U.S.-Pakistan
Centers for Advanced Studies in Water

Mehran University of Engineering & Technology, Jamshoro

## GRADUATE SEMINAR SERIES # 12

# GLOF mapping and risk assessment in Hunza river basin using geospatial techniques

By Dr. Arjumand Zaidi
September 2nd, 2016

Partnering Universities:

THE UNIVERSITY OF UTAH

# Contents



***Disclaimer:***

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## 1. Graduate Seminar Series

Graduate seminar series is a regular features of at USPCAS-W. These seminars are usually organized on weekly basis. The main aim of these seminars are to keep students and faculty updated about the latest advancements in the field of research, facts and trends in water and related sectors. Experts from all over the country are invited to deliver lectures & presentations and give talks on the most emerging water related issues and the best practices adopted worldwide in addressing those issues.

So far; the center has organized following seminars;

| S. No. | Topic | Speaker(s)/Presenter(s) | Date |
|---|---|---|---|
| 1 | Spate Irrigation: Potential and Challenges in Sindh | Mr. Karim Nawaz Baloch,<br>Water Expert from Balochistan<br>Dr. Kamran Ansari, USPCAS-W<br>Dr. Altaf Ali Siyal, USPCAS-W | 4/9/2015 |
| 2 | Health, Safety and Environment | Engr. Nizamuddin Domki,<br>HSE Trainer | 18/09/2015 |
| 3 | Impact of Climate Change on Water Resources of Sindh Province | Senator Nisar A. Memon<br>Dr. Ghulam Rasul,<br>Pakistan Meteorological Department | 5/11/2015 |
| 4 | Water quality around us: Overview of situation in Hyderabad and Tharparkar | Prof. Dr. Muhammad Iqbal Bhanger , University of Karachi | 12/11/2015 |
| 5 | Water: Resources , Issues and Management | Prof. Dr. Iqbal Ahmed Panhwar,<br>Bahria University Karachi | 11/12/2015 |
| 6 | How to review research paper & write a research proposal | Dr. Sajjad Ahmad,<br>University of Nevada, Los Vegas USA | 22/01/2016 |
| 7 | Empowering the Irrigation<br>Reforming Institutions in Sindh | Mr. Nazeer A. Essani General Manager (Transition) Sindh Irrigation Drainage Authority | 29-1-2016 |
| 8 | Sustainable Development and WEF Nexus | | 12-02-2016 |

| | | | |
|---|---|---|---|
| 9 | "Linkages between Engineering Research and Entrepreneurship" | Dr. Shahid Qureshi<br>IBA Sukkur | 01-04-2016 |
| 10 | Hydrology and water resources engineering | Dr. Habib ur Rehman | 29-04-2016 |
| 11 | Urban climate research: application of remote sensing and GIS | Dr. Haroon Stephen<br>Assistant Professor Civil and Environmental Engineering<br>Director GIS and Remote Sensing Core Lab<br>University of Nevada, Las Vegas | 06-06-2016 |
| 12 | GLOF mapping and risk assessment in Hunza river basin using geospatial techniques | Dr. Arjumand Zaidi<br>Assistant Professor<br>National Centre for Remote Sensing & Geo Informatics<br>Institute of Space Technology | 2-9-2016 |

## 2. Speaker's profile

### Dr. Arjumand Zaidi

Dr. Arjumand Zaidi is PhD in Information Technology from School of Information Technology, George Mason University, Fairfax, Virginia. USA. Dr. Zaidi has extensive experience in the field of environmental evaluation and decision making. Her research interests include optimization and modeling of water resources, environmental and disaster management systems. Most of her research work deals in environmental decision making with the help of various numerical techniques and Geographical Information Systems (GIS) using satellite data.

## 3. GLOF mapping and risk assessment in Hunza river basin using geospatial techniques

On Friday January 29, 2016, Dr. Arjumand Zaidi, Senior research fellow USPCAS-W, delivered the seminar with on "**GLOF mapping and risk assessment in Hunza river basin using geospatial techniques**".

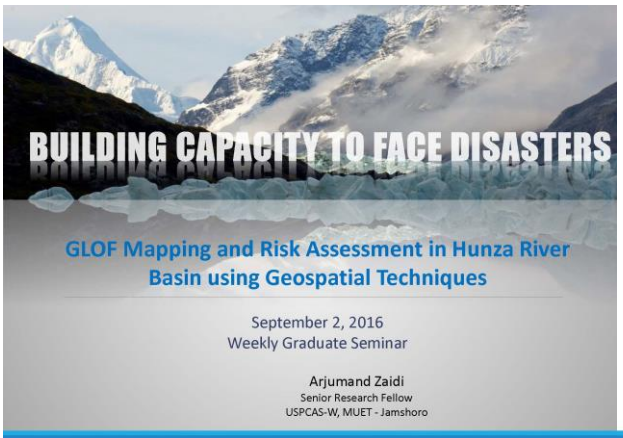
Dr. Arjumand Zaidi – the speaker of the seminar started her lecture while discussing about the dangers of glaciers that are often responsible of forming lakes at their termini. Having outburst potential, these lakes

could turn to be dangerous. In Pakistan, at Hindu Kush Himalayas (HKH) region, a number of dangerous glacier lakes have been created in the recent past. Rupturing of the dangerous lakes has caused severe flooding in the region called "GLACIAL LAKE OUTBURST FLOODING (GLOF)". The lecture was based on a study conducted for the International Centre for Integrated Mountain Development (ICIMOD) on Vulnerability Assessment for Potential Glacial Lakes Outburst Floods (GLOFs) events in Passu and Bagrot Valley. The lecture was an effort to use satellite data for glacier lake monitoring and flood extent modeling. An addition to that, speaker attempted to identify the GLOF hazard areas in Hunza Basin.

In later parts of her presentation she talked specifically about the terrain surrounding the Hunza River. The speaker told the students about the combination of GIS and ArcGIS that she had used for her research. The speaker elaborated that the Passu Lake located at the terminus of Passu glacier in Hunza Basin is a dangerous glacier lake with a past history of several GLOFs. HEC- GeoRAS and HEC-RAS were used to model an anticipated flooding in Hunza River due to Passu Lake outburst. Flood hazard mapping predicts the possible flood

extent may be used to determine floodplain zones. Flood hazard map prepared in this study were presented to develop an understanding of the impact of such disasters in order to lower the risk of the vulnerable communities.

## 4. Annexure: Presentation




### Background

- Global warming causing alteration in natural phenomenon including
  - Glacier retreat
  - Creation of lakes on glaciers' terminus
- These lakes are very unstable and burst resulting in a discharge of huge amounts of water and debris called Glacial Lake Outburst Flood (GLOF)
  - Causing destruction of downstream valleys
- GLOF is a common problem in the Hindu Kush - Himalayan (HKH) countries -Bhutan, China, India, Nepal and Pakistan (ICIMOD)

### What is Glacial Lake Outburst Flood (GLOF)?

- Occurs when dam containing a glacial lake fails
- GLOFs may be developed abruptly in a lake with no prior history of outburst
- Therefore, magnitude and frequency can not be predicted using standard statistical methods

### How to reduce potential GLOF impact?

- Continuous monitoring of potentially dangerous lakes
  - Spatial
  - Temporal

*Problem?*

- Due to remote locations of these lakes continuous monitoring is a *challenge!!!!!*

### Role of Geospatial Techniques?

- Using RS and GIS techniques, status of glaciers and glacier lakes can be continuously monitored
- Hydraulic modeling – for hazard mapping

### Hydraulic Modeling

- Functions
  - Pre- processing of GIS data
  - Model Execution
  - Post-processing/visualization of results
- Use
  - Floodplain management
  - Disaster Management
  - Flood insurance studies

## HEC-RAS

- Hydraulic model developed by
  - Hydrologic Engineering Center (HEC), U.S. Army Corps of Engineer
- Types of River Analysis
  - Performs one dimensional steady and non-steady flow river hydraulics calculations
  - Computes water surface elevation along the channels
- Results are transferred back to GIS

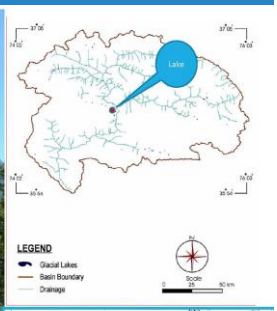
## HEC-GeoRAS

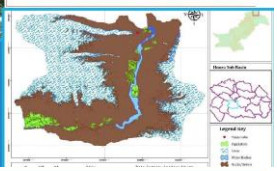
- Extension of ArcGIS to extract river geometry
- Preprocessor to export geometry data to HEC-RAS
- Post Processor for data imported from HEC-RAS

### Case Study

- Watershed delineation
- Discharge calculation
- Simulation model setup
- Simulation run
- Flood maps

### Hydraulic Modeling of Passu Glacier Lake Outburst Flooding at Hunza Watershed



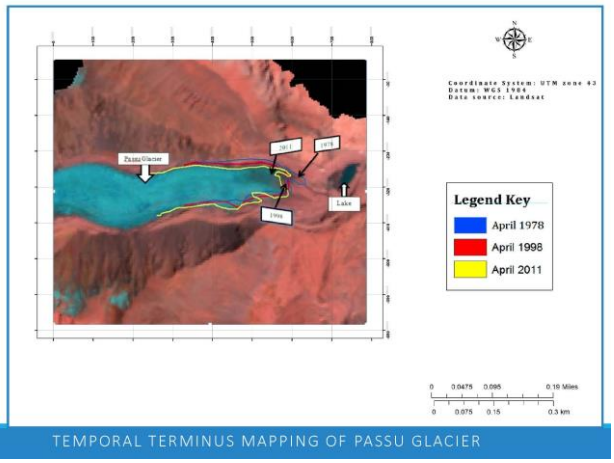



### Study Area

Hunza Watershed

### River Basins in Indus


### Project Area

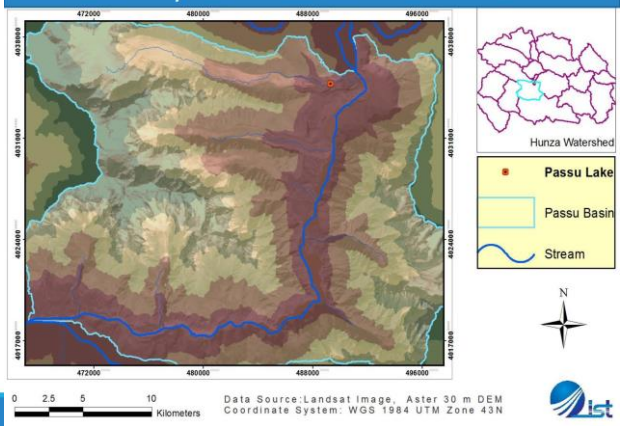




TEMPORAL TERMINUS MAPPING OF PASSU GLACIER

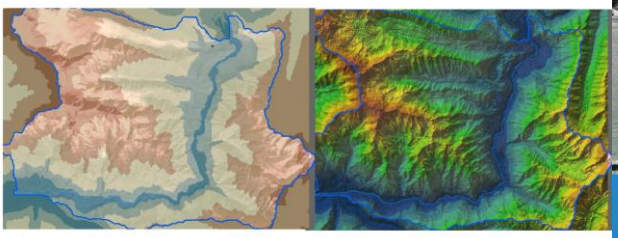
## Data used in Hydraulic Modeling

- HEC- GeoRAS
  - Digital Elevation Model
  - Landsat classified image (June 2011)
- HEC-RAS
  - Flow data
  - Boundary conditions

## Study Area: Passu subwatershed




## Elevation Data

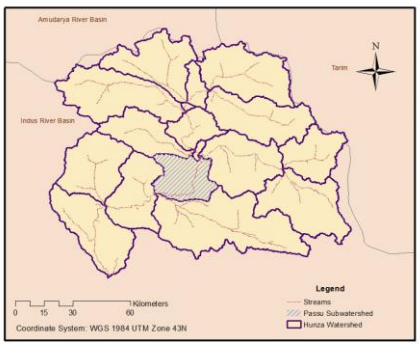


(ASTER 30 meters resolution DEM) (TIN generated from ASTER DEM)

## Data Preparation

Estimation of Probable Maximum Discharge

## Watershed Delineation




Utilizing Arc Hydro

## Lake Volume & Discharge

| SN | Relation | Reference |
|---|---|---|
| 1 | $Q_{max} = 0.00077V^{1.017}$ | Huggel 2002 |
| 2 | $*Q_{max} = 0.00013PE^{0.60}$ | Costa and Schuster 1988 |
| 3 | $Q_{max} = 0.0048V^{0.896}$ | Popov 1991 |
| 4 | $**Q_{max} = 2V/t$ | Huggel 2002 |
| *PE = 9800 x dam height (h in m) x V | | |
| ** t = 1000 sec, duration of outburst | | |

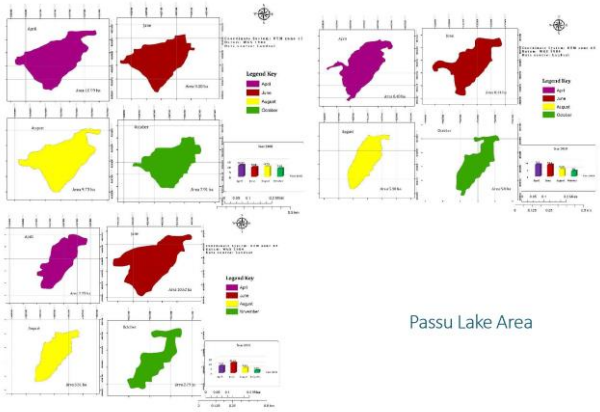
- Modeled Relationships between Lake volume and discharge in Moraine Dam Failure

$V = m^3$, $Q_{max} = m^3/sec$

## Lake Volume and Area

| SN | Relation | Reference |
|---|---|---|
| 1 | $V = 0.035A^{1.5}$ | Evans 1986 |
| 2 | $V = 0.104A^{1.42}$ | Huggel 2002 |

Modeled relationship between lake area and volume



Passu Lake Area

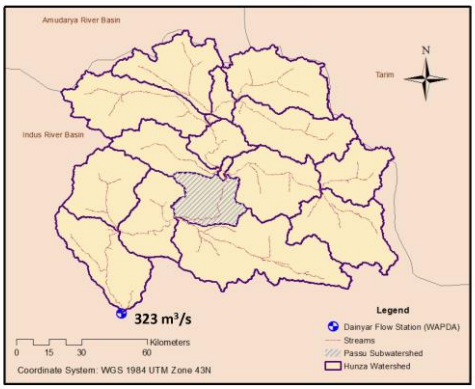
A = $m^2$, V = $m^3$

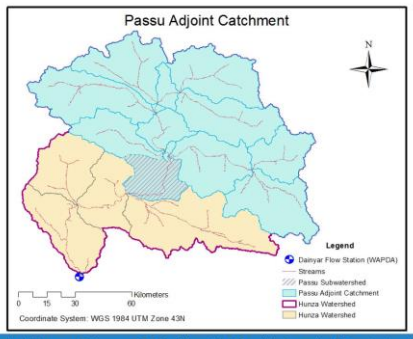
Lake area derived from April 2005 Google Earth image 12.53 hac (125,300 $m^2$) is used in this analysis

## GLOF Discharge

- **Lake Volume**
  - $V = 0.104A^{1.42}$ Huggel 2002
  - $V = 0.104 * (125{,}300)^{1.42}$
  - $V = 1.8 \times 10^6\ m^3$
- **Probable Maximum Discharge**
  - $Q_{max} = 0.00077\ V^{1.017}$ Huggel 2002
  - $Q_{max} = 0.00077 \times (1.8 \times 10^6)^{1.017}$
  - $Q_{max} = 1{,}774\ m^3/sec$
  - Total Flow = $Q_{max}$ + River Discharge

## River Discharge



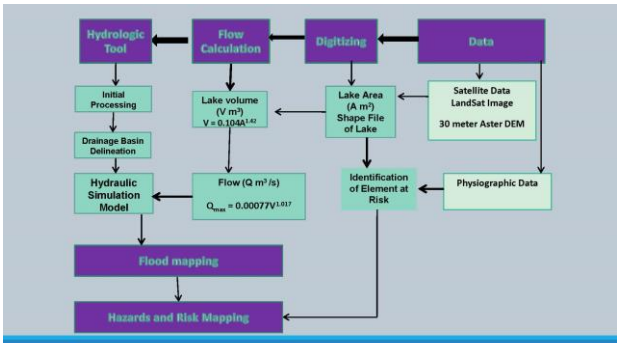

Recorded Flow at Dainyar = 323 $m^3/s$ with 69 $m^3/s$ Standard Deviation (SD)

| Location | Catchment Area ($Km^2$) | Discharge Mean Annual ($m^3/s$) | Discharge Mean+1SD ($m^3/s$) CI=84% | Discharge Mean+3SD ($m^3/s$) CI= 99.85% | Comment |
|---|---|---|---|---|---|
| Hunza River at Dainyar Bridge | 13,733 | 323 | 392 | 530 | Measured |
| Hunza River at Passu | 9,082 | 214 | 259 | 351 | Estimated |

## Flow Profiles Selected for Simulation

| Flow Profile | Description | Total Flow ($m^3/s$) |
|---|---|---|
| PF1 (Baseline) | MAF | **214 $m^3/sec$** |
| PF2 | $Q_{max}$ + MAF | **1988 $m^3/sec$** |
| PF3 | $Q_{max}$ + 1S | **2033 $m^3/sec$** |
| PF4 | $Q_{max}$ + 3S | **2125 $m^3/sec$** |

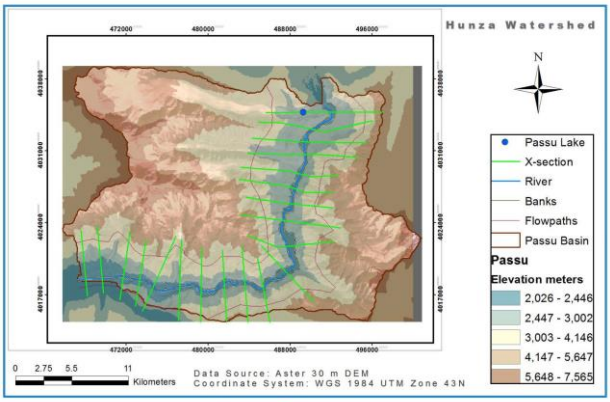
MAF = Mean Annual Flow (estimated)
$Q_{max}$ = GLOF discharge
1S= MAF + 1SD (estimated)
3S = MAF + 3SD (estimated) – Assumed to be an extreme event linked with higher precipitation value.



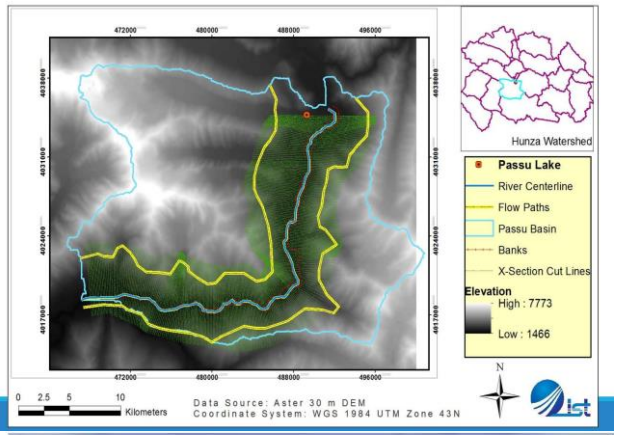

Methodology

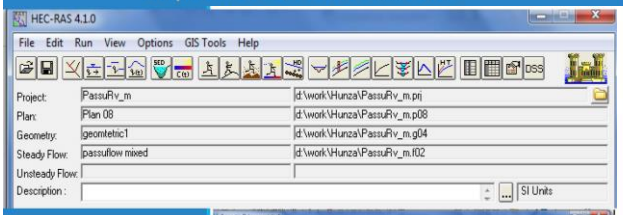
## Model Development

- A geo-referenced HEC-RAS geometry file was created using ArcGIS
- GeoRAS extension was used to create the HEC-RAS geometry file from the cross-section lines, centerline and surface

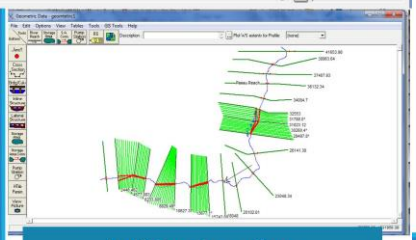



Preparation of Geometric Data

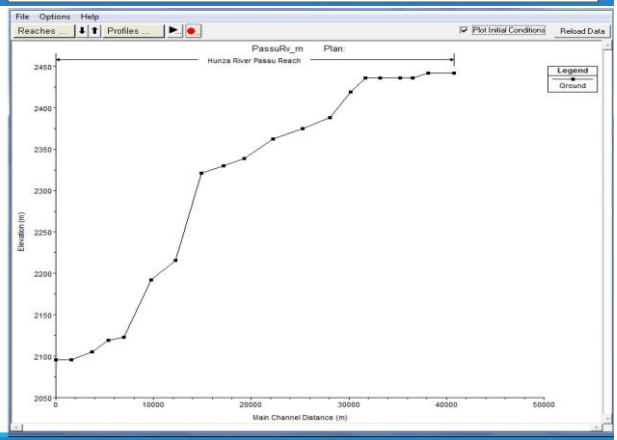


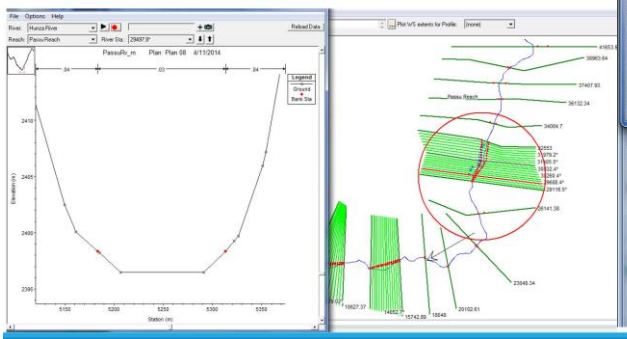

HEC-RAS geometric editor

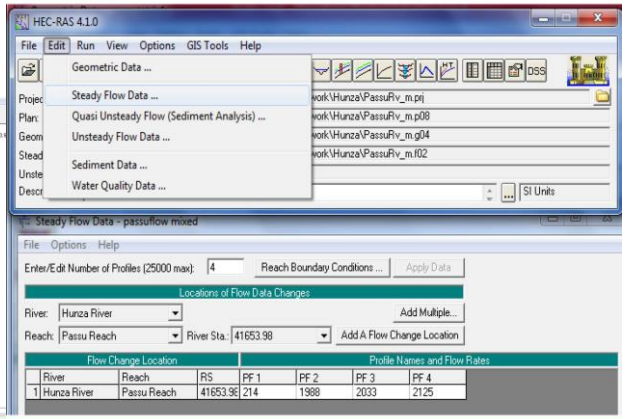


Additional x-sections

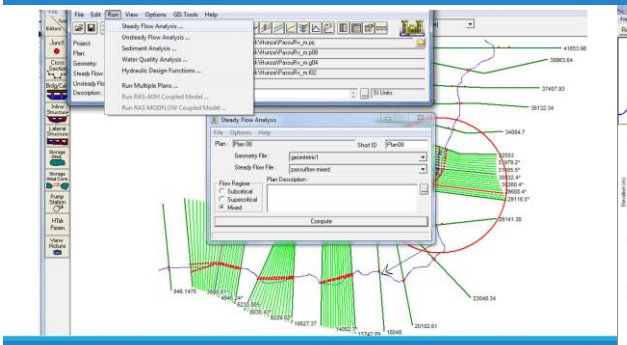


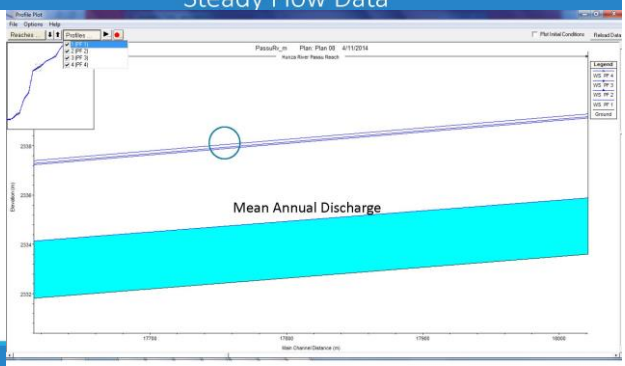
Cross Section Plot





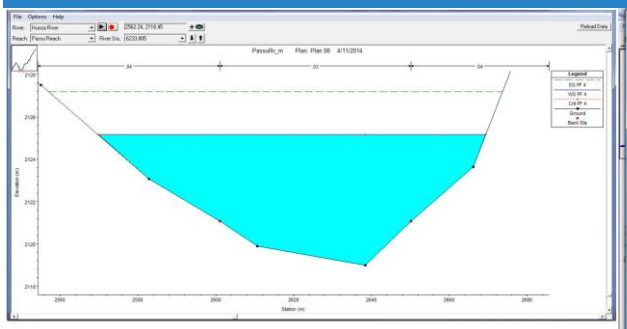

Steady Flow Data

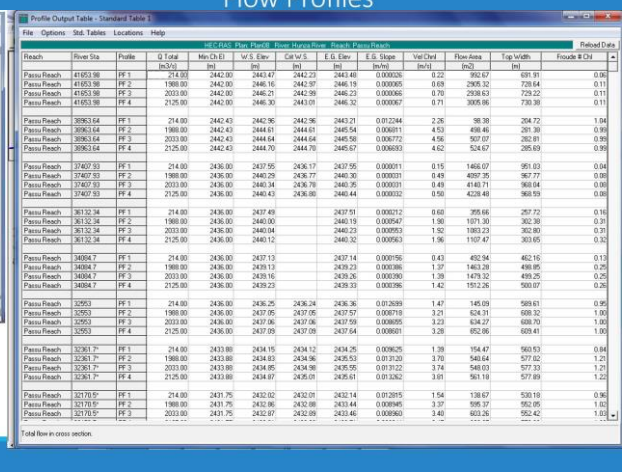





Run the developed HEC-RAS model for the estimated peak flood discharge

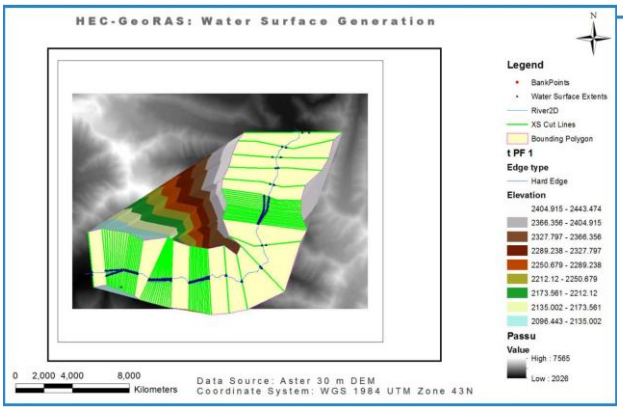
Flow Profiles



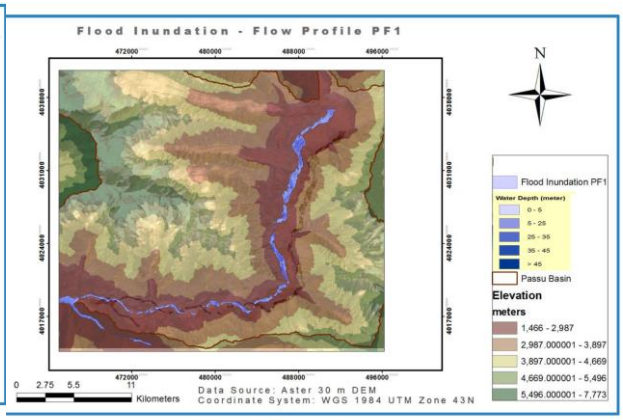



Water Surface Profile

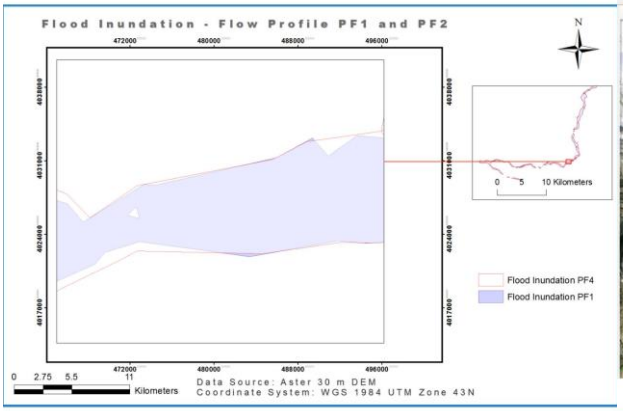
x-sect view



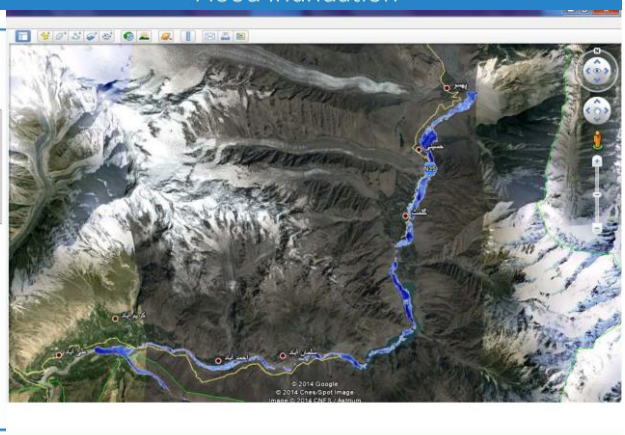

Water Surface Generation



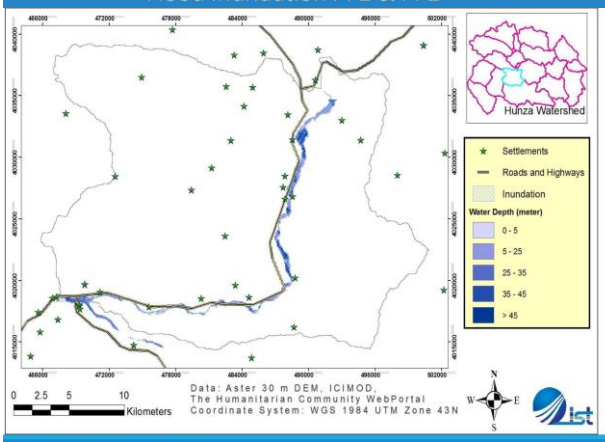

Flood Inundation




Flood Inundation PF1 & PF2




Risk Mapping




## Conclusions

- GLOF mapping using geospatial techniques may be helpful
  - to develop a capacity of DM authorities to
    - develop early warning systems in the vulnerable areas.
    - respond and recover from emergency and disaster events

***Greater capacity to face these disasters also reduces their impacts***

RISK MAPPING

## 5.