International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
ENERGY SECURITY – UNDER CHANGING CLIMATE

THDC India Ltd.

New Delhi
Central Board of Irrigation & Power

INCOLD
Indian National Committee on Large Dams

A Comparative Modelling Study of Glacial Lake and Associated Glacial Lake Outburst Floods at Dugar Hydro-Electric Project in Chenab River Basin

Author

Ankit Kumar, Deputy Director, CWC
Samir Kumar Shukla, Director, CWC
Yogesh Kumar Gupta, Assistant Director, CWC

Presented by

Ankit Kumar

Deputy Director

FE&SA Directorate

Dam Safety Organisation (DSO)

Central Water Commission (CWC)

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
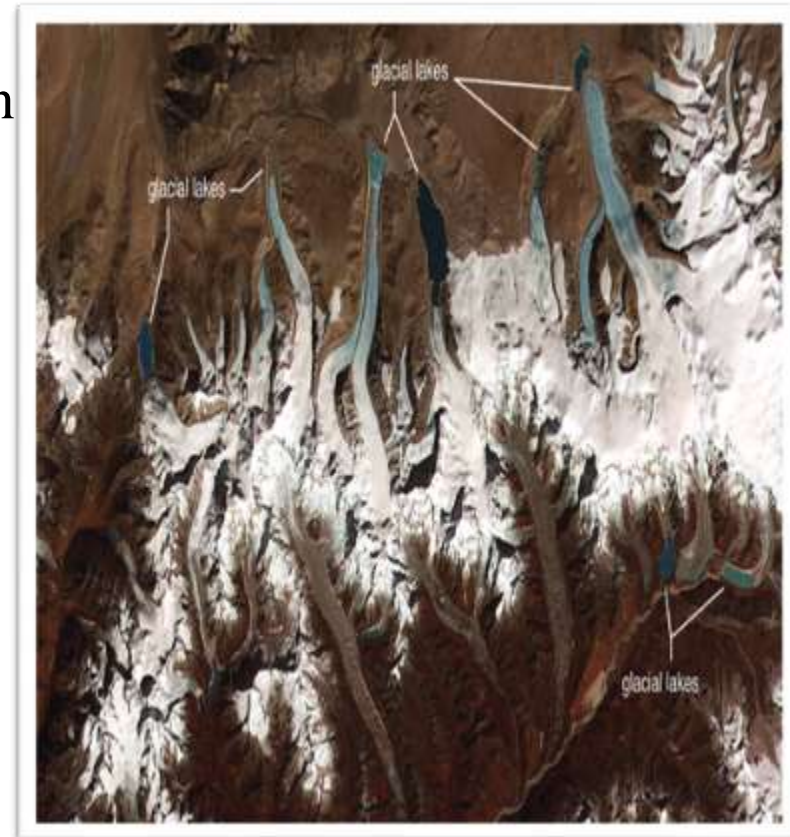**ENERGY SECURITY – UNDER CHANGING CLIMATE**

THDC India Ltd.

Central Board of
Irrigation & Power
New Delhi

INCOLD
Indian National Committee
on Large Dams

Content

1. Glacial Lakes in Himalayan Region
2. Types of Glacial Lakes
3. Moraine and its structure
4. Monitoring of Glacial Lakes
5. GLOF: A Dam Break Modelling
6. Input Data and Breach Parameters
7. Case Study (Dugar HEP)
8. Results and Discussion
9. Conclusion

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
ENERGY SECURITY – UNDER CHANGING CLIMATE

THDC India Ltd.

Central Board of Irrigation & Power   INCOLD Indian National Committee on Large Dams

Glacial Lakes in Himalayan Region

✓ The Himalayan region has permanent snow cover and in winter, most of the high altitude region experience snowfall. Himalayan glaciers are important source of fresh water for northern Indian rivers.

✓ Due to this global warming, recession of glaciers is causing formation of new glacial lakes and also resulting in expansion of existing glacial lakes in Himalayan region.

✓ Gangotri glacier has been receding since 1780, although studies show its retreat quickened after 1971.

✓ Over the last 25 years, Gangotri glacier has retreated more than 850 meters, with a recession of 76 meters from 1996 to 1999 alone.

Source: earthobservatory.nasa.gov

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND ENERGY SECURITY – UNDER CHANGING CLIMATE

THDC India Ltd.

Central Board of Irrigation & Power

INCOLD
Indian National Committee on Large Dams

Glacial Lakes in Himalayan Region

✓ The glacial lakes, if breached, can result in instant release of water and cause great destruction in downstream areas.

✓ This instant release of stored water on breaching of glacial lakes with very high velocity is known as Glacial Lake Outburst Flood i.e. GLOF.

✓ Naturally, when large volume of water comes down at such a massive speed, it will wash away sediments, rocks and boulders.


Source: europeanscientist.com

Monitoring of Glacial Lakes

- ✓ Due to the hazard potential associated with glacial lakes, regular monitoring of vulnerable lakes is necessary.

- ✓ As per CWC's **"Monitoring of Glacial Lakes & Water Bodies in the Himalayan Region of Indian River Basins for the Year 2021"** a total of 477 glacial lakes & water bodies in Himalayan region of size more than 50 ha are monitored regularly.

- ✓ Satellite images of AWiFS sensor received from NRSC, Hyderabad are used to create inventory of glacial lakes having size greater than 50 ha.
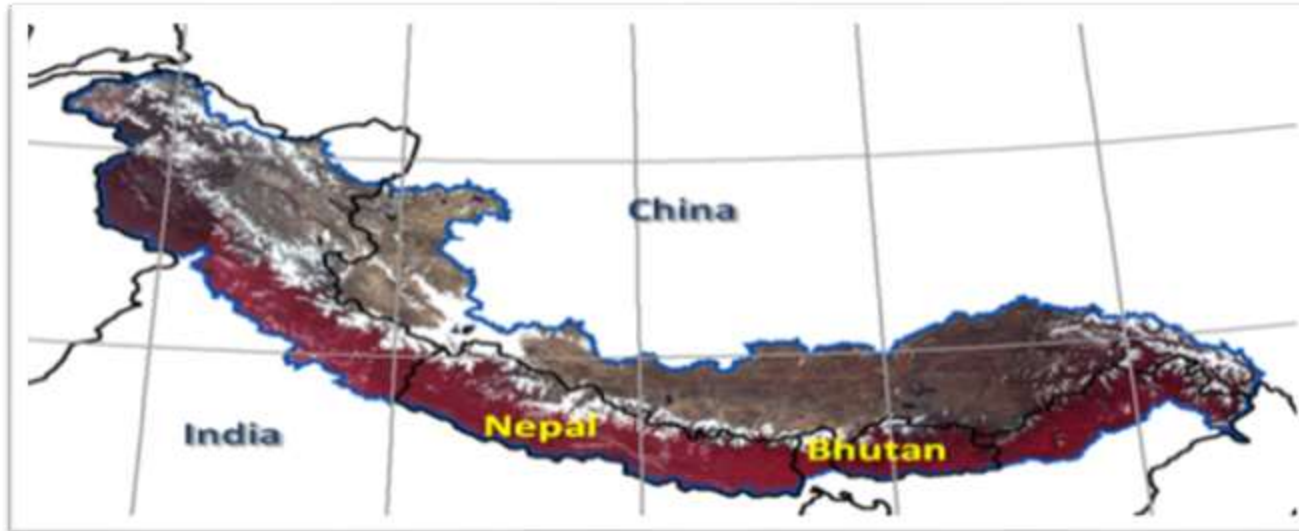
- ✓ http://cwc.gov.in/glacial-lakeswater-bodies-himalayan-region

Source : CWC Inventory

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
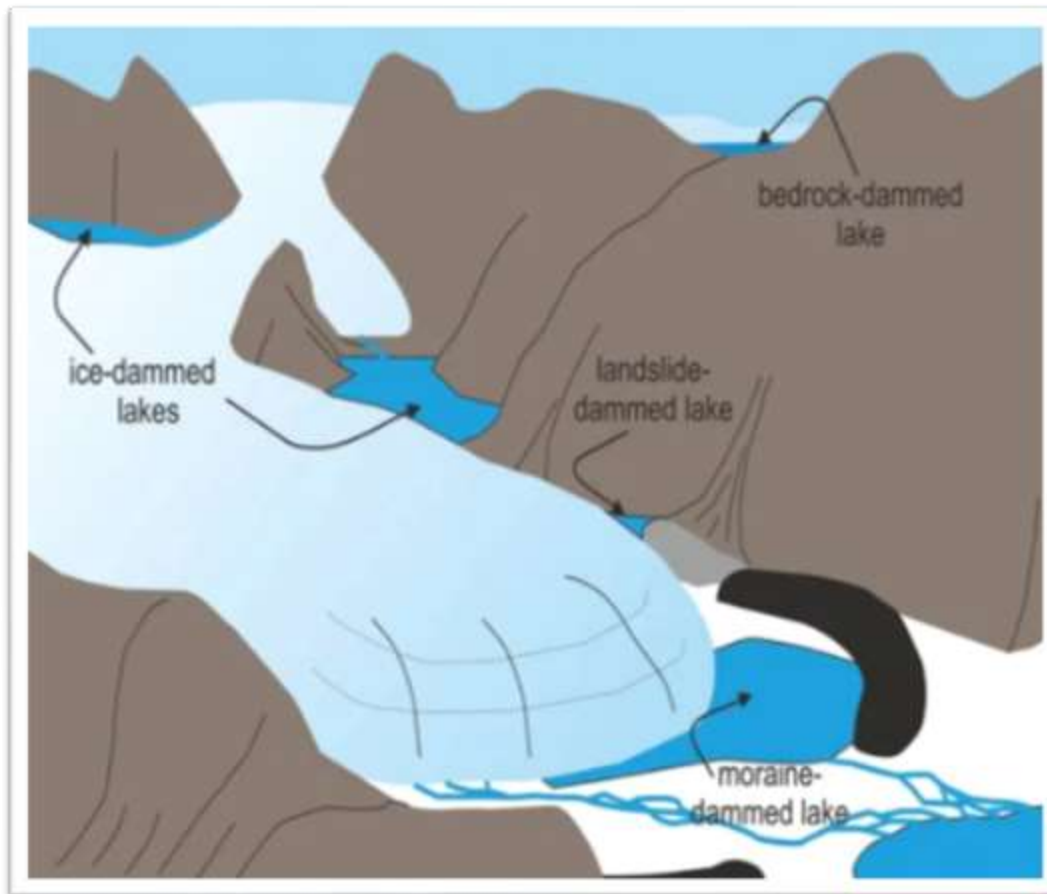**ENERGY SECURITY – UNDER CHANGING CLIMATE**

THDC India Ltd.

New Delhi
Central Board of Irrigation & Power

INCOLD
Indian National Committee on Large Dams

Types of Glacial Lakes

Source: Tweed & Carrivick (2015)

Moraine dammed lakes are considered to be more vulnerable to breaching due to its loose consolidation and porous nature.
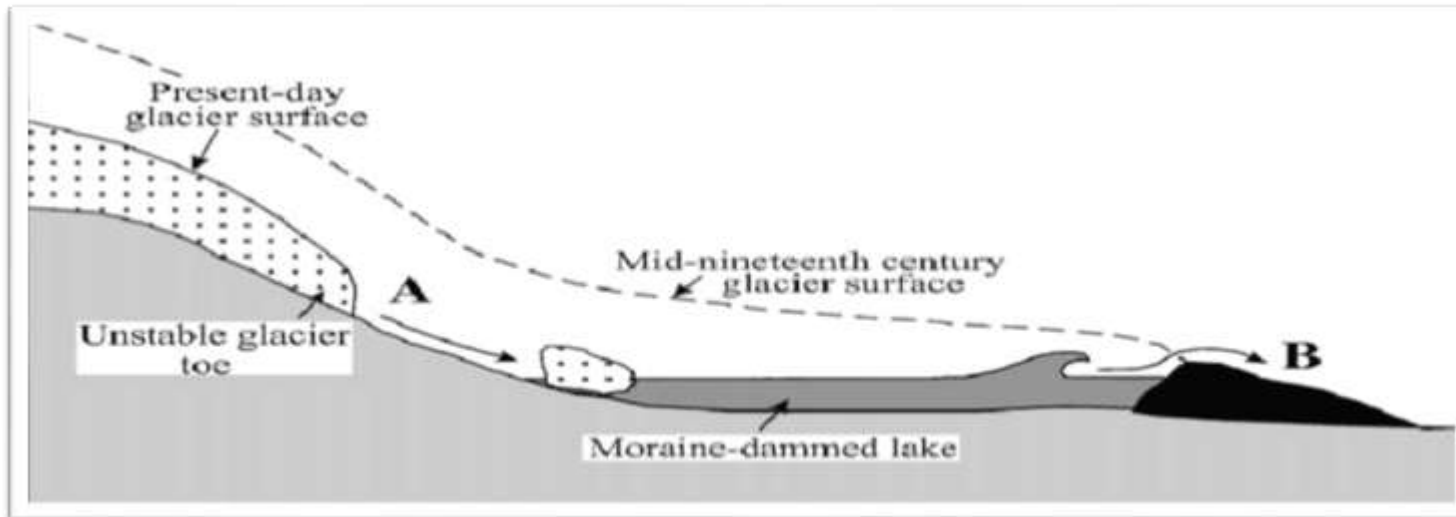
International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
ENERGY SECURITY – UNDER CHANGING CLIMATE

THDC India Ltd.

Central Board of Irrigation & Power   Indian National Committee on Large Dams
New Delhi   INCOLD

Moraines and its structure

- ✓ When the slope and weight of the ice and other conditions are sufficient to overcome the friction, the ice begins to slide by the mountain slope. This moving ice is a glacier.

- ✓ The glacial ice acts as a natural bulldozer and conveyer belt and carries all the loose material in its path.

- ✓ This material eroded by glacier is dropped at their edges (both terminal and lateral). Thus a moraine includes clay, silt, sand and coarse sediments of varying dimensions like gravels, large boulders, coarse sand, rocks etc. This moraine acts as a natural dam across narrow mountain valleys.

- ✓ Growth of water volume in the lakes, retreat of glacier terminus, slope of glacier, weak moraine layer, moraine erosion, potential piping, seepage, the presence of hanging glacier that can fall in to the lake, landslides and Earthquake etc. increases risk.
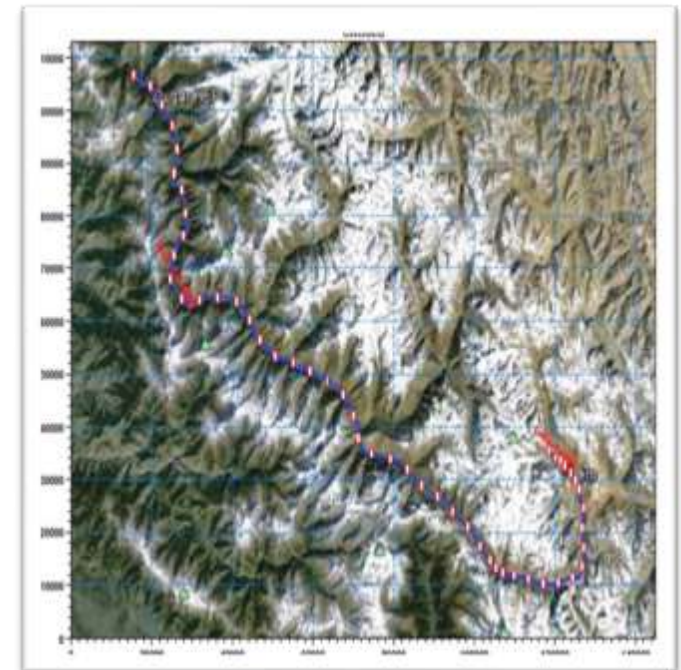
Source : John J. Clague

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
ENERGY SECURITY – UNDER CHANGING CLIMATE

THDC India Ltd.

Central Board of Irrigation & Power   INCOLD Indian National Committee on Large Dams

GLOF – A Dam Break Modelling

✓ GLOF is a type of dam break unsteady flow modelling.

✓ The possible failure mechanism associated with moraine dammed lakes are almost the same as of an earthen dam with difference being only in the time of full breach development.

✓ Further there are two objective of a GLOF modelling:

i. Estimation of outburst flood hydrograph just downstream of glacial lake

ii. Hydrodynamic channel routing of outburst flood to get the GLOF output at a project site through proper attenuation and translation mechanism.

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
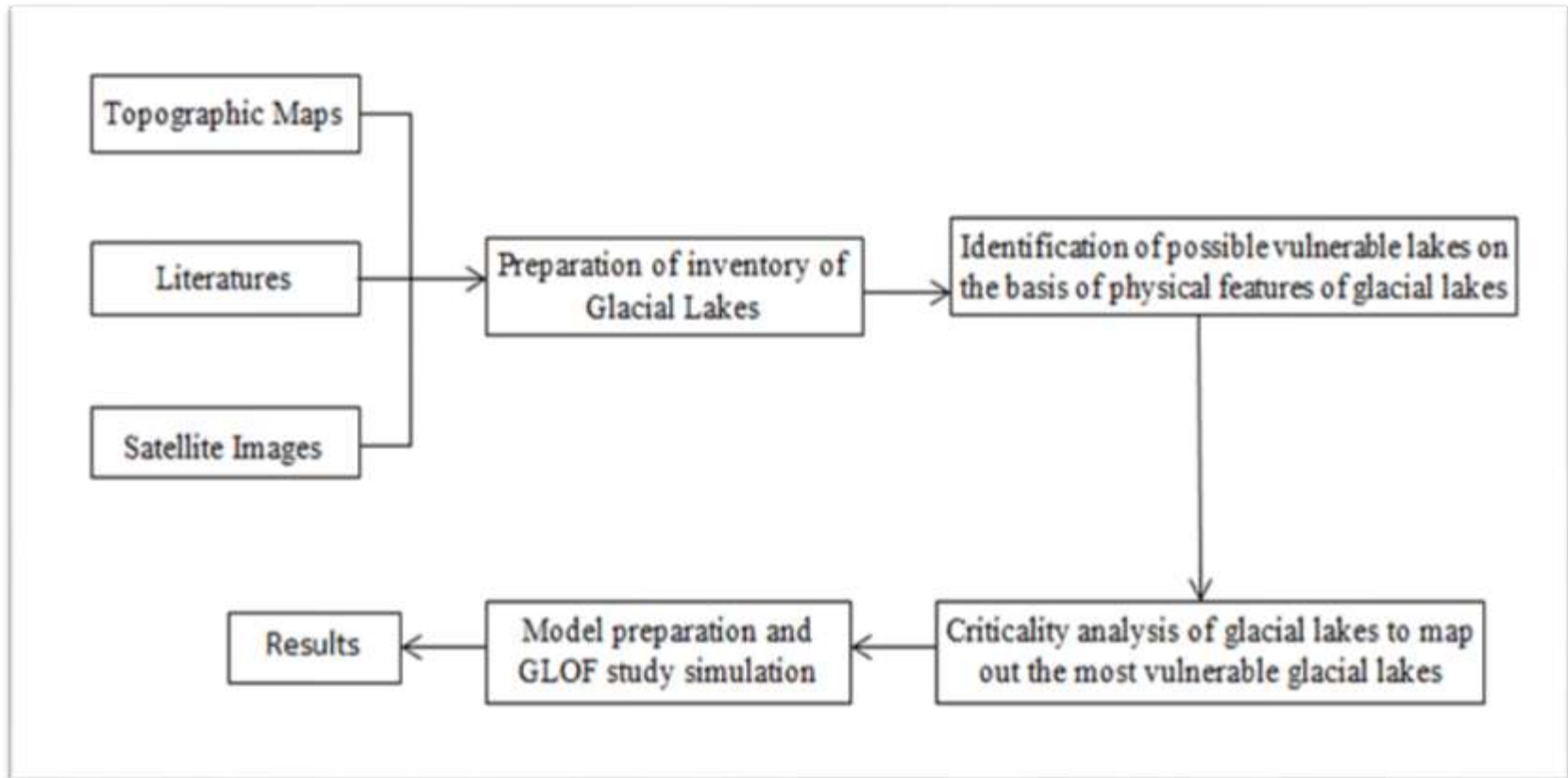**ENERGY SECURITY – UNDER CHANGING CLIMATE**

THDC India Ltd.

New Delhi

Central Board of   Indian National Committee
Irrigation & Power   on Large Dams

INCOLD

Flow Diagram for GLOF Study

Input Data and Breach Parameters

✓ International Centre for Integrated Mountain Development (ICIMOD) guidelines and Christian Huggel's equations are widely used.

✓ Moraine Lake- 30 m

✓ The Christian Huggel's equations are developed for moraine glacial lakes in Swiss Alps region, but are being used satisfactorily for glacial lakes of Himalayan regions as well.
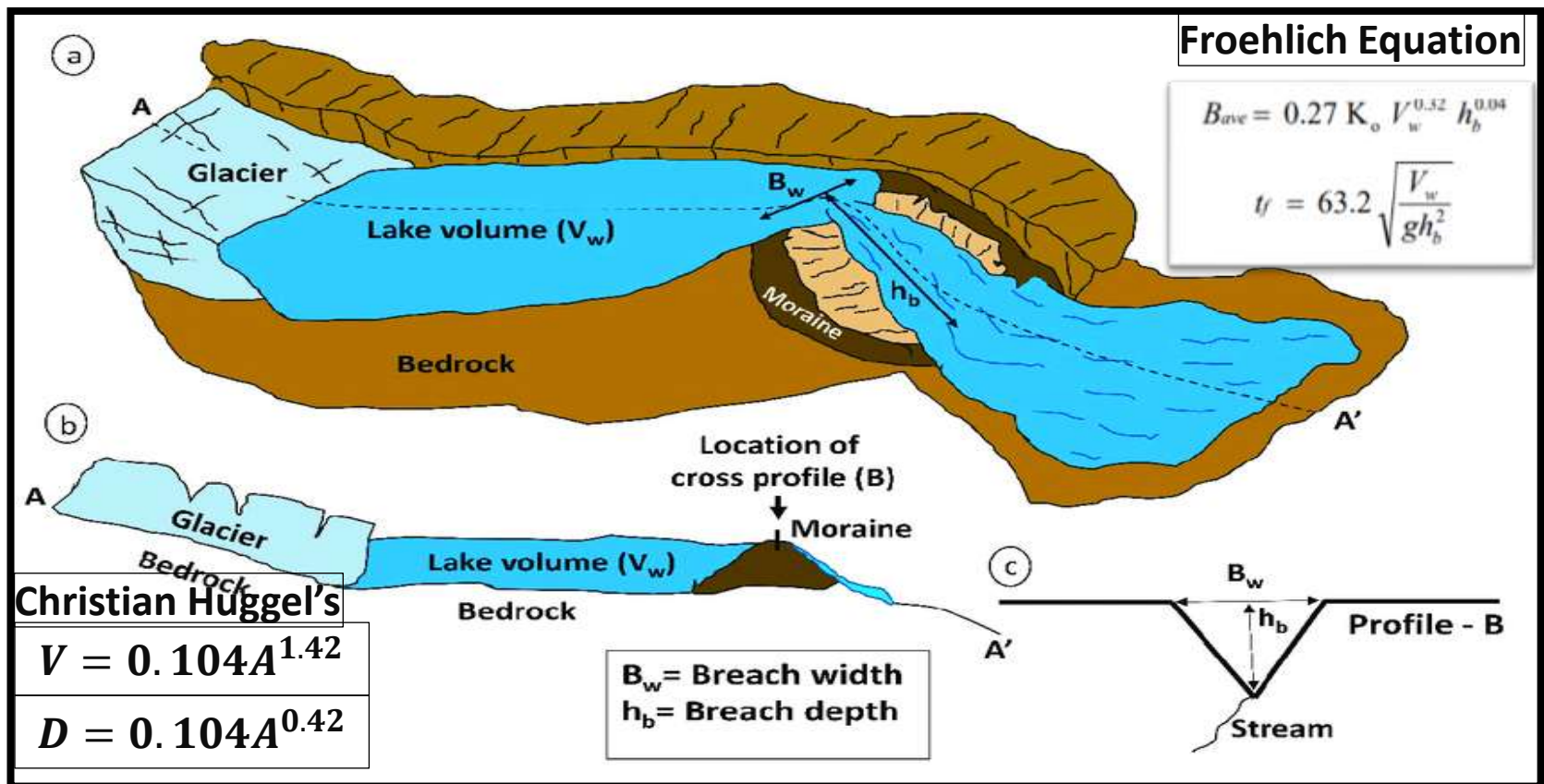
International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
ENERGY SECURITY – UNDER CHANGING CLIMATE

THDC India Ltd.

New Delhi

INCOLD
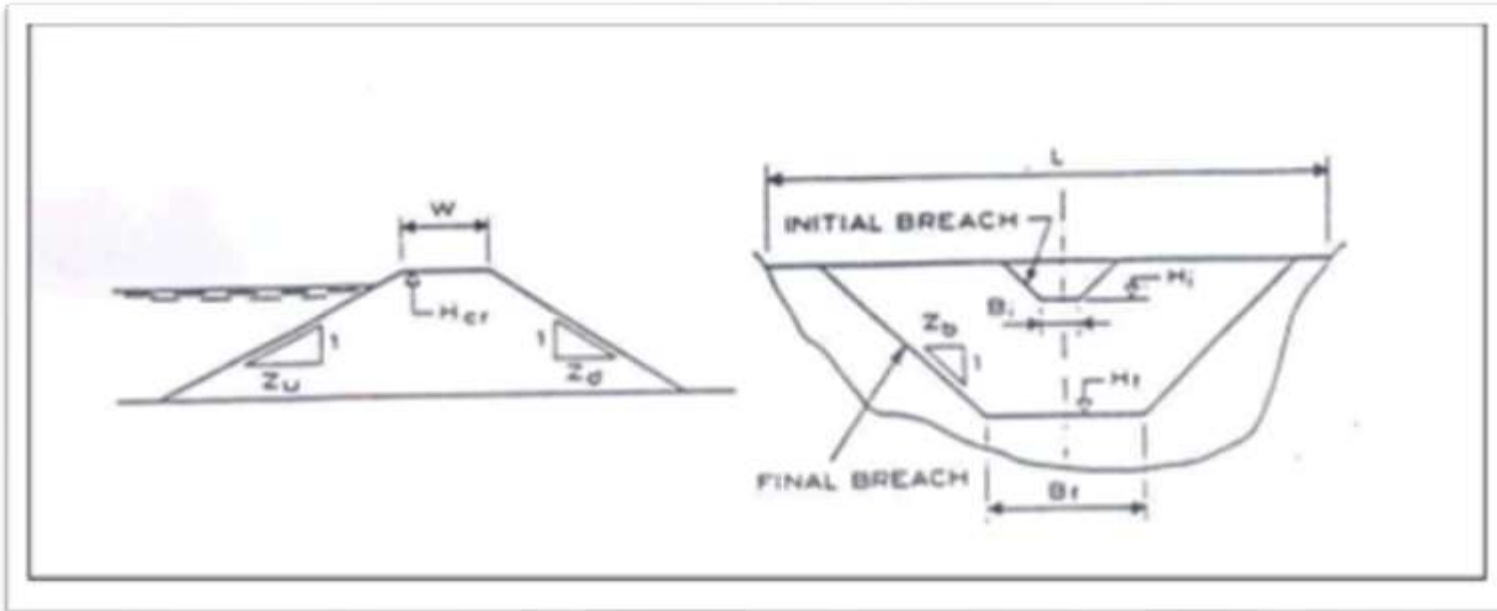
Central Board of Irrigation & Power

Indian National Committee on Large Dams

Input Data and Breach Parameters

Froehlich Equation

$$B_{ave} = 0.27\ K_o\ V_w^{0.32}\ h_b^{0.04}$$

$$t_f = 63.2\sqrt{\dfrac{V_w}{gh_b^2}}$$

Christian Huggel's

$$V = 0.104 A^{1.42}$$

$$D = 0.104 A^{0.42}$$

B_w = Breach width
h_b = Breach depth

Source: Sattar & Goswami (2020)

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
ENERGY SECURITY – UNDER CHANGING CLIMATE
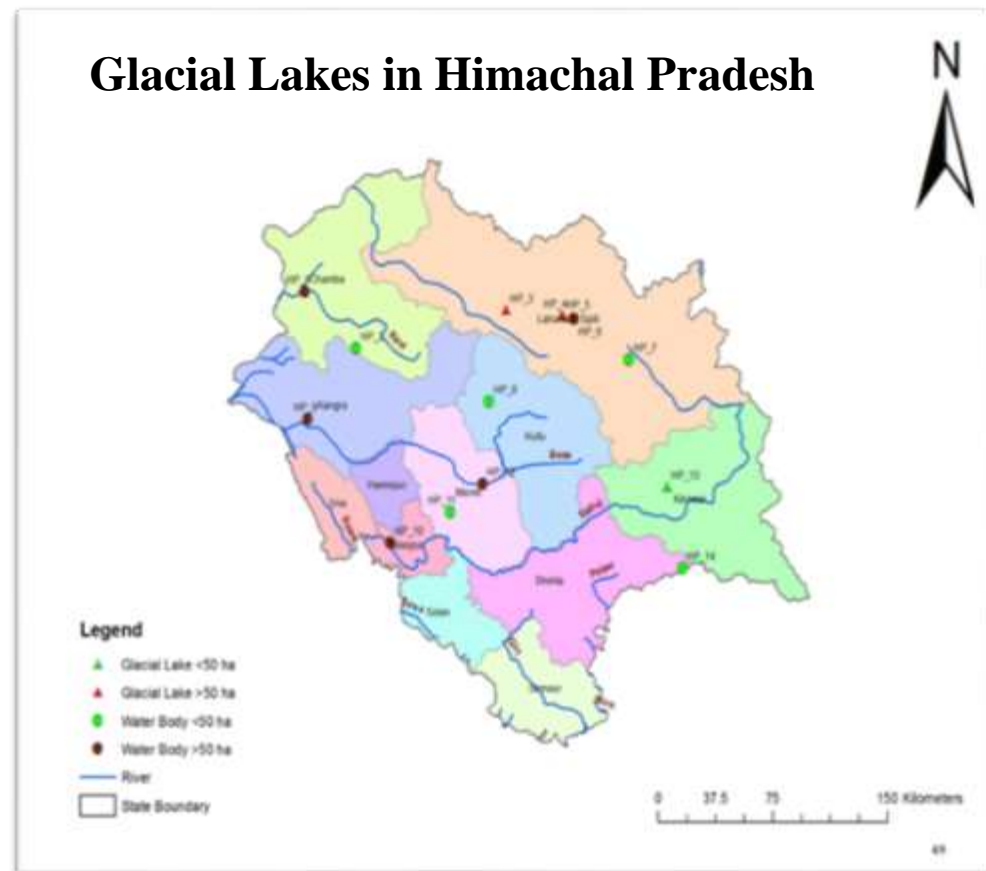
THDC India Ltd.

New Delhi
Central Board of Irrigation & Power
INCOLD
Indian National Committee on Large Dams

Case Study of Dugar HEP

✓ Present case study is related with the glacial lakes present in the upstream of Dugar Hydro-Electric Project (HEP).

✓ Dugar HEP is proposed on Chenab river in the state of Himachal Pradesh.

Glacial Lakes in Himachal Pradesh

Legend
▲ Glacial Lake <50 ha
▲ Glacial Lake >50 ha
● Water Body <50 ha
● Water Body >50 ha
— River
☐ State Boundary

0   37.5   75   150 Kilometers

Source: CWC Inventory

Case Study (Cont...)

✓ In 2014, the GLOF study was carried out for Dugar HEP in Chenab river basin.

✓ Three glacial lakes upstream of Dugar HEP having size more than 50 ha were identified based on vulnerability analysis.

✓ It was observed that while no new lake has been formed in the basin, the lake sizes of previously identified vulnerable lakes have increased.

Lake ID as per CWC Inventory	Elevation (m)	Area in ha (2014)	Area in ha (2020)	Distance from Dugar HEP (km)	Type
01_52H_002	4068	65	105	142	Moraine
01_52H_004	4150	88	160	205	Moraine
01_52H_005	4275	48	51	202	Cirque

After detailed criticality analysis, moraine dammed glacial lake 01_52H_004 was found to be most critical glacial lake.

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND ENERGY SECURITY – UNDER CHANGING CLIMATE

THDC India Ltd.
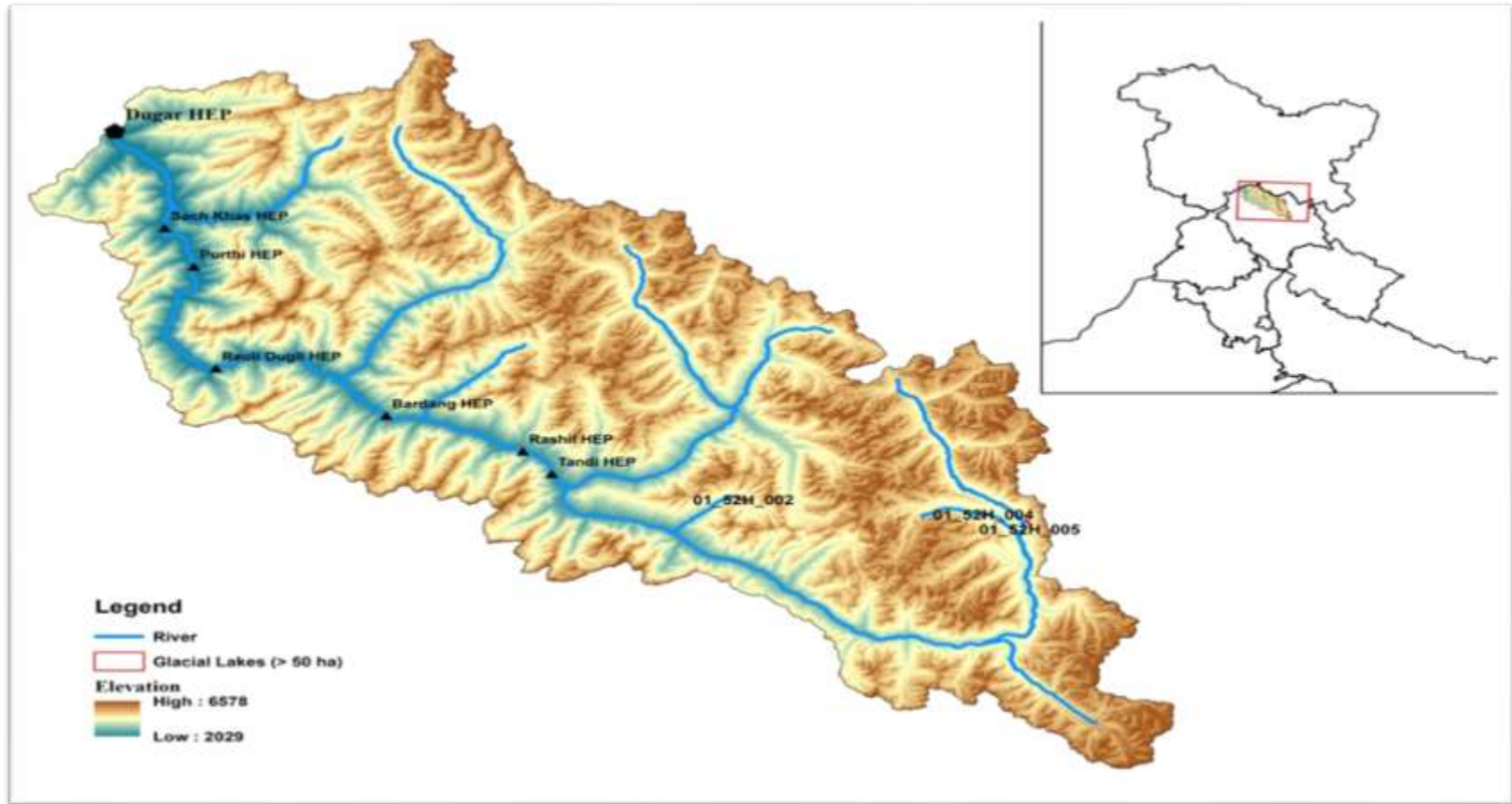
Central Board of Irrigation & Power

INCOLD
Indian National Committee on Large Dams

Catchment Area Map of Chenab Basin

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
ENERGY SECURITY – UNDER CHANGING CLIMATE

THDC India Ltd.

Central Board of Irrigation & Power

INCOLD
Indian National Committee on Large Dams

Glacial Lake 01_52H_004

Google Earth Image of Glacial Lake
01_52H_004 (88 ha) **(2014)**

Google Earth Image of Glacial Lake
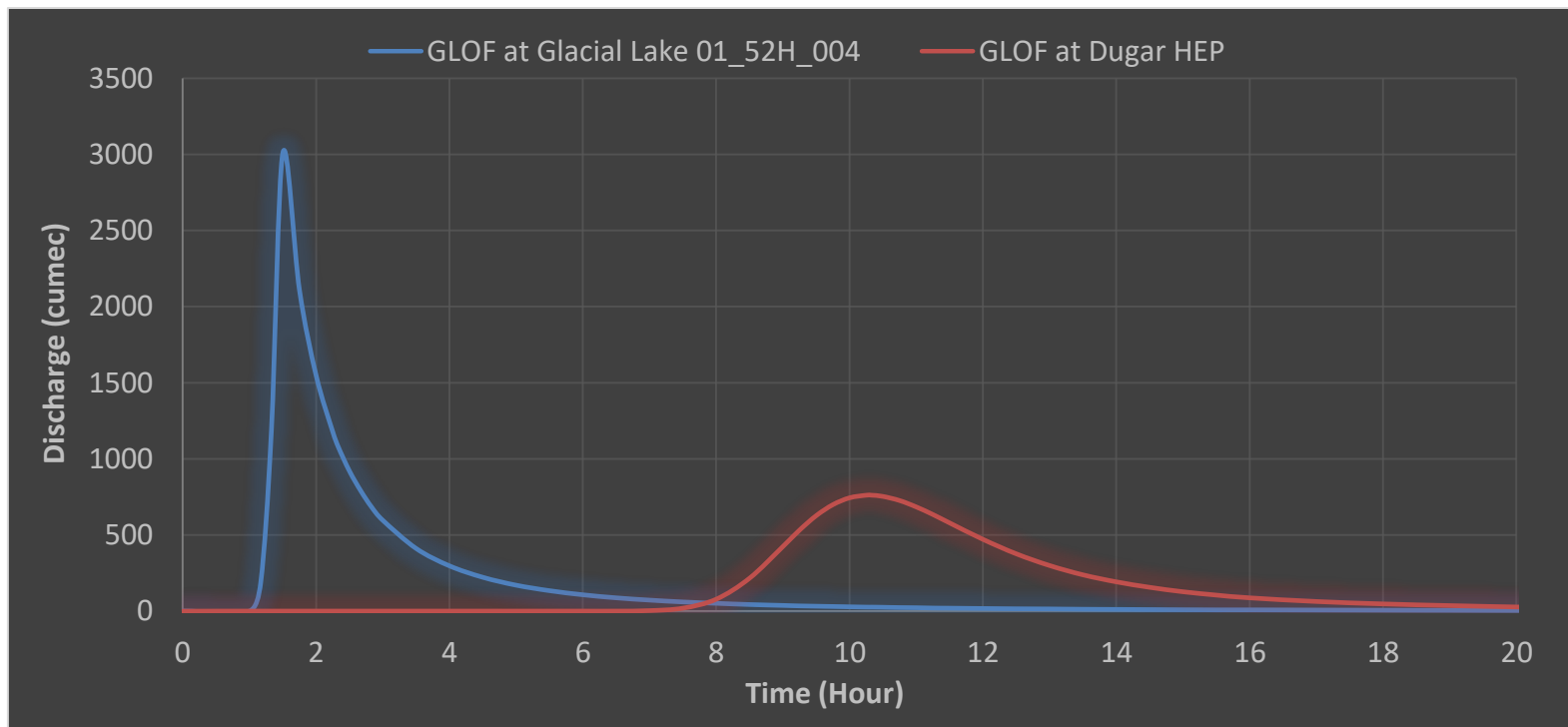01_52H_004 (160 ha) **(2020)**

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
ENERGY SECURITY – UNDER CHANGING CLIMATE

THDC India Ltd.

New Delhi

Central Board of
Irrigation & Power

INCOLD
Indian National Committee
on Large Dams

Results and Discussion

Based on the study of 2014, GLOF peak is found to be 3008 cumec at its origin i.e. just downstream and gets attenuated to 761 cumec at Dugar HEP
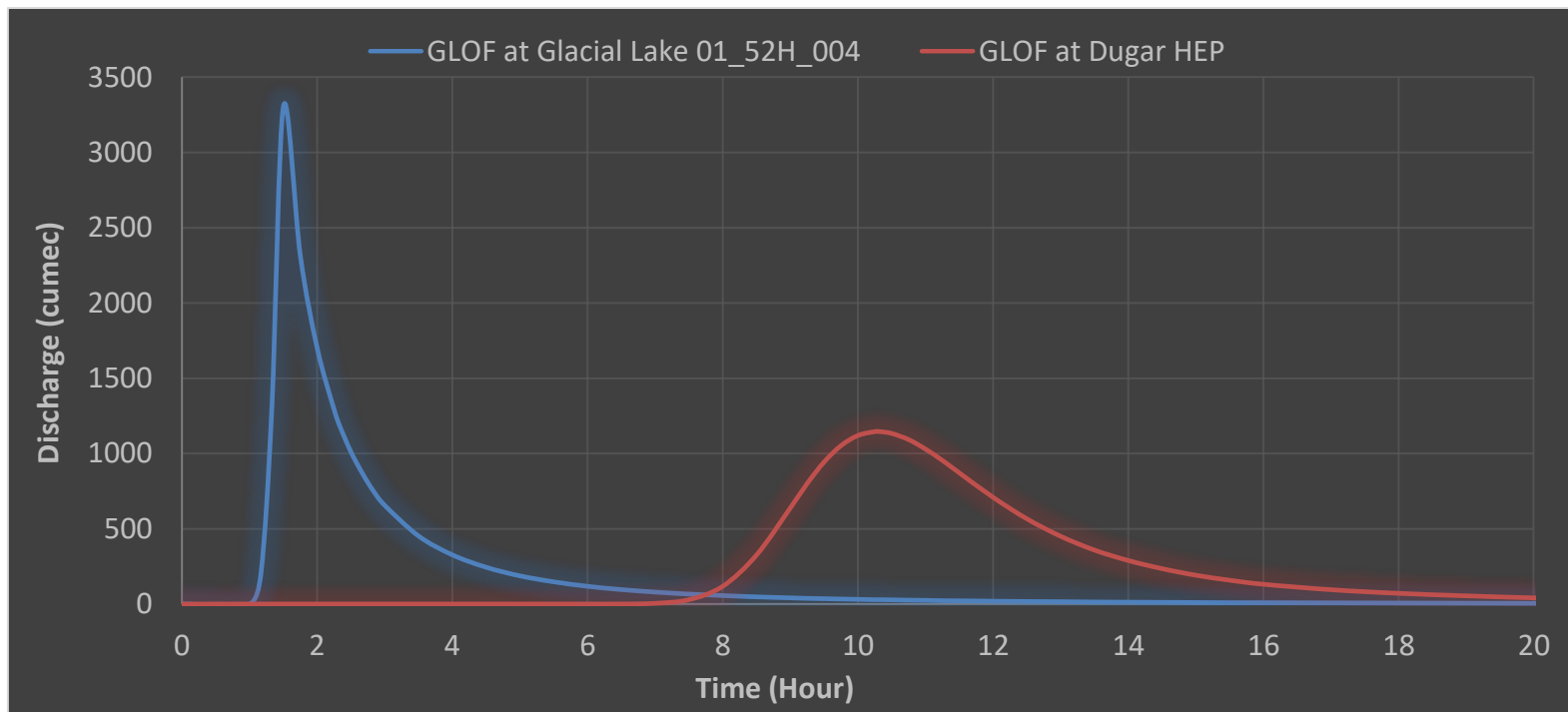
International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND
ENERGY SECURITY – UNDER CHANGING CLIMATE

THDC India Ltd.

Central Board of
Irrigation & Power
New Delhi

INCOLD
Indian National Committee
on Large Dams

Results and Discussion

Based on the study of 2020, GLOF peak is found to be 3305 cumec at its origin
i.e. just downstream and gets attenuated to 1145 cumec at Dugar HEP

Conclusion

- ✓ The spread area of glacial lake was increased by about 80% and the GLOF by about 50% at project site between 2014 and 2020.

- ✓ This study is a fit case to conclude that assessment of GLOF not only necessary during planning of project, but also all others project which are already being constructed. The possible impact on them also needs regular review.

- ✓ The designer should keep in the mind , how change in the glacial lakes size have to be accounted in the projects.

- ✓ The very first step in minimizing the threat can be to start the monitoring of vulnerable lakes more actively and regularly. The next step would be to carry out detailed studies and model simulation of potentially vulnerable lakes and to share the outcome with the concerned stakeholders.

- ✓ It is also important to closely assess the bathymetric changes of identified lakes, instead relying only on satellite and remote sensing data.

- ✓ Early Warning System (EWS) or the transmitter station at glacial lakes sites may be installed, that receives signals from sensors and transmits to other remote warning stations.

Thank You
For Your Attention