HIMJHEEL NETRA

GLACIER LAKE OUTBURST FLOOD EARLY WARNING SYSTEM (GLOF-EWS)

A JOINT INITIATIVE BY NDMA & C-DAC

GLOF | Early Warning System | Himalayas



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Safeguarding Downstream Communities Through Edge Technology

Objectives

- Development of Indigenous GIS-based Glacial Lake Outburst Floods Early Warning System (GLOF-EWS).
- Field survey and Bathymetric study and volumetric analysis of glacial lake as part of pilot Implementation.
- Field Deployment of Buoy System, AWS and Glacier vision Unit (GVU) to establish a pilot implementation.

Deliverables

The Technology: C-DAC

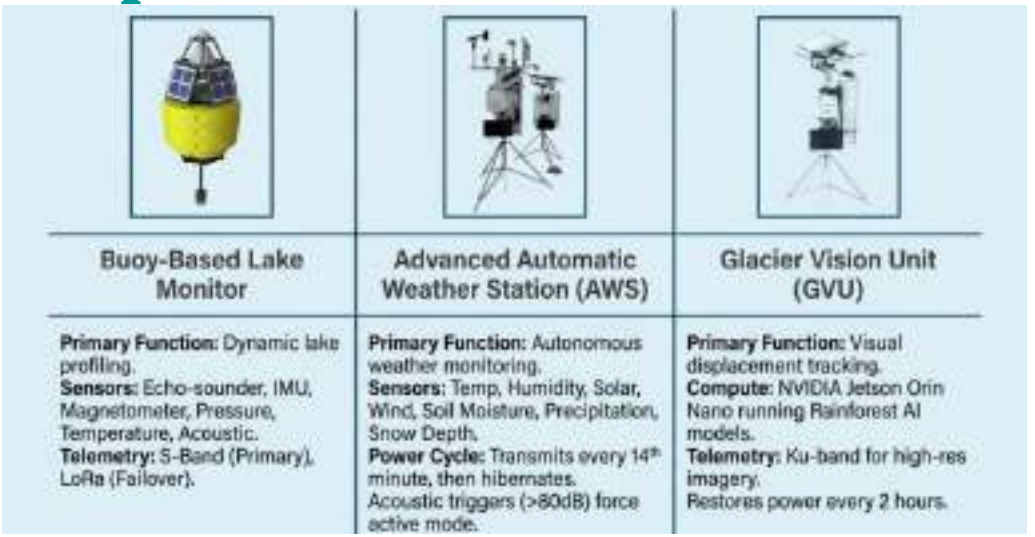
- GIS based Spatial Decision Support System (SDSS)
- Fail-Safe Edge Sensor Network
- High-performance Hydro-dynamic simulation

The GLOF-EWS bridges the gap between raw glacial data and life-saving evacuation time, engineering out failure points in the harshest environments on Earth.

Software Modules/Sub-Modules/Components of EWS

- **API for data collection from AWS, Buoy & GVU**
- **Unified Web Portal** – Access Controlled for display, query and analysis
  - Central and State Agencies will have different login credentials and views
- **Sensor Data Display Module** –Data Visualization in Tabular, Graphical Plots and Image
  - Glacial Lake Water Level, Temperature, Water Pressure Data etc.
  - AWS Data – Temp, Pressure, Wind Direction, Snow Depth etc.
  - Glacier Vision Unit Data – Daily Images
- **Spatial Decision Support System** – Visualization, Query and Analysis
  - Glacial Lakes, Administrative Boundaries, Satellite Images etc. (to be provided by SDMAs)
  - Glacial Lake Data, Sensor Data, Image Data, Simulation Results etc.
  - Lake Bathymetry Data, Lake Profile, Lake Volume and Discharge Computation
- **Algorithm for Automated GLOF Event Detection and Assessment**
- **Automated GLOF Simulation Model**
- **Warning and Alert Dissemination through SMS/Email/Whatsapp**

Components of EWS Hardware



Buoy-Based Lake Monitor	Advanced Automatic Weather Station (AWS)	Glacier Vision Unit (GVU)
Primary Function: Dynamic lake profiling. **Sensors:** Echo-sounder, IMU, Magnetometer, Pressure, Temperature, Acoustic. **Telemetry:** S-Band (Primary), LoRa (Failover).	**Primary Function:** Autonomous weather monitoring. **Sensors:** Temp, Humidity, Solar, Wind, Soil Moisture, Precipitation, Snow Depth. **Power Cycle:** Transmits every 14th minute, then hibernates. Acoustic triggers (>80dB) force active mode.	**Primary Function:** Visual displacement tracking. **Compute:** NVIDIA Jetson Orin Nano running Rainforest AI models. **Telemetry:** Ku-band for high-res imagery. Restores power every 2 hours.





SATCOM Architecture



The Dual-Band Synergy

S-Band: Unbreakable Reliability

All-Weather Resilience

Low-frequency wave propagation provides near-total immunity to rain and snow fade, ensuring the INSAT network link survives severe Himalayan weather events.

Mission-Critical Telemetry

Designed as the persistent backbone for constant, low-latency status updates when high-altitude conditions degrade other communication vectors.

Ku-Band: High-Capacity Imaging

Glacial Image Transmission

High-throughput bandwidth specifically engineered for the rapid transmission of large visual data packages from remote glacial sites.

Hardware Application

Powered by the Skysat Smartelite™ Dynamic Ku-band 8x8 unit. A ruggedized, highly efficient terminal designed for demanding remote deployments.



Redundant Communication Network



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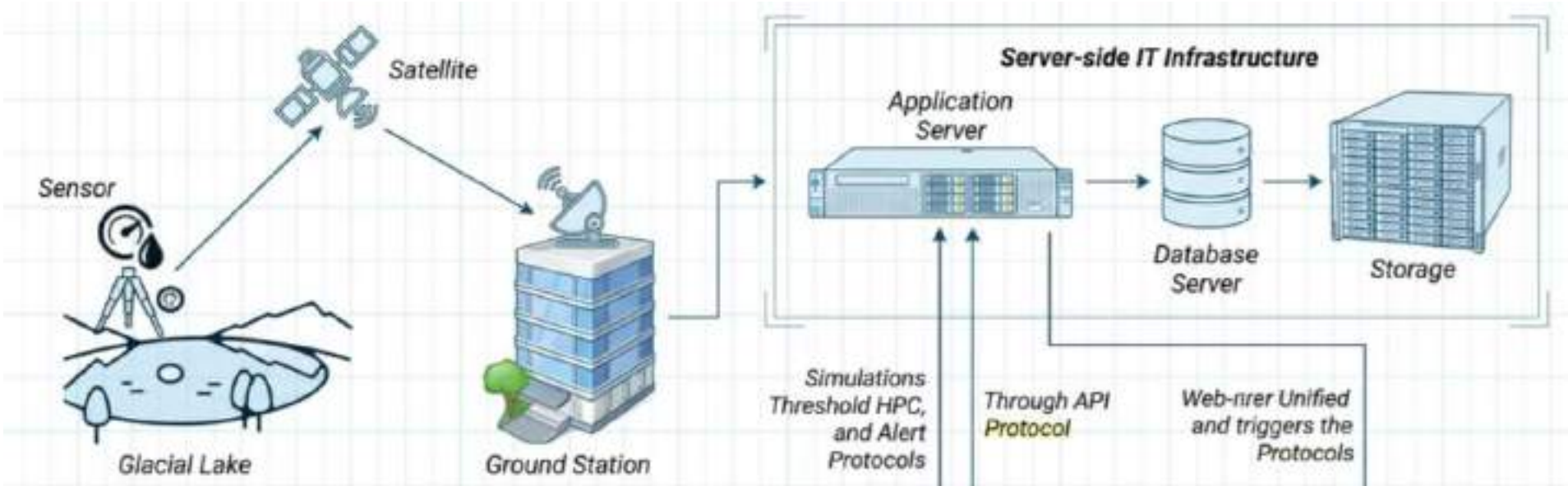
EWS SOFTWARE

Early Warning. Real-time Monitoring. Safer Tomorrow.

Real-time Monitoring | Early Warnings | Multi-hazard Detection | Reliable & Secure



Him Jheel Software System Architecture



Ingestion

Raw packets from the Glacial Lake (Sensor -> Ground Station -> Satellite) hit the secure firewall.

Application & Processing Servers

Data is routed through API layers into High-Performance Computing (HPC) nodes for continuous storage and visualization.



Dissemination

The Application Server simultaneously updates the web-based Unified Portal and triggers the SMS Gateway / E-Mail Server to push alerts directly to local administration and users.

HimJheel EWS Software Suite



SDBMS & SDSS (Spatial Decision Support System)

Access-controlled unified web **portal** mapping glacial lakes, administrative boundaries, and satellite images.

Displays real-time Buoy data (Water Level, Temp, Pressure) and AWS Data (Wind, Snow Depth) in tabular and graphical plots.

GLOFPRO (Event Detection)

Automated algorithms identifying abrupt water level drops, abnormal **GPS displacement**, and **acoustic anomalies.**

GLOFSIM (Simulation & Prediction)

Automated **Hydrodynamic** Simulation running over **HPC** to **predict water arrival times, depth**, and provide **GIS-based inundation mapping.**

System Architecture

End-to-end data flow from sensors to dashboard



Spring Security + JWT

· Secure endpoints · Authentication & Authorization
· Role-based access control

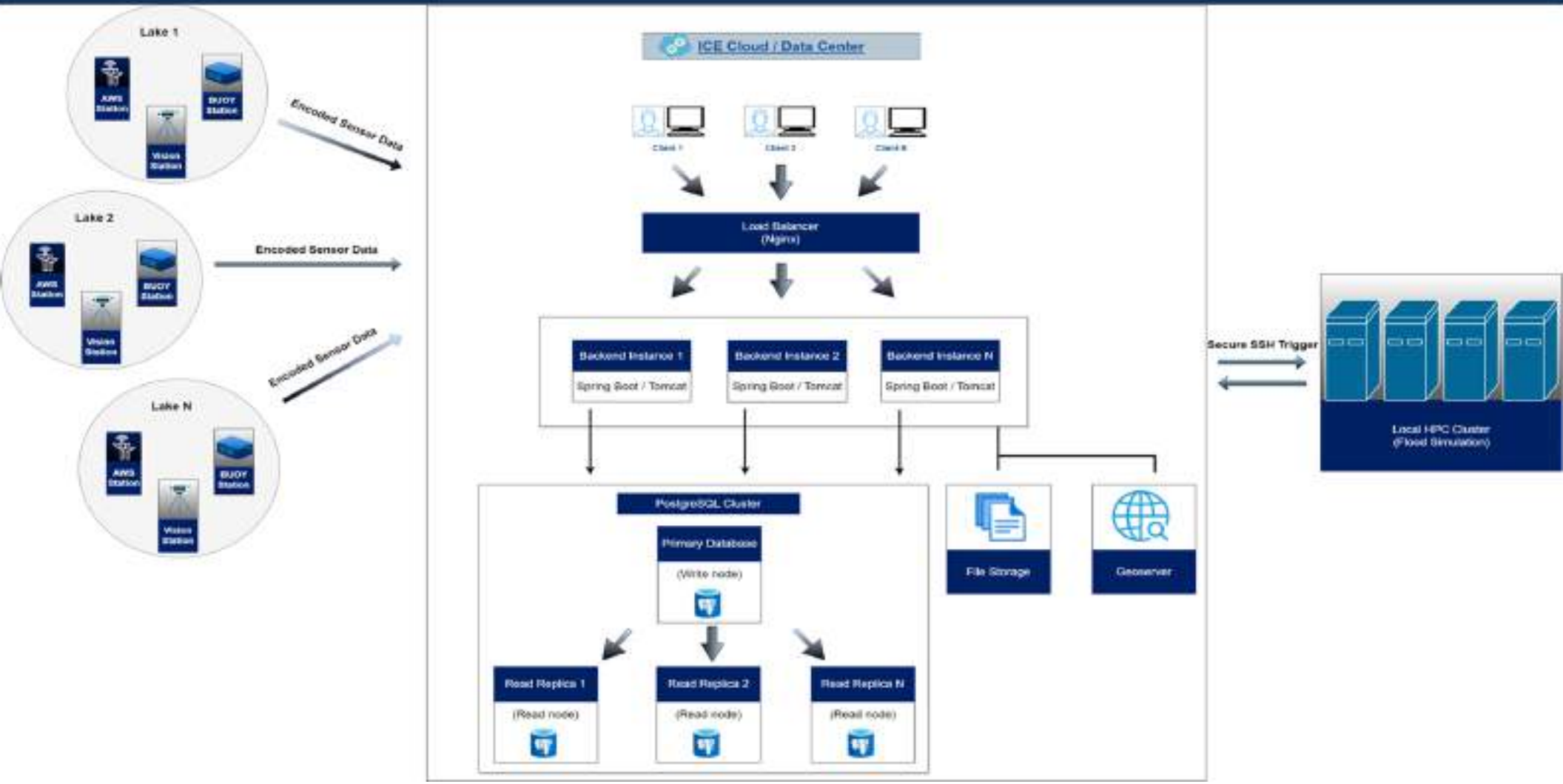
Real-Time Alert Engine

· Threshold/drop triggers · Multi-channel notify

< 2s	HPC	PostGIS	WMS/WFS
Alert Latency	Parallel Compute	Spatial Queries	GeoServer Layers

Spring Boot · Java 17 · Maven · Spring Data JPA · Hibernate

Scalable Hybrid Deployment Architecture For GLOF-EWS



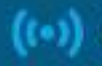
Major Software Modules

6 core modules



Lake Management

- CRUD for glacial lakes
- PostGIS geometry storage
- Lake spatial configuration
- Threshold & alert configuration



Sensor Monitoring

- Real-time data ingestion
- Multi-sensor aggregation
- Anomaly detection rules
- Historical trend analysis



Alert Management

- Multi-level alert tiers
- Automated alert generation
- Email dispatch



Simulation Engine

- Flood simulation scenario configuration
- HPC cluster job execution
- Anuga-based flood modelling
- Result processing & storage



GIS & Visualization

- GeoServer layer publish
- WMS endpoints
- DEM & TIFF rendering
- Flood inundation maps

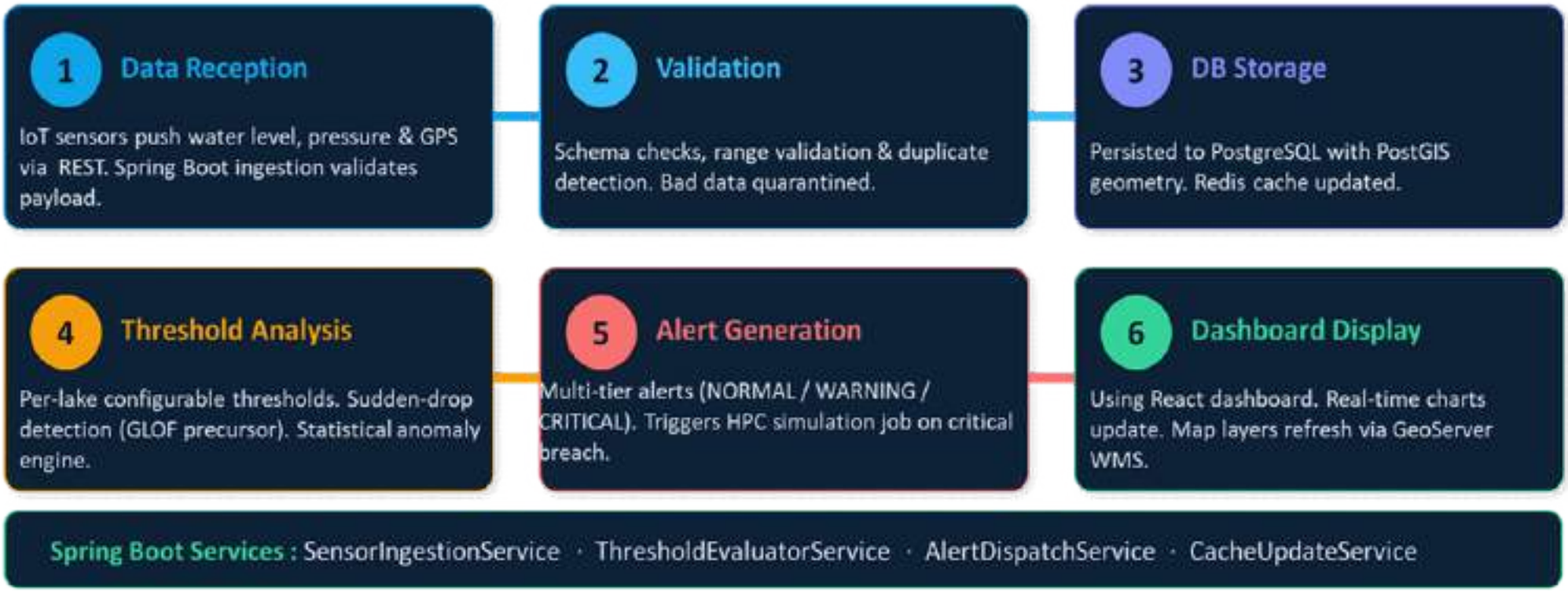


Auth & Security

- JWT + Spring Security
- Role-based access
- Audit logging

Sensor Data Workflow

From raw sensor reading to dashboard alert



Near real-time sensor data ingestion · Redis cache layer · HPC job auto-triggered on CRITICAL alert

Database & Caching Architecture

PostgreSQL + PostGIS

Lakes Table	Geometry(Polygon), thresholds, NDMA id
Sensors Table	Type, min, max, station
Sensor Readings	Indexed on timestamp + sensor_id
Alerts Table	Severity , triggered_at, type
Settlement Table	Geometry(Point), state, district, population
GIS Functions	ST_Within, ST_Distance, ST_Area, ST_Intersection

Redis Cache

- Caches frequently accessed application data
- Reduce database load
- Improves API response time

Performance Gains

~30%
DB load reduction

< 50ms
Cached response

GIS & DEM Processing

1. **DEM / TIFF Ingestion**
   Upload DEM files via Spring Boot API. GeoTools reads raster data.

2. **Water Volume Calculation**
   Integrate DEM elevations within lake polygon boundary. Volume = Σ(cell_area × depth). Stored per water level reading.

3. **Flood Extent Estimation**
   ANUGA for precise hydrodynamic simulation. Results published to GeoServer.

4. **Risk Zone Generation**
   Classify downstream zones: High / Medium / Low risk. PostGIS ST_Buffer + ST_Intersection with roads, settlements.

GIS Tech Stack

GeoServer 2.x
WMS, WFS endpoints
Layer groups & styling

GeoTools
Java GIS library
Raster + vector processing

PostGIS
Spatial SQL extensions
Geometry indexing (GIST)

GDAL
DEM format conversion
Projection transforms

OpenLayers / Leaflet
React map components
WMS tile rendering

HPC-Based Flood Simulation

ANUGA Hydrodynamic Model



Simulation time: vary depending on domain size · Output: peak flood depth, timing, affected settlement count

Alert & Early Warning System

Normal

CONDITION

- Water level within normal range.

ACTION

- Save to DB
- Update dashboard indicator

WARNING

CONDITION

- Water level crossed warning threshold.

ACTION

- Email to all users
- Yellow alert on dashboard

CRITICAL

CONDITION

- Danger/below threshold breached
- Sudden drop
- GLOF precursor pattern detected.

ACTION

- Email blast
- Trigger HPC simulation
- Red alert on dashboard

Technical Implementation

Receive data · Analysis engine for threshold scan · Event detected · Alert generation

Key Features & Capabilities

< 2s

Alert Latency

From sensor ingestion to dashboard notification

PostGIS

Spatial Engine

Full GIS capabilities — geometry ops, spatial indexing, raster storage

HPC

Simulation Power

ANUGA on parallel cluster

30%

DB Load Cut

Redis cache-aside reduces PostgreSQL read pressure significantly

JWT

Secure Auth

Spring Security + JWT with role-based access, audit log

WMS

Live GIS Layers

GeoServer streams simulation outputs layers in real-time

Daily Report

Daily buoy analysis report

Daily analysis of buoy monitoring data featuring seven-day water level trends, impact event assessment, and system health indicators.

Hazard Map

Worst-Case GLOF Risk Assessment Map

Assessment of flood arrival times, inundation extent, and risk exposure for downstream settlements .

Scalability

Layered & Scalable

Supports independent scaling of backend, database, simulation component

Daily Buoy Analysis Report

4. WATER LEVEL TREND ANALYSIS

A. Water Level Change Assessment

Comparison Period : From 20 Jun 2026 To 21 Jun 2026

1. Depth Comparison & Trend Interpretation :

Assessment	Raw Depth	Assessment Depth	Date & Time
Old Depth	0.872 m	0.872 m	20 Jun 2026 12:00 am
New Depth	0.930 m	0.930 m	21 Jun 2026 11:00 pm
Water Level Difference	0.058 m	0.058 m	
Trend Type	Water Level Increased		

2. Motion & Position Difference Comparison :

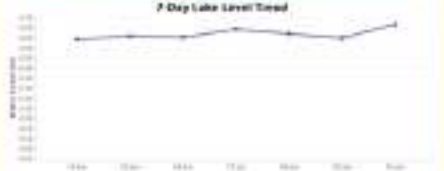
Parameter	Value
Pitch Difference	0.10°
Roll Difference	0.10°
GPS Drift Difference	0.00 m

3. Summary :

Water trend analysis between matched buoy states indicates that the water level increased by 0.058 m between 20 Jun 2026 and 21 Jun 2026

B. Previous 7 Days Lake Level Trend (3 May Reference)

The reference buoy position used for analysis was established from the observation recorded on 01 May 2026, 01:00 pm, with coordinates (22.478446, 77.129439), a low depth of 0.88 m, a recreational depth of 5.00 m, and orientation values of Pitch 7.26°, Roll -10.73°, and Yaw 103.20°.



Date	Lake Level (m)	Status
14 Jun	0.880 m	Stable
15 Jun	0.905 m	Stable
16 Jun	0.893 m	Stable
17 Jun	0.942 m	Water Level Increased
18 Jun	0.928 m	Stable
20 Jun	0.930 m	Stable

7. Water Temperature Trend Analysis

A. Water Temperature Assessment (21 Jun 2026)

1. Daily Temperature Statistics :

Parameter	Value
Opening Temperature	12.20 °C
Closing Temperature	13.04 °C
Minimum Temperature	10.41 °C
Maximum Temperature	14.38 °C
Average Temperature	13.11 °C
Daily Temperature Range	3.97 °C

2. Previous Day Comparison :

Comparison Period : From 20 Jun 2026 To 21 Jun 2026

Comparison	Difference
Average Temperature Change	-0.05 °C
Minimum Temperature Change	0.20 °C
Maximum Temperature Change	-0.12 °C

3. Temperature Trend Windows :

Time Window	Trend
1 AM – 05:00 am	Cooling
05:00 am – 09:00 am	Warming

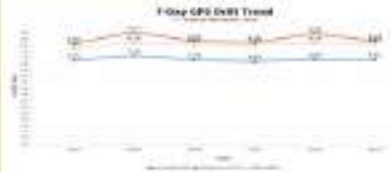
8. GPS Position Stability Analysis

Observed Anchored Latitude	22.478433
Observed Anchored Longitude	77.129380

A. GPS Stability Statistics :

Parameter	Value
Total Readings	96
Valid Readings	96
Invalid Readings	0
Maximum Drift	8.77 m
Average Drift	6.75 m

B. Previous 7 days Trend Analysis :



9. Power System Analysis

A. Power Assessment (21 Jun 2026)

1. Power Statistics :

Parameter	Value
Opening Voltage	12.53 V
Closing Voltage	13.53 V
Minimum Voltage	13.11 V
Maximum Voltage	14.12 V
Average Voltage	13.45 V
Net Change	0.00 V

2. Day vs Night Analysis :

Parameter	Value
Day Average Voltage	13.58 V
Night Average Voltage	13.35 V
Solar Hours	13.07 hrs

3. Battery and Charging Status :

Parameter	Status
Battery Status	Healthy
Charging Status	Charging Normal
Trend Status	Stable

8. Noise and Impact Events Analysis

A. Event Summary :

No Significant Noise or Impact Events Detected

The Noise and Impact Monitoring module is designed to continuously evaluate buoy stability, environmental disturbances, and acoustic activity within the monitored lake region. The system analyzes multiple sensor parameters including buoy pitch, roll, yaw orientation, GPS displacement, and sound intensity to identify unusual motion patterns, strong wave activity, impact disturbances, floating materials, or abnormal environmental activities events that may require operational attention. The analysis logic combines data from multiple sensors to reduce false alarms and improve system reliability. Significant events are identified only when measured parameters exceed configured operational thresholds for an uninterrupted GPS drift, wave elevation intensity. Less significant events are not treated as critical, events because floating buoys naturally experience heading changes due to wind, currents, and wind direction. During the system's monitoring period, no significant motion disturbances, impact events, lake surge events, or abnormal activities, submitted were detected. Observed buoy motion remained within acceptable operational limits, and recorded wave and wind conditions did not exceed the configured monitoring thresholds. A 5 hz GPS movement. GPS displacement remained within normal floating behavioral limits of 20. meters, indicating that the buoy maintained stable positional conditions during the analysis interval. accurately maintaining near the real indicates any significant event. Simultaneously, all the configured alert thresholds of 10.00. Meter. Consequently, no alert conditions were triggered during the monitoring period. Overall, the system recorded stable buoy operation and no evidence of significant physical disturbance or abnormal environmental activity during the monitoring period.

10. Daily Summary Report

Consolidated Summary for 21 Jun 2026

This section consolidates the key observations and status findings from all sensor systems monitored during the reporting period. Each summary below represents the automated analysis generated from the respective sensor module.

Water Level	Water trend analysis between matched buoy states indicates that the water level increased by 0.058 m between 20 Jun 2026 and 21 Jun 2026
Water Temperature	Water temperature ranged from 12.41 °C to 14.38 °C with an average of 13.11 °C. The temperature remained stable compared to the previous day, with an average temperature change of -0.09 °C.
Acoustic	No significant acoustic activity detected
Impact Events	No Significant Noise or Impact Events Detected .
Position (GPS)	GPS analysis indicates that 95% of recorded positions remained within 8.01 m . 0 sudden position changes were observed. Buoy remained within configured safe distance (20.0m) from anchor throughout the day. Overall position status: Normal.
Power System	The buoy station recorded an average battery voltage of 13.45 V. The minimum and maximum voltages observed were 13.11 V and 14.12 V respectively. The system reported battery status as Healthy with charging status marked as Charging Normal.

* All summaries are system-generated based on sensor data collected for 21 Jun 2026. Please refer to the respective sections for detailed analysis and trend charts.

Flood Hazard Assessment Map

NATIONAL DISASTER MANAGEMENT AUTHORITY

WORST-CASE GLOF REPORT

SISSU (Admin008)

LAKE INFORMATION

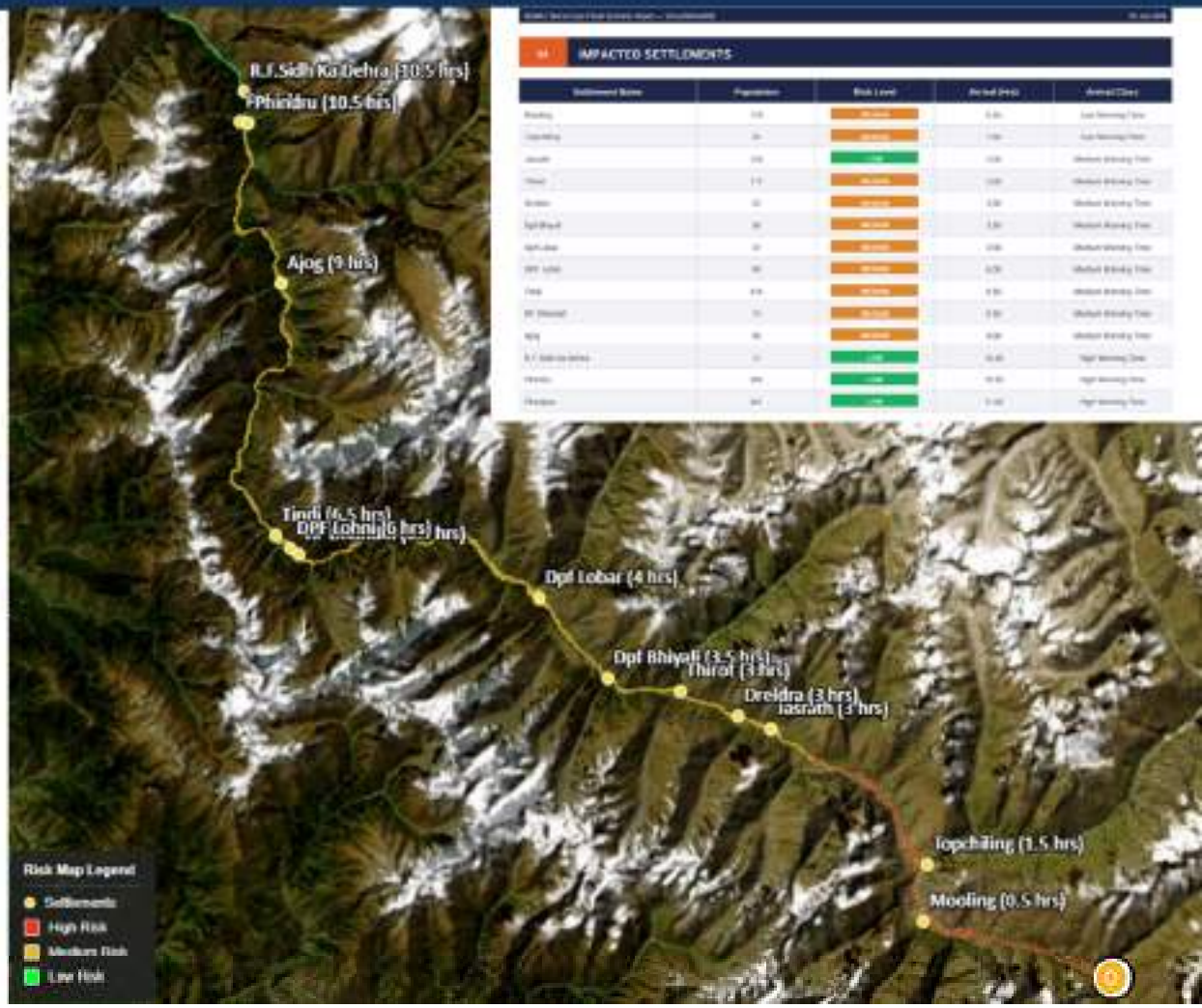
Lake ID Admin008	Lake Name Sissu	State HIMACHAL PRADESH
District Lahaul Spiti	Report Type Worst Case Scenario	Generated On 01 Jul 2026, 15:48

EXECUTIVE SUMMARY

14	1805	Mooling	0.1	6
Total Settlements Assessed	Total Population at Risk	First Impacted Settlement	Lakshmi Flood Arrival (hrs)	Average Flood Arrival (hrs)

02 RISK STATISTICS

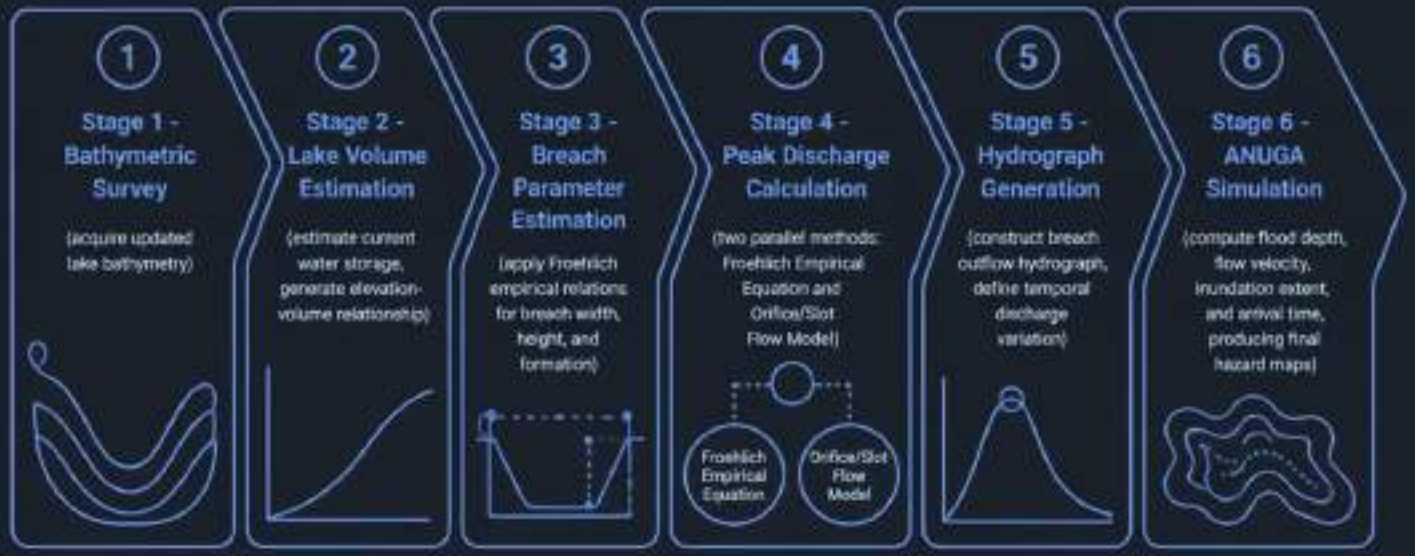
Risk Category	Settlements	Population
Low	4	662
Medium	10	1143
High	0	0
Very High	0	0
Total Population at Risk	14	1805



03 IMPACTED SETTLEMENTS

Settlement Name	Population	Risk Level	Arrival (hrs)	Arrival (Clock)
Phinidru	113	Medium	0.00	Jun Morning 10:48
Tindi Ring	95	Medium	1.00	Jun Morning 11:48
Jasrath	115	Low	3.00	Jun Morning 13:48
Thirot	113	Medium	3.00	Jun Morning 13:48
Sissu	95	Medium	3.00	Jun Morning 13:48
Ajog Khurd	95	Medium	3.00	Jun Morning 13:48
Tindi Lobar	95	Medium	3.00	Jun Morning 13:48
DPF Lohni	95	Medium	3.00	Jun Morning 13:48
Ring	95	Medium	3.00	Jun Morning 13:48
R.F. Sidh Ka Dehra	113	Low	10.00	Jun Morning 20:48
Mooling	95	Low	10.00	Jun Morning 20:48
Thodpa	95	Low	11.00	Jun Morning 21:48

GLOF Scenario Generation



Froehlich Peak Discharge(2008) :

$$Q_p = 0.607\ V_w^{0.295}\ h_b^{1.24}$$

Orifice / Slot Flow Equation :

$$Q = C_d\ A\ \sqrt{2gh}$$

BREACH WIDTH Froehlich (2008) :

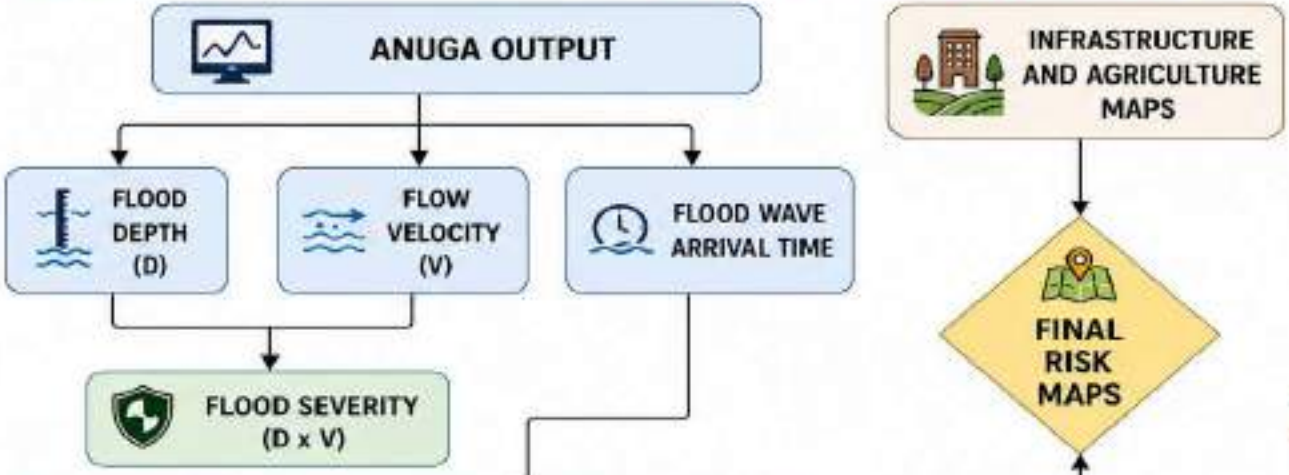
$$B_w = 0.18 \times V^{0.32} \times H_b^{0.19}$$

BREACH HEIGHT Froehlich (2008) :

$$H_b = 0.00254 \times V^{0.53}$$

METHODOLOGY OF GLOF RISK ASSESSMENT

FLOW CHART OVERVIEW



RISK CLASSIFICATION MATRIX

ARRIVAL TIME / SEVERITY	LOW	MEDIUM	HIGH
HIGH SEVERITY	H	M	L
MEDIUM SEVERITY	H	M	L
LOW SEVERITY	M	L	L

FLOOD SEVERITY CLASSIFICATION

FLOOD SEVERITY	D x V THRESHOLD
LOW SEVERITY	≤ 0.6
MEDIUM SEVERITY	> 0.6 to ≤ 10
HIGH SEVERITY	> 10

FLOOD WAVE ARRIVAL TIME CLASSIFICATION

ARRIVAL TIME	DEFINITION
≤ 2 HRS	No time for authorities to provide warning
2 – 10 HRS	Less time for authorities to provide warning
> 10 HRS	Sufficient time for authorities to provide warning

Integrating Anuga model outputs, infrastructure & agriculture data, and risk classification to generate actionable GLOF risk maps for informed decision-making.

Future Enhancements

Apache Kafka Streaming

Phase 2

Replace REST ingestion with Kafka topics for sub-100ms sensor data streaming.

Enhanced Reporting

Phase 2

Automated generation of comprehensive weekly and monthly reports featuring combined Buoy and AWS analysis

ML Anomaly Detection

Phase 2

Different ML models on sensor time-series for early GLOF precursor detection beyond simple thresholds.

Digital Twin

Phase 2

Creates a virtual replica of the lake that continuously updates with live data to support monitoring, analysis, and simulation.

Emergency Evacuation Planning

Phase 2

calculates the nearest safe evacuation routes for communities in affected areas.

Scenario Generation Engine

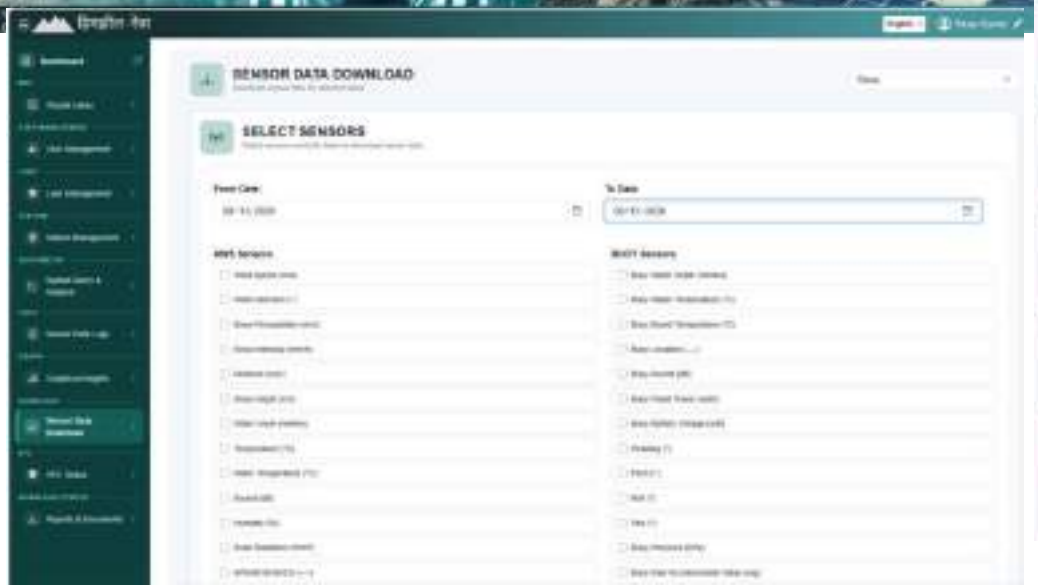
Phase 2

Stores pre-generated flood simulations for different lake volume-drainage levels, allowing immediate retrieval of likely inundation impacts when a similar water-loss event is detected

Built on open standards · Cloud-ready (AWS / Azure) · Designed for replication across glacial lake monitoring programs

HimJheel Netra EWS Screen Shots



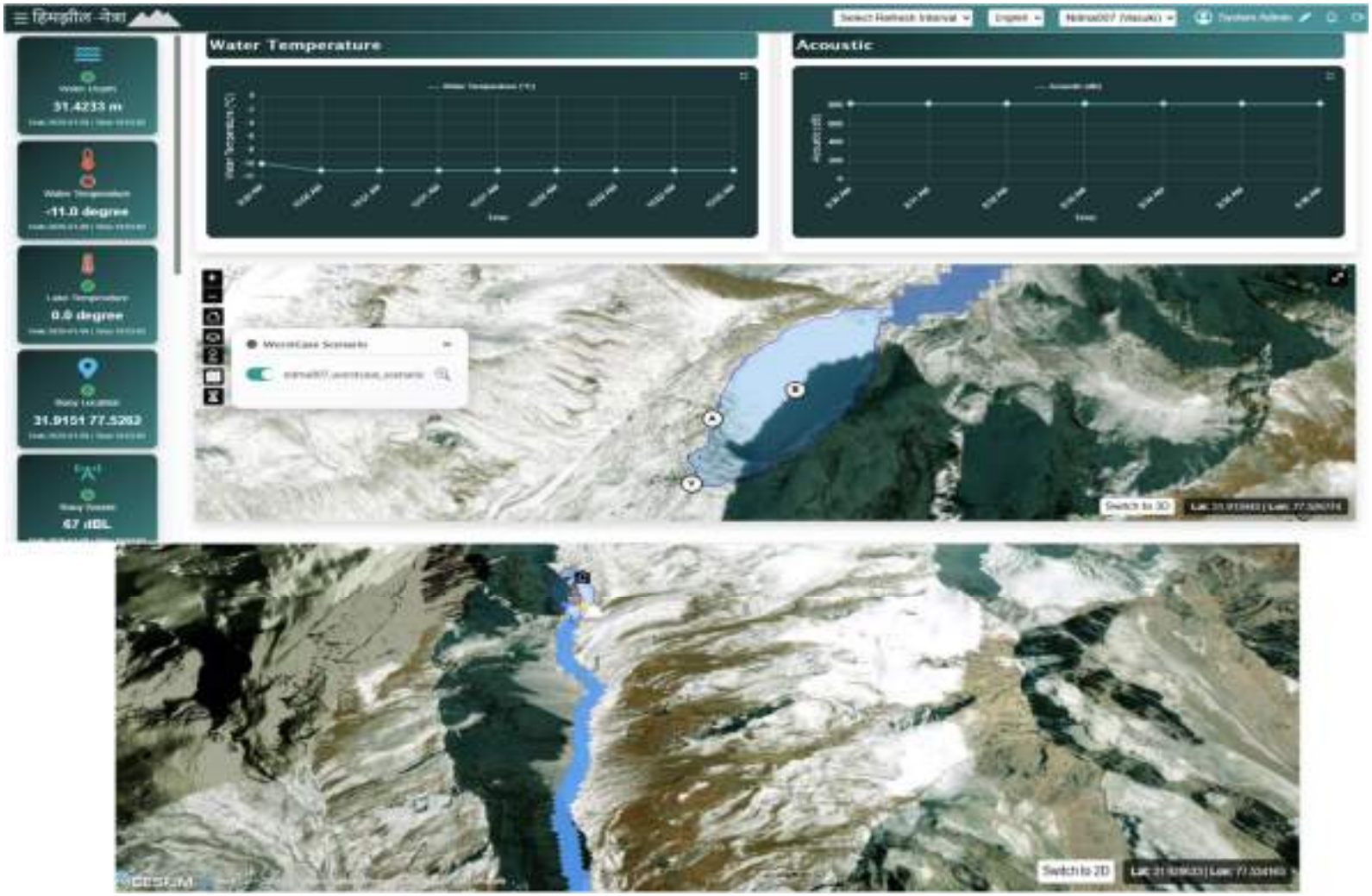




HimJheel Netra EWS Screen Shots



HimJheel Netra EWS Screen Shots




Thank You
Applying Advanced Computing for Human Advancement