	90.807	4818	0.03615	E	
102	Cham_gl 127	G090812E27906N	Chamkhar Chhu	27.906	90.812	4805	0.34797	E	
103	Cham_gl 28	G090509E27968N	Chamkhar Chhu	27.968	90.509	5077	0.01537	E	
104	Cham_gl 26	G090507E27966N	Chamkhar Chhu	27.966	90.507	5061	0.01964	E	
105	Cham_gl 12	G090566E27892N	Chamkhar Chhu	27.892	90.566	4949	0.02663	E	
106	Cham_gl 14	G090586E27904N	Chamkhar Chhu	27.904	90.586	4745	0.08116	M(l)	
107	Cham_gl 18	G090536E27920N	Chamkhar Chhu	27.920	90.536	4936	0.36933	M(e)	
108	Cham_gl 32	G090514E27982N	Chamkhar Chhu	27.982	90.514	5172	0.03132	E	
109	Cham_gl 34	G090516E27988N	Chamkhar Chhu	27.988	90.516	5260	0.02258	E	
110	Cham_gl 19	G090544E27924N	Chamkhar Chhu	27.924	90.544	4903	0.01469	E	
111	Cham_gl 17	G090559E27916N	Chamkhar Chhu	27.916	90.559	4935	0.10277	E	

112	Cham_gl 25	G090553E27949N	Chamkhar Chhu	27.949	90.553	4625	0.04656	E	
113	Cham_gl 11	G090574E27884N	Chamkhar Chhu	27.884	90.574	4799	0.01261	E	
114	Cham_gl 10	G090569E27880N	Chamkhar Chhu	27.880	90.569	4666	0.40733	E	
115	Cham_gl 60	G090611E27973N	Chamkhar Chhu	27.973	90.611	5045	0.02092	E	
116	Cham_gl 65	G090624E27995N	Chamkhar Chhu	27.995	90.624	5083	0.07604	E	
117	Cham_gl 53	G090582E27995N	Chamkhar Chhu	27.995	90.582	5284	0.01654	E	
118	Cham_gl 63	G090593E27998N	Chamkhar Chhu	27.998	90.593	5108	0.14886	E	
119	Cham_gl 64	G090607E27996N	Chamkhar Chhu	27.996	90.607	5249	0.04891	E	
120	Cham_gl 51	G090575E28000N	Chamkhar Chhu	28.000	90.575	5171	0.02544	E	
121	Cham_gl 5	G090587E27846N	Chamkhar Chhu	27.846	90.587	5133	0.05396	E	
122	Cham_gl 105	G090796E27998N	Chamkhar Chhu	27.998	90.796	5113	0.01510	E	
123	Cham_gl 104	G090798E27999N	Chamkhar Chhu	27.999	90.798	5114	0.02477	E	
124	Cham_gl 102	G090796E28007N	Chamkhar Chhu	28.007	90.796	5072	0.01210	E	
125	Cham_gl 125	G090804E27895N	Chamkhar Chhu	27.895	90.804	5032	0.03987	E	
126	Cham_gl 115	G090737E27930N	Chamkhar Chhu	27.930	90.737	5147	0.01340	E	
127	Cham_gl 16	G090553E27913N	Chamkhar Chhu	27.913	90.553	4968	0.06374	M(l)	
128	Cham_gl 40	G090544E28044N	Chamkhar Chhu	28.044	90.544	5118	0.01771	E	
129	Cham_gl 49	G090568E28011N	Chamkhar Chhu	28.011	90.568	5164	0.01899	E	
130	Cham_gl 46	G090573E28016N	Chamkhar Chhu	28.016	90.573	5186	0.01548	E	
131	Cham_gl 94	G090730E28010N	Chamkhar Chhu	28.010	90.730	5178	0.01885	E	

DRANGME CHHU SUB BASIN									
132	Drang_gl 1	G091534E27898N	Drangme Chhu	27.898	91.534	4432	0.26954	E	
133	Drang_gl 5	G091595E27888N	Drangme Chhu	27.888	91.595	4611	0.16375	E	
134	Drang_gl 4	G091592E27894N	Drangme Chhu	27.894	91.592	4751	0.04707	M(o)	
135	Drang_gl 2	G091543E27905N	Drangme Chhu	27.905	91.543	4476	0.04131	E	
136	Drang_gl 3	G091596E27896N	Drangme Chhu	27.896	91.596	4761	0.05448	M(e)	
137	Drang_gl 6	G091604E27878N	Drangme Chhu	27.878	91.604	4444	0.06898	E	
138	Drang_gl 8	G091615E27869N	Drangme Chhu	27.869	91.615	4668	0.07064	M(o)	
139	Drang_gl 9	G091589E27870N	Drangme Chhu	27.870	91.589	4618	0.01053	M(e)	
140	Drang_gl 7	G091618E27872N	Drangme Chhu	27.872	91.618	4650	0.04632	M(o)	
KURI CHHU SUB BASIN									
141	Kuri_gl 45	G091233E27968N	Kuri Chhu	27.968	91.233	4563	0.07414	E	
142	Kuri_gl 43	G091269E27931N	Kuri Chhu	27.931	91.269	4733	0.38382	M(e)	
143	Kuri_gl 36	G091241E27910N	Kuri Chhu	27.910	91.241	4348	0.13912	E	
144	Kuri_gl 35	G091241E27902N	Kuri Chhu	27.902	91.241	4183	0.09088	E	
145	Kuri_gl 34	G091239E27899N	Kuri Chhu	27.899	91.239	4185	0.04124	M(e)	
146	Kuri_gl 33	G091248E27896N	Kuri Chhu	27.896	91.248	4173	0.07827	E	
147	Kuri_gl 37	G091305E27893N	Kuri Chhu	27.893	91.305	4062	0.19443	M(e)	
148	Kuri_gl 46	G091243E27997N	Kuri Chhu	27.997	91.243	4366	0.08322	E	

149	Kuri_gl 47	G091262E28001N	Kuri Chhu	28.001	91.262	4480	0.18028	E	
150	Kuri_gl 48	G091287E27996N	Kuri Chhu	27.996	91.287	4539	0.24077	E	
151	Kuri_gl 49	G091292E28011N	Kuri Chhu	28.011	91.292	4629	0.10944	E	
152	Kuri_gl 56	G091418E28006N	Kuri Chhu	28.006	91.418	4724	0.03097	E	
153	Kuri_gl 57	G091423E27971N	Kuri Chhu	27.971	91.423	4758	0.03855	E	
154	Kuri_gl 58	G091430E27967N	Kuri Chhu	27.967	91.430	4824	0.06549	M(e)	
155	Kuri_gl 40	G091299E27929N	Kuri Chhu	27.929	91.299	4372	0.15952	M(l)	Terja Tse Tsho
156	Kuri_gl 38	G091301E27921N	Kuri Chhu	27.921	91.301	4560	0.07908	E	
157	Kuri_gl 60	G091468E27953N	Kuri Chhu	27.953	91.468	4690	0.01784	M(e)	
158	Kuri_gl 31	G091255E27849N	Kuri Chhu	27.849	91.255	4544	0.03704	E	
159	Kuri_gl 59	G091426E27963N	Kuri Chhu	27.963	91.426	4856	0.13714	E	
160	Kuri_gl 44	G091257E27936N	Kuri Chhu	27.936	91.257	4855	0.07393	M(e)	
161	Kuri_gl 52	G091317E27990N	Kuri Chhu	27.990	91.317	4768	0.06395	E	
162	Kuri_gl 51	G091325E28002N	Kuri Chhu	28.002	91.325	4806	0.05926	E	
163	Kuri_gl 42	G091276E27926N	Kuri Chhu	27.926	91.276	4859	0.07280	M(e)	
164	Kuri_gl 39	G091308E27929N	Kuri Chhu	27.929	91.308	4235	0.01520	E	
165	Kuri_gl 55	G091377E28006N	Kuri Chhu	28.006	91.377	4731	0.01813	E	
166	Kuri_gl 32	G091255E27867N	Kuri Chhu	27.867	91.255	4716	0.05378	M(e)	
167	Kuri_gl 41	G091291E27939N	Kuri Chhu	27.939	91.291	4818	0.03408	E	

168	Kuri_gl 53	G091338E27988N	Kuri Chhu	27.988	91.338	4680	0.01609	E	
169	Kuri_gl 54	G091341E27989N	Kuri Chhu	27.989	91.341	4679	0.01386	E	
170	Kuri_gl 61	G091388E27936N	Kuri Chhu	27.936	91.388	4675	0.04278	E	
171	Kuri_gl 24	G090929E28011N	Kuri Chhu	28.011	90.929	4795	0.01390	E	
172	Kuri_gl 22	G090900E28020N	Kuri Chhu	28.020	90.900	4863	0.01270	E	
173	Kuri_gl 19	G090883E28027N	Kuri Chhu	28.027	90.883	4872	0.01705	M(l)	
174	Kuri_gl 25	G090929E28017N	Kuri Chhu	28.017	90.929	4801	0.19229	E	
175	Kuri_gl 26	G090943E28023N	Kuri Chhu	28.023	90.943	4594	0.09392	E	
176	Kuri_gl 20	G090893E28032N	Kuri Chhu	28.032	90.893	4962	0.01453	M(e)	
177	Kuri_gl 21	G090900E28030N	Kuri Chhu	28.030	90.900	5028	0.01588	E	
178	Kuri_gl 28	G090954E28019N	Kuri Chhu	28.019	90.954	4556	0.02348	E	
179	Kuri_gl 27	G090950E28022N	Kuri Chhu	28.022	90.950	4565	0.01474	E	
180	Kuri_gl 30	G091100E27994N	Kuri Chhu	27.994	91.100	4128	0.01099	M(e)	
181	Kuri_gl 23	G090905E28004N	Kuri Chhu	28.004	90.905	4754	0.83200	E	
182	Kuri_gl 29	G091064E27993N	Kuri Chhu	27.993	91.064	4319	0.01192	E	
183	Kuri_gl 5	G090781E27932N	Kuri Chhu	27.932	90.781	5070	0.01074	E	
184	Kuri_gl 6	G090791E27945N	Kuri Chhu	27.945	90.791	5026	0.03151	E	
185	Kuri_gl 15	G090834E28008N	Kuri Chhu	28.008	90.834	4778	0.01366	E	
186	Kuri_gl 17	G090840E28022N	Kuri Chhu	28.022	90.840	4994	0.17034	E	
187	Kuri_gl 16	G090843E28019N	Kuri Chhu	28.019	90.843	4972	0.20056	E	

188	Kuri_gl 14	G090836E28005N	Kuri Chhu	28.005	90.836	4776	0.01888	E	
189	Kuri_gl 18	G090876E28013N	Kuri Chhu	28.013	90.876	4647	0.02898	M(e)	
190	Kuri_gl 7	G090818E27974N	Kuri Chhu	27.974	90.818	4799	0.01639	E	
191	Kuri_gl 8	G090827E27984N	Kuri Chhu	27.984	90.827	4739	0.10626	E	
192	Kuri_gl 10	G090823E27990N	Kuri Chhu	27.990	90.823	4847	0.03768	E	
193	Kuri_gl 9	G090817E27988N	Kuri Chhu	27.988	90.817	4913	0.09854	E	
194	Kuri_gl 3	G090828E27922N	Kuri Chhu	27.922	90.828	4617	0.05776	E	
195	Kuri_gl 4	G090833E27925N	Kuri Chhu	27.925	90.833	4661	0.01342	E	
196	Kuri_gl 11	G090819E27991N	Kuri Chhu	27.991	90.819	4911	0.02008	E	
197	Kuri_gl 1	G090844E27912N	Kuri Chhu	27.912	90.844	4514	0.14249	E	
198	Kuri_gl 2	G090854E27917N	Kuri Chhu	27.917	90.854	4294	0.02246	E	
199	Kuri_gl 12	G090816E27994N	Kuri Chhu	27.994	90.816	4924	0.01544	E	
200	Kuri_gl 13	G090831E28005N	Kuri Chhu	28.005	90.831	4788	0.01141	E	
201	Kuri_gl 50	G091307E28018N	Kuri Chhu	28.018	91.307	4973	0.09209	E	
MANGDE CHHU SUB BASIN									
202	Mang_gl 121	G090485E28008N	Mangde Chhu	28.008	90.485	5013	0.05005	I(v)	
203	Mang_gl 125	G090507E27932N	Mangde Chhu	27.932	90.507	5063	0.02096	M(e)	
204	Mang_gl 124	G090503E27933N	Mangde Chhu	27.933	90.503	5058	0.08082	M(o)	
205	Mang_gl 127	G090502E27921N	Mangde Chhu	27.921	90.502	5081	0.12742	M(o)	
206	Mang_gl 122	G090486E27962N	Mangde Chhu	27.962	90.486	5116	0.01486	M(e)	

207	Mang_gl 5	G090260E27816N	Mangde Chhu	27.816	90.260	4910	0.01528	E	
208	Mang_gl 2	G090272E27813N	Mangde Chhu	27.813	90.272	4896	0.01083	E	
209	Mang_gl 18	G090377E27838N	Mangde Chhu	27.838	90.377	4873	0.03642	E	
210	Mang_gl 15	G090371E27835N	Mangde Chhu	27.835	90.371	4980	0.02835	M(e)	
211	Mang_gl 16	G090381E27835N	Mangde Chhu	27.835	90.381	4976	0.02383	E	
212	Mang_gl 19	G090344E27842N	Mangde Chhu	27.842	90.344	4997	0.06514	E	
213	Mang_gl 14	G090346E27837N	Mangde Chhu	27.837	90.346	4976	0.07584	E	
214	Mang_gl 35	G090290E27891N	Mangde Chhu	27.891	90.290	5060	1.14755	M(e)	Metatshota Tsho
215	Mang_gl 32	G090293E27884N	Mangde Chhu	27.884	90.293	5114	0.09232	M(e)	
216	Mang_gl 31	G090298E27883N	Mangde Chhu	27.883	90.298	5119	0.15683	M(e)	
217	Mang_gl 30	G090296E27879N	Mangde Chhu	27.879	90.296	5209	0.03078	M(o)	
218	Mang_gl 27	G090295E27862N	Mangde Chhu	27.862	90.295	4964	0.20619	M(o)	
219	Mang_gl 37	G090272E27904N	Mangde Chhu	27.904	90.272	5158	0.01127	M(o)	
220	Mang_gl 36	G090271E27902N	Mangde Chhu	27.902	90.271	5154	0.01377	M(o)	
221	Mang_gl 38	G090268E27908N	Mangde Chhu	27.908	90.268	5182	0.09049	M(o)	
222	Mang_gl 34	G090276E27882N	Mangde Chhu	27.882	90.276	5044	0.02820	E	
223	Mang_gl 26	G090310E27859N	Mangde Chhu	27.859	90.310	4951	0.09779	M(o)	
224	Mang_gl 25	G090319E27859N	Mangde Chhu	27.859	90.319	5065	0.05491	M(e)	
225	Mang_gl 24	G090313E27850N	Mangde Chhu	27.850	90.313	5046	0.02364	E	

226	Mang_gl 20	G090341E27844N	Mangde Chhu	27.844	90.341	5000	0.01679	E	
227	Mang_gl 6	G090254E27813N	Mangde Chhu	27.813	90.254	4820	0.11057	E	
228	Mang_gl 1	G090272E27818N	Mangde Chhu	27.818	90.272	4898	0.20794	E	
229	Mang_gl 50	G090323E27893N	Mangde Chhu	27.893	90.323	5106	0.08009	E	
230	Mang_gl 22	G090333E27849N	Mangde Chhu	27.849	90.333	5051	0.12998	M(e)	
231	Mang_gl 21	G090331E27844N	Mangde Chhu	27.844	90.331	5010	0.01381	M(e)	
232	Mang_gl 12	G090330E27838N	Mangde Chhu	27.838	90.330	4992	0.01512	E	
233	Mang_gl 9	G090256E27831N	Mangde Chhu	27.831	90.256	5063	0.04824	M(e)	
234	Mang_gl 10	G090277E27847N	Mangde Chhu	27.847	90.277	4911	0.01194	E	
235	Mang_gl 4	G090260E27814N	Mangde Chhu	27.814	90.260	4905	0.01273	E	
236	Mang_gl 3	G090263E27812N	Mangde Chhu	27.812	90.263	4976	0.01221	E	
237	Mang_gl 96	G090407E27893N	Mangde Chhu	27.893	90.407	5095	0.03837	M(o)	
238	Mang_gl 95	G090398E27894N	Mangde Chhu	27.894	90.398	5017	0.01311	E	
239	Mang_gl 39	G090276E27907N	Mangde Chhu	27.907	90.276	5161	0.23088	M(e)	
240	Mang_gl 42	G090344E27863N	Mangde Chhu	27.863	90.344	5033	0.01105	E	
241	Mang_gl 29	G090292E27875N	Mangde Chhu	27.875	90.292	5163	0.11884	M(o)	
242	Mang_gl 97	G090413E27910N	Mangde Chhu	27.910	90.413	5044	0.02920	M(e)	
243	Mang_gl 17	G090387E27835N	Mangde Chhu	27.835	90.387	4851	0.05716	M(e)	
244	Mang_gl 41	G090342E27863N	Mangde Chhu	27.863	90.342	5033	0.02632	E	
245	Mang_gl 64	G090322E27972N	Mangde Chhu	27.972	90.322	5366	0.03867	M(e)	

246	Mang_gl 51	G090334E27905N	Mangde Chhu	27.905	90.334	5200	0.01259	E	
247	Mang_gl 81	G090364E28037N	Mangde Chhu	28.037	90.364	5217	0.84615	M(e)	
248	Mang_gl 85	G090374E28015N	Mangde Chhu	28.015	90.374	5184	0.90020	M(e)	
249	Mang_gl 118	G090423E28019N	Mangde Chhu	28.019	90.423	5310	0.01282	I(s)	
250	Mang_gl 117	G090411E28018N	Mangde Chhu	28.018	90.411	5364	0.03084	M(e)	
251	Mang_gl 11	G090303E27846N	Mangde Chhu	27.846	90.303	4902	0.18937	M(o)	
252	Mang_gl 33	G090280E27877N	Mangde Chhu	27.877	90.280	5038	0.30862	M(o)	
253	Mang_gl 28	G090303E27873N	Mangde Chhu	27.873	90.303	5047	0.41209	M(e)	
254	Mang_gl 80	G090355E28046N	Mangde Chhu	28.046	90.355	5278	0.48290	M(e)	
255	Mang_gl 77	G090353E28014N	Mangde Chhu	28.014	90.353	5302	0.16417	M(e)	
256	Mang_gl 74	G090328E28005N	Mangde Chhu	28.005	90.328	5376	0.35515	M(e)	
257	Mang_gl 71	G090318E28005N	Mangde Chhu	28.005	90.318	5422	0.04351	M(o)	
258	Mang_gl 78	G090357E28026N	Mangde Chhu	28.026	90.357	5345	0.05556	M(e)	
259	Mang_gl 116	G090404E28015N	Mangde Chhu	28.015	90.404	5371	0.01928	M(e)	
260	Mang_gl 115	G090407E28012N	Mangde Chhu	28.012	90.407	5287	0.08565	M(e)	
261	Mang_gl 75	G090330E28000N	Mangde Chhu	28.000	90.330	5377	0.01572	E	
262	Mang_gl 76	G090331E27997N	Mangde Chhu	27.997	90.331	5369	0.01347	E	
263	Mang_gl 65	G090329E27985N	Mangde Chhu	27.985	90.329	5271	0.07149	M(o)	
264	Mang_gl 63	G090331E27970N	Mangde Chhu	27.970	90.331	5317	0.24123	M(e)	
265	Mang_gl 62	G090282E27956N	Mangde Chhu	27.956	90.282	5234	0.04908	E	

266	Mang_gl 61	G090283E27950N	Mangde Chhu	27.950	90.283	5218	0.02164	M(o)	
267	Mang_gl 60	G090302E27941N	Mangde Chhu	27.941	90.302	5245	0.01470	M(o)	
268	Mang_gl 56	G090310E27936N	Mangde Chhu	27.936	90.310	5103	0.03668	M(o)	
269	Mang_gl 57	G090319E27943N	Mangde Chhu	27.943	90.319	5251	0.04533	M(o)	
270	Mang_gl 58	G090320E27951N	Mangde Chhu	27.951	90.320	5304	0.01554	M(e)	
271	Mang_gl 92	G090377E27940N	Mangde Chhu	27.940	90.377	5215	0.09267	M(e)	
272	Mang_gl 68	G090312E27989N	Mangde Chhu	27.989	90.312	5445	0.02483	M(o)	
273	Mang_gl 55	G090295E27932N	Mangde Chhu	27.932	90.295	5187	0.09567	E	
274	Mang_gl 40	G090275E27913N	Mangde Chhu	27.913	90.275	5185	0.06814	M(e)	
275	Mang_gl 54	G090320E27920N	Mangde Chhu	27.920	90.320	5154	0.02501	M(e)	
276	Mang_gl 79	G090359E28025N	Mangde Chhu	28.025	90.359	5319	0.01584	M(o)	
277	Mang_gl 53	G090321E27920N	Mangde Chhu	27.920	90.321	5154	0.01563	M(e)	
278	Mang_gl 69	G090311E28003N	Mangde Chhu	28.003	90.311	5459	0.09900	M(o)	
279	Mang_gl 67	G090310E27988N	Mangde Chhu	27.988	90.310	5446	0.01654	M(e)	
280	Mang_gl 84	G090368E28020N	Mangde Chhu	28.020	90.368	5167	0.01400	M(o)	
281	Mang_gl 82	G090367E28022N	Mangde Chhu	28.022	90.367	5172	0.01337	M(o)	
282	Mang_gl 105	G090404E27941N	Mangde Chhu	27.941	90.404	5236	0.01176	M(o)	
283	Mang_gl 102	G090414E27928N	Mangde Chhu	27.928	90.414	5015	0.07690	M(o)	
284	Mang_gl 101	G090418E27926N	Mangde Chhu	27.926	90.418	5009	0.01063	M(o)	
285	Mang_gl 108	G090412E27969N	Mangde Chhu	27.969	90.412	5206	0.23585	M(e)	

286	Mang_gl 107	G090417E27960N	Mangde Chhu	27.960	90.417	5288	0.01130	M(e)	
287	Mang_gl 72	G090322E28011N	Mangde Chhu	28.011	90.322	5507	0.01651	M(e)	
288	Mang_gl 111	G090427E27981N	Mangde Chhu	27.981	90.427	5130	0.01706	M(o)	
289	Mang_gl 119	G090437E27984N	Mangde Chhu	27.984	90.437	5094	0.25579	I(v)	
290	Mang_gl 112	G090418E27991N	Mangde Chhu	27.991	90.418	5182	0.41246	I(v)	
291	Mang_gl 120	G090452E27998N	Mangde Chhu	27.998	90.452	5002	0.08869	E	
292	Mang_gl 110	G090409E27976N	Mangde Chhu	27.976	90.409	5278	0.01628	M(o)	
293	Mang_gl 109	G090404E27968N	Mangde Chhu	27.968	90.404	5271	0.02556	M(e)	
294	Mang_gl 106	G090397E27940N	Mangde Chhu	27.940	90.397	5205	0.18958	M(e)	
295	Mang_gl 104	G090417E27940N	Mangde Chhu	27.940	90.417	5188	0.02194	E	
296	Mang_gl 103	G090418E27938N	Mangde Chhu	27.938	90.418	5172	0.02105	E	
297	Mang_gl 123	G090505E27938N	Mangde Chhu	27.938	90.505	5122	0.01536	E	
298	Mang_gl 126	G090496E27928N	Mangde Chhu	27.928	90.496	5030	0.03407	M(o)	
299	Mang_gl 128	G090558E27898N	Mangde Chhu	27.898	90.558	5105	0.01561	M(e)	
300	Mang_gl 129	G090552E27895N	Mangde Chhu	27.895	90.552	4985	0.23600	M(e)	
301	Mang_gl 45	G090338E27870N	Mangde Chhu	27.870	90.338	5120	0.02407	M(e)	
302	Mang_gl 44	G090343E27871N	Mangde Chhu	27.871	90.343	5077	0.06625	M(e)	
303	Mang_gl 43	G090349E27869N	Mangde Chhu	27.869	90.349	5071	0.06419	M(e)	
304	Mang_gl 13	G090336E27835N	Mangde Chhu	27.835	90.336	4973	0.01377	E	
305	Mang_gl 87	G090380E27987N	Mangde Chhu	27.987	90.380	5247	0.13692	M(e)	

306	Mang_gl 88	G090381E27981N	Mangde Chhu	27.981	90.381	5233	0.20437	M(e)	
307	Mang_gl 86	G090382E27994N	Mangde Chhu	27.994	90.382	5293	0.01996	M(e)	
308	Mang_gl 113	G090398E27997N	Mangde Chhu	27.997	90.398	5353	0.04226	M(e)	
309	Mang_gl 100	G090408E27919N	Mangde Chhu	27.919	90.408	5144	0.16993	M(e)	
310	Mang_gl 99	G090401E27918N	Mangde Chhu	27.918	90.401	5216	0.04163	M(e)	
311	Mang_gl 98	G090404E27915N	Mangde Chhu	27.915	90.404	5134	0.01188	M(o)	
312	Mang_gl 90	G090365E27957N	Mangde Chhu	27.957	90.365	5259	0.04879	M(o)	
313	Mang_gl 89	G090369E27959N	Mangde Chhu	27.959	90.369	5259	0.03665	M(e)	
314	Mang_gl 91	G090378E27946N	Mangde Chhu	27.946	90.378	5268	0.13007	M(e)	
315	Mang_gl 94	G090380E27916N	Mangde Chhu	27.916	90.380	5149	0.02477	E	
316	Mang_gl 93	G090388E27925N	Mangde Chhu	27.925	90.388	5230	0.01123	M(o)	
317	Mang_gl 59	G090311E27951N	Mangde Chhu	27.951	90.311	5375	0.01431	M(e)	
318	Mang_gl 66	G090321E27985N	Mangde Chhu	27.985	90.321	5301	0.05061	M(e)	
319	Mang_gl 49	G090321E27887N	Mangde Chhu	27.887	90.321	5217	0.03036	M(e)	
320	Mang_gl 46	G090333E27879N	Mangde Chhu	27.879	90.333	5228	0.01178	M(e)	
321	Mang_gl 47	G090325E27883N	Mangde Chhu	27.883	90.325	5169	0.01204	M(e)	
322	Mang_gl 48	G090328E27885N	Mangde Chhu	27.885	90.328	5109	0.01342	E	
323	Mang_gl 52	G090317E27915N	Mangde Chhu	27.915	90.317	5199	0.07013	I(s)	
324	Mang_gl 23	G090318E27852N	Mangde Chhu	27.852	90.318	5094	0.01467	E	
325	Mang_gl 7	G090265E27827N	Mangde Chhu	27.827	90.265	5148	0.01087	M(e)	

326	Mang_gl 8	G090257E27827N	Mangde Chhu	27.827	90.257	4945	0.01229	M(e)	
327	Mang_gl 130	G090554E27837N	Mangde Chhu	27.837	90.554	4793	0.10749	E	
328	Mang_gl 114	G090414E28005N	Mangde Chhu	28.005	90.414	5259	0.03046	I(v)	
329	Mang_gl 83	G090365E28019N	Mangde Chhu	28.019	90.365	5168	0.03181	M(o)	
330	Mang_gl 70	G090319E28001N	Mangde Chhu	28.001	90.319	5423	0.02239	M(e)	
331	Mang_gl 73	G090330E28011N	Mangde Chhu	28.011	90.330	5441	0.01294	M(e)	
MO CHHU SUB BASIN									
332	Mo_gl 3	G089392E27848N	Mo Chhu	27.848	89.392	4222	0.09321	I(s)	
333	Mo_gl 2	G089369E27836N	Mo Chhu	27.836	89.369	4429	0.05027	E	
334	Mo_gl 1	G089389E27839N	Mo Chhu	27.839	89.389	4330	0.17658	E	
335	Mo_gl 66	G089833E27899N	Mo Chhu	27.899	89.833	4835	0.01800	M(e)	
336	Mo_gl 65	G089838E27897N	Mo Chhu	27.897	89.838	4953	0.01140	M(e)	
337	Mo_gl 58	G089896E27974N	Mo Chhu	27.974	89.896	5139	0.23705	M(e)	
338	Mo_gl 57	G089896E27982N	Mo Chhu	27.982	89.896	5144	0.35542	M(e)	
339	Mo_gl 55	G089892E27988N	Mo Chhu	27.988	89.892	5129	0.12273	E	
340	Mo_gl 52	G089883E28005N	Mo Chhu	28.005	89.883	5038	0.01073	E	
341	Mo_gl 48	G089863E28007N	Mo Chhu	28.007	89.863	4842	0.23079	E	
342	Mo_gl 49	G089868E28012N	Mo Chhu	28.012	89.868	4894	0.08231	E	
343	Mo_gl 47	G089861E28018N	Mo Chhu	28.018	89.861	5152	0.01582	E	
344	Mo_gl 46	G089855E28030N	Mo Chhu	28.030	89.855	4750	0.08315	M(e)	

345	Mo_gl 43	G089848E28067N	Mo Chhu	28.067	89.848	4764	0.03734	E	
346	Mo_gl 40	G089803E28100N	Mo Chhu	28.100	89.803	5138	0.01305	E	
347	Mo_gl 41	G089806E28082N	Mo Chhu	28.082	89.806	5017	0.01119	E	
348	Mo_gl 44	G089824E28053N	Mo Chhu	28.053	89.824	4459	0.03665	E	
349	Mo_gl 36	G089868E28156N	Mo Chhu	28.156	89.868	5051	0.05452	E	
350	Mo_gl 38	G089853E28167N	Mo Chhu	28.167	89.853	4569	0.08883	I(s)	
351	Mo_gl 37	G089848E28172N	Mo Chhu	28.172	89.848	4517	0.23821	M(e)	Sintaphu Tsho
352	Mo_gl 39	G089840E28144N	Mo Chhu	28.144	89.840	5119	0.13557	M(e)	
353	Mo_gl 64	G089884E27937N	Mo Chhu	27.937	89.884	4892	0.08888	E	
354	Mo_gl 60	G089881E27951N	Mo Chhu	27.951	89.881	4964	0.10377	E	
355	Mo_gl 59	G089888E27953N	Mo Chhu	27.953	89.888	4970	0.02729	M(l)	
356	Mo_gl 61	G089877E27955N	Mo Chhu	27.955	89.877	4939	0.04653	E	
357	Mo_gl 62	G089874E27958N	Mo Chhu	27.958	89.874	4935	0.01521	E	
358	Mo_gl 63	G089866E27957N	Mo Chhu	27.957	89.866	4937	0.01419	E	
359	Mo_gl 11	G089626E28042N	Mo Chhu	28.042	89.626	4706	0.16486	M(e)	
360	Mo_gl 10	G089601E28033N	Mo Chhu	28.033	89.601	4944	0.04212	E	
361	Mo_gl 12	G089554E28044N	Mo Chhu	28.044	89.554	4881	0.04879	E	
362	Mo_gl 7	G089616E28012N	Mo Chhu	28.012	89.616	4854	0.01843	M(o)	
363	Mo_gl 8	G089608E28007N	Mo Chhu	28.007	89.608	5008	0.04255	E	

364	Mo_gl 13	G089580E28069N	Mo Chhu	28.069	89.580	4263	0.07933	M(e)	
365	Mo_gl 6	G089513E28076N	Mo Chhu	28.076	89.513	5036	0.02728	M(e)	
366	Mo_gl 5	G089516E28070N	Mo Chhu	28.070	89.516	4785	0.07365	E	
367	Mo_gl 19	G089685E28172N	Mo Chhu	28.172	89.685	4784	0.10515	M(e)	
368	Mo_gl 16	G089611E28125N	Mo Chhu	28.125	89.611	4246	0.02885	M(e)	
369	Mo_gl 15	G089602E28115N	Mo Chhu	28.115	89.602	4163	0.06405	M(e)	
370	Mo_gl 21	G089743E28138N	Mo Chhu	28.138	89.743	4860	0.12048	E	
371	Mo_gl 32	G089865E28187N	Mo Chhu	28.187	89.865	5016	0.03601	E	
372	Mo_gl 33	G089869E28187N	Mo Chhu	28.187	89.869	5029	0.04631	E	
373	Mo_gl 34	G089872E28182N	Mo Chhu	28.182	89.872	5214	0.01607	E	
374	Mo_gl 35	G089874E28180N	Mo Chhu	28.180	89.874	5223	0.01074	E	
375	Mo_gl 9	G089600E28028N	Mo Chhu	28.028	89.600	4977	0.05700	M(e)	
376	Mo_gl 4	G089529E28034N	Mo Chhu	28.034	89.529	4860	0.04240	E	
377	Mo_gl 53	G089890E28001N	Mo Chhu	28.001	89.890	5086	0.08723	M(e)	
378	Mo_gl 42	G089784E28082N	Mo Chhu	28.082	89.784	4889	0.01940	E	
379	Mo_gl 22	G089760E28132N	Mo Chhu	28.132	89.760	4846	0.01575	E	
380	Mo_gl 23	G089771E28144N	Mo Chhu	28.144	89.771	4996	0.01062	M(l)	
381	Mo_gl 45	G089867E28048N	Mo Chhu	28.048	89.867	5041	0.02605	E	
382	Mo_gl 50	G089883E28010N	Mo Chhu	28.010	89.883	5017	0.23031	E	
383	Mo_gl 56	G089898E27991N	Mo Chhu	27.991	89.898	5131	0.01389	M(e)	

384	Mo_gl 26	G089803E28202N	Mo Chhu	28.202	89.803	4925	0.01222	E	
385	Mo_gl 25	G089777E28205N	Mo Chhu	28.205	89.777	5295	0.02566	E	
386	Mo_gl 24	G089778E28203N	Mo Chhu	28.203	89.778	5291	0.02374	E	
387	Mo_gl 18	G089680E28133N	Mo Chhu	28.133	89.680	4566	0.01917	E	
388	Mo_gl 14	G089614E28106N	Mo Chhu	28.106	89.614	4433	0.05968	E	
389	Mo_gl 17	G089623E28135N	Mo Chhu	28.135	89.623	4363	0.03052	E	
390	Mo_gl 31	G089867E28203N	Mo Chhu	28.203	89.867	5045	0.01662	E	
391	Mo_gl 51	G089885E28008N	Mo Chhu	28.008	89.885	5016	0.06029	E	
392	Mo_gl 54	G089871E28001N	Mo Chhu	28.001	89.871	4949	0.02214	M(e)	
393	Mo_gl 20	G089726E28154N	Mo Chhu	28.154	89.726	4254	0.06725	E	
394	Mo_gl 29	G089830E28214N	Mo Chhu	28.214	89.830	5284	0.02732	M(e)	
395	Mo_gl 30	G089834E28214N	Mo Chhu	28.214	89.834	5205	0.03137	M(e)	
396	Mo_gl 28	G089830E28206N	Mo Chhu	28.206	89.830	5280	0.01701	E	
397	Mo_gl 27	G089812E28217N	Mo Chhu	28.217	89.812	5017	0.01542	E	
PAA CHHU SUB BASIN									
398	Pa_gl 11	G089345E27821N	Pa Chhu	27.821	89.345	4493	0.04422	M(l)	
399	Pa_gl 13	G089350E27819N	Pa Chhu	27.819	89.350	4455	0.02501	M(l)	
400	Pa_gl 12	G089345E27818N	Pa Chhu	27.818	89.345	4512	0.01319	I(s)	
401	Pa_gl 4	G089350E27804N	Pa Chhu	27.804	89.350	4355	0.15169	M(e)	Karma Tsho

402	Pa_gl 9	G089312E27800N	Pa Chhu	27.800	89.312	4394	0.04917	M(e)	Lhaluphu Gom Tsho
403	Pa_gl 5	G089319E27795N	Pa Chhu	27.795	89.319	4332	0.02867	M(e)	Lhaluphu Wom Tsho
404	Pa_gl 6	G089294E27781N	Pa Chhu	27.781	89.294	4721	0.03550	E	
405	Pa_gl 8	G089267E27789N	Pa Chhu	27.789	89.267	4497	0.01382	E	
406	Pa_gl 7	G089259E27783N	Pa Chhu	27.783	89.259	4403	0.02469	E	
407	Pa_gl 10	G089325E27817N	Pa Chhu	27.817	89.325	4637	0.01147	I(s)	
408	Pa_gl 2	G089409E27687N	Pa Chhu	27.687	89.409	4798	0.18000	M(e)	
409	Pa_gl 1	G089414E27684N	Pa Chhu	27.684	89.414	4861	0.01247	M(e)	
410	Pa_gl 3	G089401E27713N	Pa Chhu	27.713	89.401	5022	0.01466	M(e)	
PHO CHHU SUB BASIN									
411	Pho_gl 19	G089949E27886N	Pho Chhu	27.886	89.949	4572	0.05781	E	
412	Pho_gl 94	G090146E27964N	Pho Chhu	27.964	90.146	4883	0.20075	E	
413	Pho_gl 16	G089933E27904N	Pho Chhu	27.904	89.933	4840	0.01134	E	
414	Pho_gl 17	G089945E27896N	Pho Chhu	27.896	89.945	4874	0.07968	M(e)	
415	Pho_gl 18	G089943E27893N	Pho Chhu	27.893	89.943	4856	0.09670	E	
416	Pho_gl 43	G089955E28091N	Pho Chhu	28.091	89.955	4929	0.02401	E	
417	Pho_gl 31	G089887E28097N	Pho Chhu	28.097	89.887	4753	0.03675	E	
418	Pho_gl 32	G089899E28106N	Pho Chhu	28.106	89.899	4274	0.24628	M(e)	Tarina 1

419	Pho_gl 33	G089909E28114N	Pho Chhu	28.114	89.909	4348	0.44995	M(e)	Tarina 2
420	Pho_gl 35	G089898E28146N	Pho Chhu	28.146	89.898	5129	0.04837	M(e)	
421	Pho_gl 38	G089934E28139N	Pho Chhu	28.139	89.934	5083	0.03672	E	
422	Pho_gl 39	G089936E28140N	Pho Chhu	28.140	89.936	5063	0.01927	E	
423	Pho_gl 30	G089892E28064N	Pho Chhu	28.064	89.892	4861	0.03486	E	
424	Pho_gl 29	G089889E28061N	Pho Chhu	28.061	89.889	4902	0.03168	E	
425	Pho_gl 99	G090129E27991N	Pho Chhu	27.991	90.129	5088	0.02534	E	
426	Pho_gl 102	G090135E28003N	Pho Chhu	28.003	90.135	5065	0.02413	E	
427	Pho_gl 101	G090139E28002N	Pho Chhu	28.002	90.139	5066	0.14916	E	
428	Pho_gl 15	G089933E27908N	Pho Chhu	27.908	89.933	4844	0.04444	M(e)	
429	Pho_gl 14	G089929E27921N	Pho Chhu	27.921	89.929	4830	0.02311	E	
430	Pho_gl 13	G089933E27924N	Pho Chhu	27.924	89.933	4829	0.08401	E	
431	Pho_gl 12	G089932E27930N	Pho Chhu	27.930	89.932	4942	0.01657	E	
432	Pho_gl 11	G089936E27932N	Pho Chhu	27.932	89.936	4923	0.02225	E	
433	Pho_gl 9	G089922E27933N	Pho Chhu	27.933	89.922	4983	0.02629	E	
434	Pho_gl 8	G089930E27941N	Pho Chhu	27.941	89.930	5002	0.72996	M(e)	
435	Pho_gl 10	G089931E27936N	Pho Chhu	27.936	89.931	5008	0.02110	E	
436	Pho_gl 7	G089933E27950N	Pho Chhu	27.950	89.933	5054	0.07222	M(e)	
437	Pho_gl 6	G089925E27951N	Pho Chhu	27.951	89.925	5072	0.05003	E	
438	Pho_gl 5	G089923E27948N	Pho Chhu	27.948	89.923	5076	0.02127	E	

439	Pho_gl	G089914E27948N	Pho Chhu	27.948	89.914	5077	0.01517	E	
440	Pho_gl 3	G089910E27948N	Pho Chhu	27.948	89.910	5086	0.01638	E	
441	Pho_gl 2	G089906E27941N	Pho Chhu	27.941	89.906	5031	0.13746	E	
442	Pho_gl 1	G089909E27937N	Pho Chhu	27.937	89.909	4994	0.01112	E	
443	Pho_gl 25	G089895E28036N	Pho Chhu	28.036	89.895	5199	0.05939	E	
444	Pho_gl 24	G089893E28030N	Pho Chhu	28.030	89.893	5039	0.11584	E	
445	Pho_gl 65	G090029E28013N	Pho Chhu	28.013	90.029	4429	0.03421	E	
446	Pho_gl 51	G090019E28057N	Pho Chhu	28.057	90.019	4596	0.02529	E	
447	Pho_gl 54	G089986E28123N	Pho Chhu	28.123	89.986	5003	0.01059	M(l)	
448	Pho_gl 21	G089930E27973N	Pho Chhu	27.973	89.930	5078	0.64554	M(e)	
449	Pho_gl 55	G090007E28116N	Pho Chhu	28.116	90.007	4645	0.02161	I(s)	
450	Pho_gl 20	G089931E27964N	Pho Chhu	27.964	89.931	5132	0.02996	M(e)	
451	Pho_gl 103	G090139E28007N	Pho Chhu	28.007	90.139	5064	0.09165	M(e)	
452	Pho_gl 100	G090142E27992N	Pho Chhu	27.992	90.142	4978	0.09434	E	
453	Pho_gl 93	G090119E27964N	Pho Chhu	27.964	90.119	4884	0.04462	E	
454	Pho_gl 92	G090103E27961N	Pho Chhu	27.961	90.103	5110	0.01244	E	
455	Pho_gl 91	G090079E27954N	Pho Chhu	27.954	90.079	4784	0.08291	E	
456	Pho_gl 22	G089956E28006N	Pho Chhu	28.006	89.956	4615	0.15586	M(e)	
457	Pho_gl 90	G090095E28008N	Pho Chhu	28.008	90.095	4687	0.02435	E	
458	Pho_gl 89	G090106E28007N	Pho Chhu	28.007	90.106	4542	0.10644	E	

459	Pho_gl 67	G090043E28096N	Pho Chhu	28.096	90.043	5127	0.06522	M(e)	
460	Pho_gl 66	G090042E28092N	Pho Chhu	28.092	90.042	5049	0.09108	E	
461	Pho_gl 46	G089978E28056N	Pho Chhu	28.056	89.978	5006	0.03151	M(e)	
462	Pho_gl 42	G089955E28104N	Pho Chhu	28.104	89.955	5147	0.02050	E	
463	Pho_gl 44	G089953E28085N	Pho Chhu	28.085	89.953	4839	0.01236	E	
464	Pho_gl 48	G089992E28079N	Pho Chhu	28.079	89.992	5059	0.01355	E	
465	Pho_gl 47	G089989E28068N	Pho Chhu	28.068	89.989	5004	0.01579	M(e)	
466	Pho_gl 52	G089988E28117N	Pho Chhu	28.117	89.988	4913	0.01236	M(l)	
467	Pho_gl 56	G090011E28123N	Pho Chhu	28.123	90.011	4714	0.01191	E	
468	Pho_gl 53	G089985E28119N	Pho Chhu	28.119	89.985	4956	0.01112	E	
469	Pho_gl 50	G089985E28104N	Pho Chhu	28.104	89.985	5043	0.03653	E	
470	Pho_gl 27	G089877E28056N	Pho Chhu	28.056	89.877	4990	0.01999	M(l)	
471	Pho_gl 28	G089871E28059N	Pho Chhu	28.059	89.871	5127	0.04463	M(l)	
472	Pho_gl 23	G089928E28008N	Pho Chhu	28.008	89.928	5041	0.07217	M(e)	
473	Pho_gl 45	G089946E28078N	Pho Chhu	28.078	89.946	4710	0.03705	E	
474	Pho_gl 26	G089900E28038N	Pho Chhu	28.038	89.900	5221	0.03331	M(e)	
475	Pho_gl 49	G089990E28084N	Pho Chhu	28.084	89.990	5017	0.05353	E	
476	Pho_gl 37	G089924E28130N	Pho Chhu	28.130	89.924	5087	0.03918	M(e)	
477	Pho_gl 36	G089925E28119N	Pho Chhu	28.119	89.925	4620	0.03618	I(s)	
478	Pho_gl 59	G090026E28069N	Pho Chhu	28.069	90.026	4417	0.01320	I(s)	

479	Pho_gl 59	G090029E28060N	Pho Chhu	28.060	90.029	4396	0.07106	I(s)	
480	Pho_gl 60	G090034E28060N	Pho Chhu	28.060	90.034	4390	0.01565	I(l)	
481	Pho_gl 61	G090035E28057N	Pho Chhu	28.057	90.035	4382	0.06227	I(l)	
482	Pho_gl 62	G090036E28053N	Pho Chhu	28.053	90.036	4380	0.02175	I(l)	
483	Pho_gl 63	G090033E28050N	Pho Chhu	28.050	90.033	4377	0.01619	I(l)	
484	Pho_gl 68	G090113E28084N	Pho Chhu	28.084	90.113	4150	0.08955	I(l)	
485	Pho_gl 69	G090111E28089N	Pho Chhu	28.089	90.111	4178	0.01302	I(l)	
486	Pho_gl 98	G090131E27988N	Pho Chhu	27.988	90.131	5042	0.20377	M(e)	
487	Pho_gl 96	G090139E27975N	Pho Chhu	27.975	90.139	5024	0.02866	E	
488	Pho_gl 58	G090027E28113N	Pho Chhu	28.113	90.027	4695	0.36997	M(e)	
489	Pho_gl 41	G089938E28123N	Pho Chhu	28.123	89.938	4655	0.02148	I(s)	
490	Pho_gl 40	G089945E28124N	Pho Chhu	28.124	89.945	4754	0.06398	M(e)	
491	Pho_gl 34	G089916E28117N	Pho Chhu	28.117	89.916	4444	0.04237	E	
492	Pho_gl 57	G090016E28115N	Pho Chhu	28.115	90.016	4676	0.01108	E	
493	Pho_gl 64	G090035E28042N	Pho Chhu	28.042	90.035	4345	0.03980	I(l)	
494	Pho_gl 142	G090219E27893N	Pho Chhu	27.893	90.219	4994	0.16934	M(e)	
495	Pho_gl 155	G090237E27837N	Pho Chhu	27.837	90.237	4772	0.07102	E	
496	Pho_gl 143	G090207E27876N	Pho Chhu	27.876	90.207	4914	0.41131	M(e)	
497	Pho_gl 151	G090255E27847N	Pho Chhu	27.847	90.255	4879	0.03096	M(e)	
498	Pho_gl 156	G090232E27832N	Pho Chhu	27.832	90.232	4733	0.04854	E	

499	Pho_gl 152	G090258E27844N	Pho Chhu	27.844	90.258	5025	0.05914	M(e)	
500	Pho_gl 145	G090232E27870N	Pho Chhu	27.870	90.232	5010	0.01343	E	
501	Pho_gl 144	G090200E27868N	Pho Chhu	27.868	90.200	4976	0.03082	E	
502	Pho_gl 147	G090243E27897N	Pho Chhu	27.897	90.243	5153	0.02383	E	
503	Pho_gl 148	G090241E27899N	Pho Chhu	27.899	90.241	5180	0.01934	M(e)	
504	Pho_gl 141	G090207E27902N	Pho Chhu	27.902	90.207	4959	0.03198	E	
505	Pho_gl 150	G090249E27892N	Pho Chhu	27.892	90.249	5102	0.01941	E	
506	Pho_gl 153	G090253E27841N	Pho Chhu	27.841	90.253	5003	0.09114	M(e)	
507	Pho_gl 132	G090259E27925N	Pho Chhu	27.925	90.259	5129	0.12063	M(e)	
508	Pho_gl 107	G090179E28002N	Pho Chhu	28.002	90.179	5116	0.01478	E	
509	Pho_gl 110	G090194E28023N	Pho Chhu	28.023	90.194	5217	0.05522	M(l)	
510	Pho_gl 105	G090167E28014N	Pho Chhu	28.014	90.167	5144	0.02221	E	
511	Pho_gl 85	G090276E28008N	Pho Chhu	28.008	90.276	5279	0.08238	M(l)	
512	Pho_gl 88	G090261E27996N	Pho Chhu	27.996	90.261	5146	0.20196	M(e)	
513	Pho_gl 140	G090209E27917N	Pho Chhu	27.917	90.209	4907	0.07992	M(l)	
514	Pho_gl 146	G090238E27891N	Pho Chhu	27.891	90.238	5022	0.03746	E	
515	Pho_gl 154	G090246E27848N	Pho Chhu	27.848	90.246	4804	0.12355	E	
516	Pho_gl 139	G090215E27922N	Pho Chhu	27.922	90.215	5188	0.05552	M(e)	
517	Pho_gl 73	G090164E28123N	Pho Chhu	28.123	90.164	4353	0.01838	I(l)	
518	Pho_gl 72	G090158E28111N	Pho Chhu	28.111	90.158	4312	0.01177	I(l)	

519	Pho_gl 71	G090167E28091N	Pho Chhu	28.091	90.167	4233	0.04202	I(l)	
520	Pho_gl 70	G090163E28083N	Pho Chhu	28.083	90.163	4193	0.01312	I(l)	
521	Pho_gl 74	G090231E28103N	Pho Chhu	28.103	90.231	4354	0.39227	M(e)	Bechung
522	Pho_gl 136	G090244E27916N	Pho Chhu	27.916	90.244	5176	0.17344	M(e)	
523	Pho_gl 75	G090247E28108N	Pho Chhu	28.108	90.247	4372	1.35378	M(e)	Rapstreng
524	Pho_gl 76	G090269E28109N	Pho Chhu	28.109	90.269	4474	4.20438	M(l)	Thorthormi
525	Pho_gl 77	G090302E28093N	Pho Chhu	28.093	90.302	4533	1.57196	M(e)	Luggye
526	Pho_gl 78	G090327E28086N	Pho Chhu	28.086	90.327	4708	0.13404	M(e)	Drukchung
527	Pho_gl 79	G090330E28079N	Pho Chhu	28.079	90.330	4739	0.02570	I(l)	
528	Pho_gl 120	G090259E27964N	Pho Chhu	27.964	90.259	5222	0.38133	M(e)	
529	Pho_gl 112	G090225E28005N	Pho Chhu	28.005	90.225	5045	0.02600	E	
530	Pho_gl 104	G090161E28010N	Pho Chhu	28.010	90.161	5054	0.07782	E	
531	Pho_gl 106	G090179E28023N	Pho Chhu	28.023	90.179	5082	0.17399	E	
532	Pho_gl 109	G090187E28012N	Pho Chhu	28.012	90.187	5145	0.20930	E	
533	Pho_gl 80	G090331E28067N	Pho Chhu	28.067	90.331	4976	0.02065	I(l)	
534	Pho_gl 137	G090244E27923N	Pho Chhu	27.923	90.244	5113	0.05672	M(e)	
535	Pho_gl 108	G090182E28003N	Pho Chhu	28.003	90.182	5119	0.02203	E	
536	Pho_gl 138	G090209E27932N	Pho Chhu	27.932	90.209	5000	0.12222	E	
537	Pho_gl 111	G090211E28016N	Pho Chhu	28.016	90.211	5127	0.53753	E	Tsho Chena
538	Pho_gl 86	G090289E27996N	Pho Chhu	27.996	90.289	5328	0.42574	E	

539	Pho_gl 114	G090234E27997N	Pho Chhu	27.997	90.234	4985	0.11312	M(e)	
540	Pho_gl 115	G090222E27995N	Pho Chhu	27.995	90.222	4937	0.23020	E	
541	Pho_gl 116	G090216E27992N	Pho Chhu	27.992	90.216	4936	0.18288	E	
542	Pho_gl 113	G090231E28005N	Pho Chhu	28.005	90.231	5073	0.04981	M(e)	
543	Pho_gl 118	G090244E27983N	Pho Chhu	27.983	90.244	5103	0.18441	M(e)	
544	Pho_gl 117	G090244E27985N	Pho Chhu	27.985	90.244	5100	0.01238	M(e)	
545	Pho_gl 119	G090233E27978N	Pho Chhu	27.978	90.233	5073	0.69051	M(l)	
546	Pho_gl 122	G090252E27960N	Pho Chhu	27.960	90.252	5176	0.02619	E	
547	Pho_gl 123	G090253E27956N	Pho Chhu	27.956	90.253	5172	0.02455	E	
548	Pho_gl 124	G090255E27953N	Pho Chhu	27.953	90.255	5184	0.15031	M(e)	
549	Pho_gl 126	G090244E27956N	Pho Chhu	27.956	90.244	5144	0.09897	E	
550	Pho_gl 125	G090245E27954N	Pho Chhu	27.954	90.245	5145	0.02895	E	
551	Pho_gl 127	G090240E27953N	Pho Chhu	27.953	90.240	5130	0.04745	E	
552	Pho_gl 131	G090244E27940N	Pho Chhu	27.940	90.244	5107	0.02678	E	
553	Pho_gl 129	G090249E27941N	Pho Chhu	27.941	90.249	5139	0.01687	E	
554	Pho_gl 130	G090249E27939N	Pho Chhu	27.939	90.249	5119	0.04097	E	
555	Pho_gl 128	G090256E27943N	Pho Chhu	27.943	90.256	5199	0.05189	M(e)	
556	Pho_gl 133	G090263E27920N	Pho Chhu	27.920	90.263	5151	0.23078	M(e)	
557	Pho_gl 134	G090257E27918N	Pho Chhu	27.918	90.257	5200	0.01663	M(e)	
558	Pho_gl 135	G090255E27916N	Pho Chhu	27.916	90.255	5210	0.01321	M(e)	

559	Pho_gl 83	G090270E28029N	Pho Chhu	28.029	90.270	5210	0.21205	M(e)	
560	Pho_gl 84	G090279E28013N	Pho Chhu	28.013	90.279	5286	0.15491	M(l)	
561	Pho_gl 87	G090300E27992N	Pho Chhu	27.992	90.300	5349	0.14938	M(e)	
562	Pho_gl 82	G090308E28043N	Pho Chhu	28.043	90.308	5278	0.02020	E	
563	Pho_gl 81	G090313E28059N	Pho Chhu	28.059	90.313	5105	0.08036	E	
564	Pho_gl 121	G090259E27957N	Pho Chhu	27.957	90.259	5199	0.02286	M(e)	
565	Pho_gl 149	G090252E27897N	Pho Chhu	27.897	90.252	5170	0.08621	M(e)	
566	Pho_gl 95	G090141E27973N	Pho Chhu	27.973	90.141	4965	0.03791	E	
567	Pho_gl 97	G090134E27976N	Pho Chhu	27.976	90.134	5130	0.01317	M(l)	

Side view of Lunana Complex 2012

Most types of natural hazards are projected to change in frequency, magnitude and areas affected as the cryosphere continues to decline (high confidence). Glacier retreat and permafrost thaw are projected to decrease the stability of mountain slopes and increase the number and area of glacier lakes (high Confidence). Resulting landslides and floods, and cascading events, will also emerge where there is no record of previous events (high confidence)

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