MITIGATION AND ADAPTATION OF CLIMATE CHANGE IMPACT IN HYDRO PROJECTS

जल परियोजनाओं में जलवायु परिवर्तन के प्रभाव का शमन और अनुकूलन

Prepared by:
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NHPC Ltd.
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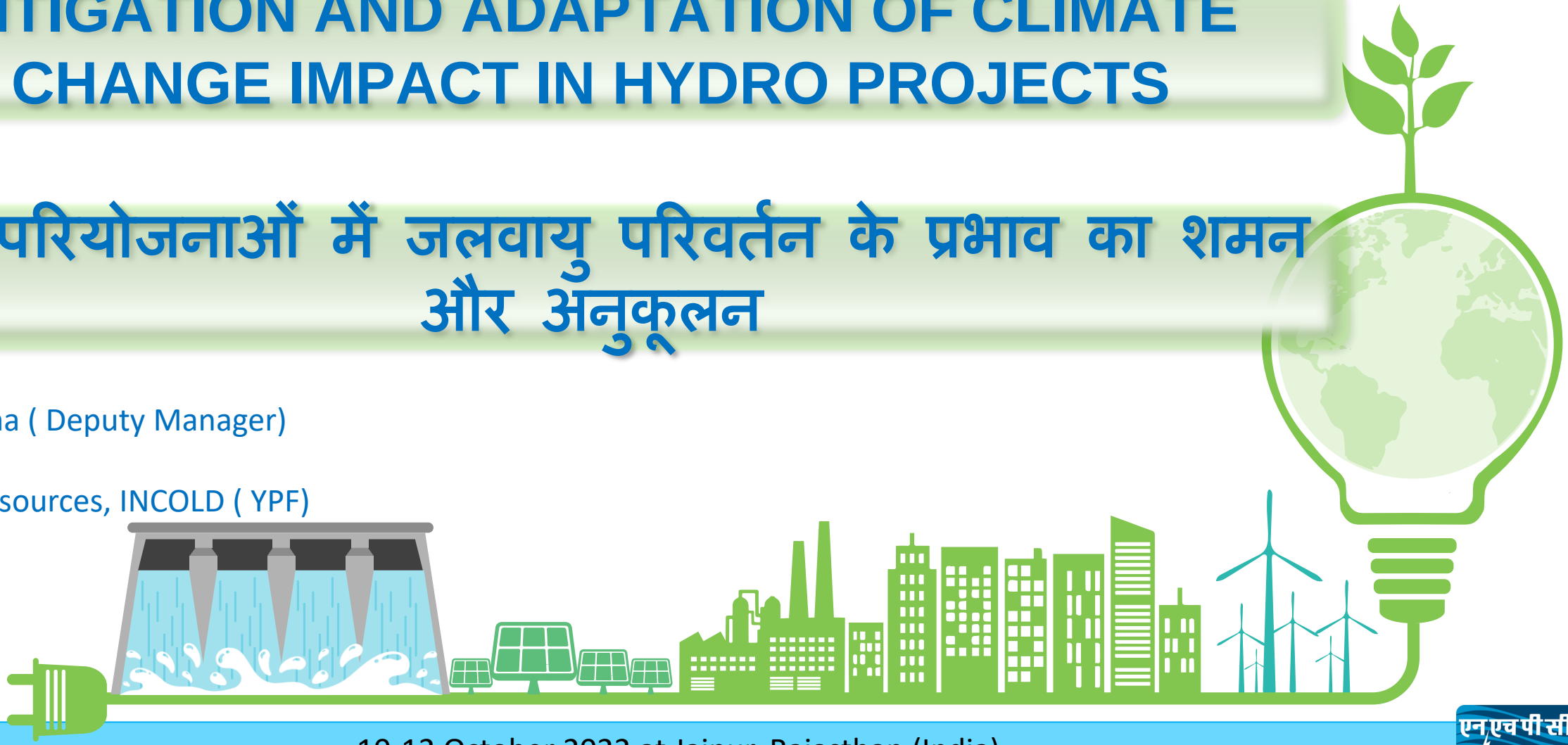

Indian Committee on Large Dams
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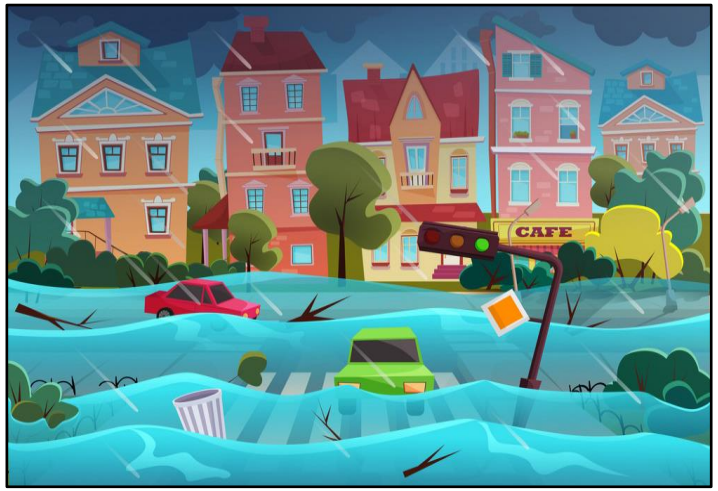
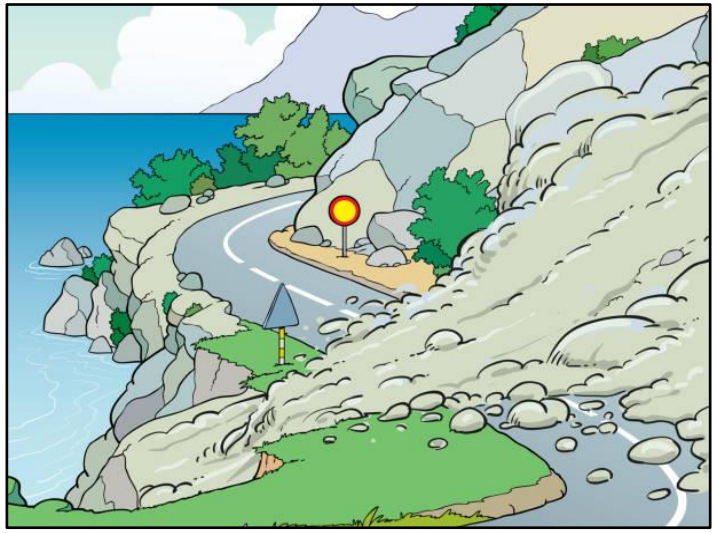
Dam Rehabilitation & Improvement Project

Central Water Commission

We will discuss……

- What is Climate change
- Its Impact on Hydro Projects
- Adaptation Techniques
- Mitigation Techniques
- How Hydropower can minimizes climate change





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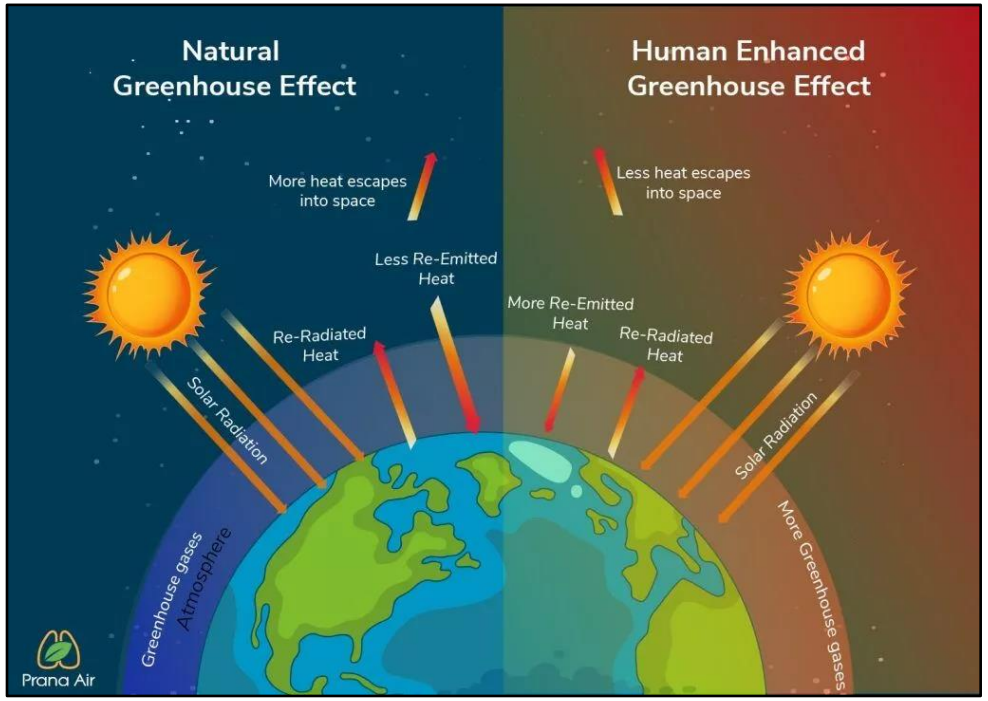
Global Warming & Climate Change

- Global warming is the **long-term rise in the average temperature of the Earth's climate.**
- Global warming is the **mainly human-caused** increase in global surface temperatures, while climate change includes both global warming and its effects, such as changes in precipitation, wind, etc.
- The current Earth climate warming trend is extremely likely (over 95% probability) to be the **result of human activity** since the mid-20th century.



Evidence of Rapid climate change

- •Global Temperature Rise
- •Warming Oceans
- •Shrinking Ice Sheets and Snow Cover
- •Ocean Acidification
- •Extreme Weather Events
- •Change in Precipitation pattern

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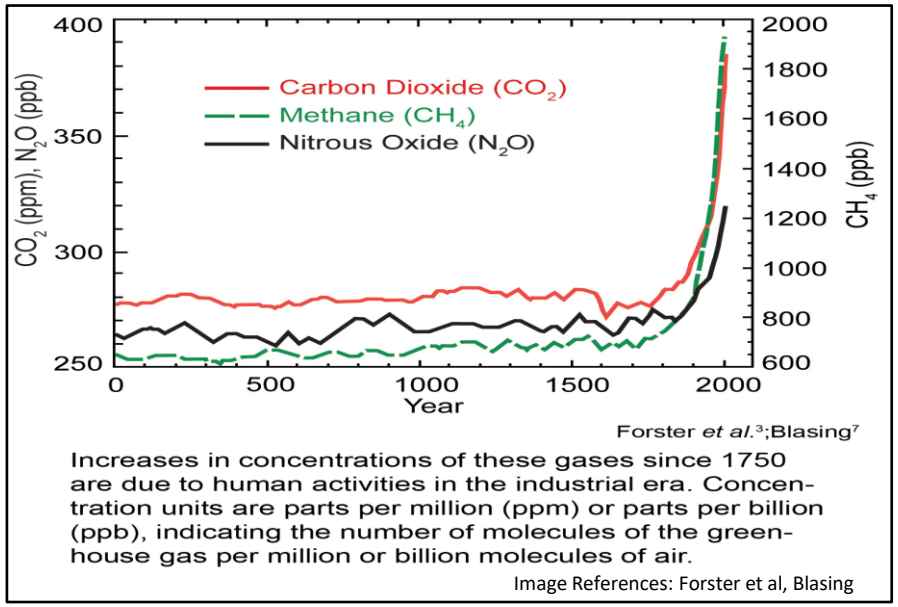
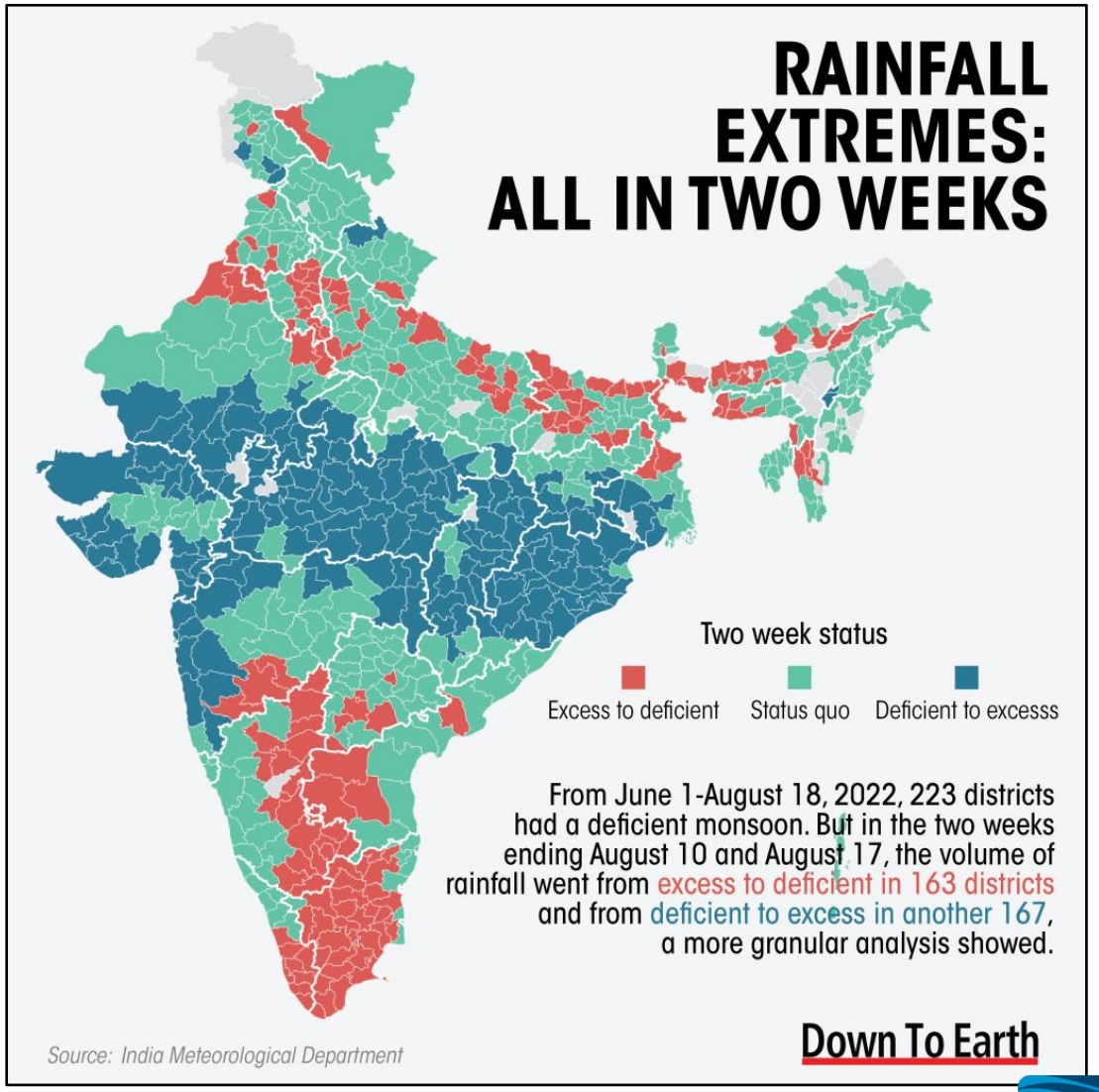


Forster *et al.*[3];Blasing[7]

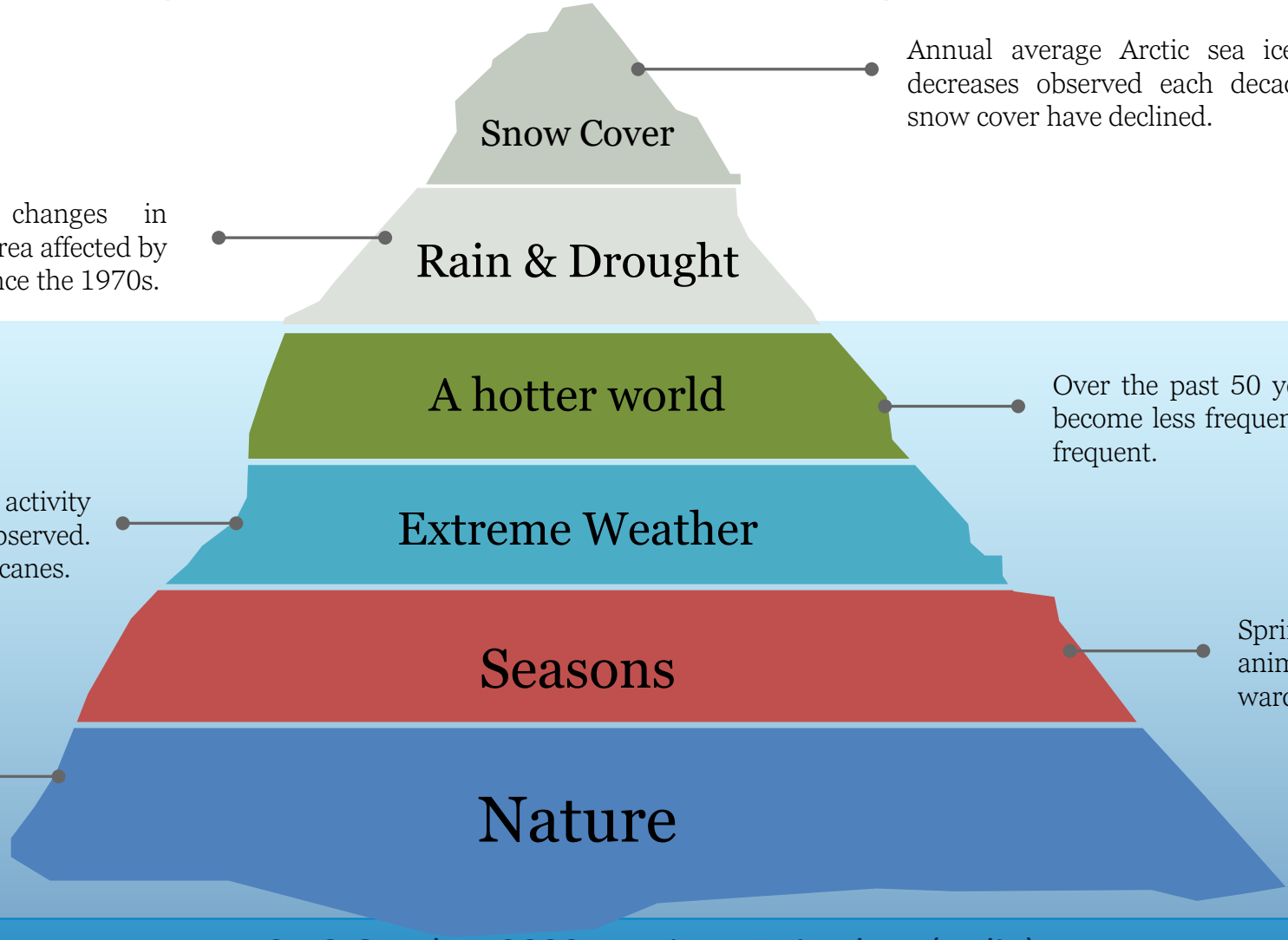
Increases in concentrations of these gases since 1750 are due to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion molecules of air.

Image References: Forster et al, Blasing



- A decline in monsoon rainfall since the 1950s has already been observed.
- The frequency of **heavy rainfall events has also increased**.
- A **2°C rise** in the world's average temperatures will make India's summer monsoon highly unpredictable

Assessment of global change in temperature by IPCC (Intergovernmental panel on climate change)



Annual average Arctic sea ice has shrunk, with larger decreases observed each decade. Mountain glaciers and snow cover have declined.

There have been significant changes in precipitation patterns globally. The area affected by drought is likely to have increased since the 1970s.

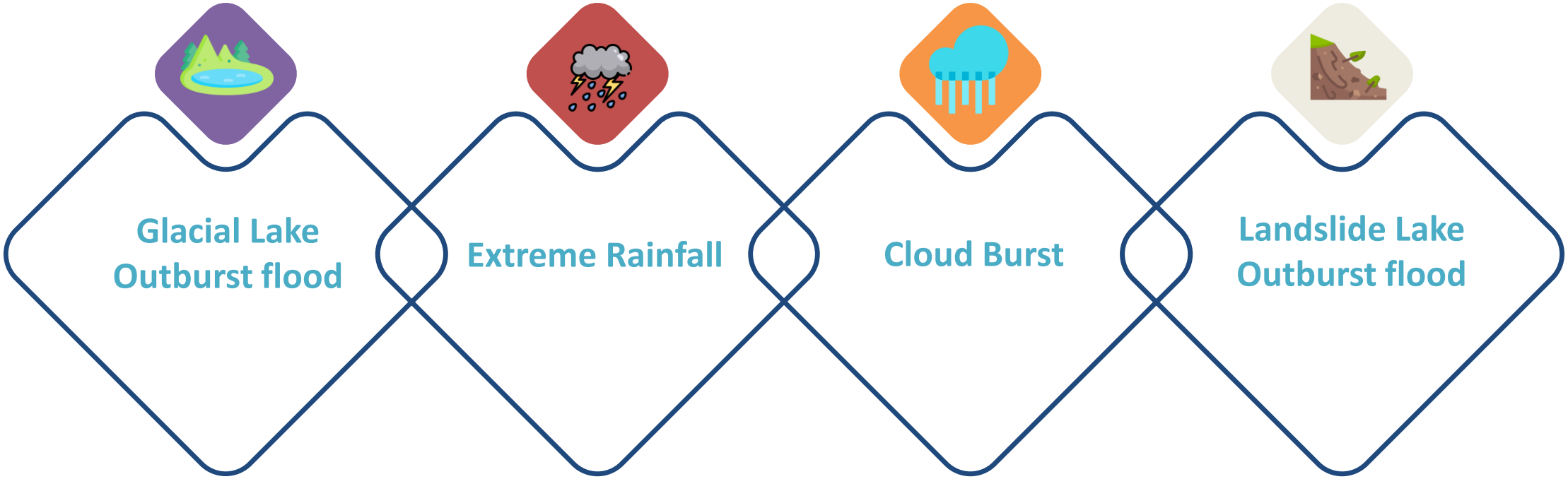
Over the past 50 years, cold days & nights, frosts have become less frequent and hot days and hot nights, more frequent.

An increase in intense tropical cyclone activity in the North Atlantic has been observed. Warm air is fuel for cyclones and hurricanes.

Spring events come earlier and plants and animals are moving upwards and pole wards because of recent warming trends.

Scientists have observed climate-induced changes in at least 420 physical processes and biological species or communities.

Some of the Impacts of Climate Change on Hydro Projects



Impact of Climate Change on Hydro Projects

Glacial Lake Outburst flood (GLOF)

- A glacier lake is a water body existing in sufficient quantities and extending with a free surface over an ice shelf and/or glacier floor. A lake usually forms between valley glaciers and ice streams in restricted areas.
- A glacial lake outburst flood (GLOF) is a catastrophic glacially-driven natural calamity, occurring when dams containing glacial lakes fail, leading to rapid surging of water in the bed of the drainage system.
- Results in huge loss of property and life at downstream.

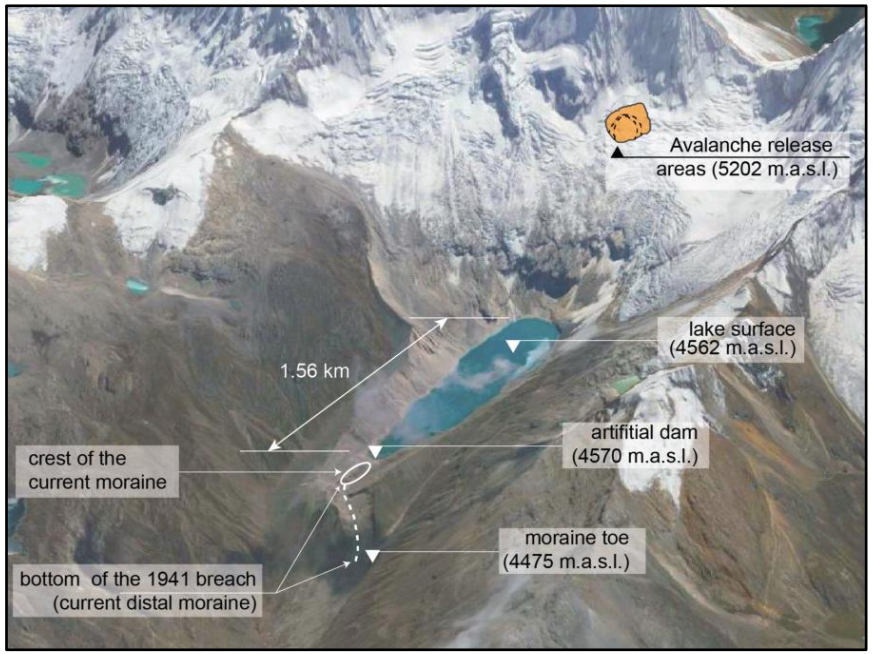


Image reference: (Article)Modeling a glacial lake outburst flood process chain: The case of Lake Palcacocha and Huaraz, Peru

Its triggering factors

S	A	H	R	R	G	E	V	W
Size of Lake	Avalanches	Heavy Rain	Rise in Temperature	Rock Fall	Glacier Fall	Earthquake	Volcanic Eruption	Water Pressure

Extreme rainfall/ Cloud Burst

- A cloudburst is an extreme amount of precipitation in a short period of time.
- Sometimes accompanied by hail and thunder, which is capable of creating flood conditions.
- Rainfall rate equal to or greater than 100 millimeters (3.9 in) per hour is a cloudburst.


Image Credit: https://weather.com/news/trending/video/amazing-rainfall-spotted-in-austria

- Orographic Lift:- when an air mass is forced from a low elevation to a higher elevation as it moves over rising terrain. As the air mass gains altitude it quickly cools down adiabatically and creates clouds and, under the right conditions, precipitation
- When a warm air parcel mixes with cooler air, resulting in sudden condensation

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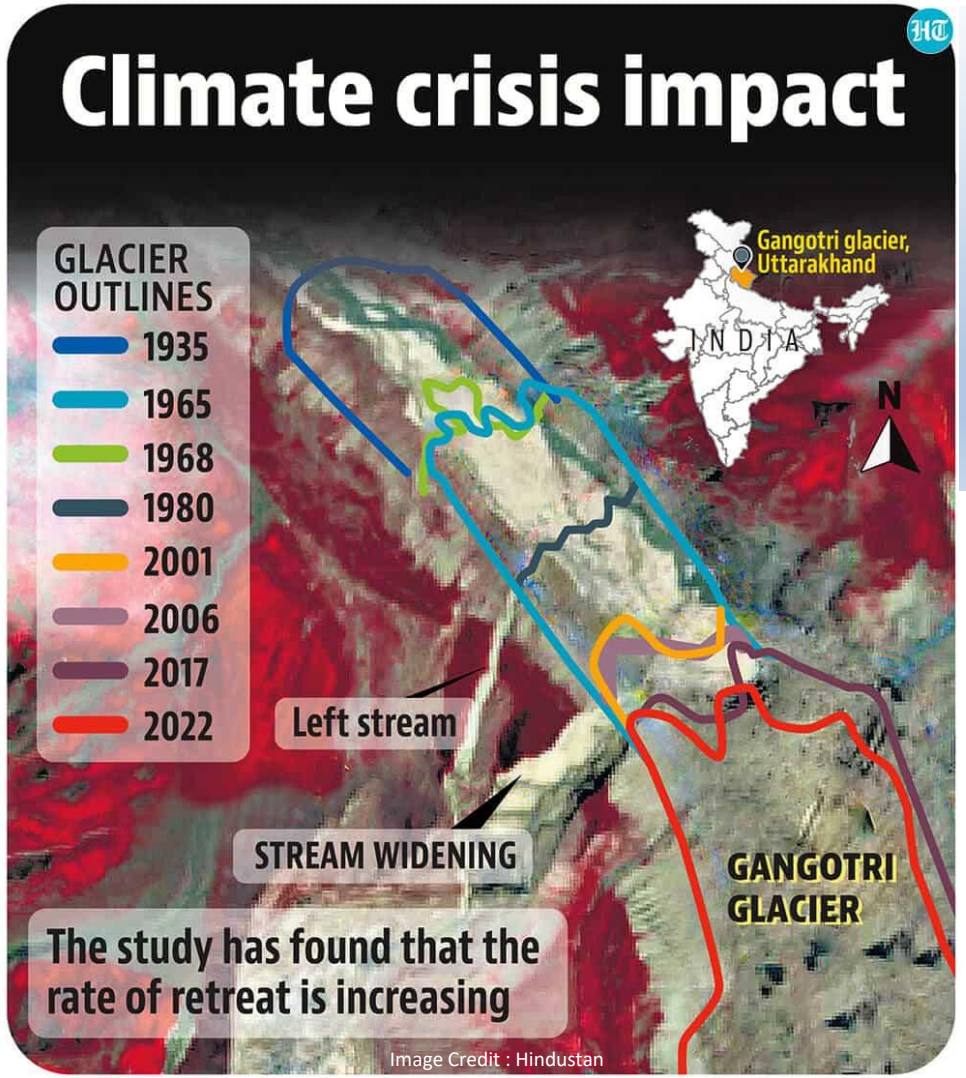
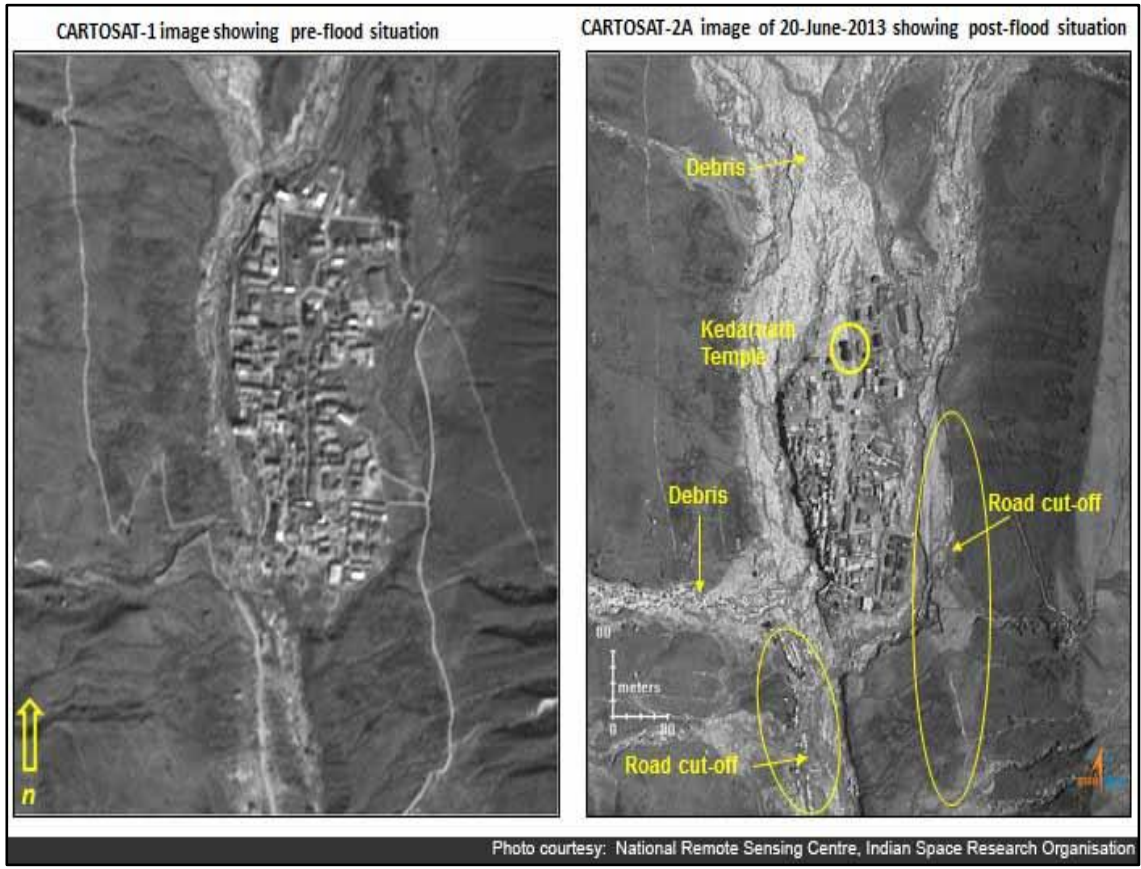


The Gangotri glacier in the Uttarakhand Himalayas, from where the Ganga river originates, retreated by 1,700 meters between 1935 and 2022



Satellite imaginary before and after Kedarnath (Extreme rainfall + GLOF event)

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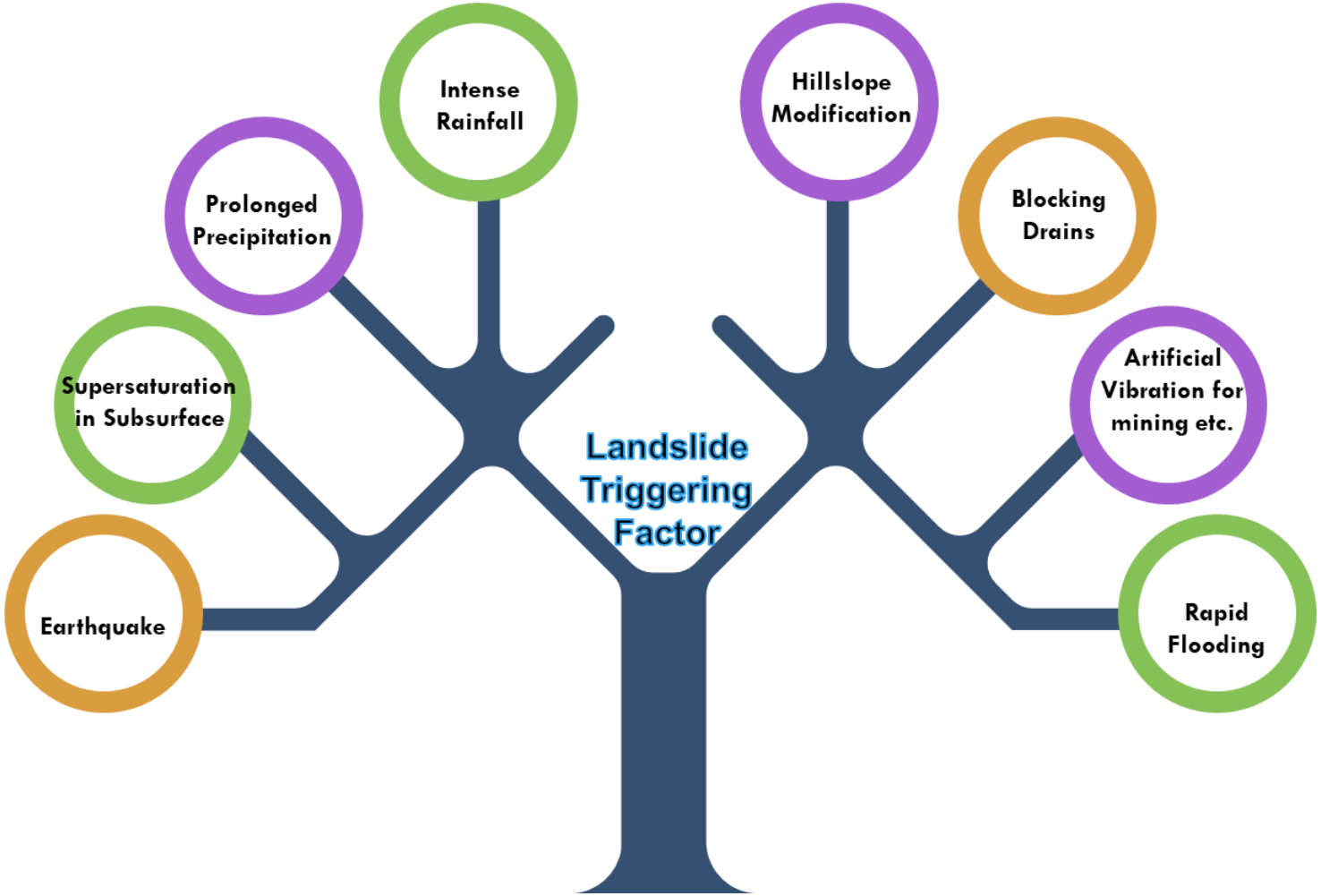
S.No.	Date	State	Area
1	September 28, 1908	Telangana	Musi River
2	January 8, 1966	India/Bangladesh	Ganges Delta
3	**July 1970**	**Uttarakhand**	Alaknanda Valley
4	**August 15, 1997**	**Himachal Pradesh**	Chirgaon (Shimla)
5	**August 17, 1998**	**Uttarakhand**	Malpa village
6	**July 16, 2003**	**Himachal Pradesh**	Shilagarh in Gursa area of Kullu
7	**July 6, 2004**	**Uttarakhand**	Chamoli district
8	26 July 2005	Maharashtra	Mumbai
9	**August 14, 2007**	**Himachal Pradesh**	Bhavi village in Ganvi
10	**August 7, 2009**	**Uttarakhand**	Munsiyari in Pithoragarh district
11	**August 6, 2010**	**Ladakh**	Leh
12	**September 15, 2010**	**Uttarakhand**	Almora
13	September 29, 2010	Maharashtra	NDA Khadakwasla, Pune
14	October 4, 2010	Maharashtra	Pashan, Pune
15	**June 9, 2011**	**J&K**	Near Jammu
16	**20 July 2011**	**Himachal Pradesh**	Upper Manali
17	September 15, 2011	National Capital Territory of Delhi	Palam area
18	**September 14, 2013**	**Uttarakhand**	Ukhimath in Rudraprayag district
19	**June 15, 2013**	**Uttarakhand**	Kedarnath and Rambara region of Rudraprayag
20	**July 31, 2014**	**Uttarakhand**	Tehri Garhwal district
21	**September 6, 2014**	**J&K**	Kashmir valley
22	December 2, 2015	Tamil Nadu	Chennai
23	**July 1, 2016**	**Uttarakhand**	Pithoragarh
24	**July 20, 2017**	**J&K**	Thathri town of Doda district
25	**July 28, 2021**	**J&K**	Hunzar hamlet in Kishtwar district
26	**8 July, 2022**	**J&K**	Pahalgam en route to Amarnath cave shrine

- More than 70% of Major cloud bursts recorded in India are in the Himalayan Region.
- We have to be more cautious and vigilant for such events as most of the hydro Projects owned by NHPC limited are in Himalayan region.

Landslide lake outburst flood (LLOF)

- Landslide/ Avalanche: A landslide or snow avalanche can create obstructions in the normal path of a flowing river or stream, which results in the formation of a temporary pool, or a dam-like situation.
- When this obstruction finally gives way to the force of accumulating water, it creates a situation similar to a lake burst. This is called Landslide Lake Outburst Flood.
- In the case of an avalanche, snow adds to the volume of water.



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23 September 1999

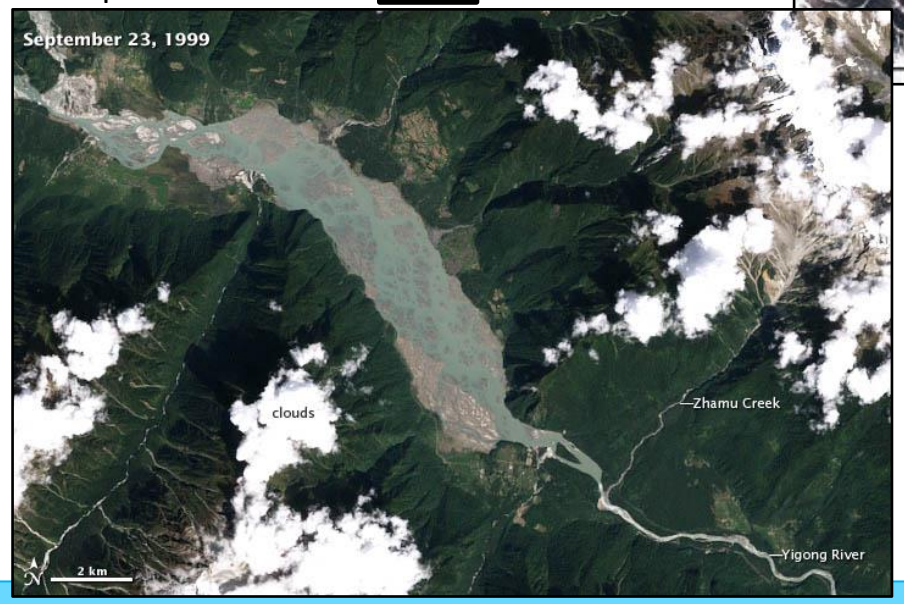

Image Source:https://landsat.visibleearth.nasa.gov

04 May 2000

15 November 2001

10-12 October 2022 at Jaipur, Rajasthan (India)

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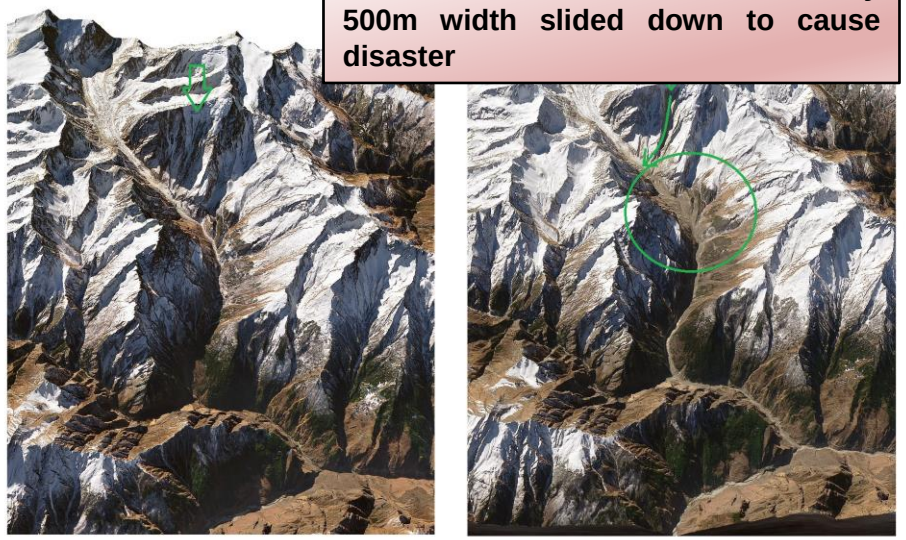
Rock mass with Glacier of nearly 500m width slided down to cause disaster

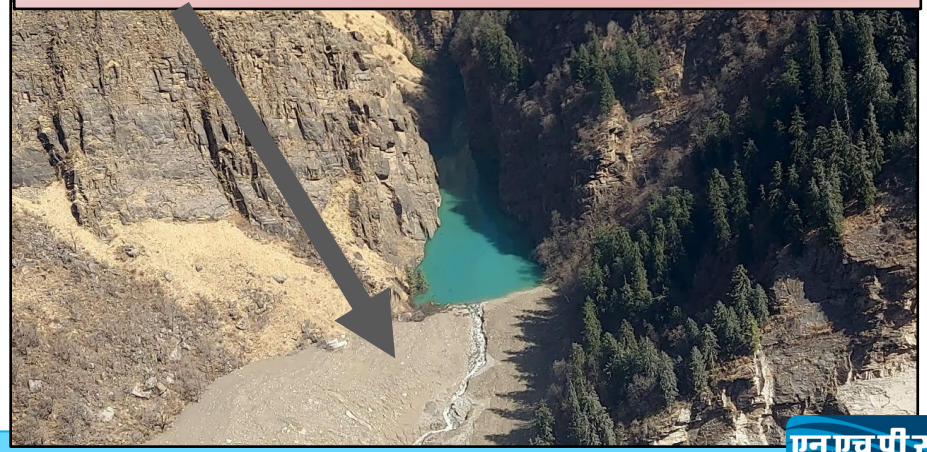


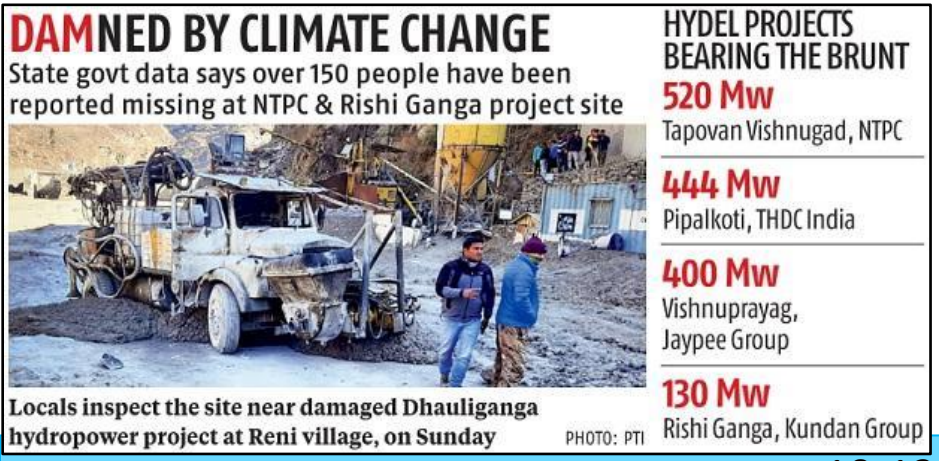
Undisturbed snow and ice on Jan 20, 2021, at origin point

Origin point, direction of slide, and debris on Feb 21, 2021

Tapovan- Vishnugadh Hydro Project after the Event.

Artificial lake formed at Rishi Ganga river due to the debris of Rockfall.





10-12 October 2022 at Jaipur, Rajasthan (India)

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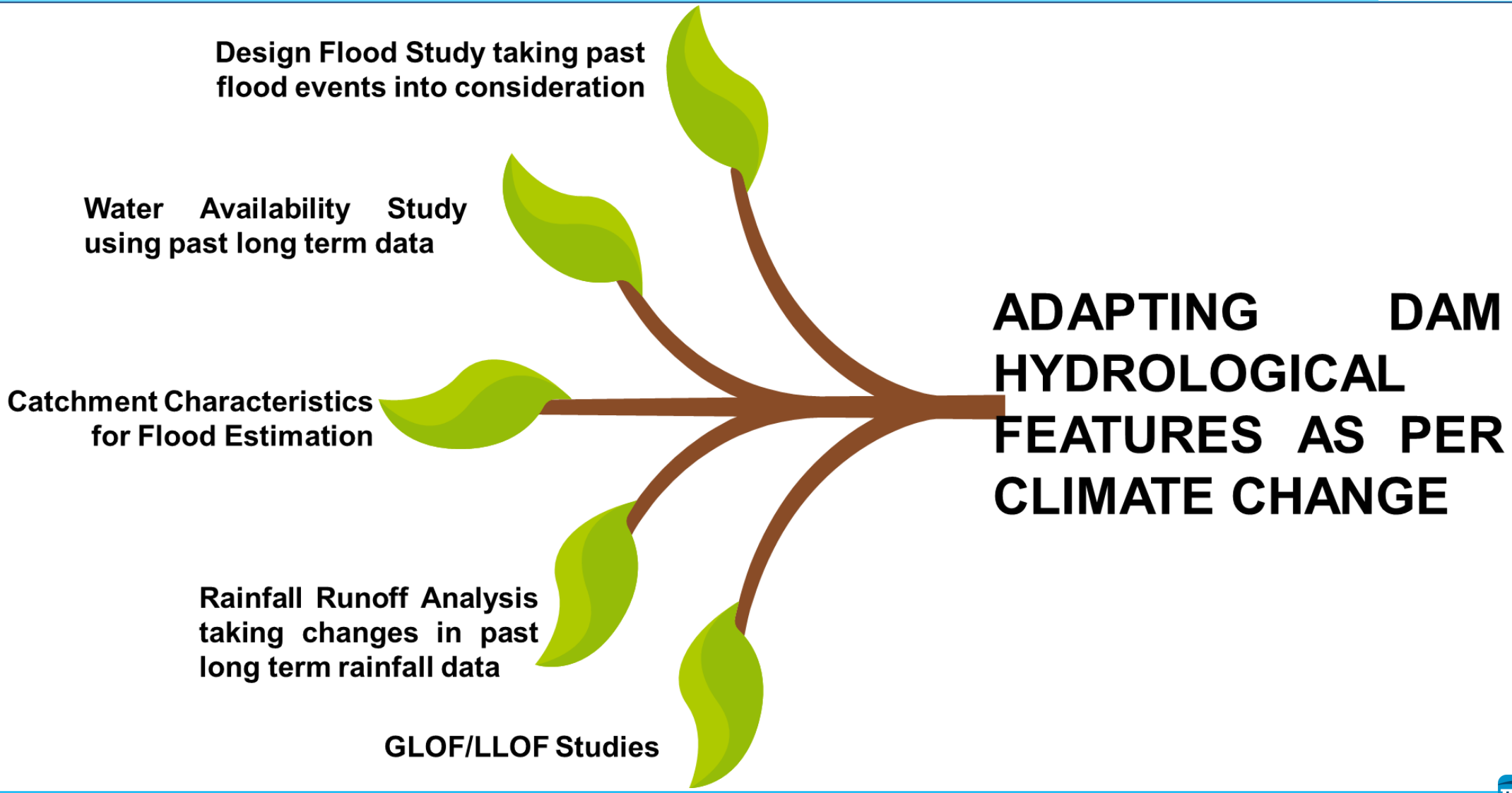
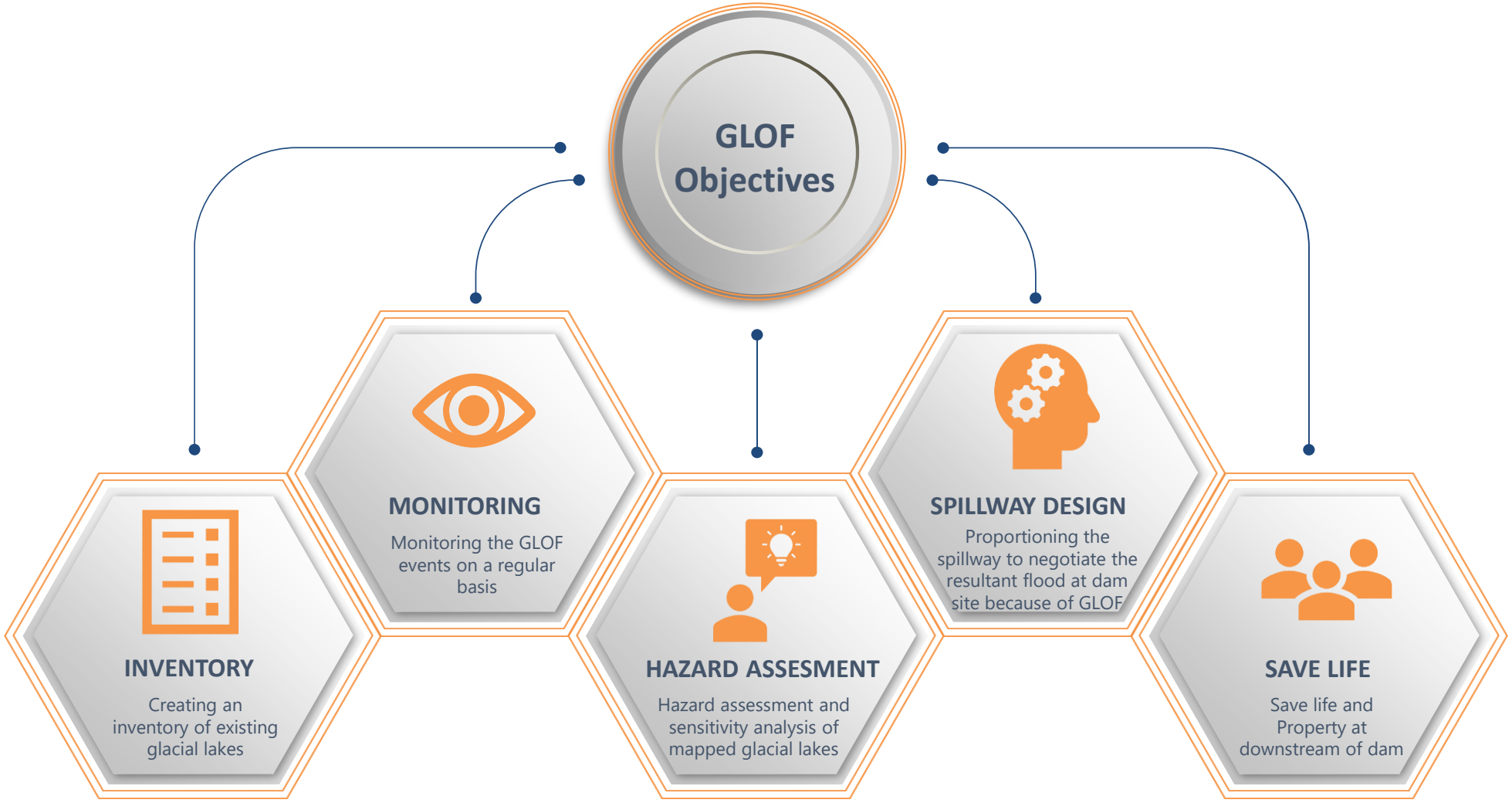

Design Flood Study taking past flood events into consideration
Water Availability Study using past long term data
Catchment Characteristics for Flood Estimation
Rainfall Runoff Analysis taking changes in past long term rainfall data
GLOF/LLOF Studies
ADAPTING DAM HYDROLOGICAL FEATURES AS PER CLIMATE CHANGE

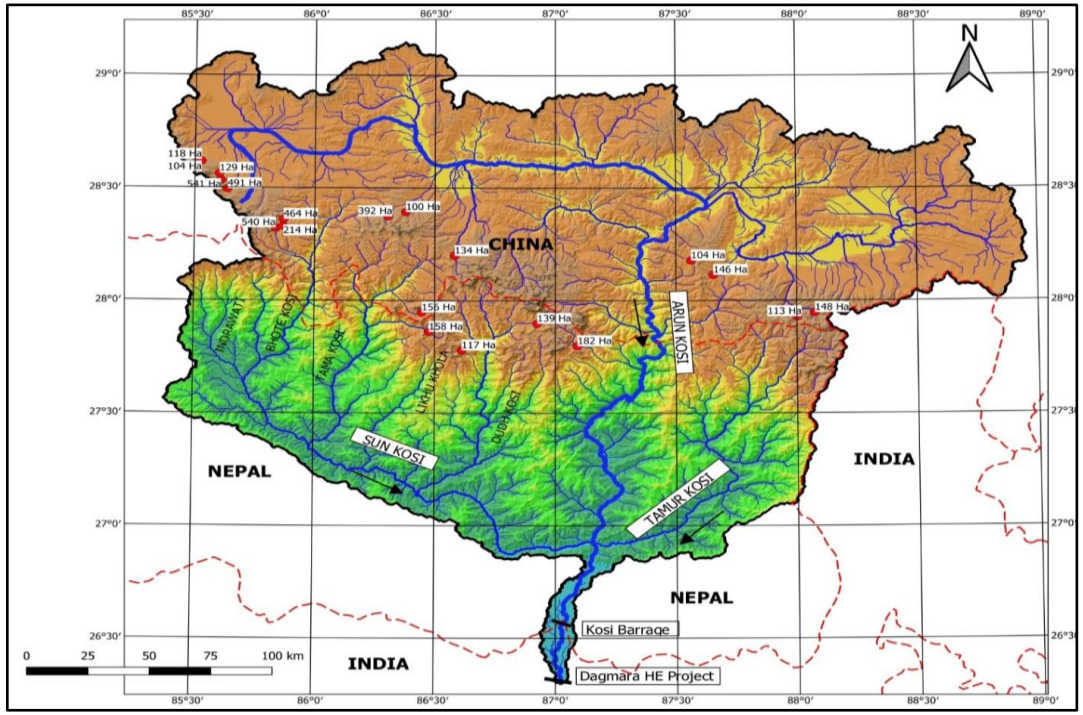
Glacial Lake Outburst Flood Studies



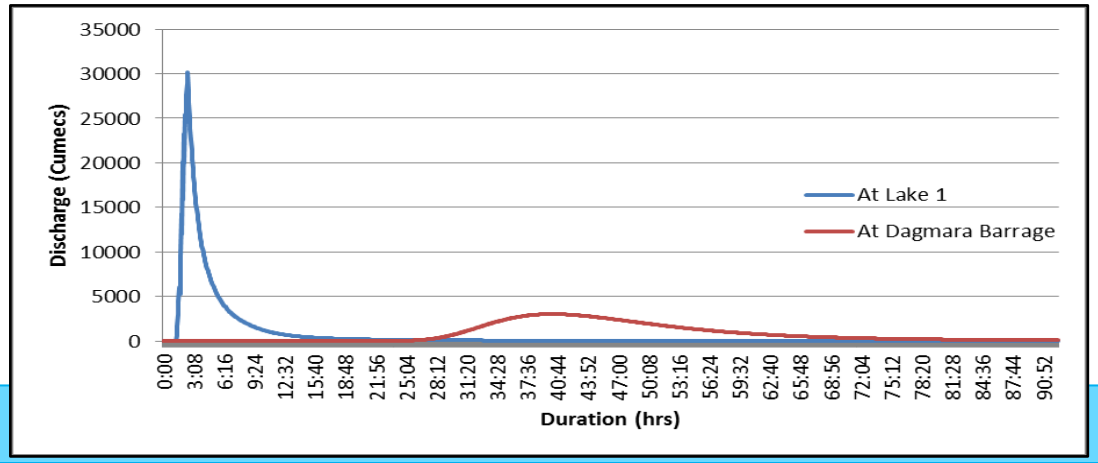
GLOF Study Steps

Selection of Lake	GLOF Scenario	Input data	Bursting Lake	Flood routing
Potentially dangerous lakes can be identified based on field observations, records of past events, geomorphologic and geotechnical characteristics of the lake/dam and surroundings, and other physical conditions.	Various scenarios of the lake breach are being decided to work upon.	Various input data like, Surface area, Lake volume (huggel's empirical formula), lake distance, Breach parameters, Cross Section of the river reach (ArcGIS), Initial flow conditions are being estimated.	Numerical simulation for bursting outflow from a lake breach is being carried out to determine the maximum flood peak at the mouth of the lake breach. Software used (Mike 11 & HEC-RAS)	Numerical simulation for the floodwaters downriver and in the valley is carried out to determine the impact of Glacial lake outburst downstream by determining lag time and peak attenuation.

Glacial Lakes In Kosi Sub Basin Of Ganga River Basin



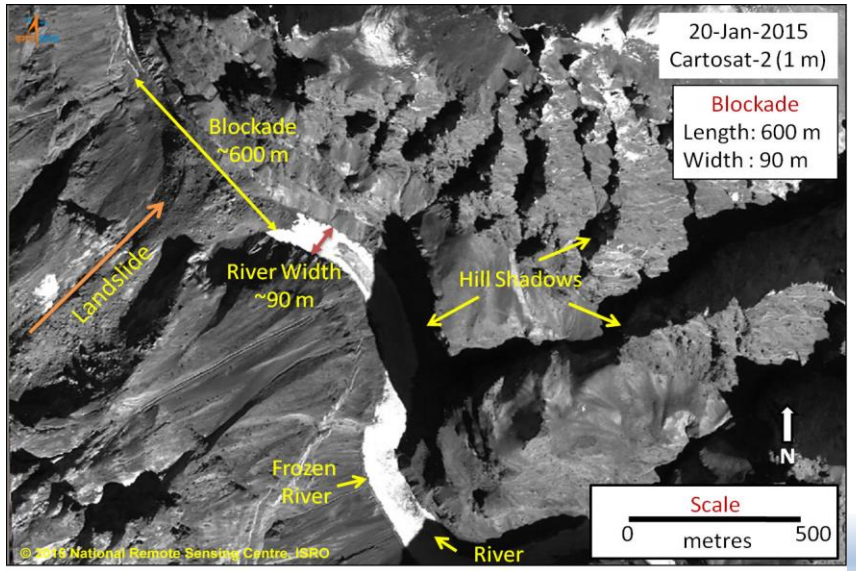
- As per the Inventory by Glacial lake atlas of ganga river basin – NRSC, May 2021, A total of 2,437 glacial lakes were mapped, covering a total area of 14,604.34 ha i.e. 0.24% of the total area of the subbasin out of which 20 lakes with area greater than 100Ha were marked.
- These lakes have also been identified by NHPC in Google Earth of which 2 potentially hazardous lakes were taken for GLOF study.
- The area of the largest lake (L1) has been estimated as 540 Ha.
- The lake is located at around 655 km u/s of the Dagmara Barrage site on Kosi River.



LLOF: Case Study by NHPC

PHUTKAL LANDSLIDE IN ZANSKAR BASIN (DEC 2014)

- An artificial lake was formed on River Phutkal, a tributary of River Zanskar due to landslide about 200 km upstream of Indus-Zanskar confluence on 31st Dec 2014.
- Dimensions of artificial dam: Length - 500-600m, Height - 50m, Width – 50m to 60m.
- Dimensions of Artificial Lake:15 km long artificial lake with surface area of 55 Ha having volume of about 40 Mcum . Surface of Artificial lake formed was completely frozen.



Satellite imaginary of the lake formed

Frozen view of the lake formed due to landslide

Landslide Lake Outburst Flood Simulation (By NHPC) – Jan 2015

Nimmo - Bazgo power station of NHPC being located on Indus river about 200 km d/s of lake, a tentative study to estimate the discharge on outburst of artificial lake was carried out. The lake busted on 07 May,2015 early morning causing flash floods.

Analysis before lake burst

- Bottom breach width-60 m, breach depth-40 m, and time of failure-1 hours was adopted.
- Cross-Sections along Zanskar and Indus river for entire 200 km reach were developed on basis of ASTER DEM using ARC GIS software @ 4 km interval.
- Based on this study it was estimated that on the outburst of artificial lake, a discharge of about 1460 cumec would reach at tail end of Nimmo-Bazgo reservoir with the time lag of about 11 hours.
- As a precautionary measure, NHPC along with local administration had been monitoring the water level at various locations enroute Zanskar river.

Landslide Lake Outburst & Flood Management – 7th May 2015

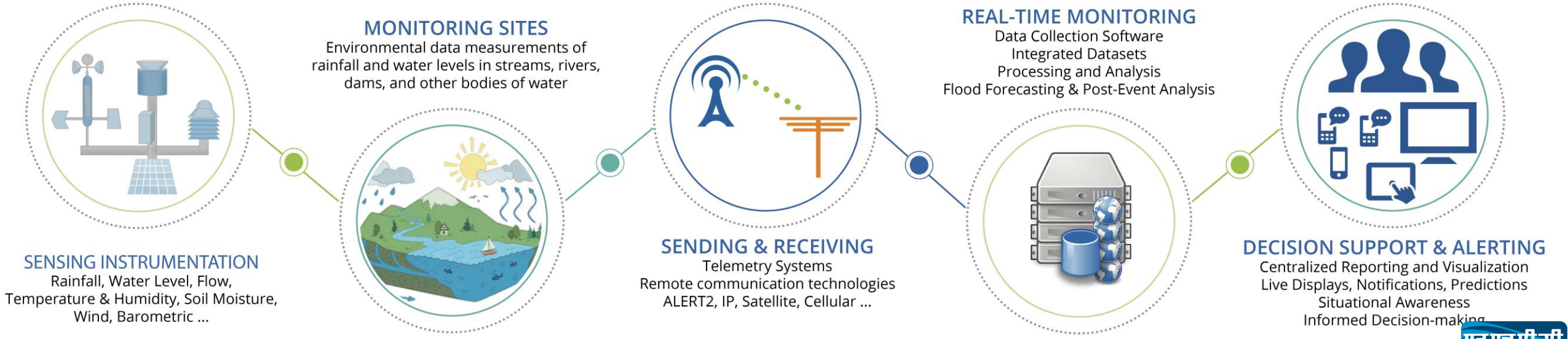
- The artificial lake formed got suddenly busted on 07 May,2015 early morning causing flash floods.
- As per analysis carried out in Jan 2015 based on preliminary breach parameters and lake volume (30MCM), the discharge at Nimmo-Bazgo dam site was estimated as 1400 cumec with lag time of about 11 hrs.
- As per actual data observed at dam site during this period, it was observed that the outburst resulted in an inflow of about 2757 cumec and had a lead time of about 12 hrs.
- The total volume released by the artificial lake was about 30 Mcum.
- For safe passage of flood in the downstream, reservoir level at the Nimmo Bazgo Power Station was kept 3 m below MDDL which could afford a capacity of 18 MCM , thus leaving about 12 MCM to be discharged d/s over a time base of about 6 hrs.
- The dam controlled the flood water in such away that the water level in the the downstream was kept below 3 m depth averting the disaster. The flood volume was absorbed effectively by the reservoir such as the maximum outflow downstream reduced to 1600 cumec.

Mitigation Techniques

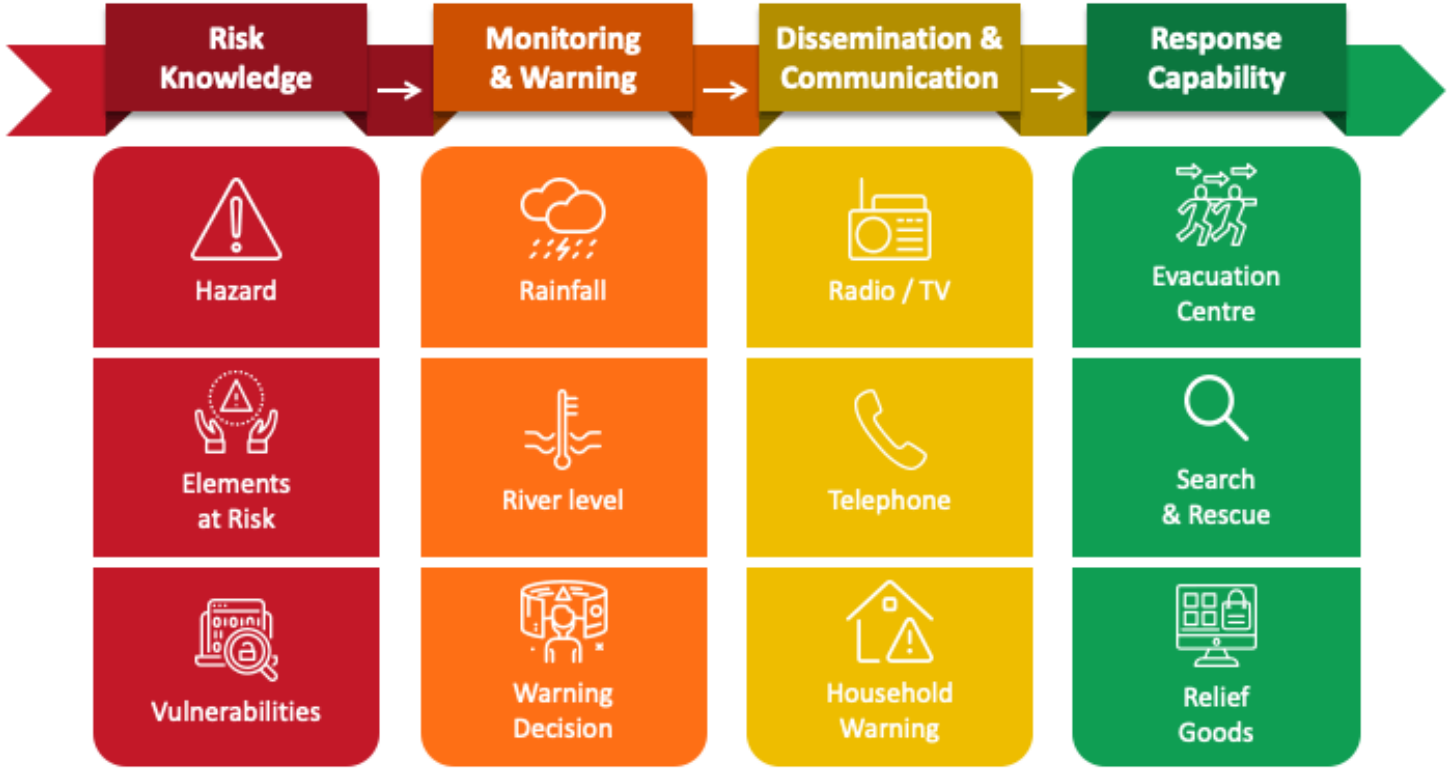
- Hydroelectric projects are predominantly located in Hilly regions. One study reveals that the project is prone to a wide variety of disasters, including floods, Earthquakes, Avalanches, Glacial outburst floods, and landslides.

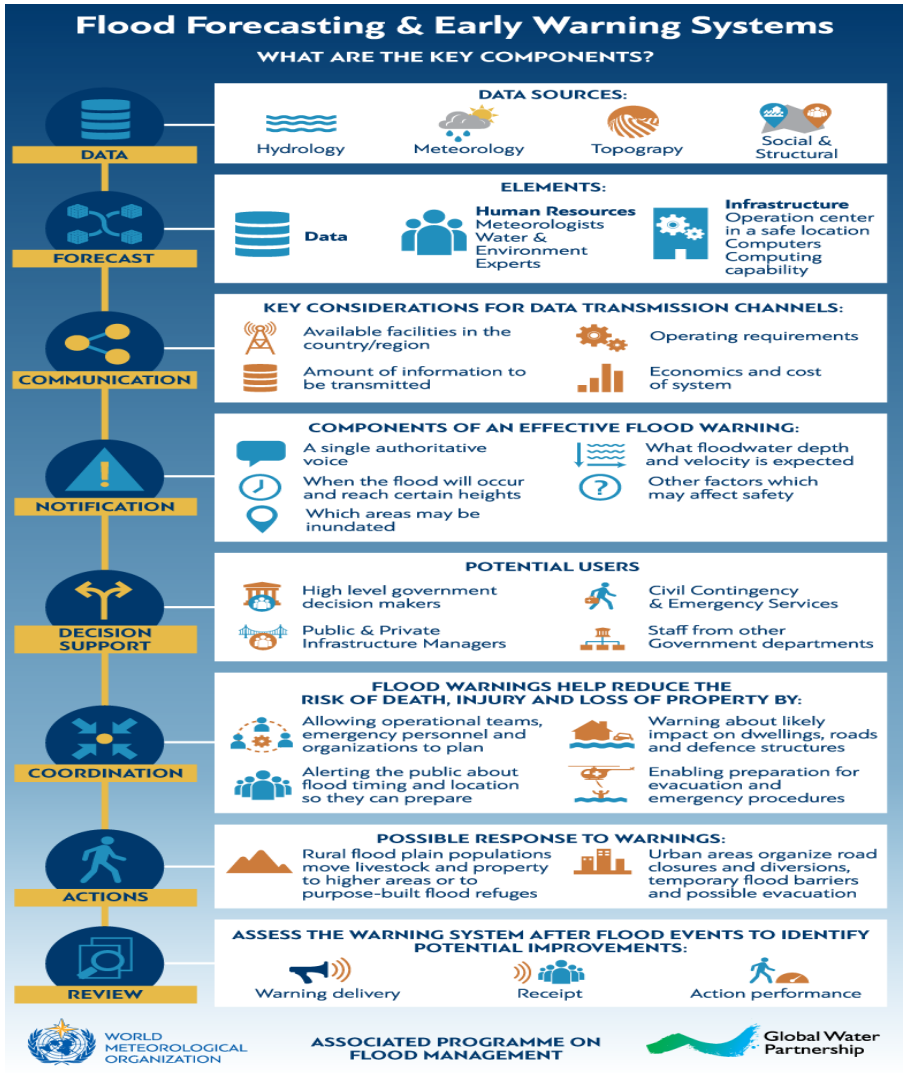
- Himalayan Region has experienced multiple disasters, resulting in floods in downstream areas that claim a lot of lives, damage hydro-electric projects, or other infrastructure.

- The Early Warning System alerts people that flash floods are coming and lets them evacuate or take shelter in advance

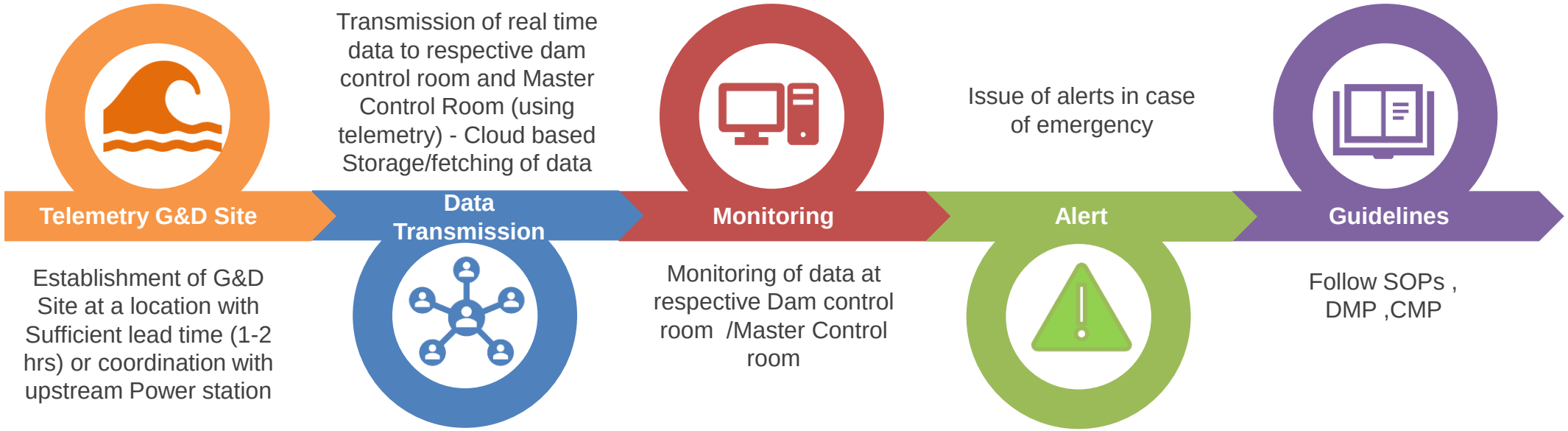


Key Components of Early Warning System

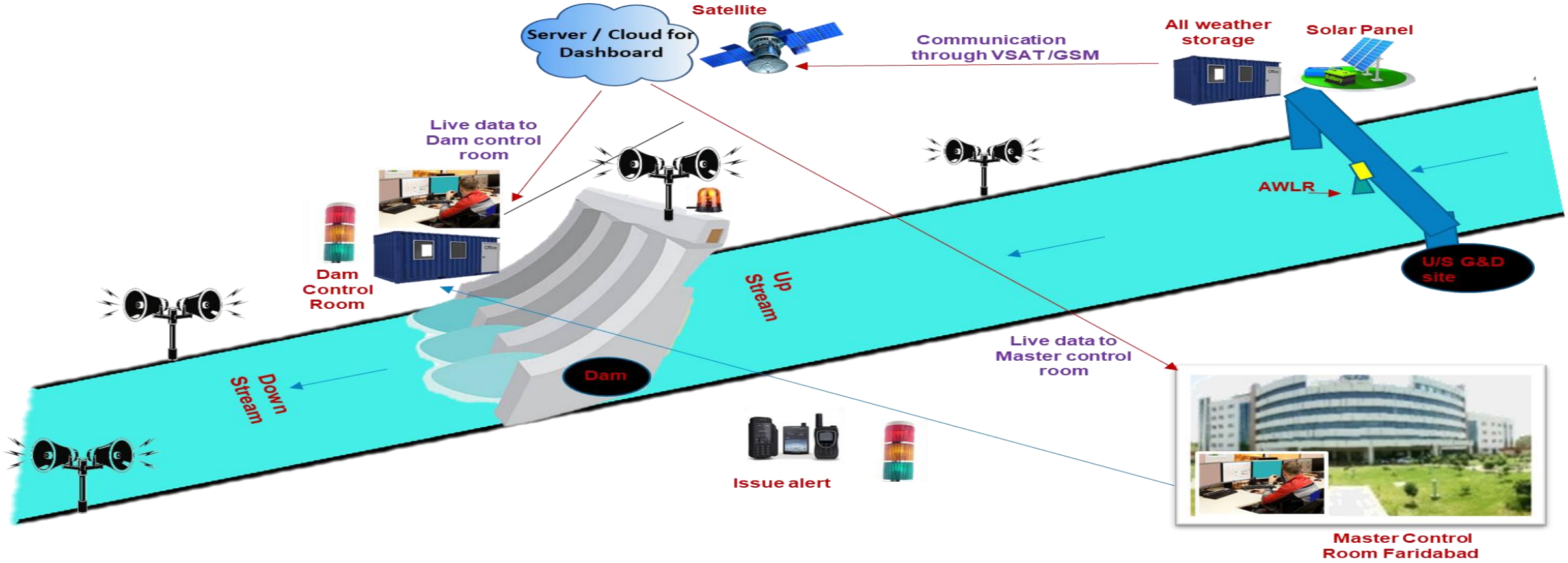




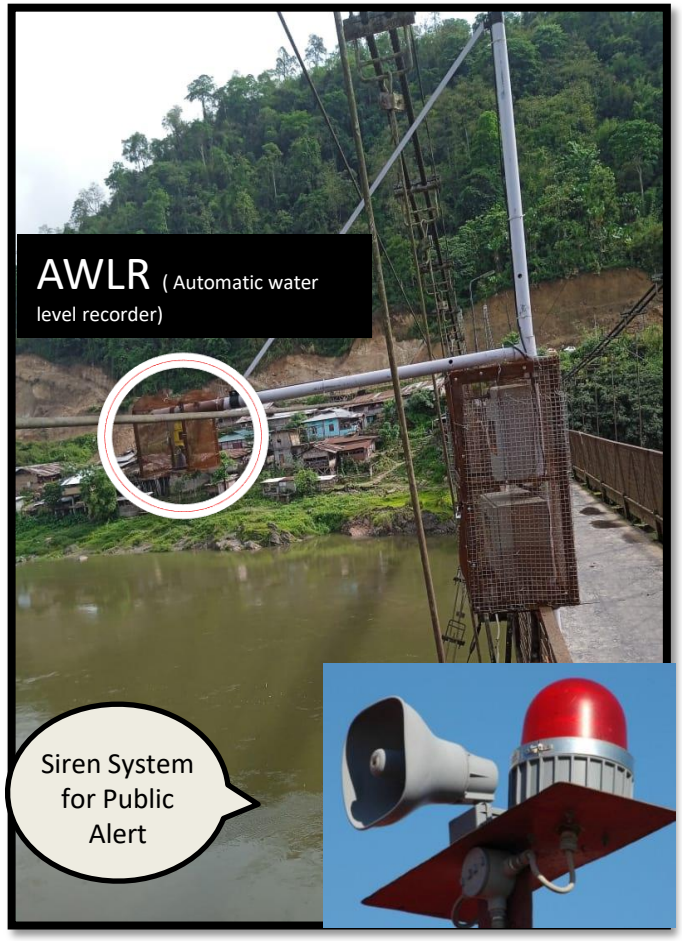
Working and steps of Early Warning System followed in NHPC

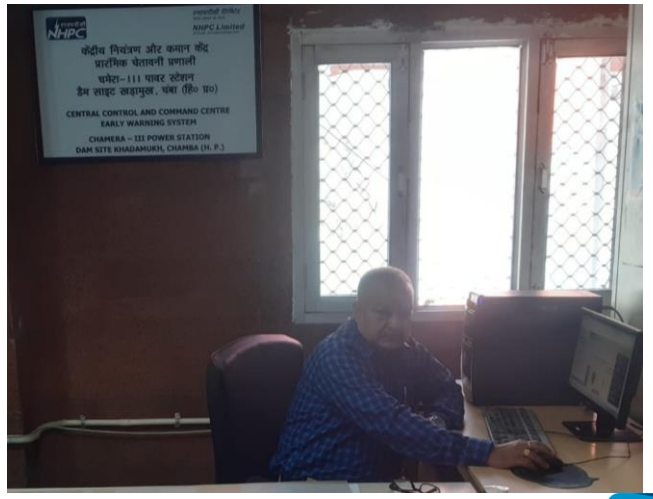


Early Warning System Established at NHPC



Early Warning System Established at NHPC Project site location





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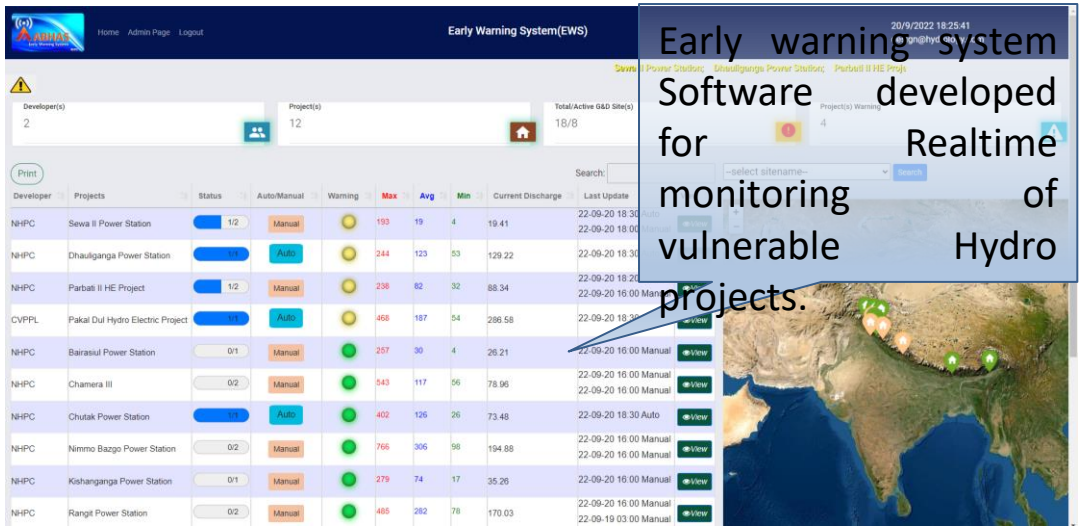
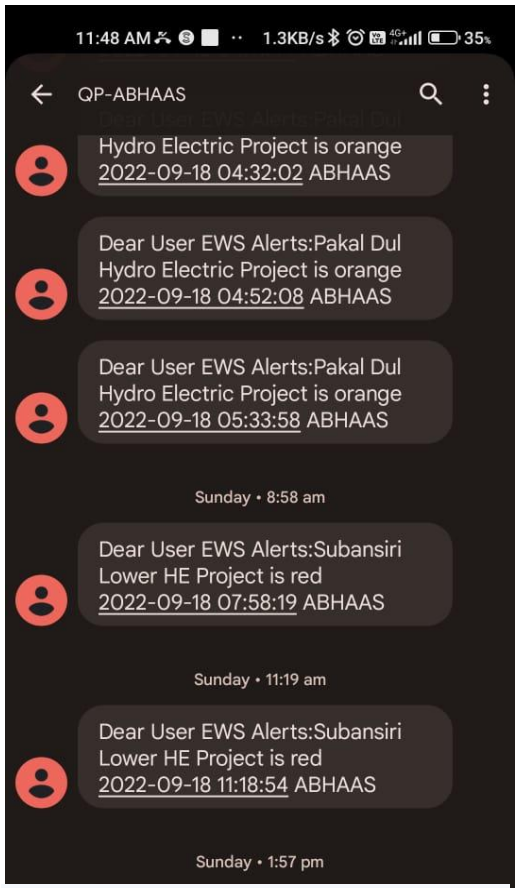


Early warning system Software developed for Realtime monitoring of vulnerable Hydro projects.

Highly Equipped 24X7 manned EWS master control room.

Alarm Panel for different levels of alert modes



Realtime SMS Alert to all stakeholders when river reaches at danger level

10-12 October 2022 at Jaipur, Rajasthan (India)

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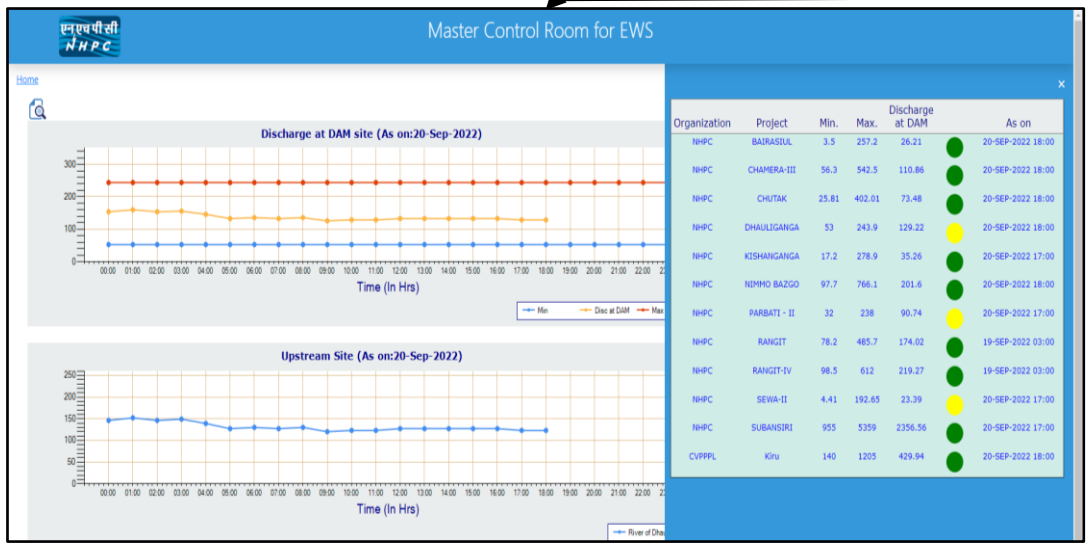
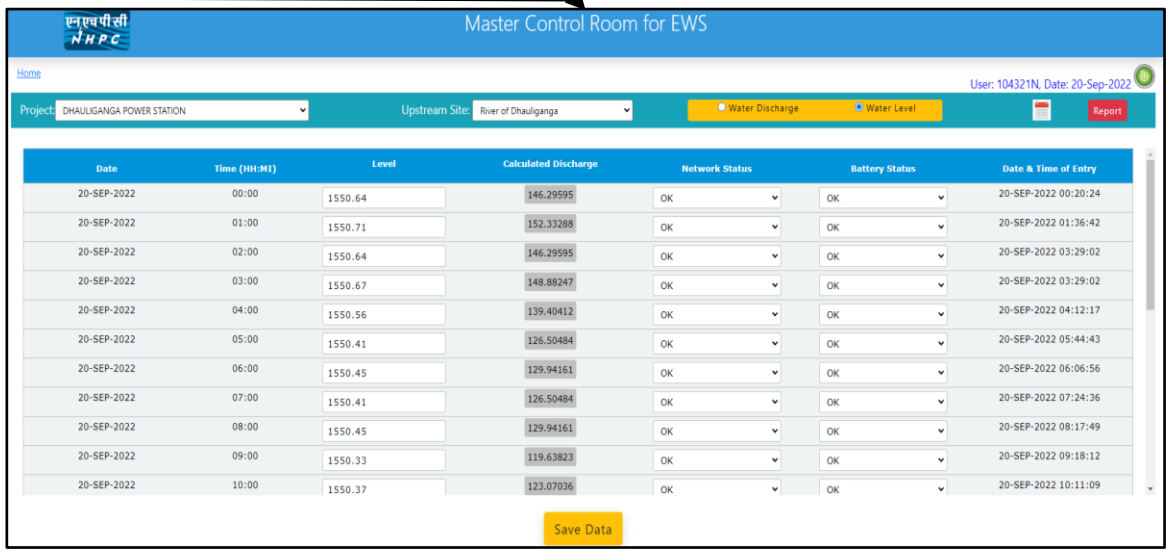
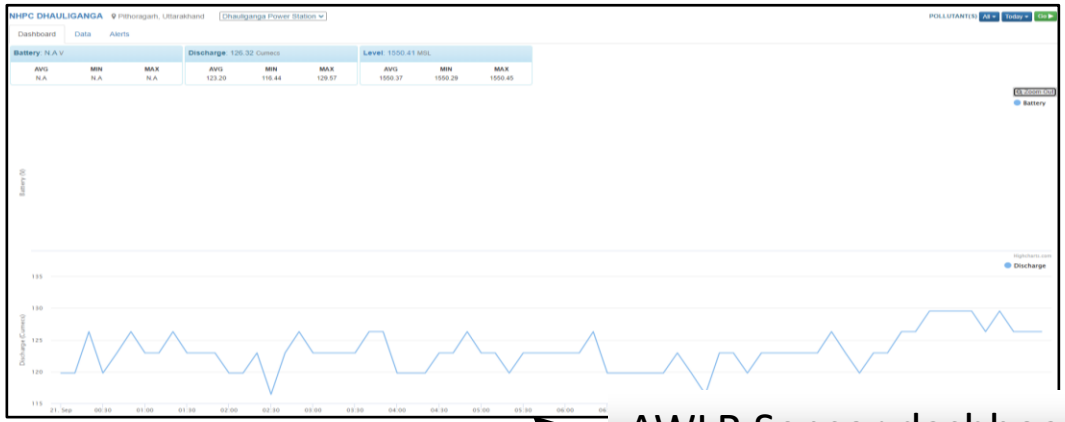
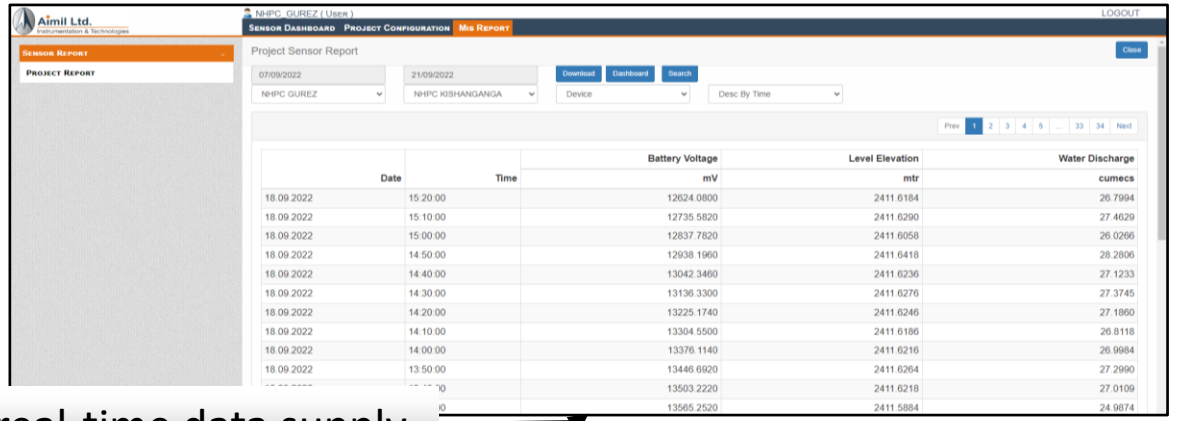
Inhouse developed EWS portal to keep monitoring the projects of NHPC



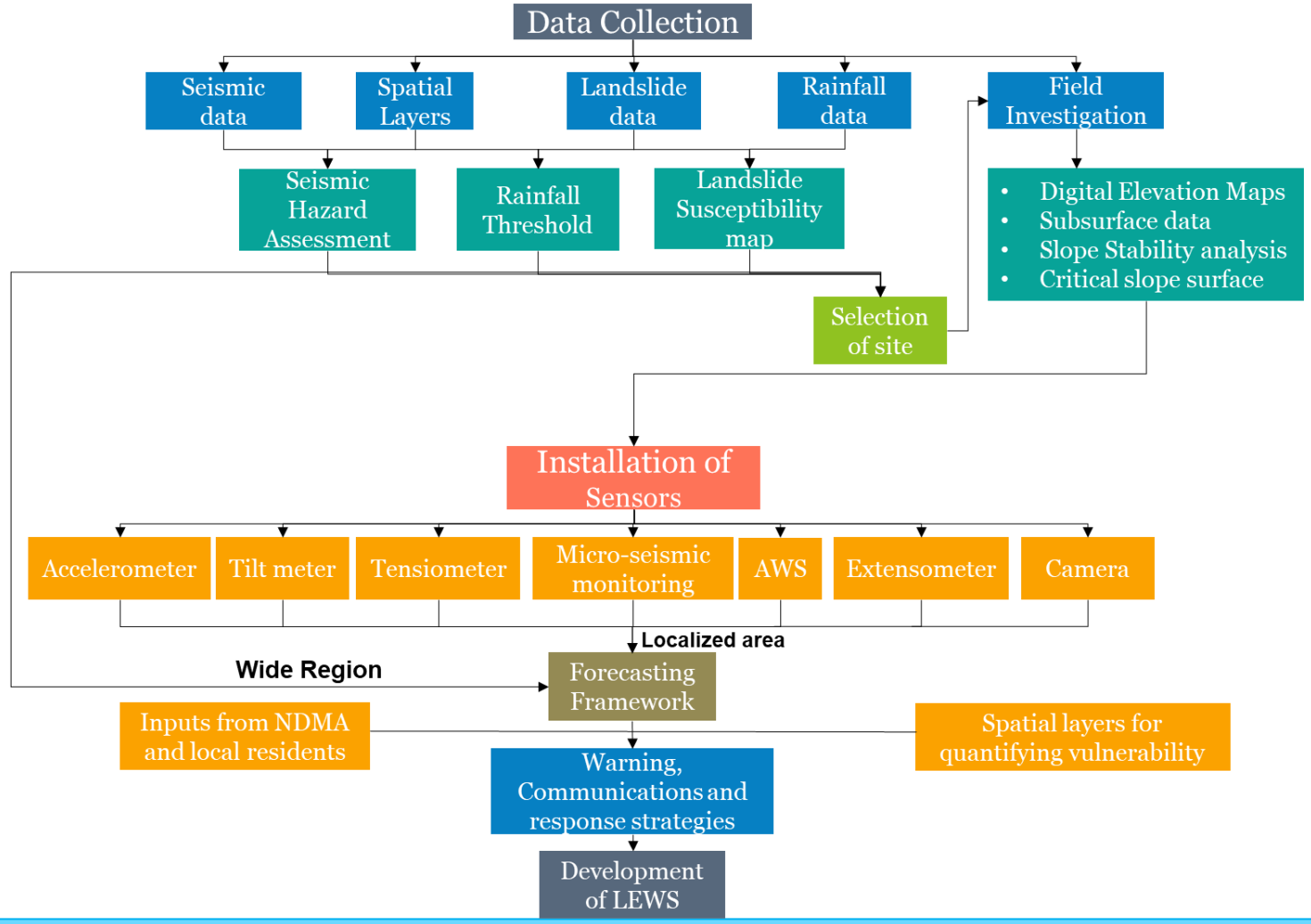




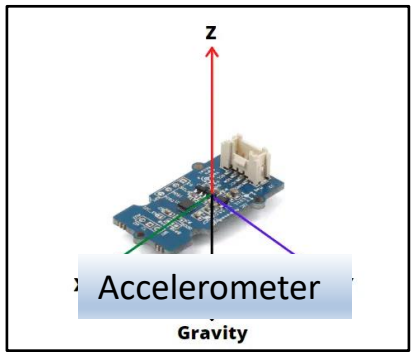


AWLR Sensor dashboard with real-time data supply

Proposed Methodology for developing LEWS (Landslide Early Warning System)

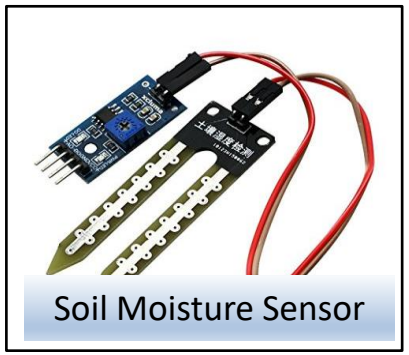


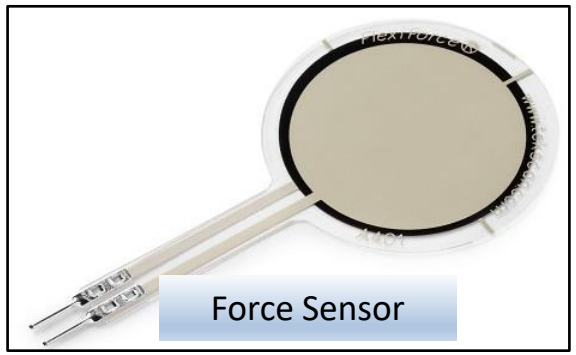
Sensors/ Equipment used in Landslide Early warning system

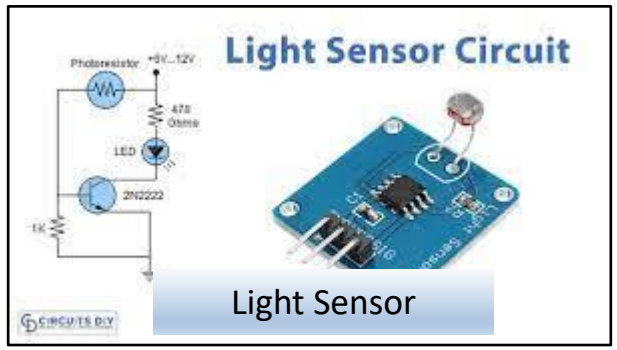


Accelerometer


Rain Gauge

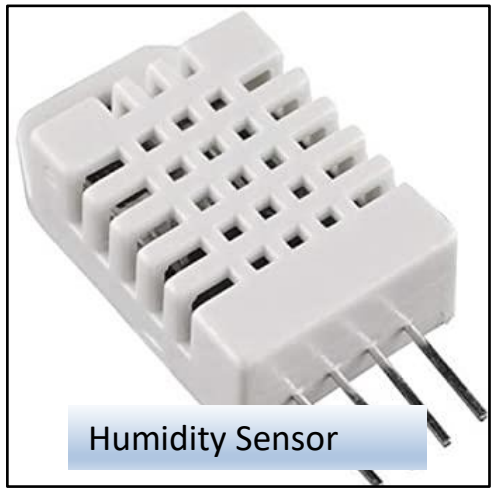

Soil Moisture Sensor

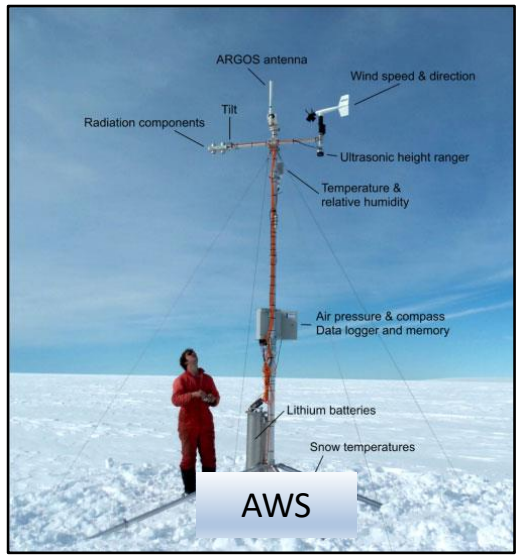

Force Sensor



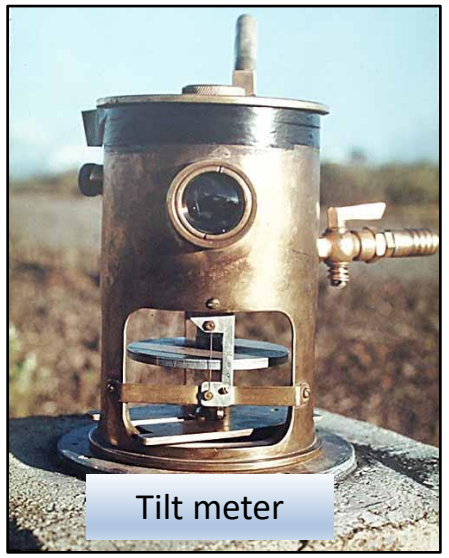
Light Sensor

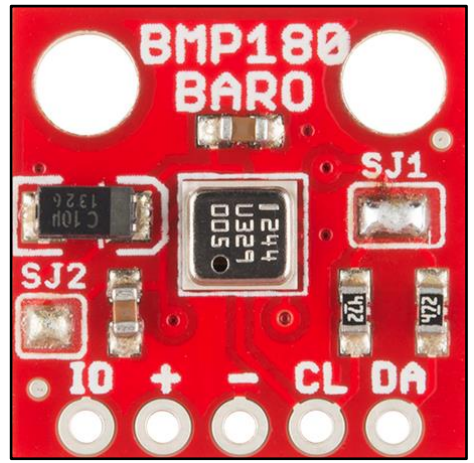

GSM Module


Humidity Sensor



AWS


Tilt meter



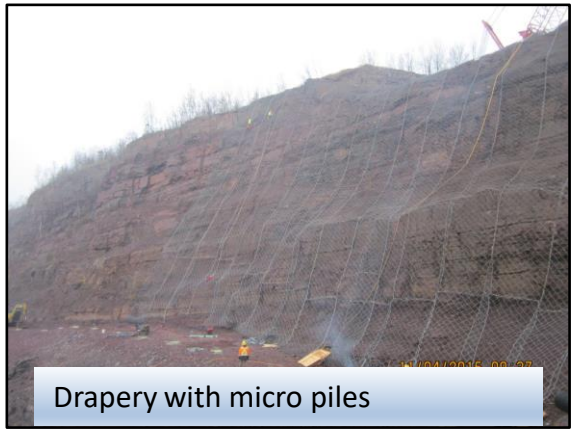
Temperature & Pressure Sensor

Various practices used to mitigate and prevent Landslide


Geocells

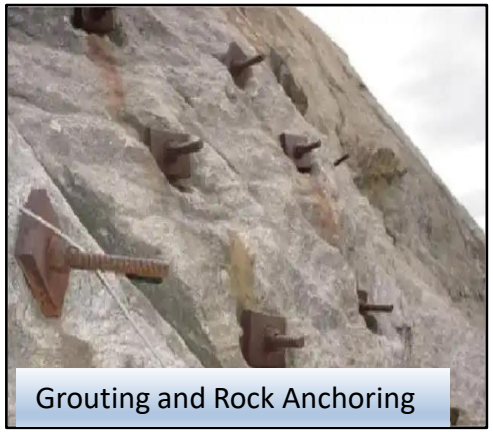

Gabion wall


Hydro Seeding


Drapery with micro piles


Snow Erdox


Shotcreting


Grouting and Rock Anchoring

Indian Committee on Large Dams
Young Engineers Forum

INTERNATIONAL DAM SAFETY CONFERENCE

Dam Rehabilitation & Improvement Project

Central Water Commission

Daily water level and forecasts level issued by Central water commission, Govt of India

Heavy rainfall forecasts issued by MOSDAC (Meteorological & Oceanographic Satellite Data Archival Centre) ISRO, Govt. Of India

National Flast Flood guidance Bulletin issued by IMD, Govt of India

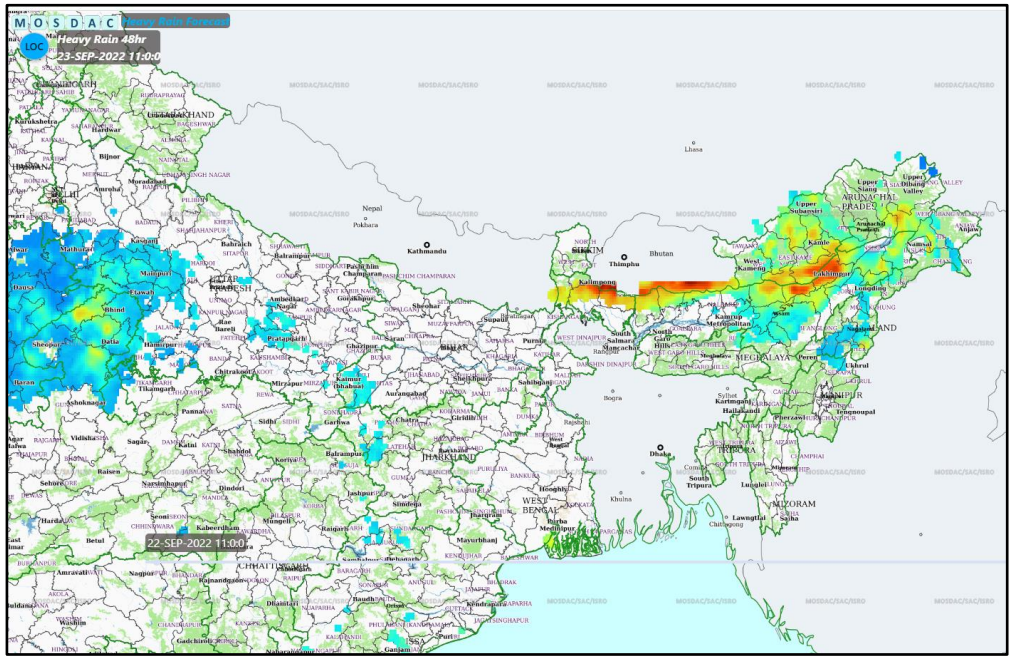
Central Water Commission Date :22/09/2022

PART-I: DAILY WATER LEVELS AND FORECASTS FOR LEVEL FORECAST SITES

B: Severe Flood Situations :

(Site (s) where water level is equalled or exceeded Danger Level but below Highest Flood Level (HFL))

S. No.	River / Station	District / State	Warning Level (m)	Danger Level (m)	Highest flood Level (m) / Date (dd-mm-yyyy)	Actual Level / Trend / Trend Magnitude (mm/hr) / Time	Forecasted Level / Trend / Date (dd-mm-yyyy) / Time
1	Kosi	SUPAUL	46.75	47.75	49.24	48.2	48.13
	Basua	Bihar			13-08-2017	Falling -20.0 14:00	Falling 22-09-2022 22:00:00
2	Ghagra	SIWAN	59.82	60.82	61.74	61.36	61.2
	Darauli	Bihar			29-08-1998	Steady 0.0 14:00	Falling 23-09-2022 08:00:00
3	Ganga	BUDAUN	161.0	162.0	162.79	162.16	162.0
	Kachhlabridge	Uttar Pradesh			24-09-2010	Falling -9.99 14:00	Falling 23-09-2022 08:00:00
4	Ghagra	BALLIA	63.01	64.01	66.0	64.88	64.65
	Turtipar	Uttar Pradesh			28-08-1998	Steady 0.0 14:00	Falling 23-09-2022 08:00:00



GOVERNMENT OF INDIA
MINISTRY OF EARTHSCIENCES
INDIA METEOROLOGICAL DEPARTMENT
HYDROMET DIVISION
FLASH FLOOD GUIDANCE CELL

National Flash Flood Guidance Bulletin

DATED: 22.09.2022 **TIME OF ISSUE: 1315 IST** **VALIDTILL: 1730 IST**

From: India Meteorological Department, New Delhi (Email Id: sasiaffg.imd@gmail.com)

To: **RMC New Delhi, RMC Nagpur, MC Jaipur, MC Dehradun, MC Lucknow, MC Bhopal and concerned FMOs.**

Area of Concern (AoC): Few watersheds and neighborhoods of East Rajasthan, West Madhya Pradesh, West Uttar Pradesh and Uttarakhand Met-Subdivisions.

Diagnostic Guidance: Based on Merged Mean Areal Precipitation at 1130 IST, recorded rainfall is up to 70 mm in last 6 hours and 130 mm in last 24 hours over few watersheds and neighborhood of AoC, East Uttar Pradesh and Assam & Meghalaya Met-Subdivisions. Land Surface Model shows few nearly saturated watersheds up to 85% to 95% over Uttarakhand, Himachal Pradesh, East Uttar Pradesh, East Madhya Pradesh, Vidarbha and Assam & Meghalaya and up to 55% soil saturation over remaining parts of the country.

Prognostic Guidance: Dynamic Global (GFS) & Mesoscale Model (WRF & NCUM) forecasts high rainfall 230 mm in next 24 hours.

Observed Flash Flood Threat (IFFT) till 1130 IST of 22.09.2022:

No flash flood threat observed in last 06 hours.

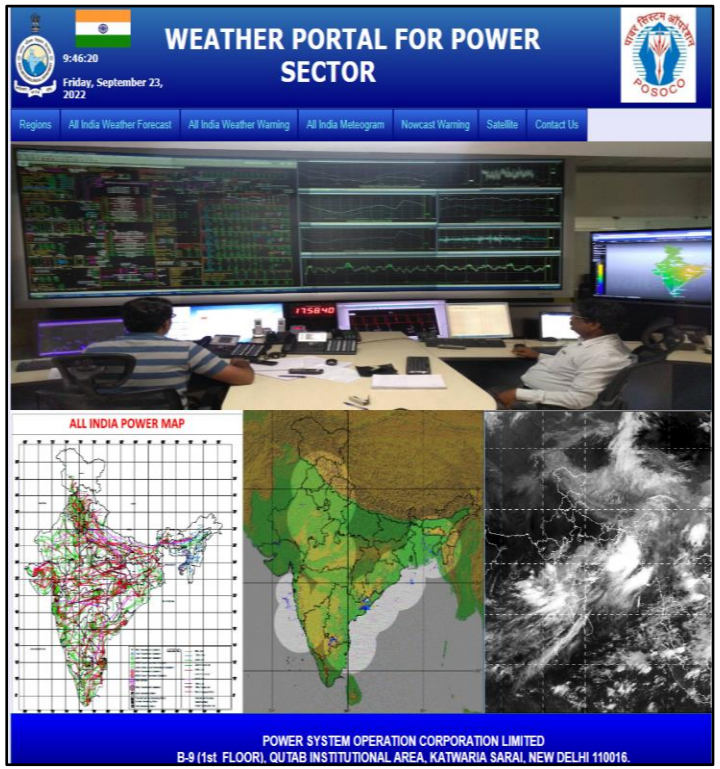
Various other sources of forecasting natural hazards used in NHPC

10-12 October 2022 at Jaipur, Rajasthan (India)

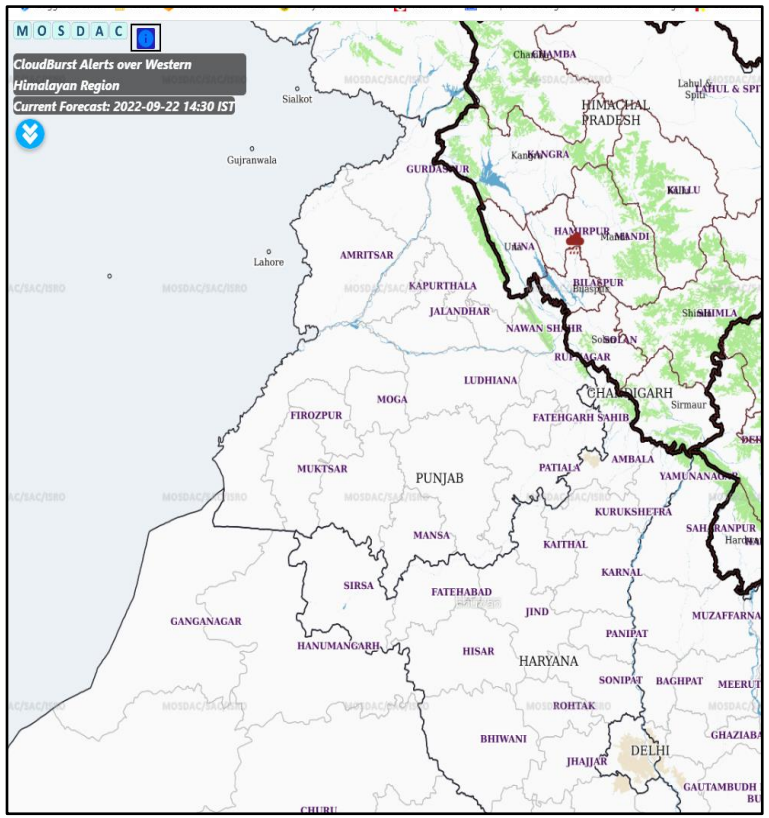
एनएचपीसी NHPC

Various other sources of forecasting natural hazards used in NHPC

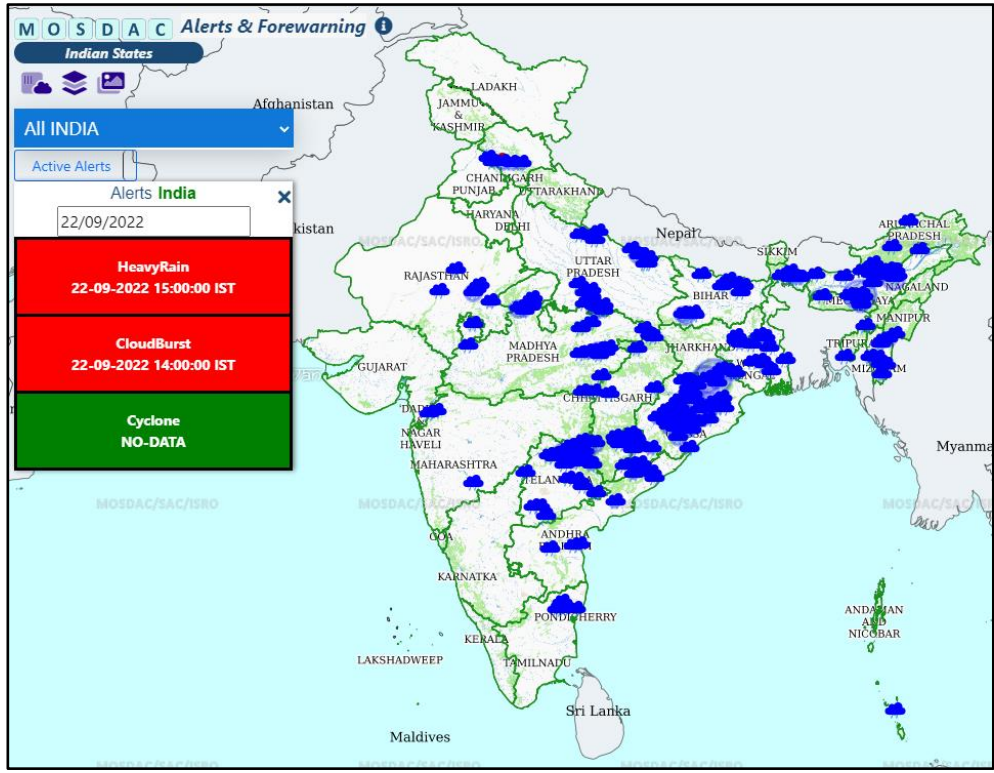
Weather Portal for power sector issued by IMD , Govt of India



Cloud Burst warnings issued by MOSDAC, Govt of India



Alerts & Forewarnings issued by MOSDAC, Govt of India

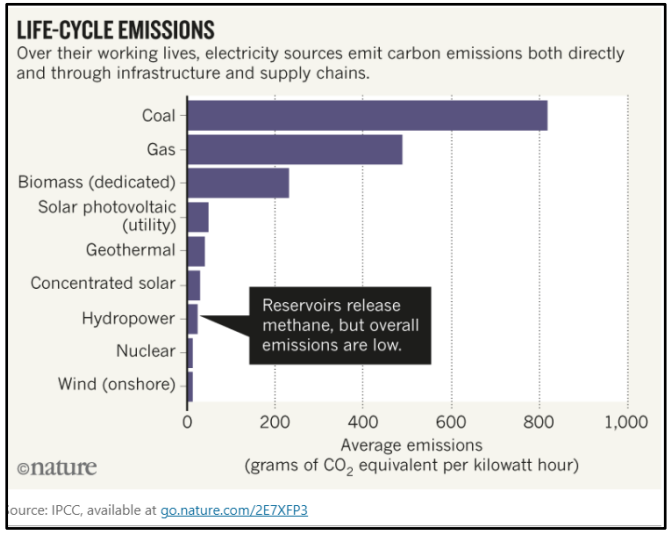


and many more.....

How Hydropower helps to mitigate Climate Change

- Reduce our reliance on fossil fuels, hydropower avoids billions of tonnes of additional GHG emissions being emitted annually, versus coalfired generation.

- Beyond its power benefits, hydropower also provides water services. Reservoir storage capacity can be used for drinking water supply, irrigation and flood control. Increasing global water storage capacity is imperative to adapting to a warmer world and meeting growing water demand.



Hydropower is also a key asset for building secure, clean, electricity systems and reaching global net zero targets.

Thank You