Multi Hazard Risk Assessment for the State of Jammu and Kashmir

Inception Report

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Prepared and Submitted by:
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For the attention of:

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Executive Summary

Subsequent to the devastating 2014 Jhelum Floods, the Government of Jammu and Kashmir (GoJ&K), with the support of the World Bank, has taken several initiatives towards disaster risk reduction and mitigation. One such key initiative is the planned Multi Hazard Risk Assessment of the state to quantify disaster risks and improve the lead time for early warning of hydro meteorological hazards to help reduce losses to life, property, and infrastructure.

The GoJ&K has entrusted RMSI to carry out this analytical study of conducting Multi Hazard Risk Assessment for the state and develop an early warning system for hydro meteorological hazards. This inception report, the first deliverable of this assignment, provides the methodology that will be adopted for various tasks, project schedule, and key steps taken during the first month – the inception phase of this assignment.

The objective of this assignment is to carry out hazard risk assessment using probabilistic and deterministic approaches and assess the risks, that will enable GoJ&K in formulating risk reduction plans and strategies. The expected outcomes of the study include analytical results in the form of reports, capacity building of state officials, a state-level Disaster Risk Database (DRDB), and an Integrated Operating Forecasting System (IOFS), which will help the state provide early warnings on impending hydro-meteorological disasters to Disaster Risk Managers and Agencies and the community at large.

The assignment is subdivided into seven components, with several activities that will be carried out in-parallel. These components have been further explained in subsequent sections. Since location-specific data related to bio physical aspects, socio economic aspects, past hazard events, and vulnerability of the assets are very critical in the development robust hazard models for this assessment, RMSI plans to carry out extensive field level surveys and onsite consultations to boost existing datasets.

The first step will be to conduct an extensive desk research to understand the data availability, information available on hazard and risk assessment in the State, existing DSS and EWS, if any, already operational in the State, and the training and capacity building needs of the stakeholders. Consultation meetings with various stakeholders are being carried out to gather this information.

For probabilistic risk modeling a stochastic scenario based approach will be adopted. Within the stochastic event set, we will also develop near-worst scenarios for all hydro-meteorological hazards based on climate change assessment. The impact of all the stochastic events will be estimated using the hazard models developed. These scenarios (including worst-case ones) will demonstrate how various hazards are likely to impact the population, buildings, infrastructure, horticulture/agriculture, etc. These scenarios will be communicated through return period hazard maps (for instance, in the case of flood, it would include extent and depth-estimates for floods corresponding to various rainfall intensities). The hazards considered for the assignment include floods (including flash floods), earthquakes, landslides, avalanches, Glacial Lake Outburst Floods (GLOF), drought, forest fire, urban fire, and industrial hazards. Depending on the availability of historical event data, we will decide whether we should adopt a probabilistic or deterministic approach for assessing risks arising from the hazards in question.

Exposure database development will be mainly based on data available with various State departments. However, critical data gaps will be filled using different methods using GIS and remote sensing techniques. The main elements of the exposure database will include demographics, buildings, infrastructure, critical facilities, utilities, agriculture and horticulture, cultural heritage sites, and ecological assets. Preliminary discussions with some of the key stakeholders suggest that several State agencies have significant information in GIS format. We are in the process of gathering, reviewing and processing this data. The details of data availability and gaps will be provided in the Data Inventory Report, which is the next deliverable.

Vulnerability assessment will involve quantifying the damage susceptibility (physical, social, and economic) with respect to different parameters of each hazard. An analytical approach complemented by engineering analyses, along with expert judgment based on international experience and damage data of historical events, will be used for developing vulnerability functions. Survey using sample methods will supplement the data for physical and social vulnerability analysis.

Risk assessment shall be based on the hazard, exposure and vulnerability assessments carried out in the steps above. The spatial resolution of exposure data and some of the bio-physical data are critical to quantify risks at a micro-level. Risk Analysis will be carried out in two broad categories: Direct Economic Losses and Social Impacts such as loss to livelihood etc.

Direct economic loss will be calculated for every deterministic scenario as well as stochastic event and for all types of assets at risk, e.g., residential, commercial, and industrial buildings, essential facilities, infrastructure, agriculture/horticulture etc. Social impacts will quantify the susceptibility of the population to casualty and injuries, loss of livelihood, and essential needs like shelter, food, rescue/evacuation, etc. in the event of a disaster. Finally, risk metrics will be derived for all categories of assets including population. Using risk metrics, vulnerable hotspots will be identified and mapped.

This will help understand location-specific vulnerabilities and associated risks, and allow GoJ&K to undertake advanced mitigation and response planning in terms of deciding evacuation routes, ideal shelter locations, and preparing appropriate emergency preparedness plans.

A web-GIS based DRDB will be developed customizing the World Bank's Geonode platform and extending it to support all the functionality needed for Disaster Risk Management/Reduction and Preparedness Planning. The DRDB will include various data sets used for analysis (hazard, exposure, and vulnerability) and analytical results - risk assessment maps. The database will provide a framework for decision support in evacuation planning, assessing shelter needs, etc.

The web-based IOFS will be developed in HEC RTS with provisions for taking real time input data like observed and forecasted rainfall, temperature, etc. from sources like IMD, JAXA, etc., to generate real-time analysis of an impending hydro-meteorological event. IOFS is expected to provide improved lead-time so that adequate precautions can be taken to avoid casualties and reduce damage.

A training and capacity building plan will be drafted based on the training needs gathered during stakeholder consultations. The training plan will the discussed with the client and will be finalized for rollout. The training plan will essentially emphasize continuous interactions with the experts, hands-on exercise, etc. to ensure that all datasets and knowledge base generated as part of the study is transferred successfully to the client. As part of maintenance and support of the DRDB and IOFS, RMSI will provide 12 months' maintenance support.

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Abbreviations Used

AHP	Analytical Hierarchy Process
ALOHA	Areal Locations Of Hazardous Atmospheres
AMC	Antecedent Moisture Conditions
ANN	Artificial Neural Networks
BCSD	Bias-Corrected Spatial Disaggregation
BLEVEs	Boiling Liquid Expanding Vapor Explosion
CAP	Common Alerting Protocol
CDF	Cumulative Distribution Function
CDO	Climate Data Operators
CGWB	Central Ground Water Board
COSMO	Consortium Organization For Strong-Motion Observation Systems
CRU	Climate Research Unit
CV	Coefficient Of Variation
CWC	Central Water Commission
DEM	Digital Elevation Model
DFO	Dartmouth Flood Observatory
DPR	Detailed Project Report
DRDB	Disaster Risk Database
DRDO	Defence Research & Development Organization
DRR	Disaster Risk Reduction
DSHA	Deterministic Seismic Hazard Analysis
DSS	Decision Support System
DTM	Digital Terrain Data
ECA	European Climate And Assessment
ECMWF	European Centre For Medium-Range Weather Forecasts
EMDAT-CRED	Emergency Events Database-Centre For Research On The Epidemiology Of Disasters
EMSD	European-Mediterranean Strong-Motion Database
EOC	Emergency Operation Centre
EPA	Environmental Protection Agency
ESMs	Earth System Models
EWS	Early Warning System
FAR	False Alarm Rate
FEMA	Federal Emergency Management Agency
FOSM	First Order-Second Moment
FTP	File Transfer Protocol

GCMs	Global Climate Models
GDP	Gross Domestic Product
GEM	Global Earthquake Model
GEV	Generalized Extreme Value
GIS	Geographic Information System
GLOF	Glacial Lake Outburst Flood
GMFD	Global Meteorological Forcing Data
GMPE	Ground Motion Prediction Equation
GPL	General Public License
GPS	Global Positioning System
GSI	Geological Survey Of India
GSMaP	Global Satellite Mapping of Precipitation
HEC-HMS	Hydrologic Engineering Center's Hydrological Modeling System
I&FC	Irrigation And Flood Control
ICG	International Center For Geo-Hazards
IITR	Department Of Earthquake Engineering, Indian Institute Of Technology, Roorkee
IMD	India Meteorological Department
IOFS	Integrated Operating Forecasting System
ISC	International Seismological Centre
ISR	Institute Of Seismological Research
JTFRP	Jhelum & Tawi Flood Recovery Project
JKPCC	Jammu Kashmir Project Construction Corporation
LIDAR	Light Detection And Ranging
LOCs	Levels Of Concern
LSI	Landslide Susceptibility Index
LULC	Land Use Land Cover
MAI	Moisture Availability Index
MDR	Mean Damage Ratio
MoEF	The Ministry Of Environment & Forests
MoM	Method Of Moments
NBSS & LUP	National Bureau Of Soil Survey And Land Use Planning
NCMRWF	National Centre For Medium Range Weather Forecasting
NDK	Native Development Kit
NGA	Next Generation Attenuation
NGRI	National Geophysical Research Institute
NN	Nearest Neighbors
NOAA	National Oceanic And Atmospheric Administration
NRSC	National Remote Sensing Centre

OSM	Open Street Maps
PDSI	Palmer Drought Severity Index
PEER	Pacific Earthquake Engineering Research Center
PGA	Peak Ground Acceleration
PMU	Project Management Unit
PNRF	Percent Of Normal Rainfall
POD	Probability Of Detection
PSHA	Probabilistic Seismic Hazard Analysis
PWD	Public Works Department
PWMs	Probability-Weighted Moments
QA	Quality Assurance
QC	Quality Checks
REI	Rainfall Extreme Index
RVS	Rapid Visual Screening
SA	Spectral Acceleration
SASE	Snow And Avalanche Study Establishment
SDMA	State Disaster Management Authority
SDRF	State Disaster Response Fund
SEISAT	Seismotectonic Atlas Of India
SOI	Survey Of India
SoVI	Social Vulnerability Index
SPI	Standardized Precipitation Index
SQA	Software Quality Analyst
SRTM	Shuttle Radar Topography Mission
TRMM	Tropical Rainfall Measuring Mission
USACE	U.S. Army Corps Of Engineers
USGS	U. S. Geological Survey
WIHG	Wadia Institute Of Himalayan Geology
WXGEN	Stochastic Weather Generator

Section 1: Understanding of the ToR

Background

The State of Jammu and Kashmir is prone to a number of natural hazards, both geological and meteorological. Climate change is potentially further accentuating the impact of these hazards. Additionally, the developmental activities in the Himalayan terrain are also increasing the occurrence of hazards like landslides, floods and inundation, and urban as well as forest fire related incidents to name a few. In recent years, the State has witnessed several natural disasters including earthquakes, landslides, and floods and flash flood, which have led to loss of life and damage or loss to assets. As an initiative towards reducing the risk from these natural hazards, the Government of Jammu and Kashmir (GoJ&K) commenced the Jhelum and Tawi Flood Recovery Project in 2015, with financial support from the World Bank. The project development objective is to support recovery and increase disaster resilience in project areas, strengthen disaster risk management capacity, establish a robust Decision Support System (DSS) at the State Emergency Operation Centre (EOC) and provide technical support for risk reduction and response preparedness activities.

Under the Jhelum and Tawi Flood Recovery Project, GoJ&K has engaged RMSI Private Limited, India to carry out the present multi hazard risk assessment for the entire State. This inception report is the first deliverable of the assignment. It covers the methodology proposed for various tasks under the assignment, key data requirements and quality procedures to be adopted for collecting and processing it, survey plans to conduct field-based data collection, project plan, IT specifications required for setting up DRDB and IOFS, and notes on stakeholder consultations carried out as part of the Inception Meeting.

Understanding of the objectives

At a broad level, the objective of the study is to establish an appropriate and scientific method for assessing the risks and vulnerabilities associated with various hazards under consideration, and prepare risk assessment outputs that will enable GoJ&K in formulating disaster risk management / reduction plans and strategies.

The key activities of the assignment include:

- Development of input datasets for probabilistic and deterministic hazard assessment at State, District, Tehsil levels, 4 urban centers, 4 rural areas, and 4 tourist destinations identified as risk-hot spot areas for the following hazards - earthquake, landslides, floods,

flash floods, GLOF, avalanche, forest fires, fire hazard potential w.r.t. built environment, drought, climate variability and climate change, and industrial hazards
- Based on the input datasets, develop deterministic/probabilistic hazard models that are used to create hazard layers depicting hazard intensity at State, District and Tehsil level for principal hazards
- Collating an inventory of buildings (residential, commercial, industrial), essential facilities and infrastructure (government/administrative buildings, transportation and utility systems) for development of exposure datasets at State, district and Tehsil level, 4 urban centers, 4 rural areas and 4 tourist destinations identified as risk-hot spot areas for analyzing the impacts from principal hazards
- Conducting physical, infrastructure, social, and economic vulnerability assessment
- Probabilistic and deterministic risk analysis for all principal hazards at State, District and Tehsil levels, 4 urban centers, 4 rural areas and 4 tourist destinations identified as risk-hot spot areas for principal hazards
- Integrate the hazard, exposure and risk assessment outputs into a Web-based software platform using open source technologies for the development of a Disaster Risk Database (DRDB) for the State of Jammu and Kashmir
- Develop hazard models for forecasting the occurrence and risk from hydro-meteorological hazards (Flood, Flash Flood, Avalanche, Drought) and integrate them in a web-based early warning software platform for the development of an Integrated Operational Forecasting System (IOFS)
- Development of user guide, trainers guide, risk information products, and communication of the risk results to support the sustainability of the initiative
- Setup the DRDB and IOFS at the state Emergency Operation Centers (EOC) and provide a detailed roadmap for sustaining and upgrading the DRDB in the future with integration with DSS platform
- Comprehensive capacity building program customized for GoJ&K, including training and transfer of technology and know-how. This would include training a few members from all concerned government agencies and key stakeholders (technical institutions and line departments) to understand and use DRDB and IOFS to communicate risk information/mapping products, developmental planning and improve their understanding of how risk information can be improved through time.
- Maintenance and support for DRDB at the EOC both at Srinagar and Jammu.

The key outputs of this study will be:

1. The DRDB and a detailed roadmap for sustaining and upgrading it
2. The IOFS
3. Hazard zonation maps
4. Risk assessment products
5. Detailed risk assessments of 4 urban hotspots (Jammu, Srinagar, Anantnag, and Doda including urban agglomerations), 4 rural hotspots (will be decided in consultation with PMU, JTFRP and 4 tourist hotspots (Sonmarg, Gulmarg, Poonch, and Patnitop).

Section 2: Methodology

Component 1: Development of Input Datasets for Hazard Assessment

High quality input data is very critical for developing the hazard models and carrying out hazard assessments. The data types to be gathered and used include bio physical data, weather data, historical event data, including damage information, which will help in calibrating the various hazard models.

Data and Data Sources

Several datasets are common for different hazards – both geological and hydro meteorological. Almost all hazards require bio physical data – land use, terrain, soil type, and historical event information. Weather data are specific to hazards and would be needed for longer duration. Higher resolution data and longer periods over which data is available improve the quality of models. Fine-tuning the reliability of models through validation and calibration, requires precise recent-events data along with associated location specific intensities and loss information.

Table 1 below summarizes the datasets that are needed for multiple hazards modeling. In addition, there are also several hazard specific data requirements, the details of which have been provided in the subsequent sub sections under the methodology of each hazard.

Table 1: Data Summary for different hazards

Hazard type		Data type								
		DEM	Slope	Soil	Geology and Geo-technical	Landuse	Historical Event catalogue	Weather data	Future Climate	Industry details
Geological	Earthquake	x	x	x	x		x			
	Landslide	x	x	x	x	x	x	x	x	
Hydro meteorological	Flood	x	x	x		x	x	x	x	
	GLOF	x	x		x				x	
	Avalanches	x	x		x	x	x	x	x	
	Drought			x		x	x	x	x	
Other hazards	Forest fire		x			x	x	x	x	
	Fire hazard in built up environment					x	x	x		
	Industrial					x	x	x		x

The data sources include global data sources, data from national, state, and district agencies as detailed in the respective hazard methodology sections.

During our consultation with various stakeholders in the State during the inception phase (details of consultations is provided below in section ”Inception Meeting Details”) it was inferred that there is a dearth of high resolution data particularly for terrain, location specific information on historical landslide, avalanche events, etc. In such areas, we plan to use alternate data sources for instance, terrain model from high resolution satellite ortho data, historical landslide and avalanche events through review of published documents, interpretation of satellite data for identification of scars and confirmation of the same through consultation with communities. Some state universities have documented some location-specific events along the roads by marking kilometer stones. We will convert this into geographic reference in GIS for analysis.

Identification of Data Source

The project team in consultation with PMU has identified various state departments and national organizations for data collection.

As elaborated in the section “Inception Meeting Details”, we have initiated data collection from various like departments. National organizations including Indian Meteorological Department (IMD), Geological Survey of India (GSI), Central Water Commission (CWC), National Geophysical Research Institute (NGRI), Snow & Avalanche Study Establishment (SASE), Wadia Institute of Himalayan Geology and regional organizations like, ICMOD will be consulted as these organization has carried out substantial work in their respective domain in the State.

Data Processing

Hazard input data processing mainly include:

1. Review of collected data in light of the methodology – frequency, resolution, accuracy, etc. If gaps are found reach out to more sources to fill the gaps.
2. Identification of outliers and verification of same
3. Validation and cleansing of data
4. Processing of data including bringing of point and polygon data in grid format which is required for the hazard modeling.

Component 2: Hazard Assessment Methodologies

Historical data availability would be a key factor for determining the methodology for carrying out hazard assessment through modeling. Wherever adequate historical event data is available, we will carry out probabilistic modeling and if the event data is insufficient we use a scenario-based or deterministic approach.

The data required varies based on the hazard and is further detailed in the respective hazard assessment subsections below.

Hazard modeling will be used to analyze the intensity of historical events and historical event information will be collated to validate and calibrate the models. At the end of this process, the model's uncertainty will be estimated. The objective of this step is to ensure that the modeled results are able to emulate any future hazard events with a known degree of uncertainty.

The calibrated and validated models will be used to assess the intensity of every probabilistic event at various locations of interest. The locations could be centroids of administrative boundaries (villages or grids defined in GIS), for population and buildings, or the specific locations (longitude, latitude) of infrastructural elements. Once all these have been estimated, probabilistic hazard maps of various return periods will be created. Every such map will indicate the hazard intensity at any location that has a chance of happening within "N" number of years. For example, a 100-year return period map will show the hazard intensity that has the annual probability of occurrence of 1% (the inverse of the return period - 1/100*100).

Wherever the number of events are insufficient, the team will carry out scenario-based analysis for those particular hazards.

The broad level framework for hazard analysis is provided in Figure 1.

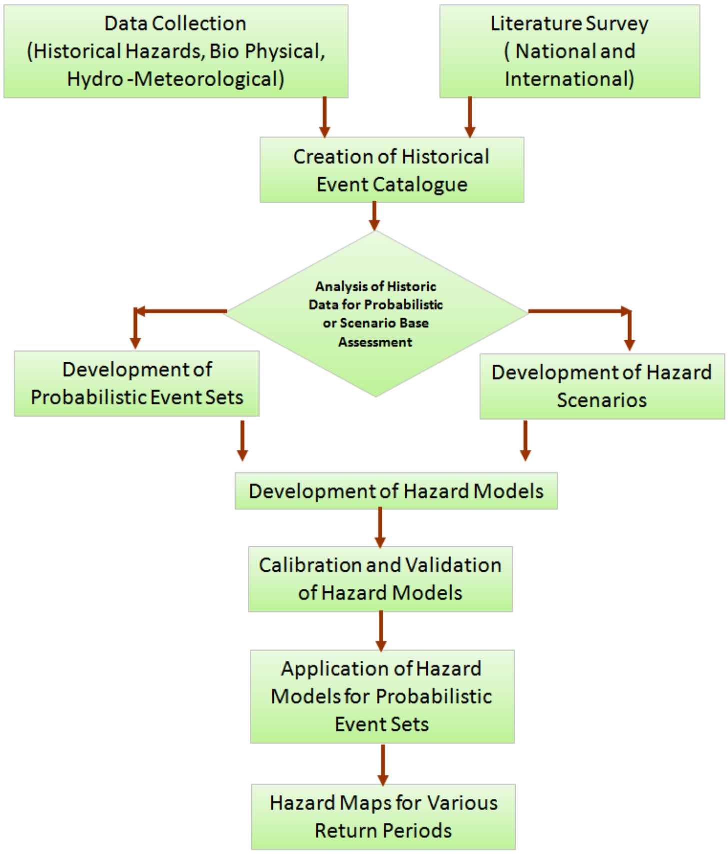

Figure 1: Overview of steps involved in hazard assessment

Earthquake Hazard

The continuous convergence of the Indian and Eurasian Plates render the Himalayas as one of the most seismically active regions in the world. Several large damaging earthquakes including the April 4, 1905 Kangra earthquake and recent October 08, 2005 Kashmir earthquake have struck the region in and around the State since historical times. Several active faults exist along the Himalayan collision zone, particularly bigger ones are the Main Boundary Thrust Fault (MBT), Main Central Thrust Fault (MCT) and Main Frontal Thrust (MFT).

The regions between the rupture zones of these great earthquakes are recognized as seismic gaps that are interpreted to have accumulated potential slip for generating future great earthquakes. With the growth of population and infrastructure, seismic vulnerability has increased and previous earthquakes have provided only a glimpse of the devastating potential of large damaging earthquakes. If these earthquakes repeat again, there would be significant loss of life and property (Wyss et al., 2017)[1].

As per Seismic Zoning map of India (IS:1893, 2016), most parts of the Kashmir Valley covering the Districts of Srinagar, Ganderbal, Baramulla, Kupwara, Bandipora, Budgam, Anantnag, Pulwama, Doda, Ramban, Kishtwar come under Seismic Zone V, where about 50 percent of the population of the State lives. Rest of the State including whole of Ladakh region and Jammu Division (90% of the total area of the state) are under the Seismic Zone IV. Thus, J&K State is highly vulnerable to earthquake and falls under the two highest seismic zones.

[1] Wyss, M., Gupta, S., Rosset, P. 2017; Casualty Estimates in Two Up-Dip Complementary Himalayan Earthquakes. Seismological Research Letters; 88 (6): 1508–1515. doi: https://doi.org/10.1785/0220170091

As a preliminary step, the information on the studies conducted on Jammu and Kashmir pertaining to earthquake hazard assessment and probabilistic scenario ground motion will be collected. The key data required for earthquake hazard modeling is provided in Table 2 below.

Table 2: Earthquake hazard model input data and potential sources

Data/Information	Source
Historical earthquakes in and around J&K State	National sources and international sources like, Global Earthquake Model's (GEM's) Historical Catalogue (http://www.globalquakemodel.org/what/seismic-hazard/historical-catalogue/)
Geological and Paleo-seismologic Investigations Data	Various published sources including publications of GSI, WIGH, NGRI
Micro earthquake monitoring data	Srinagar University, IMD, NGRI, and published research papers and reports
Active Fault Data including their dip, strike, and length	Seismo tectonic Atlas of India, Geological Survey of India, published research-papers and outputs based on the reports of various active fault-mapping exercises
Fault-plane solutions	CMT catalogue and published research papers on specific earthquake events
Strong Motion Time-History data	IIT Roorkee, IMD, NGRI, ISR, published research papers and International web-sites
Integrated Map of Vs30 values	Vs30 from topographic slope (proxy) method complimented by the Geotechnical investigations carried out in the State for various projects, and seismic microzonation studies (if any)
GPS Strain Measurements Data	Published research papers, CMMAC, Bangalore
DEM	High resolution DEM from JTFRP, GoJ&K/ freely available SRTM

Earthquake catalogues (including instrumental earthquake records) will be collected from various international sources like US Geological Survey (USGS), the US National Oceanic and Atmospheric Administration (NOAA), the International Seismological Centre (ISC), ISC-GEM Global Instrumental Earthquake Catalogue, Version 2.01) along with locally available instrumental data from key data sources in India such as India Meteorological Department (IMD), Institute of Seismological Research (ISR), National Geophysical Research Institute (NGRI), Central Water Commission (CWC), Department of Earthquake Engineering, Indian Institute of Technology, Roorkee (IITR), and Geological Survey of India (GSI). The data from the state are expected to have more information in case of smaller earthquakes (magnitude 3-5), and micro-earthquakes (magnitude less than 3) than those from international data sources. Special emphasis will be given to collect data on smaller earthquake, i.e., magnitude lower than 4.0, the detection capability would largely be dependent on number of local seismograph network. It would be highly beneficial to utilize this local data from the local seismograph network and special effort will be made to collect such data. This is based on the assumption that moderate to large earthquake could happen in the area that experience frequent small earthquakes. Moreover, any erroneous data will be determined and corrected (e.g. earthquake location, magnitude estimation, etc.) in this stage.

We will combine all these datasets from different sources, check their quality, data completeness, eliminate duplicate data to develop complete earthquake catalogue for seismic hazard assessment.

Seismic source modeling: For seismic source modeling include studies on active fault zones, area sources, etc. Data will be collected from various sources, such as Seismotectonic Atlas of India (SEISAT) published by GSI, Wadia Institute of Himalayan Geology (WIHG), IITs and other national and international publications. Our experts will review all these studies before making their interpretation and evaluation on active seismic sources within and around study area.

Strong Ground Motion Time History Data and GMPEs: These are critical data for the selection of Ground Motion Prediction Equation (GMPE). Many strong motion records that are available from State and surrounding areas including strong motion records from 2005 earthquake will be considered. These records were collect and review along with other associated details (earthquake parameters, source type, site condition of the recording stations, data processing procedure, etc.).

Integrated Map of Vs30 values from various sources: The most reliable Vs30 data is obtained from direct field measurements, such as geotechnical investigations through boreholes and seismic monitoring. However, it is unlikely that such data are available throughout the State. We will compile all such observational data from different sources including Jammu Kashmir Project Construction Corporation (JKPCC), Public Works Department (PWD R&B) J&K State. Effort will be made to collect boreholes data carried out in different parts of the State under various infrastructure projects. In addition, we are planning to derive Vs30 from topographic slope (proxy) method, an internationally well accepted approach [Wald and Allen (2007)[2], Allen and Wald (2007)[3]] followed in such large scale area. This will be complemented by the observational data as well as interpretation from borehole logs.

Seismic microzonation studies in and around the State: The team will collect and collate information from the seismic microzonation studies carried out in different parts of the State and surrounding areas.

GPS Strain Measurements Data in and around the State: These could be GPS velocity data (displacement per year) recorded by GPS stations in J&K and surrounding areas. Available data will be collected and used for the interpretation of tectonic movements.

Digital Elevation Model (DEM): RMSI will collect and evaluate the available DEM datasets according to their suitability of use in modeling. Some of the freely available DEM dataset are described below:

Shuttle Radar Topography Mission (SRTM) elevation data with a spatial resolution of about 30 meters with absolute vertical height accuracy of less than 16m that is freely available along with spot elevations from various sources including Survey of India (SOI) toposheet and CWC gauge stations, etc. will be used for developing a refined DEM model. In case better resolution DEM is available with the state, that will be used instead of SRTM.

Earthquake hazard assessment will be carried out using probabilistic and deterministic methods. The key task planned to be carried out include:

- Development of an Earthquake Catalog in and around J&K State covering 500-km circular radius from the considered area. All the well-established catalog processing steps shall be carried out.
- The data of active faults in and around the considered area will be reassessed based on literature reviews. The long-term slip rates and estimates of earthquake size from paleo-seismological studies will be incorporated since the historical seismicity alone might not reflect the earthquake hazard, especially at long return period.

[2] Wald, D. J., and Allen, T. I.,2007, Topographic slope as a proxy for seismic site conditions and amplification, Bulletin of the Seismological Society of America, 97, no. 5, 1379-1395.
[3] Allen, T.I., and Wald, D.J., 2007, Topographic slope as a proxy for global seismic site conditions. (VS. 30) and amplification around the globe: U.S. Geological Survey Open-File Report 2007-1357

- The ground motion parameters, such as peak ground acceleration (PGA) and spectral acceleration (SA), at a given area will be estimated from the earthquake magnitude, source-to-site distance, and local site condition by appropriate ground motion prediction equations (GMPEs). Traditionally, a ground-motion model for a specific region is empirically developed from statistical regression analyses, using available earthquake strong ground motion records (e.g. Douglas 2003)[4]. Suites of available strong ground motion in local seismic network will be necessary to validate, and suitable ground motion prediction equations (GMPEs) will be selected for shallow crustal and subduction models in the proposed study area, based on the data obtained from local government agency. In case of limitations of the data availability, another solution is to assume that some existing GMPEs developed for other regions with similar seismo tectonic characteristics can adequately represent ground-motion in this region. The Next Generation Attenuation (NGA) models developed for shallow crustal earthquakes in the Western United States and similar active tectonic regions are considered to be a possible solution. For subduction zone earthquakes, the three subduction zone ground-motion models developed by Youngs et al. (1997)[5], Atkinson and Boore (2003[6]; 2008[7]) (both of which are based on global data), and Zhao et al. (2006)[8] (mainly based on data from Japan) will be reviewed. The above selected sets of GMPEs are identical to those used by USGS in their recent seismic hazard study of Southeast Asia (Petersen et al., 2014). All the NGA GMPEs and those published for Himalayan region (e.g., Harbindu et al., 2014)[9] will be reviewed for their suitability to the study area and those GMPEs that would pass the suitability test shall be used for both Deterministic and Probabilistic Seismic Hazard Assessment.

Probabilistic Seismic Hazard Analysis (PSHA)

PSHA involves three steps: 1) Specification of the seismic-hazard source model(s); 2) Specification of the ground motion model(s) (attenuation relationship(s)); and 3) Probabilistic calculation.

For developing the Probabilistic Seismic Hazard Maps for the State, the procedures developed for the preparation of latest US National Seismic Hazard Maps will be used. In contrast to earlier hazard maps, which are mostly computed using seismic source zone delineations, the current maps will be developed based on the combination of smoothed gridded seismicity, crustal-fault, subduction source models. The fundamental drawback of the earlier method is that the seismic hazard assessment results can be significantly affected by the delineation of these zones, which could be heavily dependent on the subjective judgment of the hazard analysts. The gridded seismicity source model accounts for the expectation that future large, damaging earthquakes will occur near previous small and moderate-size earthquakes.

The PSHA quantifies the hazard at a site from all earthquakes of all possible magnitudes, at all significant distances from the site of interest, as a probability by taking into account their

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[4] Douglas J (2003) Earthquake ground motion estimation using strong-motion records: a review of equations for the estimation of peak ground acceleration and response spectral ordinates. Earth-Sci Rev 61: 43–104

[5] Youngs RR, Chiou SJ, Silva WJ, Humphrey JR (1997) Strong ground motion attenuation relationships for subduction zone earthquakes. Seismol Res Lett 68(1):58–73

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[9] Harbindu, A., Gupta, S., and Sharma, M. L. (2014). Earthquake ground motion predictive equations for Garhwal Himalaya, India. Soil Dynam. Earthquake Eng. 66, 135–148. doi:10.1016/j.soildyn.2014.06.018

frequency of occurrence. The earthquake sources in the study region will be modeled by a combination of smooth gridded seismicity (grid size, say, about 5 km), crustal fault and subduction source. The seismic activity of each of these sources is characterized by a magnitude-recurrence relationship, which shows the average occurrence rate of earthquakes of a given magnitude occurring inside the source. This step is the most important and most time consuming step in the assessment work.

The hazard in the State will be evaluated, considering the effects of all earthquakes of different magnitudes, occurring at different locations from different seismic sources that are integrated into seismic hazard curves. Each hazard curve will show the probability of exceeding for PGA and SA at 0.2, 0.5, 1.0, 2.0, and 3.0 seconds at 5% critical damping ratio for key return periods at 43, 100, 250, 475, 1,000, 1,500, and 2,475, which are the return periods commonly used in the earthquake hazard assessment community. If the PMU would like to develop the earthquake hazards for any other return periods, that can also be done. From the obtained mean hazard curves, uniform hazard response spectra (UHS) for various return periods for the study area will be derived.

Deterministic Seismic Hazard Analysis (DSHA)

It is of interest to further identify the earthquake source that contributes the largest hazard to the considered location comparing to total hazard from all earthquake sources. Geographical disaggregation will be prepared for the understanding of the relative contributions of sources. In contrast to traditional disaggregation, where contributed hazard displaying from the range of values of magnitude, distance, and epsilon, geographical disaggregation shows contributed hazard on a map with vertical bars whose heights are proportional to the hazard contribution of each earthquake source. Examination of these maps enables an engineer to determine the distance, magnitude, and azimuth to controlling earthquake sources of his/her considered site. Moreover, this information can be used to generate scenario earthquakes and further applied in generating spectrum compatible acceleration time histories for seismic design and retrofit.

Seven pairs of ground motion records for each site will be generated from the Pacific Earthquake Engineering Research Center (PEER), Consortium Organization for Strong Motion Observation Systems (COSMO), and European-Mediterranean Strong-motion Database (EMSD) database, which are adjusted to be compatible with the response spectrum of controlling earthquake scenario, identifying from geographical disaggregation procedure for the nonlinear response history analysis.

Earthquake hazard maps: Several GIS-compatible probabilistic seismic hazard maps (layers) for different intensity (PGA and Spectral Accelerations) shall be developed at State, district, and Tehsil levels. In addition to this, Uniform Hazard Map for different return-period for a fixed value of intensity (PGA and Spectral Accelerations) and disaggregated seismic hazard maps for Hot-Spots (Urban, Rural, and Tourist) shall be generated. Some of these maps are listed as follows:

Scenario Earthquakes for Deterministic Analyses

- Maximum Credible Earthquake Scenarios for various source zones

Probabilistic Seismic hazard maps for PGA

- Seismic hazard map for PGA corresponding to a probability of exceedance of 69% in 50 years (43-year return period)
- Seismic hazard map for PGA corresponding to a probability of exceedance of 10% in 50 years (475-year return period)
- Seismic hazard map for PGA corresponding to a probability of exceedance of 2% in 50 years (2475-year return period)

Probabilistic Seismic hazard maps for spectral acceleration at 0.2 and 1.0 s

- Seismic hazard map for spectral accelerations at 0.2 and 1.0 s structural period, corresponding to a probability of exceedance of 69% in 50 years (43-year return period), 5% critical damping, Site Class B (Soft Rock)
- Seismic hazard map for spectral accelerations at 0.2 s structural period, corresponding to a probability of exceedance of 10% in 50 years (475-year return period), 5% critical damping, Site Class B (Soft Rock)
- Seismic hazard map for spectral accelerations at 0.2 s structural period, corresponding to a probability of exceedance of 2% in 50 years (2475-year return period), 5% critical damping, Site Class B (Soft Rock)
- Seismic hazard map for spectral accelerations at 1.0 s structural period, corresponding to a probability of exceedance of 69% in 50 years (43-year return period), 5% critical damping, Site Class B (Soft Rock)
- Seismic hazard map for spectral accelerations at 1.0 s structural period, corresponding to a probability of exceedance of 10% in 50 years (475-year return period), 5% critical damping, Site Class B (Soft Rock)
- Seismic hazard map for spectral accelerations at 1.0 s structural period, corresponding to a probability of exceedance of 2% in 50 years (2475-year return period), 5% critical damping, Site Class B (Soft Rock)
- Seven pairs of ground motion records for each zone for the State, corresponding to a probability of exceedance of 2% in 50 years (2475-year return period), based on the soil properties in each zone

Disaggregated seismic hazard maps for Hot-spots (4 Urban areas, 4 Rural areas and 4 Tourist –Hotspots)

- Disaggregated seismic hazard map for spectral accelerations at 0.2 s structural period, corresponding to a probability of exceedance of 69% in 50 years (43-year return period)
- Disaggregated seismic hazard map for spectral accelerations at 0.2 s structural period, corresponding to a probability of exceedance of 10% in 50 years (475-year return period)
- Disaggregated seismic hazard map for spectral accelerations at 0.2 s structural period, corresponding to a probability of exceedance of 2% in 50 years (2475-year return period)
- Disaggregated seismic hazard map for spectral accelerations at 1.0 s structural period, corresponding to a probability of exceedance of 69% in 50 years (43-year return period)
- Disaggregated seismic hazard map for spectral accelerations at 1.0 s structural period, corresponding to a probability of exceedance of 10% in 50 years (475-year return period)
- Disaggregated seismic hazard map for spectral accelerations at 1.0 s structural period, corresponding to a probability of exceedance of 2% in 50 years (2475-year return period)

Hazard curves for contribution of different earthquake sources to the hazard for Hot-spots (4 Urban areas, 4 rural areas and 4 Tourist –Hotspots)

- Hazard curve displaying contribution of different earthquake sources to the hazard for spectral accelerations at 0.2 s structural period
- Hazard curve displaying contribution of different earthquake sources to the hazard for spectral accelerations at 1.0 s structural period

Snowmelt Modeling

Since J&K state gets a lot of stream flow from snowmelt, therefore, for modeling of hydro-meteorological hazards for the state, it is important to consider snowmelt component also.

The temperature index method, a meteorological model in HEC-HMS, will be used for computing snowmelt. The meteorological model in HEC-HMS determines, at every time step, whether the precipitation falling is rainfall or snowfall based on the temperature data at nearby meteorological stations. The temperature index approach considers snowmelt as a mass-balanced process. At the beginning of a simulation, the characteristics of an initial snowpack will be established through the input of various parameters. When the simulation begins, precipitation falls as either rainfall or snow. Over the course of the simulation, the falling snow either builds the snowpack or warming occurs, as defined by the representative air temperature gauge, and the snowpack melts and is converted to runoff for the specific subbasin. The temperature index method also considers the effects of rainfall on the snowpack and determines the runoff volume resulting from the melting process initiated by rain falling on the snowpack. The temperature index method uses a multitude of parameters, summarized in Table 3 to define the snowfall, rain on snow, and snowmelt components of the hydrological process.

Table 3: Snowmelt parameters general to entire meteorologic model

Parameter	Typical Value	Parameter Description
PX Temp (C°)	0 to -1	Discriminates between rain or snow based on air temp
Base Temp (C°)	0	Used to determine if melt is occurring. If air temperature is less than base temperature, then no melt occurs.
Wet Meltrate (MM/C°-day)	7.2	Describes rain on snow melt rate. Functions when rainfall is occurring and when the rainfall rate is greater than the rain rate limit.
Rain Rate Limit (MM/day)	1	Discriminates between dry and wet melt. Wet meltrate is applied if rainfall rate > rain rate limit. Otherwise meltrate is computed as if no precip is occurring.
ATI Meltrate Coef	0.98	Used when welt melt is not occurring. Coefficient is used to update the antecedent meltrate index from one time interval to the next.
ATI Meltrate Fxn	Function	Used to calculate meltrate based on antecedent temperature index
Cold Limit (MM/Day)	15	Accounts for rapid changes in temperature that snowpack undergoes during high precipitation rates.
ATI Coldrate Coef	0.4	Used to update the antecedent cold content index from one time step to the next
Water Capacity (%)	3	Defines the amount of melted water that must accumulate before it can be available from infiltration or runoff. This value is a percentage of SWE.
Groundmelt Method	Constant Value	Describes the method used to account for snow on a partially frozen or completely unfrozen ground
Groundmelt (MM/Day)	0.05	Either a constant rate or annually patterned rate

Table 4: Snowmelt parameters specific to each subbasin

Parameter	Typical Value	Parameter Description
Temp Gauge	Varies	
Lapse Rate (C°/1000M)	-1 to -6	Used in the computation of temperature in various elevation bands as lapse rate times band elevation minus gauge elevation. This parameters adjusts the temperature up and/or down for each elevation band based on the gauge temperature.
Index (MM)	Not Considered	Used to adjust precipitation between elevation bands. Typically used to account for orographic trends in precip. Not included for this project
Percent (%)	Varies	Percent area of basin represent within elevation band
Elevation (M)	Varies	Average elevation of band
Index (MM)	Not Considered	Used in conjunction with the subbasin index to adjust precipitation within bands. Not included for this project.
Initial SWE (MM)	Varies	The initial volume of water represented within the snow pack
Initial Cold Content (MM)	0	Represents the heat required to raise the snowpack temp to 0 C°. Expressed as a number equivalent to mm of frozen water. Estimated as the product of depth of snow, snow density, heat capacity of snow, C° below freezing.
Initial Liquid Water (MM)	0	Amount of liquid water held within the snowpack at the beginning of the simulation
Initial Cold Content ATI (C°)	0	The snowpack temperature at the beginning of the simulation
Initial Melt ATI (C°-Day)	0	The accumulation of degree-days since the last period of sustained temps below freezing

Process flow diagram for runoff calculations considering snow melt modeling is shown below:

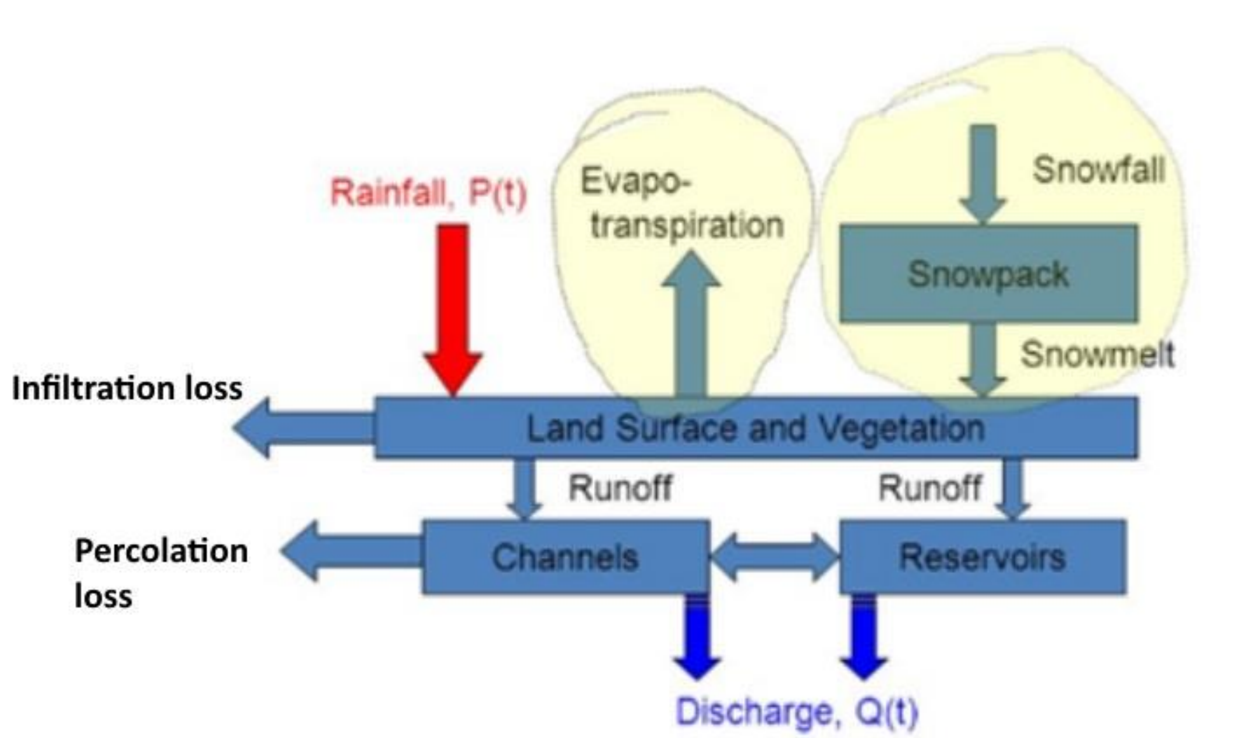


Figure 2: Flow diagram snow melt modeling in HEC-HMS

The snowmelt estimation thus generated will be used in tandem with approaches discussed in following sections for estimation of various hydro-meteorological hazards wherever relevant.

Flood Hazard Assessment

The following data will be required for carrying out probabilistic/deterministic flood modeling of the state.

Table 5:Key data required for flood hazard analysis

Data	Description
Precipitation	Historical Precipitation and Forecasted and Real time precipitation from IMD and other sources
Runoff and Reservoir Data	Daily discharge observations for at least 30 years at various gauging stations, reservoir inflows, outflows, elevation-storage-outflow, and elevation-area-outflow curves for reservoirs from Irrigation and Flood Control (I&FC), J&K and CWC
Bio-Physical Data	Soil type, land use, vegetative cover and other hydraulic structure details from various sources in the state
Flood management infrastructure	Information related to dams, dykes, levees, floodwater pumping station information, etc. from I&FC
Flood inundation maps for past events	Maps or remote-sensing imageries of major historical flood events various source including I&FC, NRSC and other published and unpublished sources
Historical Cloud-burst Events	Historical could-burst events and related weather information from IMD and other state government agencies
Historical High Flood Level	High flood level with coordinate locations from I&FC, J&K Govt.

Data	Description
Historical flood event loss information	Loss information includes loss of life and assets various state sources (Revenue Department, I&FC, Srinagar Development Authority, Jammu Development Authority, Agency specific losses like losses to schools, hospitals, if available)
Digital Terrain Data (DTM)	High resolution DTM – potential sources include SRTM, NRSA or custom DTM created using LIDAR or High Resolution Satellite imagery if made available
Historical Precipitation	Hourly Precipitation data for all the rain gauges and especially for extreme events from IMD and Satellite based hourly rainfall of 0.1 X 0.1 deg resolution from Global Satellite Mapping of Precipitation (GSMaP) and data from Tropical Rainfall Measuring Mission (TRMM),
Forecasted and Real Time Precipitation	Data from Global Forecast System (GFS) - NOAA, IMD, Open Weather Map, Weather Underground, (European Centre for Medium-Range Weather Forecasts) ECMWF and National Centre for Medium Range Weather Forecasting (NCMRWF)

Table 6: Summary of the different precipitation datasets proposed to be used for this study

S No	Data Type	Agency Type	Spatial Resolution	Period	Time Step
1	Historical rainfall	Tropical Rainfall Measuring Mission (TRMM)	0.25 deg. x 0.25 deg.	1998-2016	03-Hourly
2		IMD AWS Rainfall	Station based	2010 onwards	Hourly
3		IMD Daily Rainfall	Station based	1980 onwards	Daily
4		Weather Underground	Station based	2012-2016	Daily
5		G-Portal JAXA	-	1998-2015	Hourly
6		IMD Gridded Rainfall	0.25 x 0.25	1971-2015	Daily
7	Real time rainfall	Tropical Rainfall Measuring Mission (TRMM)	0.25 deg. x 0.25 deg.	-	03-Hourly
8		Weather Underground	Station based	-	Daily
9		Open Weather Map	Station based	-	Daily
10		IMD	Station based	-	Hourly
11	Forecast rainfall	IMD-WRF	9 km x 9 km	-	03-Days
12		IMD –GFS	0.25 deg. x 0.25 deg.	-	07-Days
13		Global Forecast System (GFS)	0.25 deg x 0.25 deg	-	03-Hourly

PROBABILISTIC FLOOD HAZARD MODELING

Probabilistic Flood Hazard Modeling will be carried out using the methodology described in this section. Flood hazard assessment identifies and demarcates those parts of the study area, which are exposed to floods. It provides information on the extent and depth of flooding throughout flood prone areas for a range of flood magnitudes. The flood hazard model development framework adopted for this study is given in the Figure 3 below and comprises of the following:

- Collection and compilation of relevant hydro meteorological and biophysical data as specified in Section Component 1: Development of Input Datasets for Hazard Assessment.
- Probabilistic analysis of runoff to simulate various return period events (2, 5, 10, 25, 50, and 100 years)
- Hydraulic modeling to estimate flood levels throughout the basins for various flows generated for key return period events.
- Flood hazard mapping to show flood extent and flood depth for different return periods.

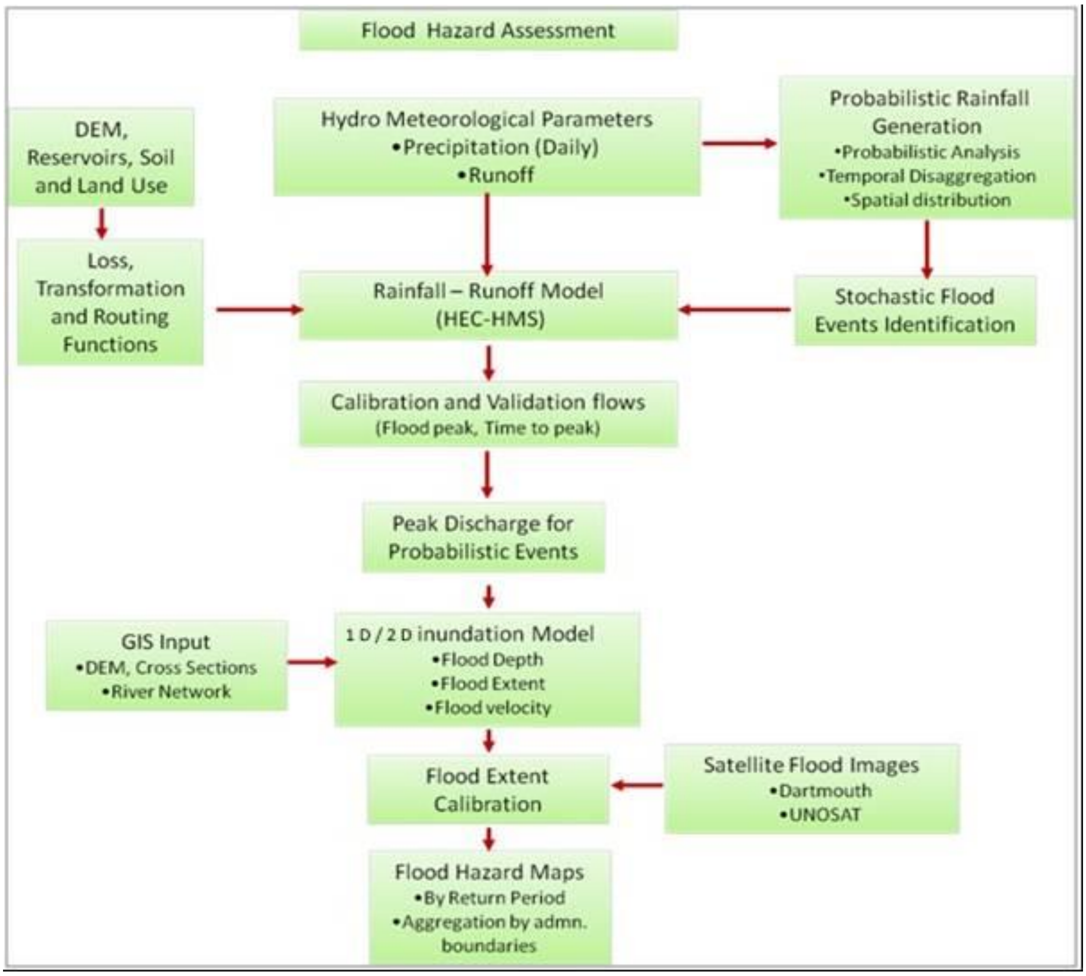


Figure 3: Flood hazard assessment framework

Flood model will be developed based on historical rainfall as well as runoff cum discharge data. The discharge based approach will help model flood events induced due to man-made interventions like dam release, infrastructure failures etc. RMSI will perform the flood modeling based on the following two approaches:

- Riverine flood modeling from runoff induced from stochastic rainfall events created using historical events of heavy rainfall in upstream areas
- Flood modeling based on return period flows derived from historical flow data

The above two approaches then will be analyzed and compared to derive and finalize the flood hazard mapping to show flood extent and flood depth.

Flood Model based on Stochastic Rainfall

The flood model based on stochastic rainfall comprises of three main components:

- Rainfall analysis to estimate temporal and spatial rainfall distribution for stochastic simulation of rainfall at river basin level as well as different return period rainfall
- Hydrological (rainfall-runoff) modeling to estimate flows for a range of known historical events and simulated stochastic events in each river basin
- Hydraulic modeling to estimate flood levels throughout the basin for various flows generated from historical and stochastic rainfall events. Flood hazard mapping to show flood extent and flood depth for a range of stochastic events, which is the end output of hazard assessment.

Flood Model based on Return Period Flows

The flood model based on return period floods comprises of three main components

- Historical discharge data analysis to estimate different return period flows (2, 5, 10, 25, 50, 100 and 500 year). For generating the hydrograph of the flood events, gage data will be analyzed and utilized.
- Hydraulic modeling to estimate flood levels throughout the basin for various return period flows generated from historical peak discharge data. Flood hazard mapping to show flood extent and flood depth for a range of different return period events, which is the end output of hazard assessment.

Estimation of rainfall events, runoff events, hydrological modeling and hydraulic modeling with flood hazard mapping has been provided in the following sections.

Stochastic Simulation of Rainfall and Return Period Rainfall:

Stochastic simulation is necessary to simulate long term risk and reduce uncertainty in event occurrence due to non-availability of historical observations for long periods. Generally, historical observations are available for a relatively short period (say 10 to 50 years). Stochastic simulation helps in generating events to capture extremes that might not be present in the available historical data sets. The stochastic simulation for rainfall will be carried out after identifying the appropriate probability distribution. The linear moment technique (Hosking, 1990[10]) will be used to determine the most appropriate distribution.

Estimated stochastic rainfall will be spatially and temporally disaggregated over existing rain gauges. These will be given as inputs to the hydrological models to estimate the resulting flows at various flow gauge stations for the stochastic events. Further, these sets of stochastic event flows will be given as inputs to the hydraulic models for determining flood extents for each stochastic event.

Return period rainfall will be estimated for all the rainfall gauge stations used in the study. The same return period rainfall will be given as an input in the validated hydrological model without modifying any parameters. The temporal and spatial distribution will be preserved in the rainfall while estimating the discharge flows for various elements of hydrological model.

There should be at least 30 years of continuous historical rainfall data to perform return period rainfall calculations. The historical rainfall will be used to extract annual maximum rainfall for each station. This annual maximum rainfall will be further processed to derive return period rainfall for 2, 5, 10, 25, 50, 100, 250 and 500 years.

Return period rainfalls will be estimated using two different distributions, namely, the Gumbel distribution and the Generalized Extreme Value (GEV) distribution. After comparing the results

[10] J. R. M. Hosking, L-Moments: Analysis and Estimation of Distributions Using Linear Combinations of Order Statistics, Journal of the Royal Statistical Society. Series B (Methodological), Vol. 52, No. 1 (1990), pp. 105-124

of the model using both the rainfall in the model with the available literature for basins in J&K, Gumbel distribution will be further used for the estimation of return period event generation. The L moments method will be used for the estimation of the parameters for GEV and Gumbel distributions.

L-Moments are based on probability-weighted moments (PWMs) and provide a greater degree of accuracy and ease. L-Moments are a modification of the PWMs, as they use the PWMs to calculate parameters that are easier to interpret and that can be used in the calculation of parameters for statistical distributions. L-Moments are based on linear combinations of data. They provide an advantage, as they are easy to work with, and more reliable as they are less sensitive to outliers. The method of L-Moments calculates more accurate parameters than the Method of Moments (MoM) technique (Kochanek, 2010). The MoM techniques only apply to a limited range of parameters, whereas L-Moments can be more widely used, and are nearly unbiased (Rowinski, 2001). The four L-Moments (λ1, λ2, λ3, λ4) are derived using the four PWMs.

λ_1=L1=M100

λ_2=L2=2M_{110}-M_{100}

λ_3=L3=6M_{120}-6M_{110}+M_{100}

λ_4=L4=20M_{130}-30M_{120}+12M_{110}-M_{100}

Where M100, M110, M120, and M130 are the four probability-weighted moments, which are defined as

$$M_{100}= 1/N \sum_{i=1}^{N} \mathrm{Q_i}$$

$$M_{110}=1/N\sum_{i=1}^{N} \frac{\mathrm{i-1}}{\mathrm{N-1}} \mathrm{Q_i}$$

$$M_{120}=1/N \sum_{i=1}^{N} \frac{\mathrm{(i-1)(i-2)}}{\mathrm{(N-1)(N-2)}} \mathrm{Q_i}$$

$$M_{130}=1/N \sum_{i=1}^{N} \frac{\mathrm{(i-1)(i-2)(i-3)}}{\mathrm{(N-1)(N-1)(N-2)}} \mathrm{Q_i}$$

In which N is the sample size Q is the data value, and i is the rank of the value in ascending order. After Estimating the 4 L- Moments ((λ1, λ2, λ3, λ4), the Gumbel's parameter α (scale parameter) and u (location parameter) can be obtained as

$\alpha = \lambda_2/\log 2$

$u=\lambda_1-(\alpha c)$

In which c = 0.58 (Euler's Constant). In addition to above four moments, L-CV, L-Skewness and L-Kurtosis are used for the distribution fitting.

L-CV is similar to the normal coefficient of variation (CV). The larger the CV value, the larger the variation of the data set from the mean. For example, in arid regions that receive few storm events, the variation will be large, as one storm will deviate greatly from the low mean.

τ_2 = L2/L1 (L-CV)

L-Skewness is a measure of the lack of symmetry in a distribution. If the value is negative, the left tail is long compared with the right tail, and if the value is positive, the right tail is longer. For GEV frequency analysis, a positive L-Skewness value is desired, as we are interested in the extreme events that occur in the right side tail of the distribution.

$\tau_3 = L3/L2$ (L-Skewness)

L-Kurtosis is difficult to interpret, however, and is often described as the measure of "peakedness" of the distribution (Hosking, 1997). L-kurtosis is much less biased than ordinary kurtosis.

$\tau_4 = L4/L2$ (L-Kurtosis)

The figure below shows a sample L-moment ratio diagram for stations used in return period rainfall estimation.

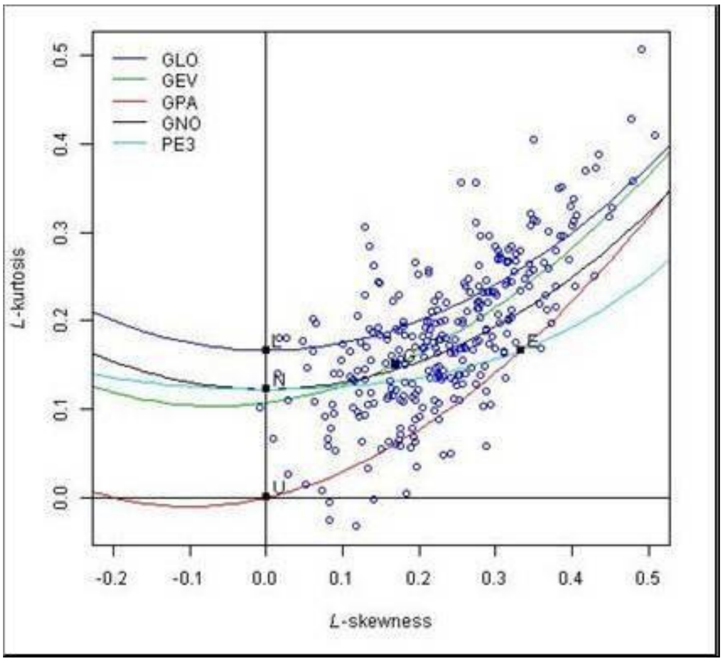


Figure 4: Sample L moment ratio diagram

These calculated return period rainfalls will be used as inputs to the validated hydrological models. In order to provide an independent check on the results of the runoff generated from the return period rainfall simulation methodology, a comparison of flows from observed annual peak flow and stochastically simulated peak flows from this methodology will be undertaken.

Return Period Runoff:

Different return period floods will be estimated based on the historical peak discharge data based on the methodology as described below:

Gumbel extreme value distribution

Gumbel distribution is a statistical method often used for predicting extreme hydrological events such as floods. In the study it can been applied for flood frequency analysis because (a) peak flow data are homogeneous and independent hence lack long-term trends; (b) the river is less regulated, hence is not significantly affected by reservoir operations, diversions or urbanization; and (c) flow data cover a relatively long record (more than 10 years) and is of good quality.

The equation for fitting the Gumbel distribution to observed series of flood flows at different return periods T is:

$Q_t = Q_{av} + K\sigma$ (1)

Where Q_t denotes the magnitude of the T-year flood event, K is the frequency factor, Q_{av} and σ are the mean and the standard deviation of the maximum instantaneous flows respectively.

The frequency factor K is expressed as:

$K=-\sqrt{6}/\pi(\lambda-\ln(\ln(T-\ln(T-1)))$ (2)

where: π =3.14, λ is the Euler constant (=0.5772) and ln is the natural logarithm.

The Chi-square χ2 test will be carried out to find the goodness of fit between the measured and predicted flood flows and applied to test the hypothesis that the flood data fit the Gumbel distribution and Log Pearson Type-III distribution. After determining the goodness of fit of the distribution to the flood discharges, flood magnitudes will be computed for 0.5, 0.2, 0.1, 0.05, 0.04, 0.02, 0.01 and 0.005 exceedance probabilities.

Log Pearson Type-III and Log Normal Distribution

The Log-Pearson Type III distribution is a statistical technique for fitting frequency distribution data to predict the design flood for a river at some site. Once the statistical information is calculated for the river site, a frequency distribution can be constructed. The probabilities of floods of various sizes can be extracted from the curve. The advantage of this particular technique is that extrapolation can be made of the values for events with return periods well beyond the observed flood events. This technique is the standard technique used by Federal Agencies in the United States.

The Log-Pearson Type III distribution is calculated using the general equation:

$$\log x = \overline{\log x} + K\sigma_{\log x}$$

Where x is the flood discharge value of some specified probability, $\overline{\log x}$ is the average of the *log x* discharge values, *K* is a frequency factor, and σ is the standard deviation of the *log x* values. The frequency factor *K* is a function of the skewness coefficient and return period and can be found using the frequency factor table. The flood magnitudes for the various return periods are found by solving the general equation. The mean, variance, and standard deviation of the data can be calculated using the two formulas below.

$$\overline{\log x} = \frac{\sum(\log x_i)}{n}$$

$$\frac{\sum_{i}^{n}(\log Q - avg(\log Q))\,^\wedge 2}{n-1}$$

and

$$\sigma_{\log x} = \sqrt{\frac{\sum\left(\log x - \overline{\log x}\right)^2}{n-1}} \qquad \text{or} \qquad \sigma \log Q = \sqrt{variance}$$

Next, the skewness coefficient C_s can be calculated as follows:

$$C_s = \frac{n\Sigma(\log x - \overline{\log x})^3}{(n-1)(n-2)(\sigma_{\log x})^3}$$

where n is the number of entries, x the flood of some specified probability and $\sigma_{\log x}$ is the standard deviation. Excel functions can also be used to calculate the variance (=VAR( )), standard deviation (=STDEV( )), and skewness coefficient (=SKEW( )).

The skewness estimate (C_s) computed using the equation above is called the station estimate, meaning that the estimate incorporates data values only from the gaging station of interest.

Error and bias in the skewness estimate increase as the number of observations (n) decreases. The "**Bulletin 17B method**" recommended by the Interagency Advisory Committee on Water Data (IACWD) uses a generalized estimate of the coefficient of skewness, C_w (for instantaneous peak flow data only), based on the equation:

$$C_w = WC_s + (1-W)C_m$$

Where W is a weighting factor, C_s is the coefficient of skewness computed using the sample data, and C_m is a regional skewness, which is determined from a map.

The weighting factor W is calculated to minimize the variance of C_w, where

$$W = \frac{V(C_m)}{V(C_s) + V(C_m)}$$

Determination of W requires knowledge of variance of C_m [$V(C_m)$] and variance of C_s[$V(C_s)$]. $V(C_m)$ has been estimated from the map of skew coefficients for the United States as 0.302. This simplifies the denominator of the above equation by substitution of 0.302 for $V(C_m)$.

The variance of the station skew C_s for log Pearson type 3 random variables can be obtained from the results of Monte Carlo experiments which shows that

$$V(C_s) = 10^{A-B\log_{10}(n/10)}$$

where

A = $-0.33 + 0.08 \mid C_s \mid$ if $\mid C_s \mid \leq 0.90$ or
A = $-0.52 + 0.30 \mid C_s \mid$ if $\mid C_s \mid > 0.90$,
B = $0.94 - 0.26 \mid C_s \mid$ if $\mid C_s \mid \leq 1.50$ or
B = 0.55 if $\mid C_s \mid > 1.50$

in which $\mid C_s \mid$ is the absolute value of the station skew (used as an estimate of population skew) and n is the record length in years.

The coefficient *K* is then found using tabulated values according to C_w and the return period for each discharge. When coefficient of skewness is zero then log person type-III will be designated as log normal distribution.

Hydrological modeling

A hydrological model establishes the flow behavior of the watershed or basin by converting the rainfall into runoff. They often represent the spatial variability of the atmosphere and land surface characteristics that control the rainfall-runoff process. In usual hydrologic practice, hydrological models are regularly applied worldwide.

Hydrological response to the flood events will be simulated using the Hydrologic Engineering Center's Hydrological Modeling System (HEC-HMS) model. This model is widely used for hydrologic modeling and is publicly available from USACE.

The core elements of the HEC-HMS model are the basin model, meteorological model, control specifications, and time-series data manager. To develop the model for a particular use and location, the following steps are generally implemented:

1. Basin Delineation (using HEC–GeoHMS)
2. Model Development
3. Creation of Basin Model (including all elements such as sub-basins, channels and reservoirs) and estimation of Physical Loss, Routing and Transformation Parameters (for each sub-basin element)
4. Addition of Time-Series Data (for various meteorological parameters) and Setting Control Specifications (for running the model)
5. Calibration and Validation
6. Return Period Flows Estimation

HEC-HMS allows the user to select from a number of methods to represent catchment characteristics for Rainfall Loss and Infiltration, Rainfall-Runoff Transformation, Stream Flow Routing, Base flow Methods and input of meteorological data (USACE, 2009[11]). The flowchart below explains the step-by-step approach proposed for the hydrological modeling;

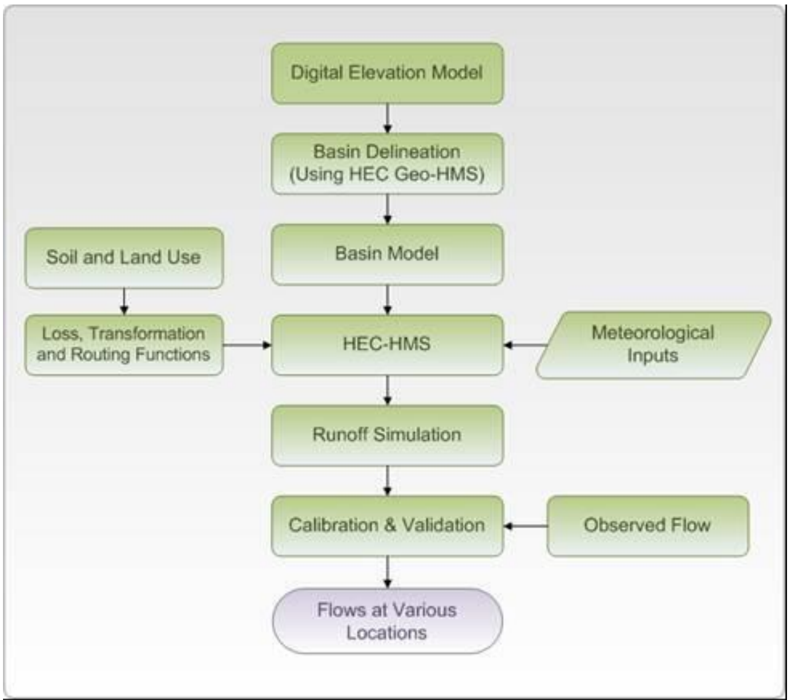


Figure 5: Flowchart for hydrological modeling

As an example, the HEC-HMS hydrological model developed for the Sebou River Basin, Morocco shows below:

[11] U.S. Army Corps of Engineers, 2009

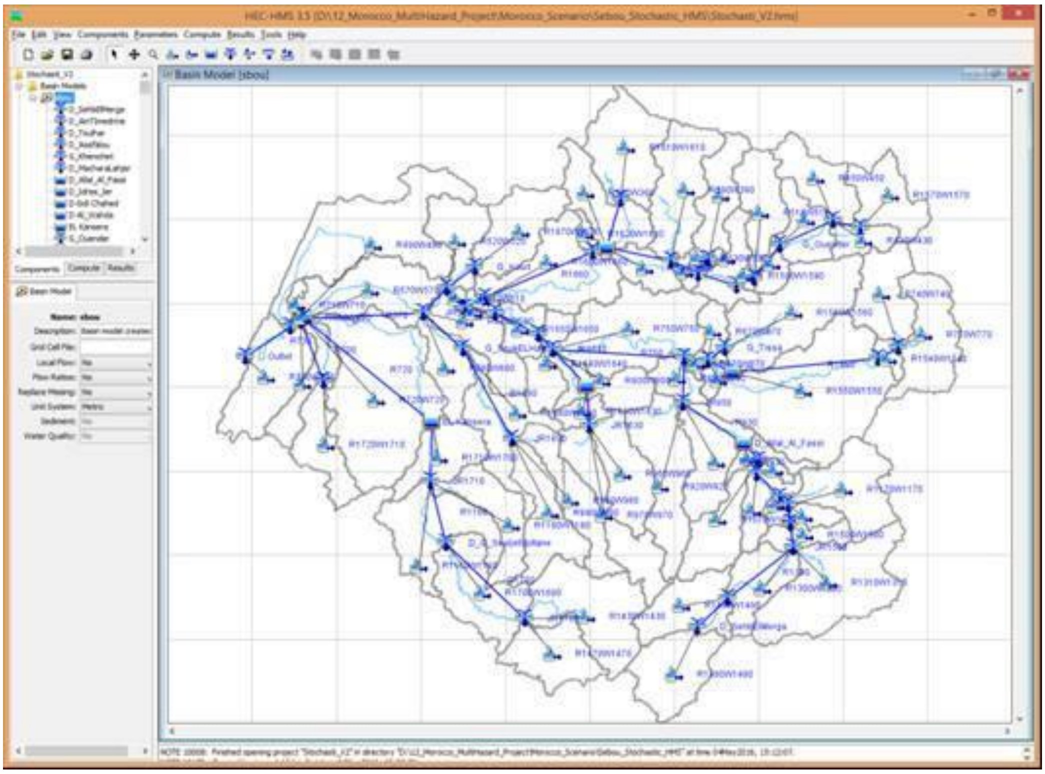


Figure 6: HEC-HMS Hydrological model developed for Sebou Basin in Morocco (shown as an example only)

Calibration and Validation of Hydrologic Model

The calibration and validation process is intended to ensure that the model parameters are well set to reflect the physical nature of entire basin and its sub-basins. A good fit in this case indicates a robust simulation, which can be used with reasonable confidence. A poor fit, on the other hand, indicates low confidence. Model calibration consists of changing values of model input parameters in an attempt to match field conditions within some acceptable criteria. This requires that field conditions at a site be properly characterized.

An independent sample of events will be used to calibrate and validate the hydrological model in terms of soil behavior (losses and imperviousness), which exerts a fundamental role over the runoff volume for the episode, and flood wave celerity in the main channels of the catchments, an important factor owing to the high flow velocities. Protocol followed for calibration and validation of model would be:

1. Subjective Assessment: Visual inspection is a fundamental approach to assess model performance in terms of its behavior. Systematic behavior like over or under prediction and dynamic behavior like timing, rising and falling limb, base flow etc. of the model will be identified in the initial stages of calibration using this approach, which will extend till model validation.
2. Objective Assessment: This approach requires the use of mathematical estimates of error between observed and simulated hydrological variables. Nash-Sutcliffe Efficiency (NSE) and R square correlation would be employed as a mathematical measure of how well the simulation fits in the available observations.

Nash–Sutcliffe Efficiency criterion (NSE):

Nash–Sutcliffe efficiency criterion (NSE; Nash and Sutcliffe 1970), a “goodness-of-fit” measure widely used in hydrological model validation (Jasper and Kaufmann 2003; Dolciné et al. 2001). The NSE values can range from - ∞ to 1, with higher values indicating a better agreement of the model results with the observations. NSE is defined as,

$$NSE = 1 - \frac{\sum_{I=1}^{N}(X_I - Y_I)^2}{\sum_{I=1}^{N}\left(X_I - \overline{X}\right)^2}$$

where x_i and y_i are the observed and model-simulated discharged values at flow gauge site at time i respectively, and $\overline{x}$ is the mean observed value.

The NSE assesses the ability of a model to correctly simulate stream flow during periods when observed stream flow deviates significantly from the mean stream flow. A perfect model would produce an NSE of 1. However, Moriasi and others (2007) indicate that the performance of a model is considered to be "good" if the NSE is between 0.65 and 0.75 and "satisfactory" when the NSE is above 0.5. NSE values will be derived using observed and simulated flows corresponding to multiple rainfall forecast models. Higher preference will be given to the forecast model, which gives NSE value closer to 1.

Coefficient of Determination (R^2):

The coefficient of determination, R^2, is defined as the squared value of the coefficient of correlation according to Bravais-Pearson (Krause et al. 2005). It is calculated as:

$$R^2 = \left(\frac{\sum_{i=1}^{n}(O_i - \bar{O})\,(P_i - \bar{P})}{\sqrt{\sum_{i=1}^{n}(O_i - \bar{O})^2} - \sqrt{\sum_{i=1}^{n}(P_i - \bar{P})^2}} \right)^2$$

where O and P are observed and predicted values respectively. It is the squared ratio between covariance and multiplied standard deviations of the observed and simulated values. Range of R squared lies between 0 and 1. Value of zero means no correlation while one depicts dispersion of simulation is equal to that of observation. If the values approach 1, the model predictions are considered perfect.

Ratio of the Root Mean Square Error to the Standard Deviation of Measured Data (RSR):

Root Mean Square Error (RMSE) is a commonly used error index statistics. It is accepted that the lower the RMSE the better the model performance. RSR standardizes RMSE using the observation's standard deviation, and it combines both an error index and the additional information recommended by Legates and McCabe (1999). RSR is calculated as the ratio of the RMSE and standard deviation of measured data, as shown in the equation

$$RSR = \frac{RMSE}{STDEV_{obs}} = \frac{\sqrt{\sum_{i=1}^{n}(X_i - Y_i)^2}}{\sqrt{\sum_{i=1}^{n}(X_i - X^{mean})^2}}$$

where xi and yi are the observed and model-simulated discharge values at flow gauge site at time i respectively. RSR incorporates the benefits of error index statistics and includes a scaling/normalization factor, so that the resulting statistics and reported values can apply to various constituents. RSR varies from the optimal value of 0, which indicates zero RMSE and therefore perfect model simulation. The lower the RSR, the lower the RMSE, better the model simulation performance.

The criteria presented by Moriasi and others (2007) designates model performance as "good" if the RSR ranges from 0.5 to 0.6 and "unsatisfactory" if the RSR is greater than 0.7.

A typical discharge calibration plot at a particular gauge location is shown in Figure 7.

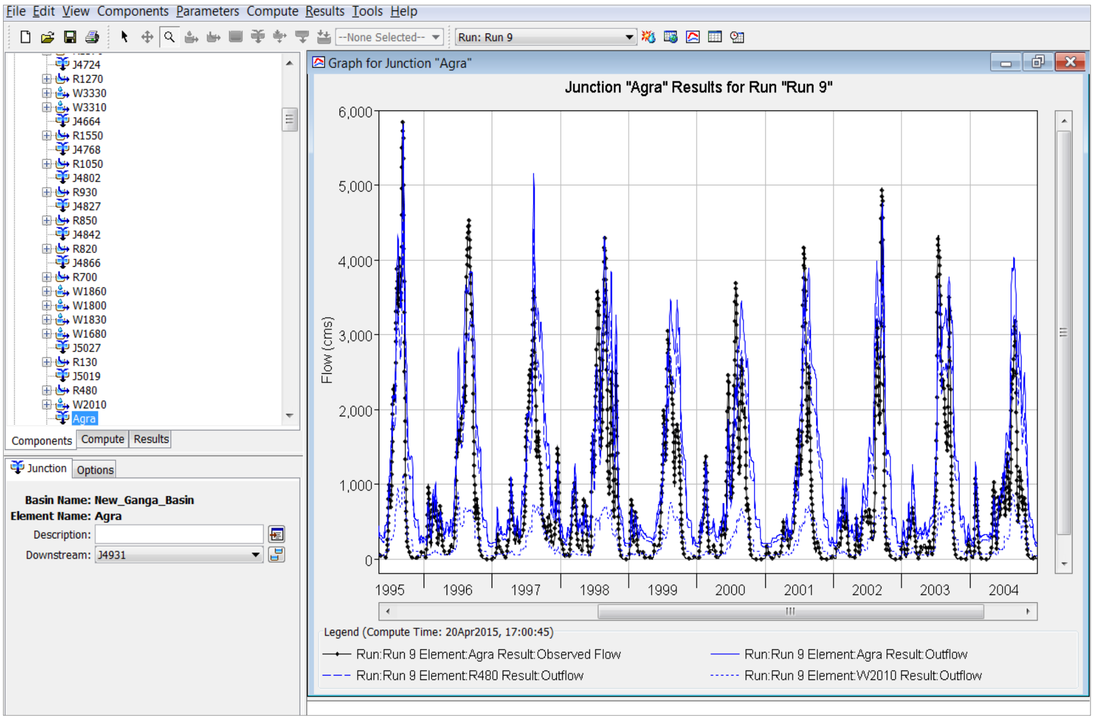


Figure 7: Sample of typical calibration of gauge data

In case of unavailability of time series gauge discharge data, peak discharge data of various flood events will be used in calibration and validation of hydrological model.

Hydraulic Modeling

The main purpose of hydraulic modeling is to route the flows from one location to another, while estimating the water surface elevations and profiles for various flow scenarios, i.e., estimate flood elevations along streams and rivers for flood flows. Generally, the flows or water surface elevations observed at a particular location are given as inputs to the model along with the channel characteristics such as cross-section, slope, and roughness. Alternatively, flows estimated in hydrologic modeling provide input to the hydraulic model. Detailed hydraulic modeling requires an inventory of drainage conveyance structures, surveyed cross-sections of streams and rivers, and topographic mapping of flood plain areas. In addition, site and aerial photographs, historical high water marks from past events, and anecdotal flood observations all serve to guide a detailed hydraulic model development.

It is proposed to make use of high resolution DEM, if available. In the absence of a high resolution DEM, the Shuttle Radar Topography Mission (SRTM) data at 30 m spatial resolution will be used for hydraulic modeling. Some areas in the study area may not have adequate survey and topographic mapping to warrant detailed hydraulic modeling to predict flood elevations. In these instances, alternative approximate methods will be applied. The team has experience in applying U.S. Federal Emergency Management Agency (FEMA)-approved approximate methods on many floodplain mapping studies.

The project team has applied hydraulic models on numerous flood hazard investigations. Many of these hydraulic investigations have been for calculating flood elevations to standards established by the U.S. FEMA.

The model will be calibrated and validation with observed floodwater levels during a flood event with simulated water levels using the hydraulic model.

As an example, Figure 8 shows a sample HEC RAS geometry, cross section, and water surface profile for a river network.

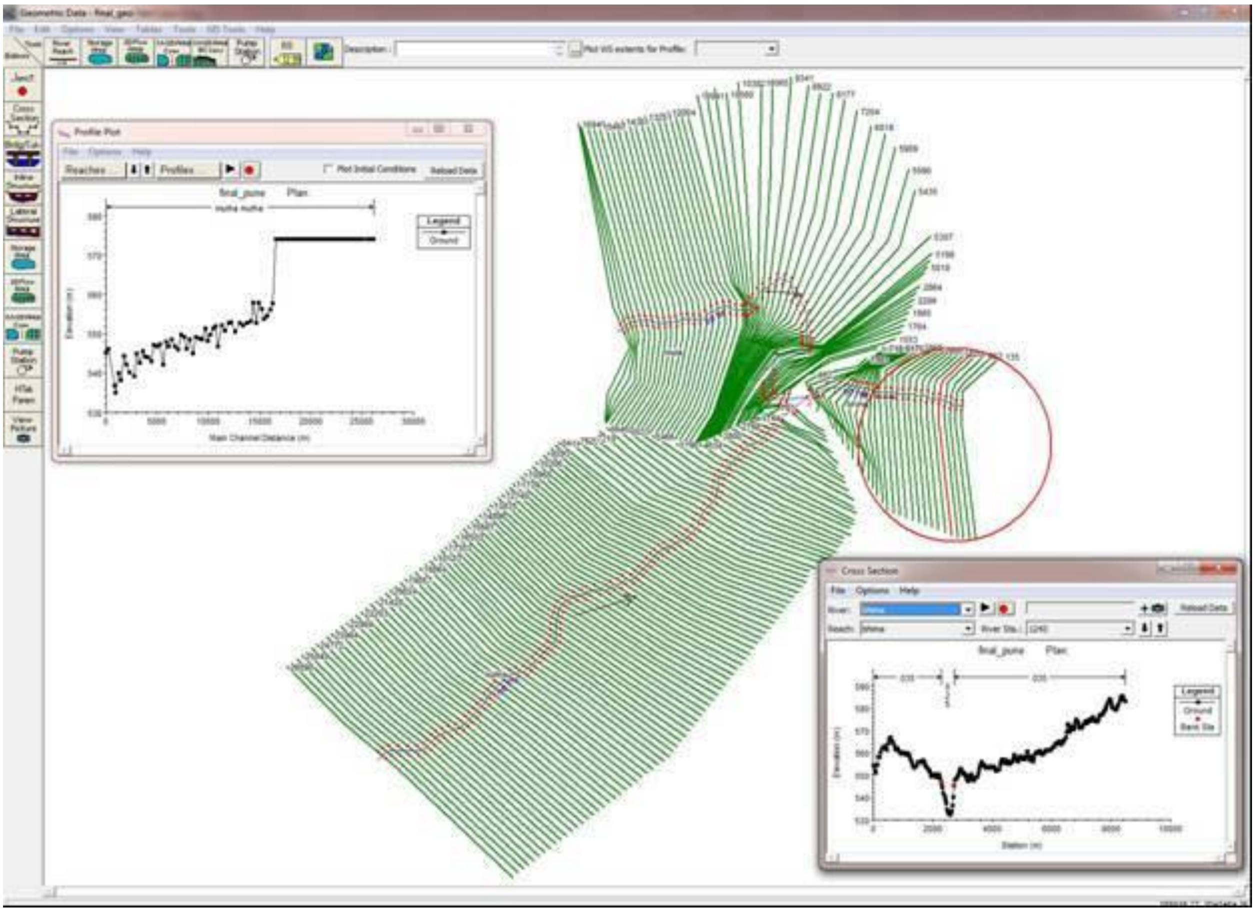


Figure 8: HEC-RAS geometry data for a sample basin

Incorporation of hydraulic structures:

A **hydraulic structure** is a **structure** submerged or partially submerged in any body of water, which disrupts the natural flow of water. They can be used to divert, disrupt or completely stop the flow. Hydraulic model developed will be incorporated with structures like, dam, bridge, culverts, embankments etc. along with roadway profiles. Multiple structures will be modeled and analyzed. For example, an inline structure incorporation has been shown in Figure 9.

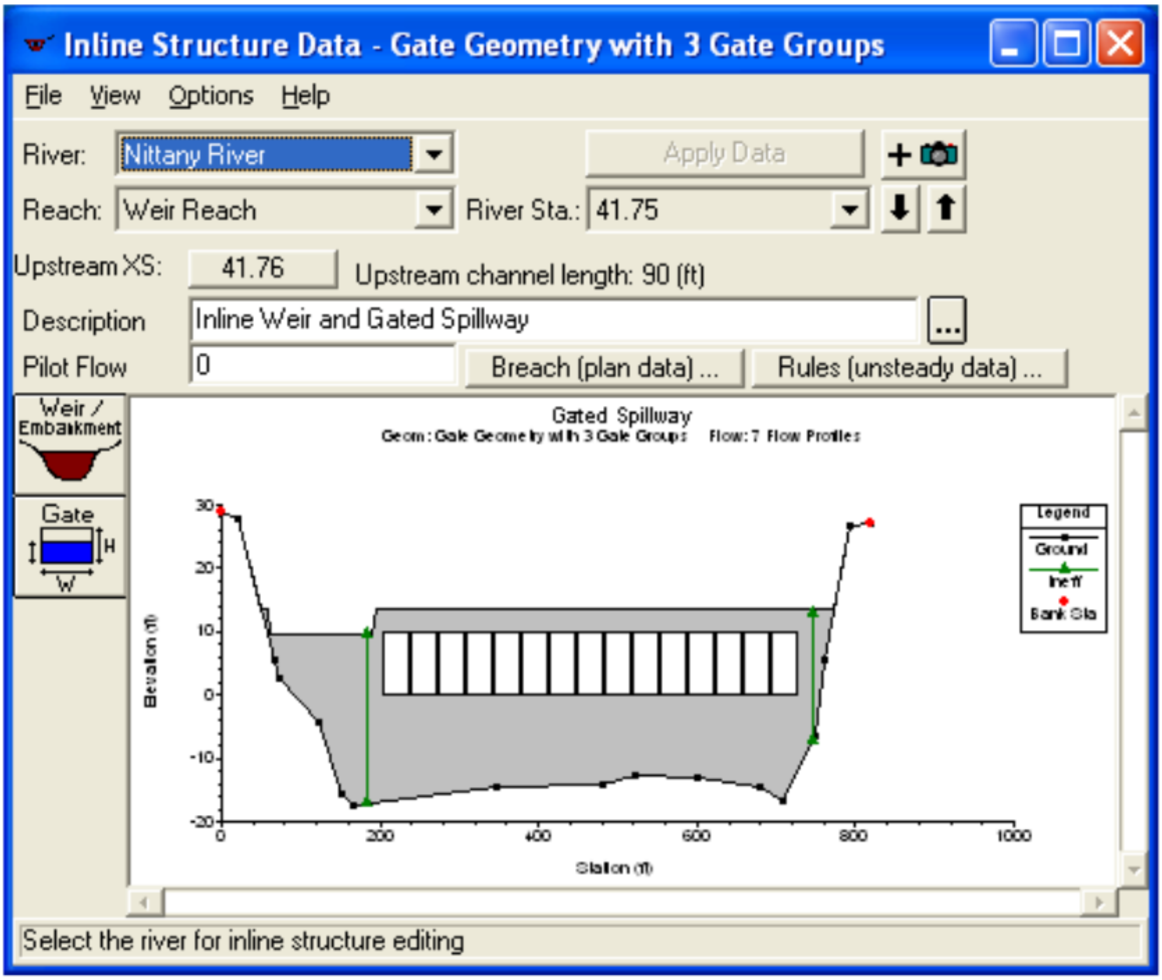


Figure 9: Typical incorporation of inline structure s in hydraulic model

Calibration and Validation of Hydraulic Model

Calibration and validation of spatial hydraulic models is often hampered by the lack of independent field measurements. The model will be calibrated and validated with observed floodwater levels during flood events with the simulated water levels from the hydraulic model.

The calibration process consists of systematically comparing observed flooding behavior within the study area against the hydraulic model's reproduction of that behavior. This process generally incorporates comparisons between simulated flood levels and observed flood levels. This can also be done by comparing the areas of inundation from historical event with simulated flood extent from the model.

The first approach requires detailed data about the flood water levels over time (temporal distribution) at discrete points of interest within and along the river at various locations to validate the simulated water level. Whereas, the second approach requires flood extent of particular historical events to validate the simulated flood extents. Global mapping agencies such as Dartmouth Flood Observatory (DFO) record the behavior of historical flood events and provide footprints of recent floods. On the other hand, government agencies including Department of Ecology, Environment and Remote Sensing, J&K and I&FC have mapped HFLs at several places in areas that were under inundation during major events like the 2014 flood as well as minor floods in the recent past. In addition, there have been some studies that have mapped the extents of historical floods in Kashmir.

A sample comparison between simulated and observed flood extent maps is shown below.

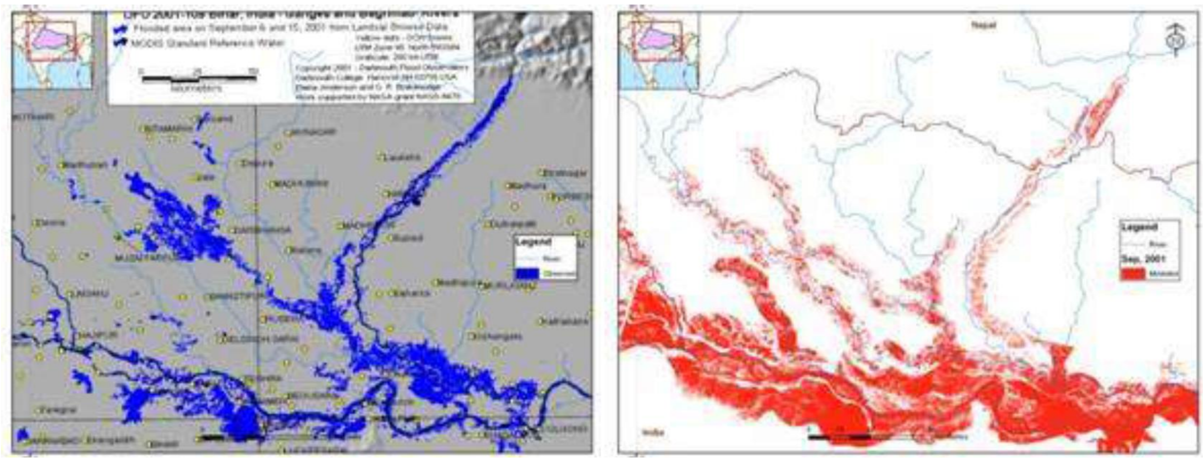


Figure 10: Comparison between observed (left) and modeled (right) flood extents for an historical flood event

RMSI will also try to calibrate the modeled water level with the available historical water levels.

Once comparisons of flood extents and water levels for simulated and historical data for various historical events, is within permissible limits, the hydraulic model is ready to derive the flood extent maps for design events of 2, 5, 10, 25, 50, 100 and 500 years.

GIS Mapping of Flood Extents

Based on return period rainfall and corresponding flow values, the team will determine the extent of flood plain inundation by using two-dimensional hydraulic modeling. Flood extent maps will be prepared by integrating model results with GIS data to produce maps with varying flood depths depicted in different colors. The corresponding flood extent maps will be generated for all return period events for each type of flood for further use in vulnerability and risk assessment. Figure 11 illustrates a sample map showing modeled flood depths for the Uttarakhand Flood of June 2013 in India.

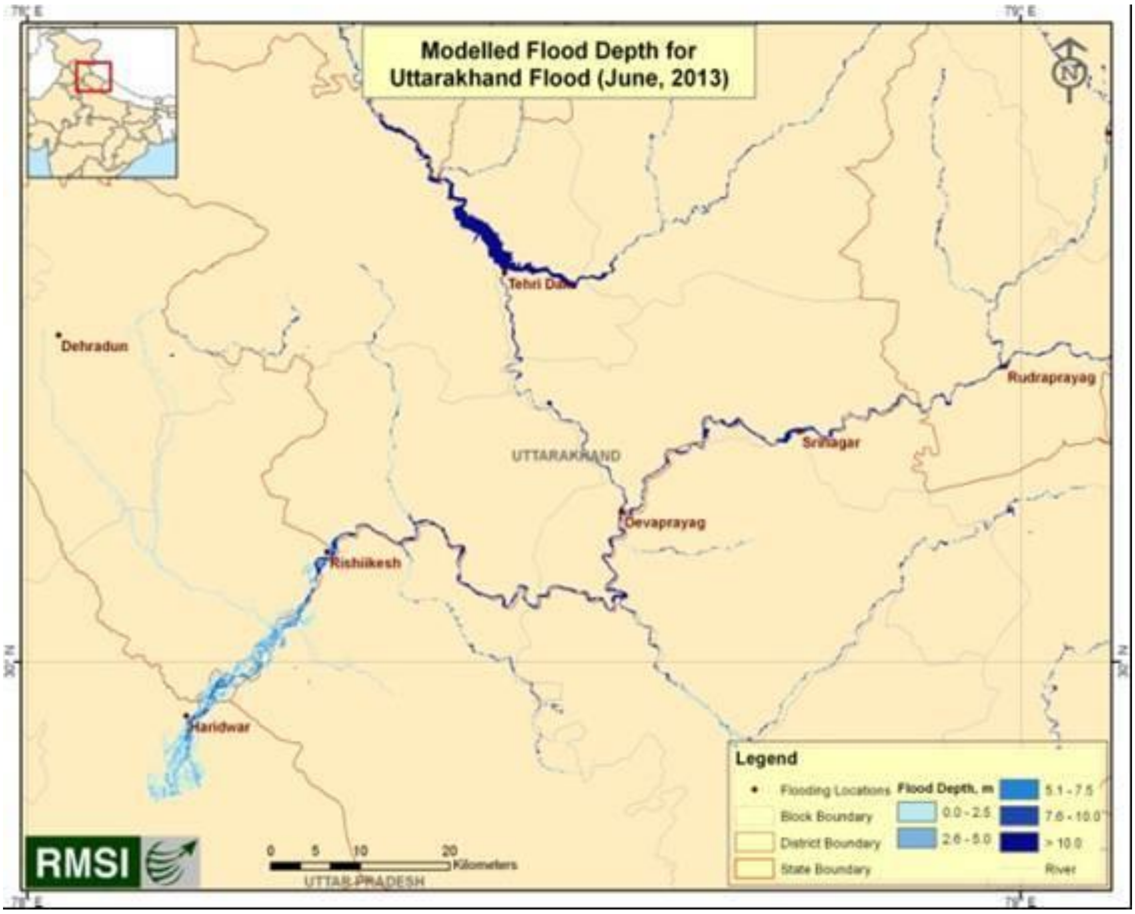


Figure 11: Modeled flood depths with contouring showing flood susceptibility

Flash floods

Flash Flooding is primarily a result of high-intensity rainfalls. The first step in a quantitative flash flood hazard assessment is to establish the characteristics of the flash flood-producing rainfall events. To accomplish this, a meteorological analysis will be undertaken to estimate rainfall volumes for the most frequent to rare events based on stochastic simulation. The number of events will be decided based on the events. The meteorological analysis will include:

- Analysis of historical rainfall records
- Review of historical storm duration and intensity to determine the critical storm duration to be used in hydrologic analysis
- Review of isopluvials in available rainfall atlases
- Frequency analysis of historical records to determine rainfall volumes for a range of return periods
- Development of a “design” rainfall distribution that would serve as input to hydrologic analyses to predict flood flows.

The remaining steps are same, viz., running the hydrological (HEC-HMS Model) and Hydraulic models (HEC-RAS) described in the previous sections.

Pluvial/Flash flooding, as a result of extreme rainfall event due to their storm characteristics, accumulate large amounts of water over the ground before it enters a natural or man-made drainage system. Pluvial flooding is associated with short duration with high intensity rainfall. It includes different dynamic processes such as flow paths and ponding, steepness, barriers to flow, wetness, permeability and antecedent soil conditions. For Pluvial flooding the road network and canal network will be used as water channels. Pluvial/Flash flooding will be incorporated in the present framework and will be used for probabilistic flood modelling.

GLOF Hazard Assessment

The degree for loss of life and damage to infrastructure due to GLOF varies depending on various factors, such as:

- Size and depth of the glacial lake
- Nature of the flood outburst
- Geomorphology of the river valley downstream of the GLOF, and
- Elements, settlements and infrastructure, exposed to the flash flood

To minimize the risk of glacial lake outburst flood and to reduce the vulnerability of nearby communities, it is important to carry out the systematic inventory of these glacial lakes, their growth analysis and simulation of lake breach with better accuracy to understand the flash flood extent more precisely (Anand, 2014). Locations of a few potential GLOFs in J&K are shown in Figure bellow.

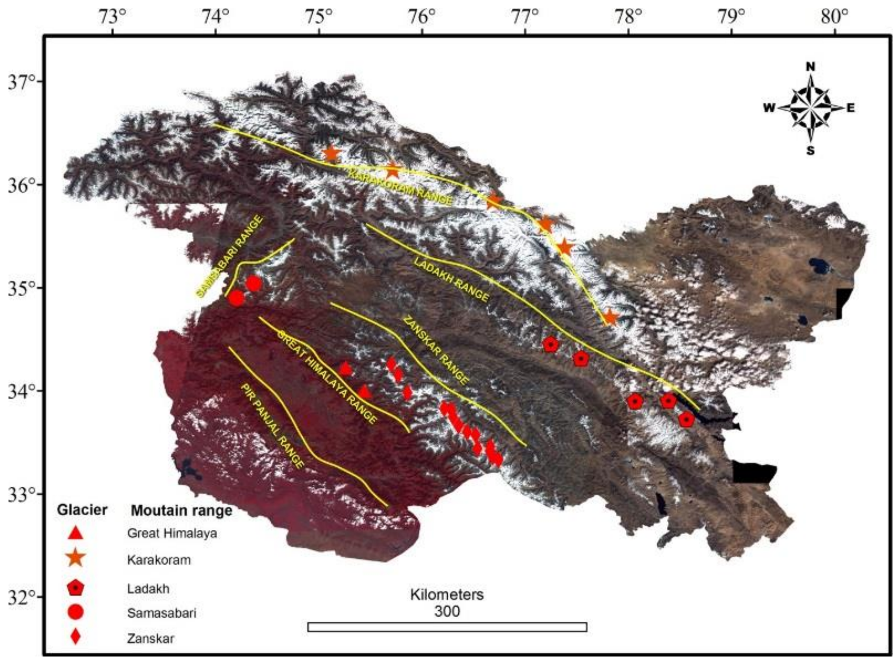


Figure 12: Location of GLOFs in J&K

Various criteria are mentioned in literature to identify the hazardous lakes that have high potential for outbursting. The major criteria used for hazard assessment are as follows:

- Large lake size and rapid growth in the lake area
- Rate of increase in lake water level
- Changes in supra-glacial lakes at different times
- Position of the lakes in relation to the associated glacier
- Dam condition
- Glacier condition
- Physical conditions of surrounding
- Geological and engineering properties of the moraines damming the lake

Ideally, all the above parameters are generally required for most detailed hazard assessment of GLOFs. However, data collection to derive the above parameters is time consuming and also expensive. Within the time and resources available, only a few of the parameters will be assessed using remote sensing images, such as lake size, area, hanging glacier presence etc., other parameters such as condition of associated glacier, height of moraine, debris cover, moraine properties etc. needs detail field investigation or compiled from literature review, if available.

In this project, highest resolution satellite (temporal) images combined with literature review and topographic data will be used to extract the glacial lakes and above-mentioned parameters for each of the glacial lakes. The methodology proposed for glacial lake inventory and assessment of the lake-bust probability and lake classification using the above parameters is given in Figure 13.

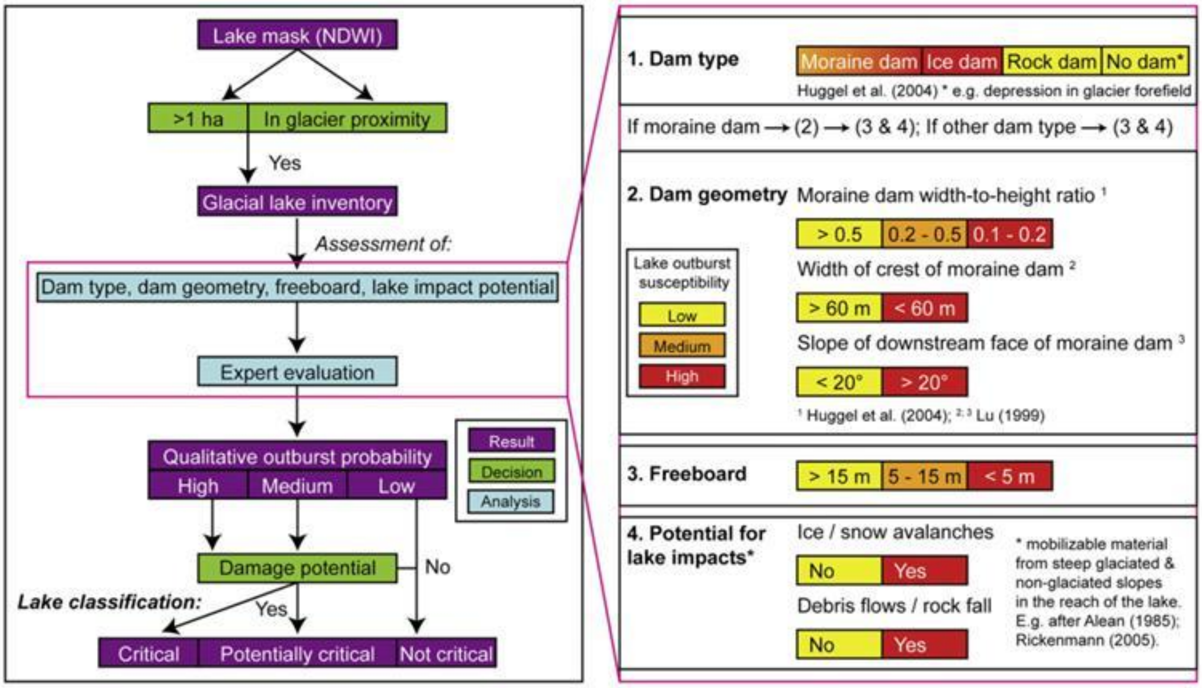


Figure 13: Methodology for Glacial Lake Inventory and Lake-Outburst probability assessment (Source: Worni, et.al, 2013).

Snow Avalanche Hazard Assessment

The parameters that influence snow avalanches are slope, aspect, elevation, rainfall, temperature, wind speed, snow depth, snow density, and snow volume. Generally, snow avalanches occur on slopes steeper than 25 degrees and majority occurs on slope angles between 35 -45 degrees. Most of the slab avalanches occur on slopes with starting zone angles between 30-45 degrees but slab avalanches occasionally occur on slopes less than 30 degrees as well. Slopes steeper than ~50 to 60 degrees tend to sluff snow constantly, and slopes about 25 degrees or less are generally not steep enough to trigger avalanches. Generally, avalanches are can occur only when if the snowpack is unstable. An avalanche can be triggered by several factors such as rapid load of precipitation, a sudden increase in temperature, windblown snow or some human activities like traffic vibration etc.

RMSI team will improve upon existing inventory of avalanche datasets available from national and international organizations, such as Center for Snow and Avalanche Study Establishment (SASE), India.

As part of Component 1, RMSI team will delineate glacier, permanent snow areas, snow-covered areas, and snow-free areas. As an example, Figure 14 shows the map indicating snow-covered areas, glacier areas and snow-free regions delineated from the remotely sensed data.

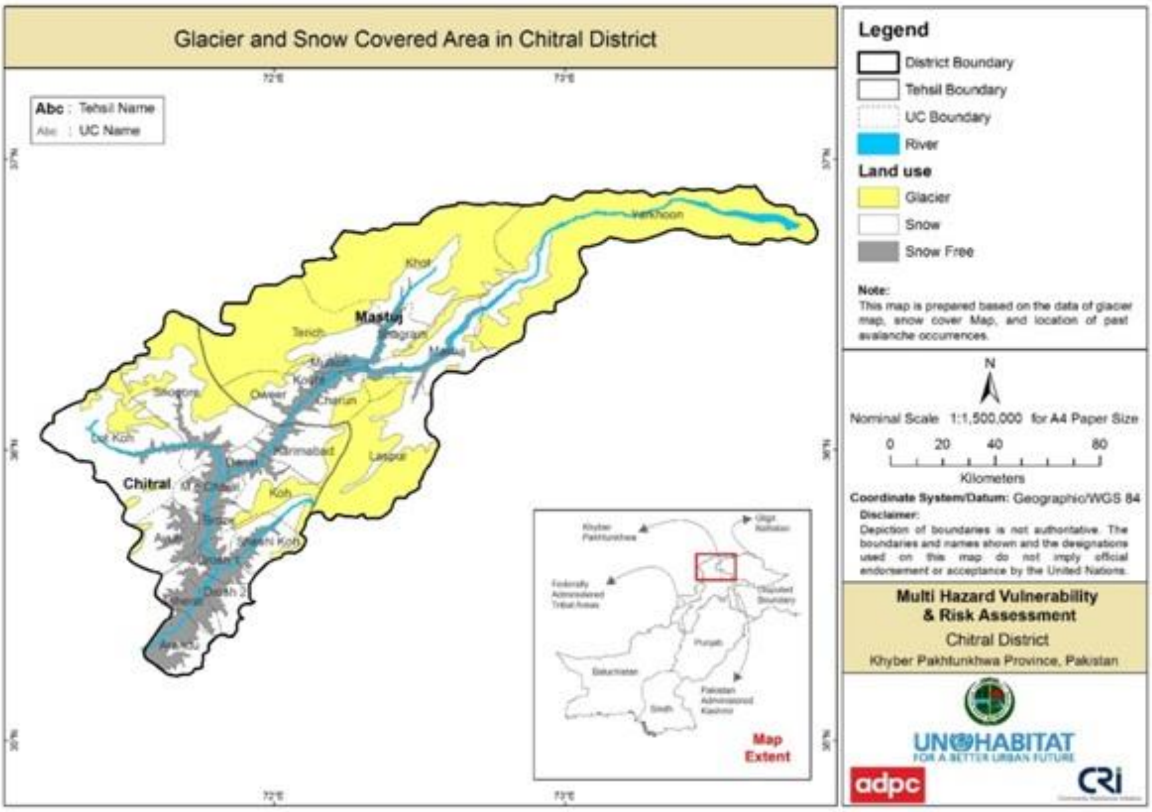


Figure 14: An example of Glacier and Snow Cover Map

For the present study, areas having suitable meteorological conditions and physical characteristics that favor avalanche will be mapped to identify the potential avalanche hazard prone areas. The steps that will be followed for assessment of avalanche hazard and vulnerability are given below:

- Gather the information on past avalanche hazards through secondary sources
- Identify areas for avalanche study and research and collect high resolution satellite data of the same, if possible
- Carry out avalanche mapping using the satellite data, topographic maps in GIS environment
- Conduct field work to measure and validate avalanche slopes, aspect, elevation, soil type and other topographic and geomorphological variables
- During field work also identify vegetation species growing on the avalanche prone slopes
- Collage climate data, hydrological data and snowpack conditions of the avalanche prone zones
- Mapping potential avalanche hazard prone areas after integrating all above data in the GIS using Multi-Criteria Analysis (MCA)
- Estimate the avalanche frequencies
- Suggest mitigation and prevention measures in order to minimize the loss to life and property
- Prepare a composite assessment report, on the basis of integrated analysis of the avalanches in the region

For avalanche hazard assessment, Nearest Neighbors (NN) Method has been very popular among avalanche forecasters since its introduction by Buser (1983). It is more popular as a data-mining or information gathering tool than as a classification tool, for its outstanding ability to provide the forecasters with all important information related to previous similar occurrences.

For the present study, the technique of Artificial Neural Networks (ANN) will be employed which takes into account respective probabilities for both occurrences of avalanche and non-occurrence of avalanche as brought out by the NN model. This approach will be implemented based on historical data for the following parameters that the model uses with their respective/suggested weights as given in Table 7.

Table 7: Nearest neighbors model input parameters, their units, observation periods/time (as on any day-t), and weights assigned.

No Parameter (Pi)	Unit	Observation period/time	Weight
1. Air Temperature	°C	0830h(t)	1
2. Snow Surface Temperature	°C	0830h(t)	1
3. Air Temperature Change	°C	0830h(t) – 0830h(t-1)	1
4. New Snow in 24 hours	cm	0830h(t-1) to 0830h(t)	3
5. New Snow in 48 hours	cm	0830h(t-2) to 0830h(t)	2
6. New Snow in 72 hours	cm	0830h(t-3) to 0830h(t)	1
7. Snowpack Depth	cm	0830h(t)	1
8. Snowpack Water Equivalent	mm	0830h(t)	2
9. Wind Speed	m/s	0830h(t)	3
10. Free Ram Penetration	cm	0830h (t)	1

The above mentioned (Table 7) parameters are very crucial for the forecasting of avalanches in any mountainous region. It is expected that these parameters can easily be collected in close collaboration with the client and the Snow and Avalanche Study Establishment (SASE), which is a laboratory of the Defense Research & Development Organization (DRDO) based in Chandigarh. The data related to an event with date associated with avalanche information (Occurred/ Not occurred, size, distance traveled, aspect, natural/artificial, mortality etc.) will also be helpful for modeling of avalanche.

As per availability of historical parameters, data will be segregated into training and the testing dataset for ANN based analysis. Based upon the output from training data set, a threshold probability will then be decided by the experts and classification will be carried out for test data.

The ANN output for test data for a particular sector and time will be validated with the actual observations. Since the ANN output is on a continuous scale from 0 to 1, a threshold value is required for crisp classification and also to test the model performance in quantitative terms.

The performance accuracy measures with different threshold ANN output values will also be calculated. Finally, the validated model will be used for simulating the historical events and its outcome such as avalanche scenarios and resulting snow avalanches paths as part of hazard assessment will be incorporated in DRDB. The team will develop Snow Susceptibility Maps in GIS environment using the output from the ANN and MCA as presented in Figure 15.

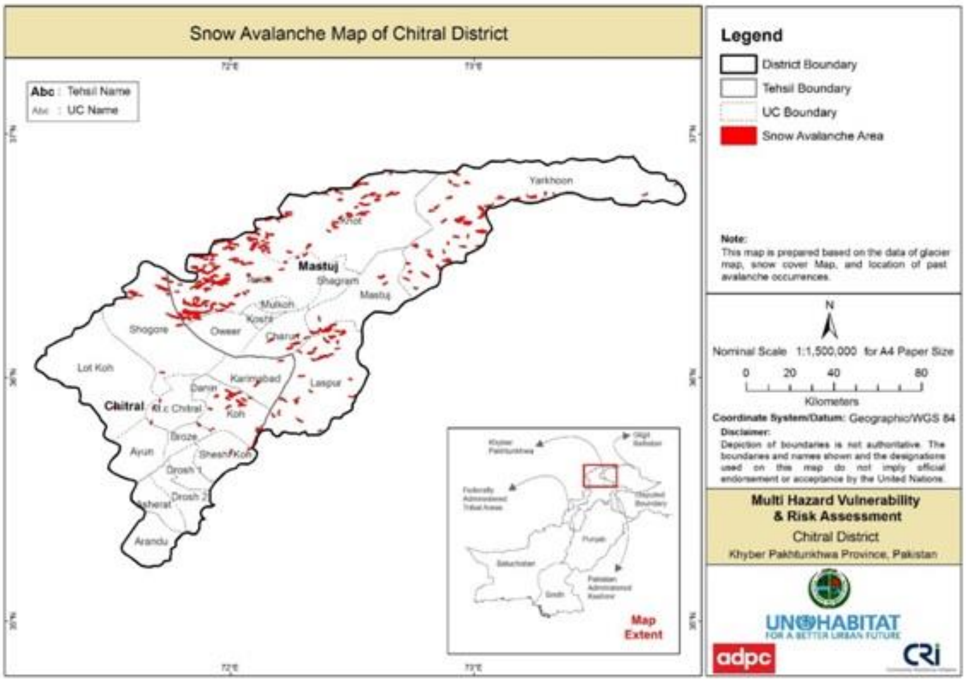


Figure 15: An example of Snow Avalanche Susceptibility Map

Drought Hazard Assessment

Most parts of Jammu division including Doda, Udhampur, Kathua, Samba, Jammu, Rajouri, Punch etc. are drought prone. The following data will be required to carry out probabilistic/ deterministic drought modeling in the state.

Drought hazard frequency of different severity levels will be derived using long time series (at least 30 years) of daily-level historical rainfall data.

This data is available with the India Meteorological Department (IMD) and GoJ&K owned weather stations. Besides, hydrological and agricultural departments also record rainfall data at several locations of their interest. Hence, we will make all efforts to collect this data from these sources. In order to validate our derived drought hazard, we will also collect historical drought events from the relevant agencies and literature.

Drought hazard at the State, District and Tehsil levels for the state needs to be quantified in terms of its severity by using some standard index.

RMSI is proposing SPI as the drought hazard index in the present study as this index has been recognized as a best drought index by World Meteorological Organization (WMO) due to various advantages that are mentioned below.

SPI was developed (McKee et al., 1993[12]) for the purpose of defining and monitoring drought. It is developed to quantify the precipitation deficit and excess for multiple time scales (e.g., 1, 3, 6, 12, 24, 48 months). This versatility allows SPI to monitor short-term water supplies such as soil moisture that is important for agricultural production, and long-term water resources such as ground water supplies, stream flows, and reservoir levels. SPI computation for a specific time scale and location requires long-term daily time series precipitation records (ideally for 30 years or more). The long-term record is fitted to a gamma probability distribution as the gamma distribution has been found to fit the precipitation distribution quite well. This is

[12] McKee, T. B., Doesken, N. J., and Kleist, J. 1993. The relationship of drought frequency and duration to time scales. Proceedings, 8th Conference of Applied Climatology, pp. 179-184. January 17-22, Anaheim, California.

done through a process of maximum likelihood estimation of the gamma distribution parameters, α (shape parameter) and β (scale parameter). Subsequently, it is then transformed into a standard normal distribution, which, by definition, has zero mean and unit variance (Edwards and McKee 1997). Positive SPI values indicate greater than mean rainfall, while negative values indicate less than mean rainfall. Because SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can be monitored using SPI. Following are the advantages of using SPI:

The advantage of this index is that it facilitates comparison of different stations in different climatic regions regardless of the fact that they may have different normal rainfalls. Therefore, the rainfall of two areas with different rainfall characteristics can be compared in terms of how badly they are experiencing drought conditions. In addition, SPI can be computed for rainfall totals of different time scales, namely, seasonal, monthly, and phenophase level rainfall totals. This flexibility enables studying rainfall deficiencies in each phase of the crop cycle. Table 8 shows how various droughts, normal, and wet events are categorized based on SPI ranges.

Table 8: Categorization of drought, normal and wet conditions based on SPI

Drought Classification	SPI Range
Extreme Drought	< -2.0
Severe Drought	-2.0 to -1.5
Moderate Drought	-1.5 to -1.0
Minor Drought	-1.0 to -0.5
Normal	-0.5 to 0.5
Wet Conditions	> 0.5

After defining the drought index, the historical drought events will be analyzed for their frequency of occurrence and their spatial variability. Historical weather data will be used to simulate 100/500 years of weather data, the return periods of simulated droughts will be assessed, and corresponding maps will be generated. The frequency of drought over periods much longer than the period of observation is proposed to be computed by using a stochastic weather generator (WXGEN), which is embedded in the agro-meteorological model.

Landslide Hazard Assessment

In landslide hazard assessment, the historical information on landslide occurrences is one of the most important considerations, as this gives insight into the frequency of the phenomena, the types of landslides involved, the volumes, spatial distribution, and the damage that they cause, as well as understanding the correlation between various factors. The team will collect information about the historical landslide events from various relevant departments of Jammu & Kashmir, Boarder Roads Organization, and other relevant agencies. Other important data required for landslide modeling is the topographic data like slope, aspect, and altitude which shall be derived from the DEM.

Other data like geology, soil, rainfall, geological structures, land use, peak ground acceleration and road network will be collected from the relevant department. In case any of these data are not available, then data from open sources will be used.

Table 9 presents a list of input data that will be used for landslide susceptibility mapping along with their probable sources.

Table 9: Input data and their potential sources for landslide susceptibility mapping

S. No.	Data Requirements	Potential Sources	Scale
1	Historical landslide inventory data	Disaster Management Department, Geological Survey of India (GSI), Department of Transport, Google images, District Collectorate Office, Department of Earth Sciences (Kashmir University) , Boarder Roads Organization, R&B Department	
2	Geology Map	Geological Survey of India (GSI), Department of Geology and Mining, Dept. of Earth Sciences, Kashmir University	1:250K
3	Tectonic Structures	Geological Survey of India (GSI), Department of Geology (Kashmir University), Satellite Image Interpretation	1:250K
4	Seismicity	It will be derived as part of Earthquake Modeling	
5	Soil types with characteristics	National Bureau of Soil Survey and Land Use Planning (NBSS & LUP)	1:250K
6	Rainfall data	India Meteorological Department (IMD)	Yearly
7	Digital Elevation Model	Shuttle Radar Topography Mission (SRTM), United States Geological Survey (USGS)	30x30 meter/pixel
8	Base data including road, rail and other transport network data	Toposheet, Department of Transport, Public Works Department (PWD), Satellite Image Interpretation	1:250K
9	Landuse- Landcover	Satellite Image Interpretation	30x30 meter/pixel
10	Drainage network data	To be extracted from SRTM, Satellite Image Interpretation	1:250K
11	Vegetation cover data	Satellite Image Interpretation	1:250K
12	Ground Water Table and Fluctuation data	Central Ground Water Board (CGWB)	Best Available

Landslide susceptibility maps will be developed using Analytical Hierarchy Process (AHP) and GIS analysis. Various factors influencing landslide will be selected based on literature survey, expert opinion and by observing their correlation with historical landslide data. Based on the outcome, several factors will be considered for landslide susceptibility mapping, which normally include slope angle, geology/ lithology, faults, soil texture, land use land cover, rainfall, seismicity etc.

AHP is a theory of measurement through pair wise comparisons and relies on the judgments of experts to derive priority scales. It was developed by Saaty (1980)[13] and gained widespread attention later on. Factor weights for each criterion are determined by a pair wise comparison

[13] Saaty, T.L., 1980. “The Analytic Hierarchy Process.” McGraw-Hill, New York

matrix as described by Saaty (1990[14], 1994[15]), and Saaty and Vargas (2001)[16]. These scales measure intangibles in relative terms. The comparisons are made using a scale of absolute judgments and historical correlation that represent how much more one element dominates another with respect to a given attribute. The overall approach for mapping landslide susceptible zones in the study area is shown in the Figure 16.

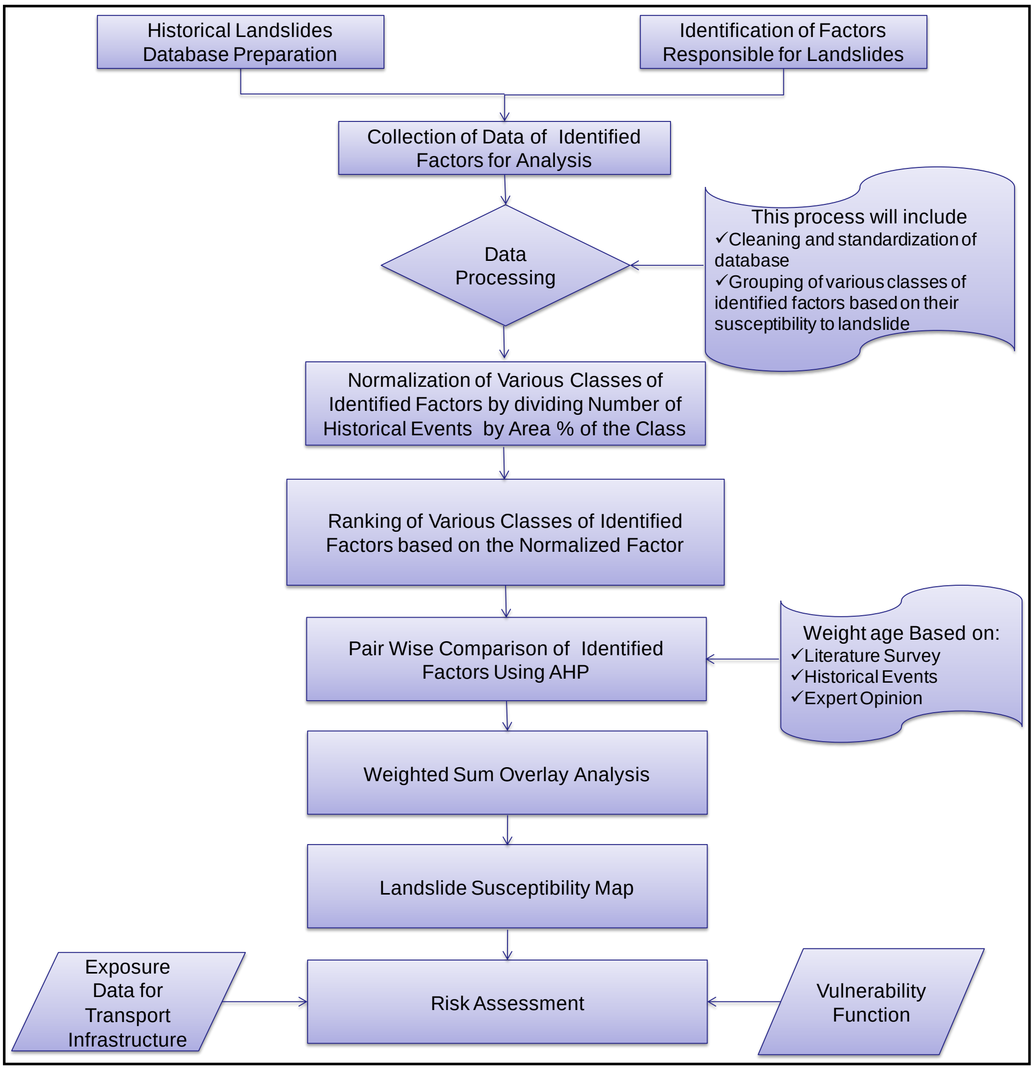


Figure 16: Overall approach for landslide susceptibility mapping

Once the factors that are responsible for landslide in the study area are finalized, the team will collect those datasets for aiding analysis. Data received from various sources are generally available in a variety of formats and different resolutions. After initial analysis, data will be processed to bring them in usable formats. Various classes of each factor of landslide will first be grouped based on their susceptibility to landslide. Classes with similar response to landslides will be grouped under one class.

[14] Saaty, T.L. (1990). An Exposition of the AHP in Reply to the Paper 'Remarks on the Analytic Hierarchy Process', Management Science36: 259-268.
[15] Saaty, T.L. (1994). Fundamentals of Decision Making and Priority Theory with the AHP RWS Publications, Pittsburgh, PA, U.S.A.
[16] Saaty, T.L. and Vargas, L.G. (2001) Models, Methods, Concepts and Applications of the Analytic Hierarchy Process. Kluwer Academic Publishers, Norwell

Historical landslide data will be analyzed with respect to these classes to understand their relation with landslides. A normalization factor will be derived for each class by dividing the number of historical events in each class of each factor by dividing total area of that class.

The normalization factors derived for each class of each factor will be further ranked on a scale 1 to 5. Using these ranking, thematic maps will be generated for each factor. Finally, each of the factors will be compared to the other factors in the set using the AHP method and weights will be derived for each factor. Comparisons will be made using a scale of absolute judgments that represent, how much more one factor dominates the other. For example, slope is normally the most important factor among all the other identified factors like land use, geology, etc. Therefore, slope will be assigned a high weightage as compared to other factor.

The weights derived from multi criteria analysis will be used for weighted sum overlay analysis of various susceptibility maps of each factor to determine the overall impact. The integration of various factors into a single landslide susceptibility index (LSI) will be accomplished by a procedure based on weighted linear sum (Voogd, 1983[17]):

$$\mathrm{LSI} = \sum_{j=1}^{n} W_j \, w_{ij}$$

Where:

LSI : Landslide susceptibility index

Wj : Weight value of parameter j

wij : Rating value or weight value of class i in parameter j

n : Number of parameters

In the above, the weight derived using AHP will be multiplied by the susceptibility value of each factor and finally added to get the overall landslide susceptibility index.

The map obtained by weighted sum analysis will be classified into five landslide susceptibility classes. The landslide susceptibility index defines the probability of a location being susceptible to landslide.

Climate Change and Climate variability

The climate change projection datasets from several Global Climate Models (GCMs - better known as Earth System Models or ESMs) are available from CMIP5 Data Archives[18] which include projections for RCP 8.5 (Business-as-usual Greenhouse Gas Emission Pathway) and RCP 4.5 (Mitigation Policy Pathway) scenarios. Each of the climate projections includes maximum surface air temperature, minimum surface air temperature, and precipitation for the selected time slices from 1951 through 2100. This dataset, when further downscaled and bias corrected, facilitates in conducting a climate change vulnerability assessment and sector-specific impacts at local scales, and thus enhances our understanding of possible future state-level climate patterns at local spatial scale. Each of these climate projections is downscaled at a spatial resolution of 0.25 degrees x 0.25 degrees (approximately 25 km x 25 km). During the downscaling process, the historical simulations serve as the baseline data and will be compared against the observational climate records for inferring the bias, if any. These downscaled climate projections preserve the frequency of periods of anomalously high and low temperature or precipitation (i.e., extreme events) within each emission scenario.

[17] Voogd, H., 1983. Multi-criteria evaluation for urban and regional planning. Pion, London. 367 pp

[18] Taylor, Karl E., Ronald J. Stouffer, Gerald A. Meehl, 2012: An Overview of CMIP5 and the Experiment Design. Bull. Amer. Meteor. Soc., 93, 485–498.

As a first step, we shall select four global climate models which are best performing in simulating the observed climatology over South Asia and shall use the outputs from these models for a stringent validation exercise in terms of seasonal and annual cycle of surface air temperature and precipitation over J&K State and its three selected regions namely, Jammu, Kashmir Valley and Ladakh as against the historically observed climatology available from India Meteorological Department and also from globally homogenized CRU climatological data sets (Climate Research Unit, University of East Anglia in Norwich, UK) for the period 1961-1990.

Next Bias-Correction will be performed. The Bias-Correction step "corrects" the bias of the GCM data through comparisons with historical data[19]. For each climate variable in a given day, the algorithm generates the cumulative distribution function (CDF) for the observed data and for the historical GCM simulations, respectively, by pooling and sorting the corresponding source values (day of year ±15 days) over the baseline period from 1961 through 1990. It then compares the two CDFs at various probability thresholds to establish a quantile map between the GCM data and the historical climate data. Based on this map, GCM values in any CDF quantile (e.g., p=90%) can be translated to corresponding Global Meteorological Forcing Data (GMFD[20]) values in the same CDF quantile. Assuming that the CDF of the GCM simulations is stable across the historical and future periods, to "correct" the projected future climate variations the algorithm simply looks up the probability quantile associated with the predicted climate values from the estimated GCM CDF, identifies the corresponding observed climate values at the same probability quantile in the observed CDF, and then accepts the latter as the adjusted climate predictions. The downscaling algorithm compares the GCM outputs with corresponding climate observations over a common period and uses information derived from the comparison to adjust future climate projections so that they are (progressively) more consistent with the historical climate records and, presumably, more realistic for the spatial domain of interest. The climate projections adjusted in this way shall have the same CDF as the GMFD data; therefore, the possible biases in the statistical structure (the variance, in particular) of the original GCM outputs are removed by this procedure.

The analytical approach is to follow Spatial-Disaggregation step, which spatially interpolates the adjusted GCM data to the finer resolution grid of the 0.25-degree observed gridded data. Other than simple linear spatial interpolation, multiple steps are adopted in the SD algorithm to preserve spatial details of the observational data. First, the multi-decade daily climatologies of the observed data variables (temperature and precipitation) are generated at both native and GCM resolutions. The climatology for the SD step is the average for each day of the year calculated over the reference baseline period, 1961-1990. Second, for each time step, the algorithm compares the adjusted GCM variables with the corresponding observed climatology to calculate "scaling factors". In particular, the scaling factors are calculated as the differences between the bias-corrected GCM and the observed data for temperature, but as the quotients (between the two datasets) for precipitation to avoid negative values for the latter. Third, the coarse-resolution scaling factors are bi-linearly interpolated to the fine-resolution observed data grid. Finally, the scaling factors would be applied, by addition or "shifting" for temperatures and by multiplication for precipitation, on the fine-resolution observed climatologies to obtain the desired downscaled climate fields. Thus, in principle, the algorithm essentially merges the observed historical spatial climatology with the relative changes at each time step simulated by the GCMs to produce the final results.

[19] Thrasher, B., E. P. Maurer, C. McKellar, and P. B. Duffy, 2012: Technical Note on Bias correcting climate model simulated daily temperature extremes with quantile mapping, Hydrol. Earth Syst. Sci., 16, 3309–3314, www.hydrol-earth-syst-sci.net/16/3309/2012/ doi:10.5194/hess-16-3309-2012.

[20] Climate dataset used are from the Global Meteorological Forcing Dataset (GMFD) for Land Surface Modeling, available from the Terrestrial Hydrology Research Group at Princeton University (Sheffield et al., 2006).

The Bias-Corrected Spatial Disaggregation (BCSD) method will be applied to data sets of downscaled CMIP5 models[21]. The NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP, 2015) dataset[22] are now archived at our database and will be used in developing climate projections for its use in a local level assessment of climate change impacts in the State of J&K. The approach to be used in generating the downscaled dataset thus inherently assumes that the relative spatial patterns in temperature and precipitation observed from 1961 through 1990 will remain constant under future climate change. Other than the higher spatial resolution and bias correction, this dataset does not add information beyond what is contained in the original GCM scenarios, and thus preserves the frequency of periods of anomalously high and low temperature or precipitation (i.e., extreme events) at all time scales.

In this assessment, we shall present the projected climate change for J&K State as a whole and also for its three selected regions as inferred from ensembles of the four ESMs for time slices centered around 2020s (i.e., 2010 to 2039 - near term), 2050s (i.e., 2040 to 2069 - medium term) and 2080s (i.e., 2070 to 2099 - long-term) relative to the baseline period of 1961-1990. These downscaled CMIP5 climate projections preserve the frequency of periods of anomalously high and low temperature or precipitation (i.e., extreme events) within each emission scenario and are now being widely used at the country, province or local level assessment of climate change impacts. We shall not use RCM generated high-resolution datasets in this study due to inherent limitations in these data sets.

A set of core climatic indicators (https://www.ncdc.noaa.gov/indicators/) shall also be calculated from the bias-corrected datasets for baseline and future time slices over the regions of interest in the J&K State. The focus would be to infer vital information required for decision-making in structuring future development plans in relevant sectors with a primary focus on water and agriculture sectors.

TOOLS TO BE DEPLOYED FOR DATA ANALYSIS

For our data analysis, we shall deploy the Climate Data Operators (CDO) software[23] which is a collection of many operators (more than 600 operators available) for standard processing of climate and forecast model outputs (gridded observational and climate model data on daily and monthly basis including time series data or horizontal gridded data). The operators include simple statistical and arithmetic functions, data selection and sub-sampling tools, and spatial interpolation. Supported data formats include GRIB 1/2, netCDF 3/4, SERVICE, EXTRA and IEG.

CDO was developed to have the same set of processing functions for GRIB and netCDF datasets in one package. The tool was developed by the Max Planck Institute for Meteorology in Hamburg. CDO has very small memory requirements and can process files larger than the physical memory. CDO is open source and released under the terms of the GNU General Public License v2 (GPL).

Further information on CDO is available from *https://code.zmaw.de/projects/cdo.* Documentation on CDO is available at *https://code.zmaw.de/embedded/cdo/1.6.1/cdo.html.* The reference card is available at *https://code.zmaw.de/files/cdo/html/1.6.1/cdo_refcard.pdf*.

The CDO data selection, sub-sampling, statistical and arithmetic functions shall be deployed over GCM model data available in NetCDF format (postscript files). Additional operators would

[21] Maurer, E. P., and Hidalgo, H. G., 2008: Utility of daily vs. monthly large-scale climate data: an inter comparison of two statistical downscaling methods, Hydrology and Earth System Sciences, 12, 551-563.

[22] NEX- GDDP (NASA Earth Exchange Global Daily Downscaled Projections), 2015: Data Access URL - https://cds.nccs.nasa.gov/nex-gddp/

[23] CDO User's Guide, 2016: Climate Data Operators (CDO) software, Developed by Uwe Schulzweida, MPI for Meteorology, 200pp.

be used to compute climate indices of temperature and precipitation extremes. The definition of these climate indices is based on those identified in the European Climate and Assessment (ECA) project. All computed climatologies shall be finally converted to ASCII format, which would be plotted in GIS.

Forest-Fires Hazard Assessment

The state is vulnerable to forest fire, induced by prolonged dry winter spells (natural) as well as human intervention (intentional & un-intentional) (MOEF Parliament Standing Committee Report No. 293). Generally, more forest fire incidences are recorded in Jammu than Kashmir region and only about 5% incidences are due to natural causes (Forest Fire Management Plan, J&K).

Input data required for forest fire analysis includes LULC (land use land cover), forest cover map showing various species of trees and shrubs, road and railway networks, settlement clusters, and historical fire occurrence hotspot points. The team will collect these data from the respective departments and from the local administration. In the absence of any data, RMSI will use either in-house available data or data available in open source.

To estimate the forest fire risk, forest fire hazard risk zone map will be prepared in GIS integrating data from secondary sources and satellite images. The following six key parameters and their respective weighted rating will aid in the determination of fire hazard risk areas:

- Vegetation types: The dry vegetation cover catches and spreads fire quicker than the moist or fresh vegetation classes. Therefore, LULC will be categorized into five fuel types with respect to its vulnerable and combustion properties. These classes are very dry, dry, moist, fresh-like and fresh. The team will either collect latest vintage LULC data from J&K Remote Sensing Application Centre or use the available LULC data published in GLCF by NASA (http://glcf.umd.edu/) for classifying vegetation types into above classes.
- Wind distribution: Spatial distribution of wind has a strong impact on the occurrence and spread of forest fire. Therefore, we will either use the spatial distribution of wind data derived from RMSI strong wind model or acquire freely available wind zone maps for the study area. The wind distribution will then be classified into suitable categories and included in the AHP process.
- Slope: Topography is an important physiographic factor, which is related to wind behavior, and hence affects the fire proneness of the area. Fire travels most rapidly up slopes and the least rapidly down slopes. In this approach, slope influence behavior of fire will be evaluated with the second highest weight. We will use the latest released SRTM 30m resolution DEM for extraction of slope and then assign weights appropriately
- Aspect: Aspect is another important parameter for determining the forest fire hazard. In this study, aspect will be assigned equal weight with slope; as more sunlight is reflected on slopes facing the south, and fire breaks out and spreads at a faster pace on the southern slopes. We will use the above mentioned DEM that has been selected for generating slope data.
- Distance from roads: Forest fires that are accidental/man-made can be the result of the movements of humans, animals, and vehicles. Thus, forest patches that are intercepted by roads are more prone to fire hazard. This makes people and animals grazing there vulnerable and also causes an increased number of fire incidents.
- Distance from settlements: Forests located near settlements can be said to be more fire-prone since the people living there can cause an accidental fire. The fire hazard risk factor decreases away from these places. This means a zone close to these places will be evaluated with a higher weighted rating.
- Historical data: Historical forest fire event data including location information will be collected from forest department as using archived satellite imageries which are available in open source. Data quality check will be carried out to assess its quality and

usefulness. Further, the usable data will be considered as major base data to integrate with other components.

Figure 17 presents the methodology that will be adopted for determination of forest fire hazard risk assessment for J&K. AHP method will be adopted for developing the forest fire susceptibility maps.

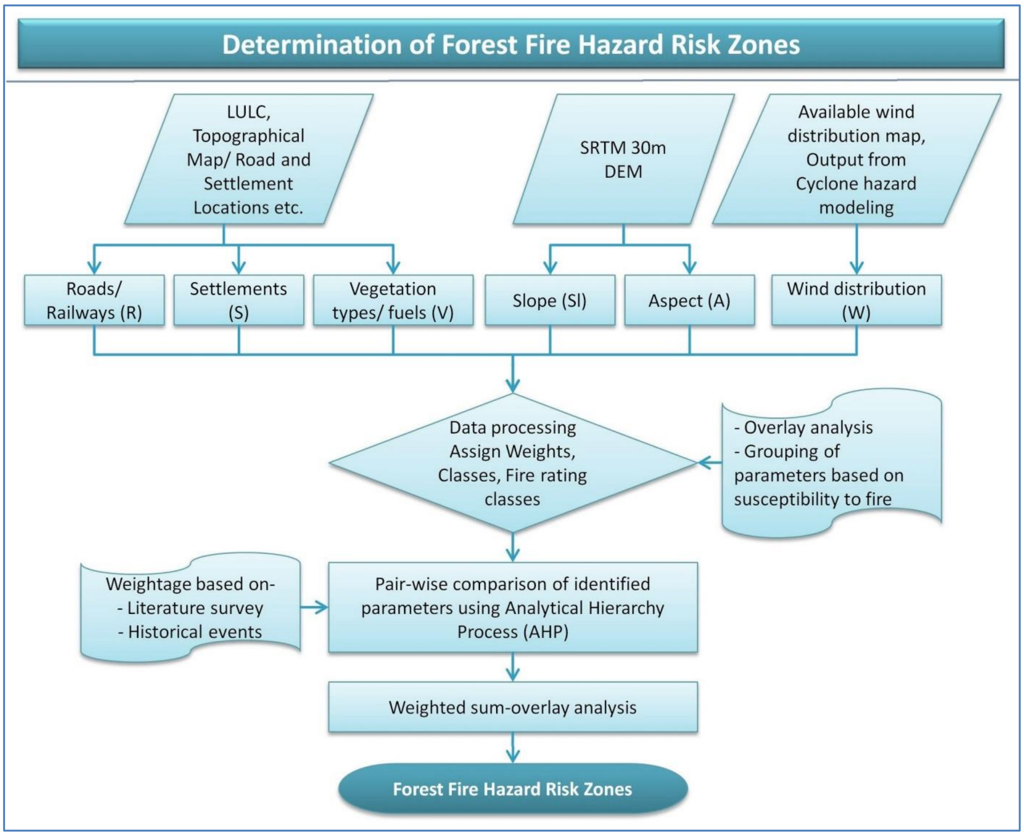


Figure 17: Determination of forest fire hazard risk zones for J&K

As explained in Figure 17, RMSI will carry out multi variate analysis using the variable mentioned above in GIS to map the forest fire susceptibility map of the state. The variables will be assigned weightage using AHP method to ensure that adequate weightage is considered for variables based on its influence to trigger forest fire events.

Fire Potential in Built- Environment

All-District Headquarters/ densely populated towns and especially Badgam, Baramulla, Samba, Gurez, Doda, Kishtwar and other inaccessible areas are prone to fire incidents in the built environment. Considering the high density of population in these cities, the events occurring in unit areas is higher in the cities and the damages are also higher.

We will map the historical fire incidences of the State based on information gathered from the State Fire Service Department and carry out a spatial mapping and analysis in the backdrop of land use to assess any correlation between fire incidents in the built environment with land use. The events will be analyzed to understand which part of the year a greater number of events occur.

In general, fire risk can be defined as the combination of hazard potential, exposure and vulnerability:

Risk = F (**H**azard potential, **E**xposure, **V**ulnerability)

The occurrence of fire incidents that constitute a threat for the population and exposed infrastructure of a certain region is associated with economic and human losses, always as a function of the exposure conditions and the vulnerability of the exposed assets to that particular region. In the present scope, Fire Risk can be defined as associated with number of small and medium fire incidents and their locations. In process of estimating hazard-score, all the hazard layers will be overlaid on top of each other and a spatial analysis will be performed to develop an integrated hazard score map at suitable level preferably Tehsil. In case of hazard for occurrences of small and medium fire incidents, only a few or low intensity natural hazard events will be significant. These natural hazards are Earthquake, Wind and Temperature zones. The assessment of above natural hazards will be based on the maps developed as part of other hazard models within this study and will be used with proper weightage factors based on their importance in overall fire risk scores. Other hazards such as industrial hazard, commercial hazard and man-made hazard will be covered through vulnerability scores.

Similarly, vulnerability score maps will be developed at the base unit level. The vulnerability score represents the level of vulnerability (very high to negligible) of a specific type of exposure in response to the occurrences of small and medium fire incidents. For vulnerability, different layers such as residential built-up areas, population density, high-rise building density, industrial areas and residential area past records of fire incidents and their density will be developed individually at base unit level. Each vulnerability layer shall be ranked on 1 to 5 score based on their degree of importance in overall risk. For example, both absolute built-up areas in sq. km by occupancy type as well as built-up areas percent (ratio of built-up areas to the total area) are important parameters in vulnerability ranking.

The data collected as part of field surveys and stakeholder interviews will also be one input for this process. In addition to the hazard and vulnerability, secondary input information and maps published in public domain for risk analysis like BMTP Atlas, city planning maps economic surveys, fire hazard response and mitigation plans for various municipalities' areas etc., will also be included in the analysis. The number of hazard and vulnerability layers used for the above analysis will be dependent on the availability of the basic hazard and vulnerability information in a format that it could be associated to geography and projected on a map.

After developing ranking of individual unit of hazard and vulnerability, GIS layers will be overlaid on top of each other and a spatial analysis will be performed for integration. Finally, a spatial overlay analysis will be carried out in GIS environment and district risk scores will be generated through Weighted Factor Analysis (WFA) in GIS environment. Techniques like buffer analysis, overlay analysis and weighted ranking techniques will be used in the integration analysis and quantified risk distribution of firefighting resource. Value of weight factor will depend upon the importance of particular vulnerability class in risk analysis.

Industrial Hazard Assessment

The chemical industry plays a vital role in the economy. The district-wise inventory of major industries, which deal with hazardous material, will be collected along with below-mentioned attributes:

- Name, location (latitude, longitude, altitude) and address of the industrial plants/factories and their types
- Key responsible person for disaster management and his/her contact details
- Name of hazardous chemicals/ flammable substances stored including quantity and medium of storage
- Physical characteristics of the containment (size, shape, dimensions, volume, possibilities of leakage openings size, duration of leaks if any, etc.)
- Flammability

As part of the industrial damage and loss database, the study team will collect information on the nature and cause of past accidents, number of people injured/death/affected, etc., and any damage to the environment (water, agriculture, and health of population, etc.). Large-scale high pressure and temperature reactors and separation equipment containing highly flammable and toxic chemicals are usual constituents of industries. Generally, industrial accidents affect these critical equipment resulting in industrial hazards such as fire-outbreak, explosion, toxic release (gas and chemical leakages) and damage to the environment. Toxic gas emissions include hydrogen sulfide, phenols, ammonia, cyanides as well as various volatile hydrocarbons. Chemical solvents vary in their toxicity and potential for exposure to workers, with highly volatile solvents presenting the greatest potential for inhalation exposure. In addition, petroleum and petrochemical processing includes thermal, high pressure, reactive and confined space hazards. Toxic and flammable solvents and high-pressure reactors, and distillation columns and separation units that produce them need to be protected from accidents as well as industrial sabotage.

Past accidents and their impacts will be developed as a GIS database.

In this study, semi-quantitative vulnerability modeling using the Seveso Directive (European Commission, 2013)[24] and a quantitative method of Areal Locations of Hazardous Atmospheres (ALOHA) will be utilized (provided the availability of supporting data).

ALOHA

A detailed assessment of dangerous chemical substances stored in each industry will be conducted using ALOHA software. ALOHA is a chemical hazard modeling software jointly developed by the National Oceanic and Atmospheric Administration (NOAA) and the Environmental Protection Agency (EPA) of the United States of America. It is designed as a tool to aid in emergency planning and response to chemical releases. Information about the physical properties of approximately 1,000 common hazardous chemicals is available in ALOHA.

ALOHA models three hazard categories related to chemical releases: toxic gas dispersion, fires, and explosions. ALOHA uses air dispersion model to simulate the movement and dispersion of chemical gas clouds, and then estimates the key hazards including toxicity, flammability, thermal radiation, or overpressure. The air dispersion model used in ALOHA (Gaussian or heavy gas) is designed to model the areas near a short-duration chemical release where key hazards may exceed user-specified Levels of Concern (LOCs). ALOHA employs additional models to estimate chemical releases associated with fires and explosions such as jet fires, pool fires, Boiling Liquid Expanding Vapor Explosion (BLEVEs), flammable areas, and vapor cloud explosions. There are four types of sources: Direct, Puddle, Tank, and Gas Pipeline that can be used to model chemical release in ALOHA. Each source may run different types of chemical hazard scenarios.

In general, the steps involved in modeling chemical release using ALOHA are:

- Locate the city or area, including the date and time, where a chemical release occurred or simulated;
- Select the chemical substances to be simulated from the ALOHA's chemical database;
- Enter information about the atmospheric and weather conditions;
- Provide detailed information on how the chemical is escaping from containment and scenarios to be considered; and
- Display a threat zone plot using MARPLOT or export to GIS systems, showing one or more areas where a hazard (toxic gas dispersion, flammable areas of a vapor cloud, thermal radiation, or overpressure from a vapor cloud explosion) may exceed the selected Levels of Concern (LOCs) and pose a threat to people and property.

[24] EC (2013). Report on the Application in the Member States of Directive 96/82/EC on the control of major-accident hazards involving dangerous substances for the period 2009-2011.

The accuracy of ALOHA simulation depends on the accuracy of the input information. Inaccurate results could result due to conditions such as very low wind speeds, very stable atmospheric conditions, wind shifts and terrain steering effects, or concentration patchiness, especially near the release source.

Component 3: Exposure Database Development

> The main elements of exposure that will be developed are demographics, buildings (including details such as number of stories, floor area, number of habitants per building, age, material of construction, and replacement value), infrastructure elements, agriculture/horticulture assets and critical facilities.

Exposure Database Development Methodology

The exposure data includes the locations and detailed attributes of all the exposure elements. Figure 18 shows broad categories of exposure elements that will be considered in the study.

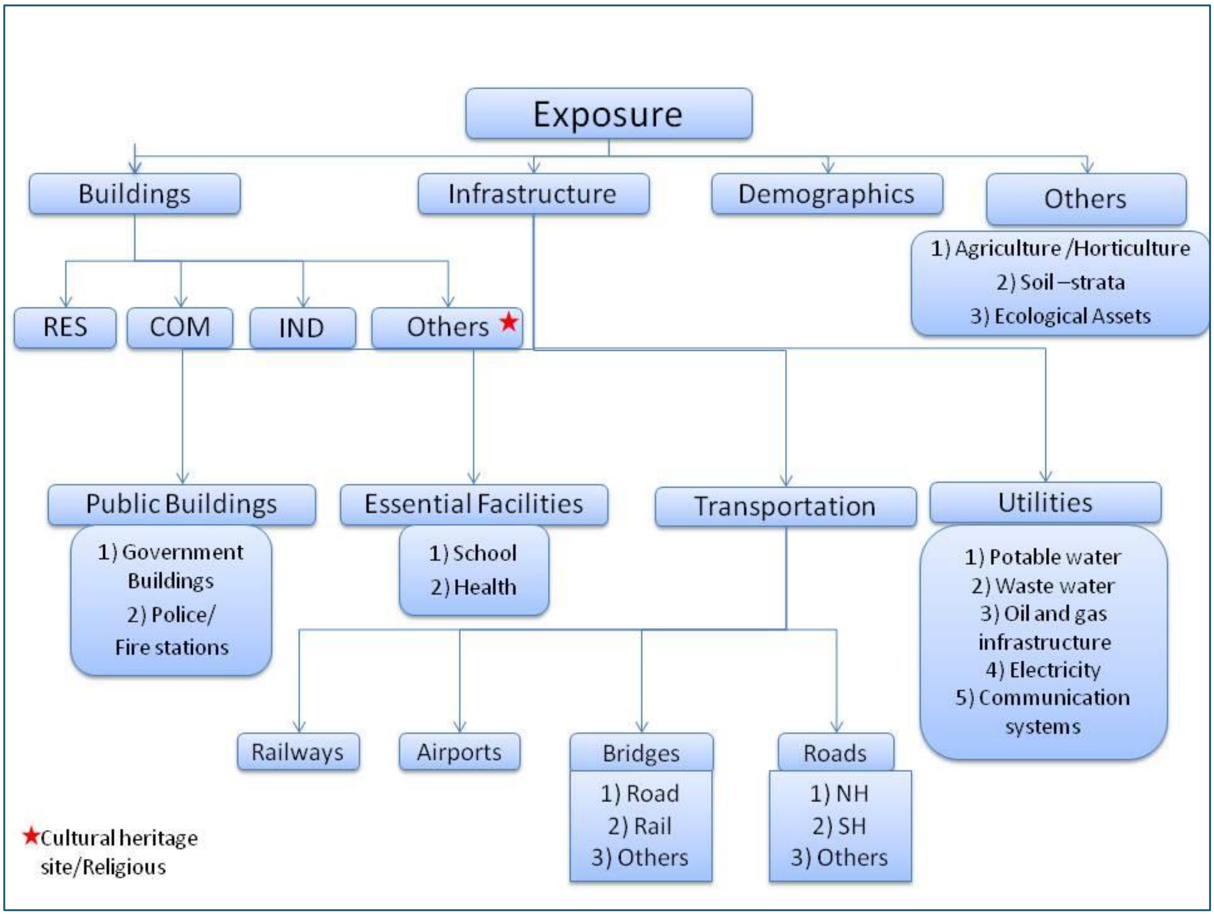


Figure 18: Broad categories of exposure elements

The overall process of developing the exposure database is illustrated in Figure 19. This is based on a "bottom-up" approach. This includes classifying the different types of buildings and infrastructure elements into different categories, estimating their count under each category, combining building counts with per unit built-up floor area in case of buildings or other infrastructure characteristics, and applying per unit costing information relevant to the category. The output of exposure will be calculated from the total monetary value by asset category.

Figure 19: Approach to exposure development

DATA COLLECTION

Data collection is very important in the exposure development process as the quality of the exposure developed is dependent on the kind of exposure information that could be collected.

Main steps in the data collection process include:

- Preparing a comprehensive list of data required
- Acquiring data
- Creating a data inventory sheet
- Identifying data gaps and alternate sources

We have started the data collection process in coordination with the PMU. The list of stakeholders that are being consulted for data collection is provided in Table 14.

DATA PROCESSING

As part of data processing, the following steps will be carry out:

- Review of existing and collected data
- Prepare a summary of data, which will be the next deliverable "Data inventory and data review report"
- Analyze data gaps
- Direct processing of exposure elements without any data gaps in required formats
- QA/QC of data separately for aggregate and site specific data

The following points are being taken care while carrying out data processing:

- Resolution of data

- Projection System
- Positional Accuracy
- Topological error of the data
- Naming Convention
- Creation of Unique Id.
- Standard Unit in all data sets
- Essential Fields.
- Logical Checks
- Meta data

Gap Analysis

The purpose of this phase is to conduct analysis of the existing processes at the macro (process) and the micro (sub-process) levels in order to identify bottlenecks and recommend opportunities for the improvement thereof. In an ideal condition, when the processed data has no gaps, it can be directly used to estimate the exposure value by multiplying total area/length/count with unit replacement cost.

Gaps would be assessed on the following dimensions:

- *Missing Location Information*.
- *Missing structure or classification information*.
- *Missing replacement cost*.
- *No data available/obtained*.

RMSI will adopt the following approaches to fill the identified gaps in the collected and processed data:

Approaches to fill the gaps	
Remote sensing and GIS	Google Earth, Open Street Maps (OSM) or building clusters extracted from satellite imagery to fill the gap of location information
Field Survey	Outcome of vulnerability survey, interaction with builders or infrastructure developers, geotagged photos from surveys to fill the gap of structural types and replacement cost
Secondary data	Literature surveys, historical event damage reports, technical papers, review of web sites like the World Bank, UN, CIA fact sheets, etc. and other government resources like annual reports, DPRs, etc. to get the information, State PWD officials will be contacted and their tender information will also be referred.

Exposure Database Development

Exposure categories can be organized into 'aggregate' or 'site specific' to analyze the impact of hazards. Aggregate data are those where area and replacement cost of exposure elements will be summed at district/tehsil/city/town/village level while the site specific data are represented by a separate location (Longitude, Latitude) with separate replacement cost. A general rule for categorizing the data as aggregated or site specific is based on the level at which the location information is available.

The data received from various governmental and non-governmental agencies are generally in tabular format. The data lacks the spatial distribution of populations and the building agglomerations within the town/village. For hazards that are mostly localized in nature, it becomes pertinent to know the spatial distribution of building exposure within the town/village.

In order to fulfill the above-mentioned requirement, the latest available high resolution satellite images in public domain or from State department will be utilized. However, for the key cities of the state, we are planning to procure high resolution satellite images (less than 1m resolution) for developing detailed exposure database for city level risk analysis. Using these images, the building agglomerations for the entire state will be captured and will be classified into residential, commercial, and industrial clusters. Although these clusters may not give exact number of buildings. it will help distribute the aggregate data over these polygons based on the area ratio for calculating the affected exposure for site specific hazards. Figure 20 shows an example of the classification of built-up areas.

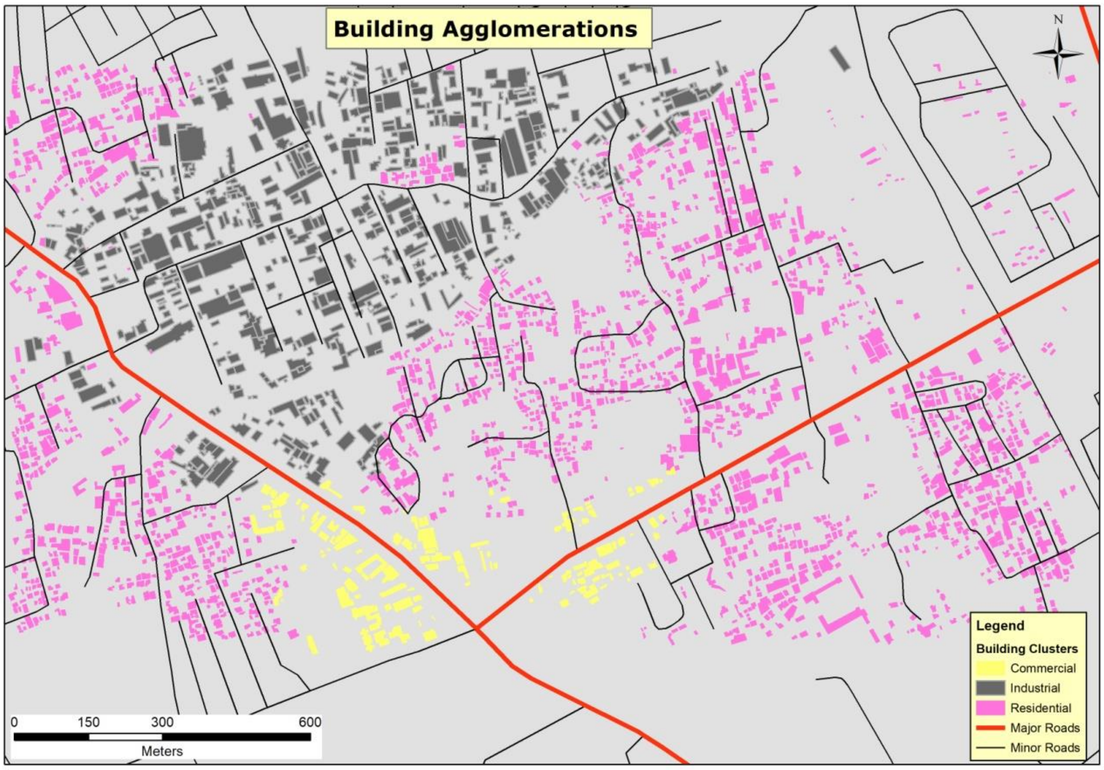


Figure 20: Example of building agglomerations data in Jammu

Components of Exposure, Required Attributes and Their Sources:

Demographic Exposure	
Population and Household	Source for Population and household data is the Census of India 2011. This data will be further projected for 2019. ***Directorate of Economics and Statistics, J&K*** will be contacted for updated data.
Residential, Commercial, and Industrial Building Exposure	For occupancy type Census is limited only to building counts at district level. For structure type, Census of India data will be used. The building location information will be compiled by creating a building agglomeration dataset. Unit replacement costs will be indirectly estimated using building authorization data and other methods. ***Department of Ecology, Environment and Remote Sensing, Kashmir, J&K Geo-spatial Data Centre, Jammu, SOI*** department will be contacted for acquiring these datasets.
Other Buildings	

Religious and cultural heritage	Religious places can be used as shelters at the time of disasters. For this, capacity in terms of number of people, location, and structure information will be collected. Tourism department will be one possible source for this data.
Agriculture/Horticulture	
Agriculture and Horticulture	Crops constitute one of the primary exposures while studying risk from the drought hazard. The impact of droughts in the state is primarily assessed by losses to crop production. Detailed agricultural/horticulture exposure database will be developed by collecting and organizing data from the ***Department of Agriculture*** and ***Department of Horticulture***. The key attributes would be area and tonnage of production over the years
Essential Facilities	
School	Data will be collected from the ***Census of India***, ***Department of Education J&K, U-DISE*** website and other state agency sources
Hospital	Data will be collected from the Census of India, **Department of Health and Medical Education J&K**, and other state agency sources
Public Buildings	
Government buildings, **Fire stations, and** **Police stations**	The common attributes that need to be captured are location, construction type, year of construction, cost of construction, and number of stories for buildings. RMSI has in-house fire station data for the entire state, which will be used and updated further. For police stations attributes like type, contact number, number of staff and their designations are important for DRM. For this, primarily state agencies data will be used other than desk research. State agencies are, ***Economics and statistics depart., J&K Police Department, Home Department, and General Administration Department, Government of J&K***
Utilities	
Electric Power systems	Data will be collected on generation plants, transmission towers, substations, and distribution lines and circuits. Jammu and Kashmir ***Power Development Department (JKPDD)*** will be contacted for this data.
Potable Water infrastructure **Waste Water system**	Potable water systems consist of potable water pipelines, water treatment plants, pumping stations, storage tanks, and tube wells. In this category, details of geographical locations and classification of various system components will be collected. For calculating the exposure value, replacement costs for facilities and pipelines will be collected. ***Public Health Engineering Department, J & K*** will be contacted for this. Municipal corporations will be contacted for GIS based data on potable water infrastructure and waste water system.
Communication Systems	RMSI will try to collect detailed information on the number of communication towers, the length of optical fiber cables, the number of communication stations, and the unit costs of the above-mentioned components for estimating exposure values of

	communication systems from the ***Department of Telecommunications, J & K.***
Oil and Gas Infrastructure	RMSI will collect details of pipelines, pumping plants, and tanks. The team will also collect the geographical locations and classification of various components. RMSI will do an analysis for the replacement costs for facilities and pipelines. The RMSI team will try to collect the data from ***ONGC***
Transportation	
Road Network	Road network information will be required in GIS format with information on types of roads as well as the construction material. In addition, corresponding unit replacement costs will also be collected for calculating the exposure value.
Railway Network	Railway network including rail tracks, tunnels, stations, and maintenance facilities will be considered and information on spatial distribution and estimated values will be collected. In addition, details on unit replacement costs will also be collected.
Bridges	Information related to bridges including location, structural type, length, number of lanes, number of spans, and skew angle will be collected. In addition to this, replacement cost by structural type and span will be collected. In case of missing information, we will resort to gap filling strategies
Airports	The airport infrastructure consists of control towers, runways, terminal buildings, parking, fuel, maintenance, and hangar facilities. The inventory data collected for airports will include the geographical locations with details of the above-mentioned components and their replacement costs.
All transportation data will be collected from *PWD, Government of J&K, Civil Aviation Department, Government of J& K, Jammu & Kashmir Geo-spatial Data Centre, Jammu, SOI*	

URBAN EXPOSURE DATA DEVELOPMENT

Overall approach to exposure development will remain the same. The various exposure elements discussed earlier will also be collected, processed as per the overall approach discussed above. The primary variation in exposure development for urban areas will be in estimating exposure more on a “site specific” basis as far as possible. This will help in more accurate risk assessment as well as in providing a better understanding of the impacts of various mitigation options in reducing the vulnerability of the exposure elements.

The primary exposure attributes that will need to be captured more precisely are:

- Location
- Structural type
- Construction Material
- Population Distribution by building agglomerations

For improving these parameters, the following approaches will be applied:

Foremost, efforts would be made to identify all the municipalities in close support of the Urban Development Department and using Census data. In this process, a few key municipal agencies would be identified and contacted. All the detailed exposure requirements will be provided and explained to them. Discussions will also be done on the importance of these data elements and how capturing them at a site specific level will make a difference and how it will benefit the urban areas in terms of a better understanding of the risks and risk mitigation steps required. For non-site-specific data, we will resort to a building agglomeration data creation process using satellite data.

Regarding structural information, the following two types of information will be needed.

- Structural types used for various types of buildings
- Percentage of every structural type amongst each type of building

The structural types and percentages will be inferred from Census data and data collected through questionnaire surveys as part of physical vulnerability assessment.

EXPOSURE DATABASE

Based on all the above exercises, a spatial exposure database will be created. At this point RMSI is flexible on the spatial format (SHP or PostGres/PostGIS/ any other). This database will be delivered back to the client as part of the risk assessment. Since local consultants will be involved at every stage of the development of the exposure, they will be able to maintain it post the completion of this engagement with RMSI. An up-to-date GIS based exposure database is a key for better risk assessment at all times.

Component 4: Vulnerability Assessment

Different schools of thought, including disaster management, environmental change research and development studies, have developed methodologies to assess vulnerability for different types of natural hazards, at different physical scales and for different purposes. The divide between disciplines and proposed methodologies is one of the main challenges within vulnerability studies Birkmann (2007)[25]. A balance of quantitative and qualitative methods is desired for effective vulnerability assessment. By making the necessary simplifications to obtain quantitative indicators useful to guide policy, key features of the complex phenomena of vulnerability may be lost. On the other hand, qualitative descriptions that increase the understanding of the phenomena have limitations with regard to effective communication and decision making.

Physical vulnerability assessment

Vulnerability assessment methodology under this project largely emphasizes on defining the damageability of specific structure typologies due to varying severity of hazard intensities. The choices of hazard intensity measures will be made based on common practice internationally as well as widely used in India. For example, the intensity of earthquakes may be represented by the Peak Ground Acceleration (PGA) and the Spectral Acceleration (SA), which have strong correlation with structural damage, while the intensity of flood will be represented by the depth of flood water at a specific location. There are several ways by which damageability can be defined. Most widely used methods include fragility and damage functions. In this project, fragility and vulnerability functions will be used for physical vulnerability assessment.

Vulnerability related data will be collected at the same time of the exposure survey for buildings and infrastructure. From the preliminary study, following Building Typology in Kashmir Valley may be deduced. This will be further refined in due course of time.

Table 10: Building Typology in Kashmir Valley

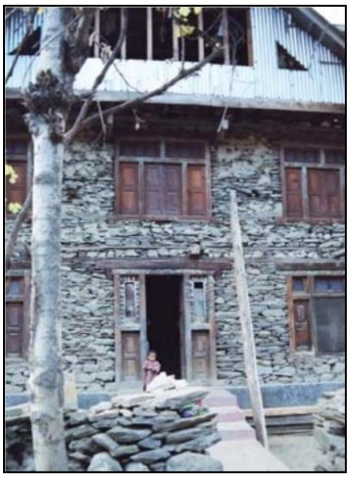
Material	Sub Types	Codes
Masonry (M)	Rubble stone (field stone) in mud/lime, mortar or without mortar (usually with timber roof) [A]	M(A)
	Massive stone masonry (in lime /cement mortar) [B]	M(B)
	Dressed stone (regular shape) masonry (in lime /cement mortar) [C]	M(C)
	Mud walls with horizontal wood elements [D]	M(D)
	Unreinforced brick masonry in mud/lime mortar [E]	M(E)
	Unreinforced brick masonry in mud mortar with vertical posts [F]	M(F)
	Taq construction [G]	M(G)
	Unreinforced brick masonry in cement mortar with reinforced concrete floor/roof slabs [H]	M(H)
	Confined brick/block masonry with concrete posts/tie columns and beams [I]	M(I)
	Unreinforced lime /cement (various floor/roof) [J]	M(J)

[25] Birkmann (2007) Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications Environmental Hazards 7 (2007) 20–31

Material	Sub Types	Codes
Structural Concrete (C)	Frame with unreinforced masonry [A]	C(A)
	Flat Slab structures [B]	C(B)
	Open Ground Structures [C]	C(C)
Steel (S)	With Brick Masonry partition [A]	S (A)
	With light weight partition [B]	S(B)
	Single story light metal frame structure [C]	S(C)
Wooden (W)	Dhajji dewari [A]	W(A)

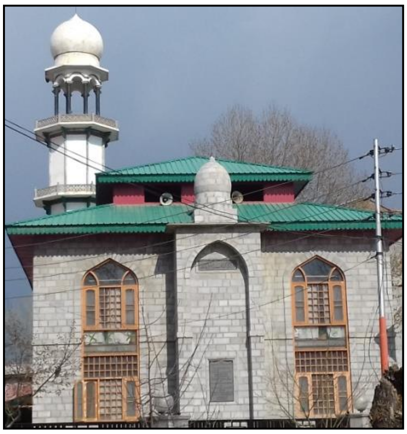
MASONRY (M)

Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof).



Massive stone masonry in (lime/cement mortar).

Dressed stone (regular shape) masonry in (lime/cement mortar).

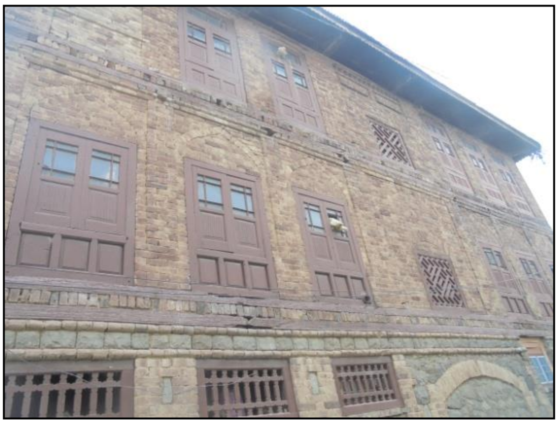



Mud walls with horizontal wood elements.

Unreinforced brick masonry in mud/lime mortar.

Unreinforced brick masonry in mud mortar with vertical posts/ columns

Taq construction



Unreinforced brick masonry in cement mortar with reinforced concrete floor/ roof slab

Confined bricks/ block masonry with concrete posts/ tie columns & beams

Unreinforced lime /mud (various floor/roof) with concrete floor/slabs

Structural Concrete (2)

Frame with unreinforced masonry

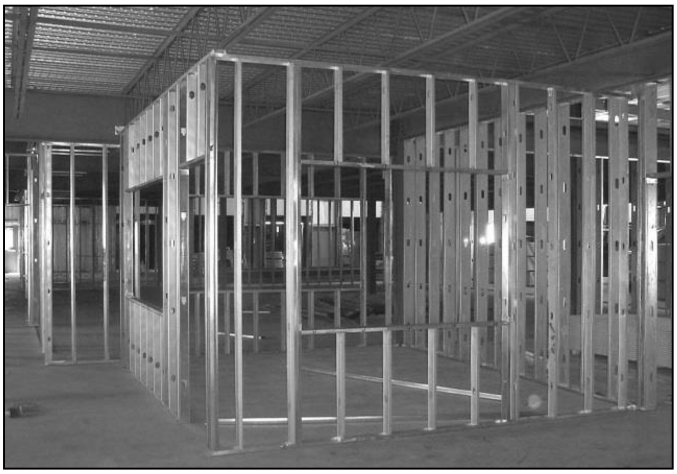
Flat slab structures

Open ground structure

STEEL

With brick masonry partition

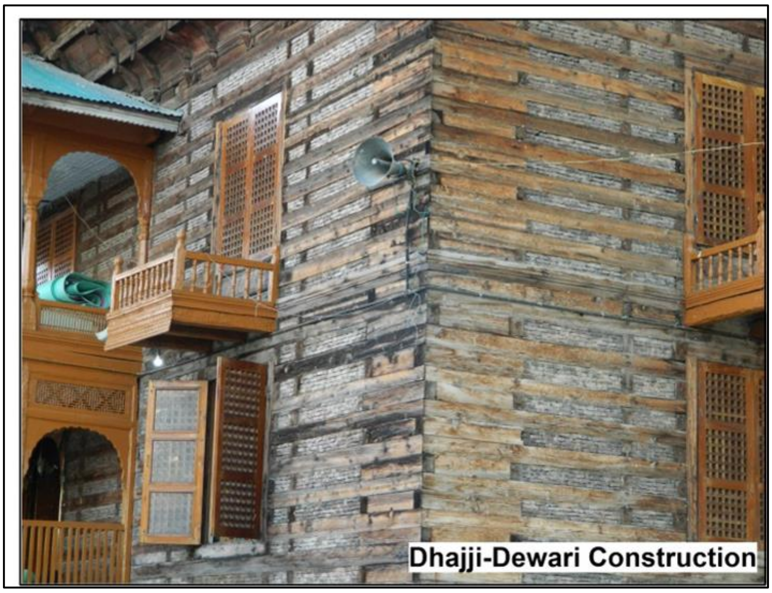
With lightweight partition



Single story light metal frame structure

WOODEN

Dhajji-diwari with lightweight sloping roof



It is envisioned that the vulnerability related surveys will be classified into 3 types, which are Basic Survey, Standard Survey, and Advanced Survey.

BASIC SURVEY

This is the simplest survey that is intended to cover large areas rapidly, which could even be done from motor vehicles. Within a short time, the survey team will obtain basic parameters of a large number of buildings and facilities in a large coverage area. In term of the vulnerability related data, the survey team will try to identify the following for each building:

1. Occupancy class (for example, Residential type, Commercial type, Industrial type, Religious & Cultural Heritage, School, Hospital, Government etc.)
2. Number of Stories (1, 2, 3, 4, …)
3. Basic Structural Type (wooden house, brick masonry, stone masonry, concrete, steel, etc.)

The purpose is to use this data set to improve the accuracy of the exposure model derived from Census information on population and housing. Many assumptions and criteria used for developing the exposure model can be checked and verified. The vulnerability team will also develop the correlation matrix between occupancy class and structural type, which will be used by the risk assessment team for risk analysis. Some correlations between other building parameters can also be studied.

STANDARD SURVEY

This is a sidewalk survey, meaning that the survey team goes from one building to another building while collecting the required data. At this level, more vulnerability characteristics of the buildings (and infrastructure) will be collected. Some of these are as follows:

1. Occupancy class (Residential type, Commercial type, Industrial type, Religious & Cultural Heritage, School, Hospital, Government etc.)
2. Number of Stories (1, 2, 3, 4…)
3. Basic Structural Type (wooden house, brick masonry, stone masonry, concrete, steel, etc.)

4. Detailed Structural Type ('Concrete' will be further classified into: concrete beam-column bare frame, concrete frame with masonry infill walls, slab-column frame. Similarly, for other types)
5. Number of Building Occupants during Daytime and during Nighttime (by interviewing people in the buildings)
6. Vulnerability characteristics related to earthquake risk (for example, presence of soft stories, arrangement of infill walls in the first story, flexible or rigid diaphragms, etc.)
7. Vulnerability characteristics related to flood risk (for example, wall material, floor material, foundation type, etc.)
8. Vulnerability characteristics related to fire risk (for example, roof material (flammable or non-flammable), building material (flammable or non-flammable), etc.)
9. Vulnerability characteristics related to other hazards relevant to this project
10. Photos with GPS information (geotagged photos)

The parameters describing 'Vulnerability Characteristics' for each type of hazards depend on the adopted risk assessment models, which will be finalized at this stage of the project. The project team is also working on defining an appropriate number of buildings, for each class, for this level of vulnerability survey.

Advanced Survey

This survey will obtain more detailed vulnerability information than that of the standard survey and will be conducted for a handful of representative buildings. The expert(s) will possess a structural engineering background and will be experienced in similar kinds of building evaluation. They will also have the knowledge of construction drawings and construction details of the buildings. For example, for a concrete building, he/she will need to know:

- Typical compressive strength of concrete, tensile strength of reinforcement steel
- Typical cross-sectional dimensions of columns & beams
- Typical steel reinforcement details
- Typical number of bays in two principal axes of the building, Typical span length
- Type of infill wall (masonry, wood panel, etc.), thickness of wall, connection to the bounding frame, strength of wall material, arrangement of infill panels.
- Foundation details (shallow or deep type, depth of footing, etc.)
- Roof details (truss or frame or concrete slab roof, the connection details between roof structure to the supporting structures, roof material, etc.)

The list will be different from one structure type to another. Detailed discussions will be made within the team and with structural engineering experts and authorities in Jammu and Kashmir to identify key structural parameters typical for building types in the study area.

Detailed computer models for some structural types will be formulated from these data to examine their vulnerability characteristics. This will be determined as the project progresses in due time.

The questionnaire for conducting physical vulnerability assessment is provided in Physical Vulnerability Survey Format.

DEVELOPMENT OF FRAGILITY FUNCTIONS

Some approaches exist for single elements (Leone et al.1996[26]; Faella and Nigro,2003[27]; Roberds, 2005[28]). For natural hazards risk zoning, it is necessary to develop specific vulnerability indicators for every element at risk, using the concept of fragility functions and appropriate definitions of relevant damage states (Pitilakis et al.2006)[29]. Fragility functions and damage states for every class of the elements at risk collected from the field surveys must be addressed. Vulnerability assessment, as a result, is not a standalone process, but will have to be planned coherently with the hazard and exposure analyses. The methodologies will be further refined as the project progresses.

Vulnerability assessment is a complex phenomenon, which needs a comprehensive understanding of the hazard and its interaction with the elements at risk. There are several ways by which damageability can be defined. The most straightforward way, (that also requires good data), is to derive vulnerability curves using actual damage data from past events. However, in most cases, past damage data may not be complete or comprehensive enough to derive all the vulnerability curves. It is proposed for this project that attempts will be made to collect as much damage data as possible, within the agreed time constraints, but the derivation of vulnerability curves will be made appropriately through engineering review and modification of similar available curves from other states or other relevant research.

This study will use available methods to quantify vulnerability for the selected elements at risk (population and assets such as buildings and infrastructure elements) for the key hazards of the State of J&K (earthquakes, floods, GLOF, landslides and snow avalanche, drought, forest fires, and industrial disasters etc.).

The vulnerability curves derived for various kinds of structures from those studies will be reviewed and selected for this project. The vulnerability curves from other countries cannot be used straight away. Detailed engineering reviews comparing the types of structures, their construction practices, design criteria, and subsequent failure modes when subjected to certain hazards will be made in order for our experts to make adjustment to the existing curves to suit the building and infrastructure stock in the State. Finally, the derived curves will be calibrated and validated with available damage data from the State.

[26] Leone, F., Asté, J.P. and Leroi, E. (1996). Vulnerability assessment of elements exposed to mass moving: working towards a better risk perception. In: Senneset, K. (Ed.), Landslides, Balkema, Rotterdam, 263-269.

[27] Faella, C. and Nigro, E. (2003). Dynamic impact of the debris flows on the constructions during the hydrogeological disaster in Campania-1998: failure mechanical models and evaluation of the impact velocity. Proc. of the Int. Conf. on "Fast Slope Movements – Prediction and Prevention for Risk Mitigation", Napoli. Vol. 1, 179-186. Pàtron Editore.

[28] Roberds, W. (2005). Estimating temporal and spatial variability and vulnerability. In: Hungr, O., Fell, R Couture, R. and Eberhardt, E. (Eds.) Landslide Risk Management, Taylor and Francis, London, 129-158.

[29] Pitilakis K, Alexoudi M, Argyroudis S, Monge O, Martin C (2006) Earthquake risk assessment of lifelines Bulletin of Earthquake Engineering 4(4):365-390 DOI: 10.1007/s10518-006-9022-1

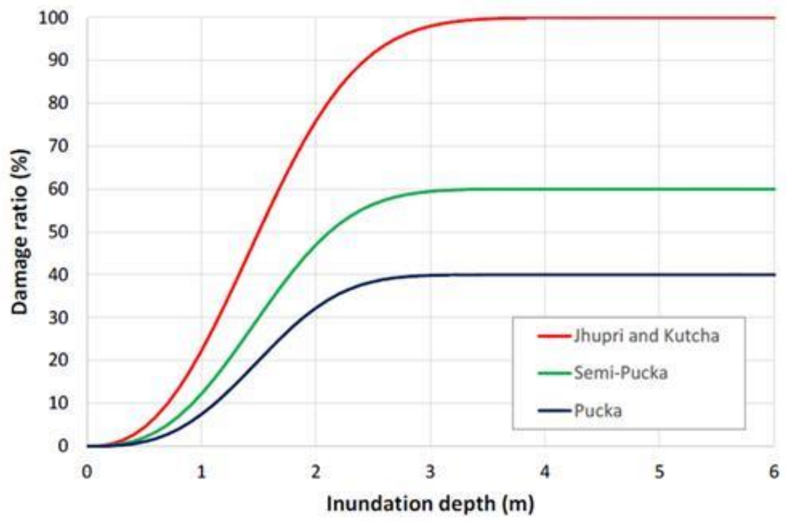


Figure 21: A typical example of vulnerability curves for residential building types due to floods

Actual past damage data can be obtained from engineering reports, scientific literature, as well as event reconnaissance reports. In addition, expert judgment will also be used for categorization of vulnerability functions for all elements at risk for different hazards to refine the damage function curves.

Many local institutions possess historical damage and loss data with regards to several recent disaster events such as earthquakes, floods, snow-avalanches, GLOFs, landslides, and droughts in India. Following would provide additional sources of information:

- EMDAT-CRED International database
- Earthquake catalogue possessed by Indian Meteorological Department and USGS
- Database developed by NGI under Global Disaster Hotspots study
- Database developed by ICIMOD under the MENRIS etc. (only for the region covered by HKH areas)
- GRIP database

Data accuracy could be of considerable concern in all the above stated databases. For example, EMDAT-CRED database provides countrywide information on disasters but minor events (events with 10 or less number of deaths) are not included in the statistics. So it is better the events can be compared in order to improve the accuracy.

Earthquake Vulnerability Assessment

Earthquakes are considered a major hazard in J&K. Special attention will be made in the earthquake vulnerability assessment under the project. The team will review the building stocks and in consultation with the client, will categorize the building stocks into buildings of different structure types for earthquake vulnerability assessment. Then the 3 levels of vulnerability data (described earlier) will be collected.

The results of these vulnerability surveys will form a basis for our earthquake engineering experts to derive vulnerability models. These analyses will determine the respective structural vulnerability to earthquakes that will be used for the building typologies. An exact nature of the simplified and detailed structural (vulnerability) assessment of each building typology will be determined, in consultation with the client and local engineering experts, post the inception period.

One of the most straight-forward approaches is to derive a set of the vulnerability curves that provide damage-intensity relationships. In the case of an earthquake, the intensity measure can be the Peak Ground Acceleration (PGA) or the Spectral Acceleration (SA) for buildings and infrastructure. The earthquake vulnerability curves can be derived based on actual earthquake damage data from past events along with recorded ground motion data, but while the damage data could be obtained from recent events where damage reconnaissance was conducted, the data on recorded ground motion where damage occurred has been sparse. Sometimes, simulated ground motion data are used to help derive vulnerability curves. Another approach for deriving vulnerability curves involves engineering response analyses of modeled buildings. This is where the level-3 survey is essential to obtain building characteristics and material properties typical for buildings and infrastructure in J&K.

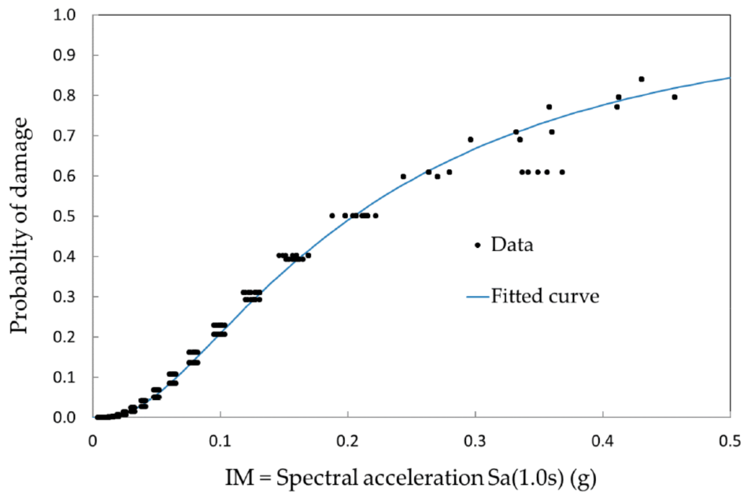


Figure 22 Example of the derivation of a vulnerability curve based on simulated damage data from scenario earthquakes, after Nollet et. al. (2018)[30]

Another approach for the earthquake vulnerability assessment follows the method used in HAZUS, a multi-hazard loss estimation software platform by the United States' Federal Emergency Management Agency (FEMA). HAZUS utilizes the well-known Capacity Spectrum Method for estimating damage from earthquakes. In this method, for each building type in J&K, capacity curves and fragility curves will be developed from engineering analyses. Earthquake intensity is represented by demand spectra curves. When the demand spectra are overlaid with the capacity, the points where the 2 curves meet represent building responses one can expect. This vulnerability and damage assessment is more complicated than the vulnerability curve approach explained in the preceding paragraph.

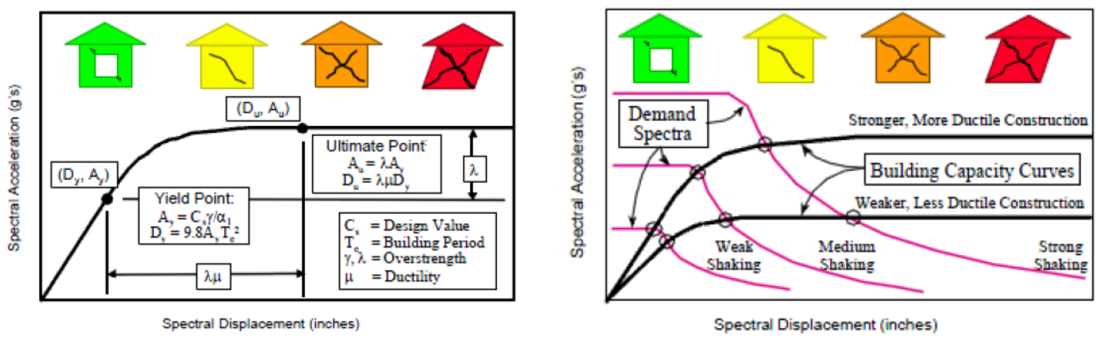


Figure 23 Illustration of the Capacity Spectrum Method: Example Capacity Curve (left) and Intersection of the Capacity Curves and Demand Spectra , after HAZUS Technical Manual

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30 Nollet, M.-J.; Abo El Ezz, A.; Surprenant, O.; Smirnoff, A.; Nastev, M. Earthquake Magnitude and Shaking Intensity Dependent Fragility Functions for Rapid Risk Assessment of Buildings. Geosciences 2018, 8, 16.

The project team will consider the availability of data and suitability of the building stock in J&K before deciding on an approach for this project.

FLOOD VULNERABILITY ASSESSMENT

In case of flood vulnerability assessment, there are methodologies established by flood experts and hydrologists based on depth-damage ratios. Dushmantha et.al., (2003)[31], Smith Di et.al., (1994)[32], Kang. et.al., (2005)[33] have developed damage depth ratio/ curves for floods suiting to diverse urban environment. However, these methods are developed for site specific conditions. These methods can't be applied on very large regional or country scales. In such situations, HAZUS (FEMA) guidelines[34] for flood damage estimation could be more appropriate to apply. The HAZUS implies depth damage curve developed by the US Army Corps of Engineers (USACE) and the USACE Institute for Water Resources. RMSI team has modified damage depth ratio suiting to conditions of India, Nepal, Timor-Leste, Yemen, Morocco and for several other countries, for flood vulnerability assessment. Similar attempts will be carried out to develop damage depth curve for the State of J&K. Further, the flood vulnerability assessment will define the grade of damage for various sectors.

LANDSLIDE VULNERABILITY ASSESSMENT

For landslides, an International Center for Geo-hazards (ICG) approach presented in Uzielli et al. (2008)[35] used for landslide sites will be scaled up to district level. The first order-second moment (FOSM) probabilistic framework assesses vulnerability for the elements at risk based on landslide intensity and spatial extent of landslide areas from the hazard evaluation. By considering epistemic and aleatory uncertainty, expert judgment can be used to evaluate uncertainty resulting from lack of data and the up-scaling from single site to district level. RMSI Team's experience in landslide vulnerability assessment in Nepal, Cambodia, Lao PDR and Myanmar will further strengthen the approach for landslide vulnerability assessment.

VULNERABILITY ASSESSMENT OF INFRASTRUCTURE

As discussed in the exposure section, there are several infrastructural exposure elements. Infrastructure such as roads and bridges are one of the key exposure element for maintaining basic functions of society. Damage to the infrastructure due to disasters such as earthquakes, floods and landslides not only will result in significant repair/reconstruction costs, but will also result in disruption for the public. The project team will address both the direct physical damage as well as the loss of services to infrastructure in J&K.

While detailed methodology of various infrastructure elements will be included in the vulnerability assessment reports, some examples of how the vulnerability assessment will be carried out are presented in this inception report.

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[31] Dushmantha et.al.,(2003), Modeling of Urban Flooding Including Underground Space; Institute of Industrial Science, the University of Tokyo 4-6-1 komaba, Meguri-ku, Tokyo 153-8505, Japan

[32] Smith Di et.al., (1994), Flood damage – A review of urban stage-damage curves and loss functions; Centre for Resource and Environment Studies, Australian National University, Canberra 0200, Australia
http://www.wrc.org.za/Knowledge%20Hub%20Documents/Water%20SA%20Journals/Manuscripts/1994/03/WaterSA_1994_03_0818.PDF

[33] Kang. et.al., (2005), A Grid Based-GIS Approach to Regional Flood Damage Assessment; Journal of Marine Science and Technology, Vol. 13, No. 3, pp.184-192.
https://www.researchgate.net/publication/257164592_A_Grid-Based_GIS_Approach_to_Regional_Flood_Damage_Assessment

[34] FEMA, HAZUS-Multi-hazard Loss Estimation Methodology
https://www.fema.gov/media-library-data/20130726-1820-25045-8743/hzmh2_1_fl_um.txt

[35] Uzielli, M., Nadim, F., Lacasse, S., Kaynia, A.M. 2008. A conceptual framework for quantitative estimation of physical vulnerability to landslides. Engineering. Geology 102:251–256.

Vulnerability Assessment of Roads

The project team will seek existing geospatial data of the road network from concerned authorities in J&K. This data set is crucial to the success of the analysis and needs to be available in the GIS format. In addition, the types of road surfaces (e.g., gravel, asphalt, concrete, etc.) as well as the classification of roads (e.g. urban versus rural roads or state highways versus local roads – these are based on the actual classification defined by the J&K government) will be needed for vulnerability assessment.

Roads can be damaged from natural hazards such as earthquakes, floods, and GLOF, while events like landslides and avalanches can block the roads and cause major disruptions. The vulnerability assessment methodology from HAZUS will be considered for roads subjected to earthquakes in J&K. In this methodology, physical damage to roads is caused by ground deformation; as a result, the earthquake intensity measure for the vulnerability assessment is defined by the Peak Ground Displacement (PGD). Damage states of the roads due to earthquakes are defined as follows.

Damage States	Ground Settlement
Slight/Minor	few inches
Moderate	several inches
Extensive	few feet
Complete	few feet

Although the ground settlement values specific to the damage states are provided by HAZUS, those values may not be suitable for J&K. The project team will conduct further study on the design and construction practices for roads in J&K before coming to a conclusion on the exact values of the ground settlement.

Because of floods, roads are damaged possibly from the amount of time they are under water. Only some types of road surface are damaged from floods. Concrete and asphalt roads are much more resistant to water damage than gravel or dirt roads. Research will be conducted on existing damage functions for roads due to floods in India or similar countries. Those functions will be adopted for J&K with appropriate adjustments to the design and construction practices in J&K.

In addition to direct physical damage, the other factors contributing to the vulnerability of roads is the loss of function when the roads are damaged. The HAZUS methodology utilizes restoration curves to define the amount of time the roads are not fully functional given different damage states. The figure below provides examples of the restoration curves used in the U.S.A. by HAZUS.

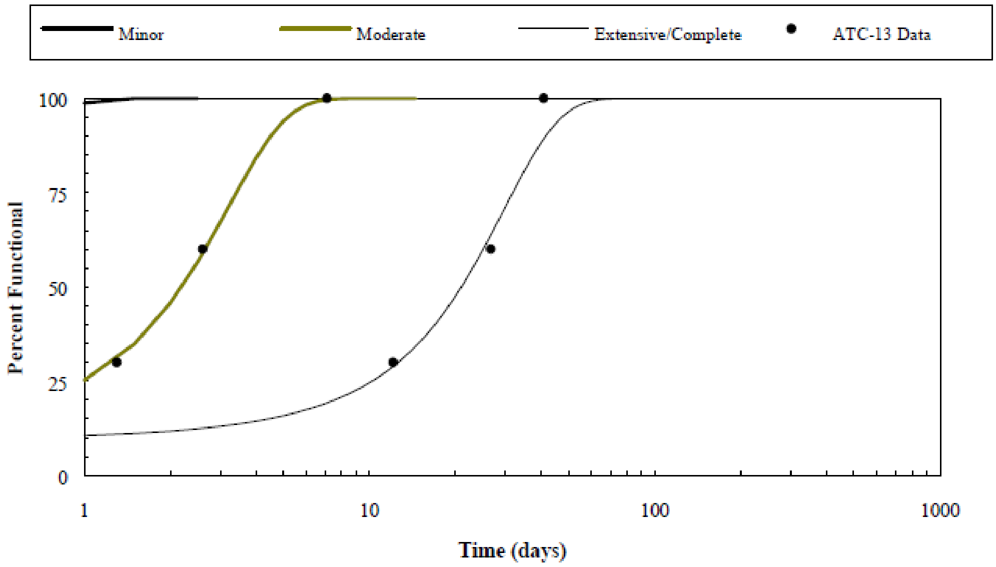

Figure 24 Example Restoration Curves for Roads, after the HAZUS Multi-hazard Loss Estimation Methodology

Nevertheless, since the HAZUS restoration curves were derived from data in the U.S.A., they will not be applicable directly for J&K and will be suitably modified for their applicability in J&K. Hence, additional research will be conducted to adopt these curves, with modification, for the project.

Vulnerability Assessment of Bridges

The vulnerability of bridges is typically a function of the geographic location of the bridges, classification of the bridges, and hazard intensity measures (e.g., Spectral Acceleration and Peak Ground Displacement for earthquakes and water depth and velocity for flood). In a similar manner of the case for roads, the vulnerability of bridges will be considered from two aspects, which are the direct physical damage and the loss of functions of the bridges.

While the exact classification of the bridges in J&K will need to be developed after consultation with authorities to understand the whole inventory of bridges and to obtain GIS data of those bridges, typical classification will be based on the following parameters.

- Structural design of the bridge (seismic versus non-seismic design)
- Number of spans (single versus multiple spans)
- Structure type (e.g., concrete, steel, others)
- Pier type (e.g., multiple column bents, single column bents, or pier walls)
- Abutment type and bearing type (monolithic versus non-monolithic, etc.)
- Span continuity (continuous versus non-continuous)

It should be pointed out that vulnerability assessment relies heavily on the availability of data. The project team will seek full support from the PMU to help acquire all relevant data from state government agencies. The HAZUS Multi-hazard Loss Estimation methodology will be adopted for the vulnerability assessment of the bridges in J&K. Modification of the parameters will be made to suit the types of bridges, their designs, and construction practices of J&K.

INDUSTRIAL HAZARD VULNERABILITY ASSESSMENT

Fire, explosion and toxic release scenarios will be considered for vulnerability assessment of various elements at risk in the industrial hazard prone zones. Temporal changes in population distribution inside the buildings and on road will be considered for vulnerability assessment. Weather, climate, wind direction, temperature, moisture, chemical and physical properties of hazardous substances will be the input parameters for vulnerability modeling. The approach will imply advance scientific models for vulnerability assessment.

AGRICULTURE/ HORTICULTURE VULNERABILITY ASSESSMENT

Based on drought hazard analysis and using major agricultural (e.g., maize, rice, black gram, green gram, etc.) and horticultural (e.g., apple, almonds, walnuts, pears, cherries, etc.) crops, crop vulnerability analysis will be carried out. Modeling vulnerability of crops to drought will involve establishing a relationship between the potential damageability of crop yield and different severity levels of the hazard. The vulnerability assessment will involve quantifying the damage susceptibility of each crop with respect to the hazard. Damage susceptibility associated with a given severity level of hazard will be measured in terms of a mean damage ratio (MDR) defined as the expected proportion of asset damaged as a consequence of the hazard expressed as a percentage. The curve that relates the MDR to the hazard is called a vulnerability function. The outcome of this exercise will be the development of crop vulnerability graphs/maps.

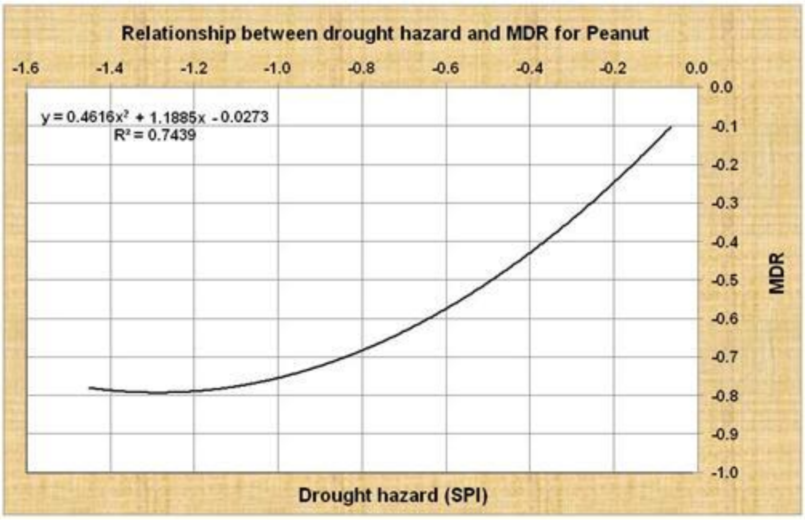

Figure 25: Vulnerability curve (and MDR) for Peanuts to drought hazard shown as an example.

Social vulnerability analysis

Social vulnerability is mostly attributed to the multiplicity of socio-economic and environmental factors. This vulnerability is accentuated in natural disaster situation. In the case of J&K, some of the key socio economic factors including ethnicity, and access to basic facilities and critical infrastructure during disaster events are important factors that can increase the vulnerability of the community. The terrain conditions and in some places the weather condition curb access to basic facilities and increase the vulnerability of the community.

We propose to have two different approaches to analyze the social vulnerability. First is to analyze based on social indicators including gender, age, income, ethnicity, literacy levels and education, occupation, skills, etc. The second approach is to carry out a spatial analysis of community clusters with reference to the infrastructure and critical facilities. The details of the methodology for carry out these two activities are detailed below. Social vulnerability analysis will be further analyzed against the hazards scenarios to identify the vulnerable communities to hazard.

Social vulnerability is partly an outcome of aspects of the social setup that influence or shape the susceptibility of various groups of the society to damages/losses during disasters and drive their ability to respond. It is, however, crucial that social vulnerability is not considered as a function of exposure to hazards alone, but also the sensitivity and resilience of the society to prepare, respond, and recover from disasters. Social vulnerability is a culmination of economic, demographic, and housing characteristics that influence a community's resilience to hazards.

RMSI will use census 2011 data for, social indicator based analyses. This will help in taking into consideration the entire population for analysis than considering selected sample. Census data shall be analyzed at village level. Some of the social indicators are not available at village level. In such cases, tehsil level data will be used and statistical methods applied to derive village level data.

There are several studies (Cutter et al., 2003[36], and Satu Kumpulainen 2006[37]) explaining the social characteristics that influence social vulnerability of the society. The socio-economic characteristics and historical hazard events will be reviewed to understand the socio-economic conditions of the communities. The following socio economic variables (Table 11) will be selected for vulnerability analysis.

Table 11: Social indicators selected for vulnerability analysis

Indicators	Description	Normalization
Population	More population means more people exposed to hazard	Population density (persons per sq. km)
Population age <6 and >60	Children and old people need support during evacuation in any emergency situation. After a disaster event also, this group needs more support in getting back to normalcy.	% population age <6 and > 60 to total population
Female headed households	Women and women headed households struggle more during disaster and recovery due to family responsibilities and lower incomes compared to males and households headed by males	% female headed households to total households
Widow, Divorcee and single woman	Widowed, divorcee and single women struggle more during disaster and recovery due to their social status in the society and due to lower incomes compared to men	% widows, divorcee and single women to total female population
Ethnic population	Ethnic population (SC and ST population) are socially and economically disadvantaged groups and may be impacted more during disasters and recovery	% Ethnic to total population

36 Cutter L Susan, Boruff J Bryan and Shirley Lynn W (2003), Social vulnerability to environmental hazards, Social science quarterly, vol. 84, No. 2 June 2003.

37 Satu Kumpulainen (2006). Vulnerability concepts in hazard and risk assessment, Geological Survey of Finland, Special Paper 42, 2006

Indicators	Description	Normalization
Economic status (based on house type)	More semi-permanent or temporary structures means a higher chance of getting exposed during any disaster	% total kutcha house to total houses
Access to critical facilities	Critical facilities include schools and hospitals	Number of population per schools/hospital

Notes: (1) Most of these indicators are used by several authors elsewhere (Cutter et al., 2003[38], and Satu Kumpulainen 2006[39]).

(2) The indicators will be finalized after conducting a reconnaissance survey on ground and consultation with the communities.

Social Vulnerability Index (SoVI)

The selected variables will be analyzed applying weightage to develop the social vulnerability index across the State at village/tehsil level. This index provides information on vulnerability distinction of different communities, and along with hazard scenarios will allow intervention by way of suitable mitigation and prevention options. SoVI will prove invaluable for the State and district agencies towards planning and decision-making, as it illustrates variations in social vulnerability across the state by reflecting the uneven capacity of disaster preparedness and response.

The following steps will be followed for SoVI analysis:

1) The secondary data on the identified indicators pertaining to the same period will be collected and used as input variables to calculate the vulnerability index.
2) The variables will be normalized as percentages, per capita values, or density functions.
3) Accuracy of the data sets will be verified using descriptive statistics.
4) Weightages will be applied to social indicators using AHP method and cumulative score will be derived, which is the SoVI.
5) The SoVI will be mapped using objective classification in the maps illustrating areas of very high, high, medium and low social vulnerability.

Community based survey

While the census data provide broad based vulnerability variation across the State it needs further drilling down to understand community specific needs and issues specific to disaster response and management. Towards this, we will carry out socio economic survey at household level. The sample strategy including sample size is further explained in Survey Plan Details section

Following are some of the key aspects we will be considering while conducting household survey

1) Reconnaissance survey by social expert, DM expert and representatives of nodal agency

[38] Cutter L Susan, Boruff J Bryan and Shirley Lynn W (2003), Social vulnerability to environmental hazards, Social science quarterly, vol. 84, No. 2 June 2003.

[39] Satu Kumpulainen (2006). Vulnerability concepts in hazard and risk assessment, Geological Survey of Finland, Special Paper 42, 2006

2) Drafting of questionnaire and customization of a mobile based application for carrying out the survey. The mobile based app will help in providing geographic distribution of sample which can be overlaid on hazard maps to make further vulnerability inferences, reduce time to carry out survey, reduce error of data entry as there will be validation mechanism during data capturing.
3) Pre-testing of questionnaire by social expert in selected locations and make necessary changes if required in the questionnaire
4) Consultation with the nodal agencies to explain the observation captured
5) Presentation to nodal agency on statistical sample selection and sizing of sampling, reaching an agreement on the sample size for the survey. The presentation will also include the rationale of selected questions detailing the kind of inferences that can be derived from the survey
6) Survey planning and mobilization of resources to conduct survey.
7) Actual survey, monitoring of data collected on daily basis and routine backup of survey data collected.
8) Data quality check, summary table preparation and report writing.

Application of SoVI to the State, Districts, Tehsils, and Hotspots

RMSI intends to use SoVI to quantify the social vulnerability in a comparative metric that facilitates the examination of the differences in social vulnerability among different geographical units. This index will provide information on the variation in vulnerability between various communities, classify tehsils into high, medium and low categories, and thus help to design interventions with appropriate mitigation and prevention activities. SoVI would prove valuable to the lower administration units and state administration in planning and decision making as it would graphically illustrate the geographic variations in social vulnerability by reflecting the uneven capacity of preparedness and response. This will also indicate the differential ability of recovery across the geographical units.

Specific consideration for social vulnerability of communities in hilly terrain

As part of the spatial analysis of community clusters with reference to the infrastructure and critical facilities, GIS based analysis will be carried out using location information of the critical infrastructure and terrain. As terrain curb the access to basic and critical facilities for a mountain region it is important to analyze the access to facilities along with terrain rather that distance.

Social vulnerability will be analyzed against the hazards to identify the hotspots to prioritize interventions.

Casualty (Mortality) Vulnerability Functions

The methodology for estimating casualties from earthquakes is well-defined in the HAZUS multi-hazard loss estimation methodology. The number of casualties, broken down by the severity levels, are estimated based on the states of damage buildings experience, number of occupants in the buildings, and time of the day when an earthquake takes place. The standard parameters defined in HAZUS will need to be adjusted based on the building stock of J&K.

For the other hazards, such as floods, landslide, and GLOF, the methodology for casualty estimation is less known. The project team will consider combining the output from the building damage function with building inventory, and social vulnerability estimates to quantify casualty status. The output of the casualty model contains estimates of four classes by general occupancy and time of the event for all the hazards considered for the study. The casualty severities range from "**Severity 1**: First aid level injuries not requiring hospitalization" to "**Severity 4**: Instantaneous dead or mortal injury." We will estimate the impact of the disaster on indoor and outdoor population separately.

For developing social vulnerability function, time series data on event and mortality are essential. For developing a statistically significant damage function curve at-least 15-20 event data would be required. The team will work with the PMU for collecting this data. Where there may not be adequate event data, the team will try to modify and adopt damage function curves of similar geographies.

Economic vulnerability assessment

Economic vulnerability assessment will be done for J&K to capture total economic impact of the potential losses of the building stock and other critical infrastructure for each hazard and its intensity, livelihood costs and impact in the sectors such as agriculture, industries and services. For this project, the economic vulnerability assessment will rely on the survey of economic activities and will also use the outputs of Component-3. The economic vulnerability assessment will be undertaken using the economic survey, vulnerability of infrastructure and critical facilities, other economic assets; upgraded forecasting and risk assessment produced from other components of this project.

The economic vulnerability assessment will include the survey of economic activities in the designated areas of coverage (types of business and livelihoods by sectors; income levels, economic assets supporting the business and livelihoods like roads, bridges, hotels, restaurants, hospitals, agricultural infrastructure, etc.; government income and budgetary allocations; debt; taxes; potential emergency expenditure; and other economic variables).

Expert opinion of the infrastructure, building, and social vulnerability assessment experts and the modelling experts would be considered to determine the probable disaster scenarios and their potential impacts on the economy. Probabilistic disaster scenarios can be used to estimate various potential financial and economic impacts, ranging from a minor localized disaster to a state-wide-catastrophe. This will include potential damages and losses across sectors and the financial requirement for recovery.

Interviews with key relevant sources of the State of J&K and desktop/literature review (such as Governments' expenditure, fiscal resources availability, government's direct and contingent liability including recovery and reconstruction of public infrastructure, and relief spending for the households) will be conducted to better understand economic vulnerability and social security nets.

Based on the analyses, a detailed report will be prepared highlighting the methodology and assessment procedure, limitations, scope for advancement and a set of recommendations for economic vulnerability reduction, financial cost of the measures and their budget implications. In addition, GIS based layers of each exposure elements discussed above including metadata will be shared in DRDB.

Component 5: Risk Assessment

Risk information, being an important component for DRR, provides a critical foundation for managing disaster risks across a wide range of sectors.

Risk is the uncertainty of future losses – if we perfectly know a future loss, it is simply a cost, not a risk. Risk is uncertain with regard to the causative hazard event, its location, date and time of occurrence, and the degree or amount of damage to assets caused by the hazard event, and what losses accrue due to the damage.

Probabilistic model-based risk profiles will be developed for the state at district and tehsil levels as well as for four urban, rural, and tourist hotspots each. Estimation of losses to various exposure elements will be expressed in terms of Event Loss Table (ELT) for every exposure type at these locations, Average Annual Loss (AAL), and Loss Exceedance Probability Curves (LEC) for various return periods. The model will also assess social impacts in terms of casualties, subsistence requirements, and shelter, food and water needs assessment along with estimating indirect economic losses in terms of losses to community livelihood etc.

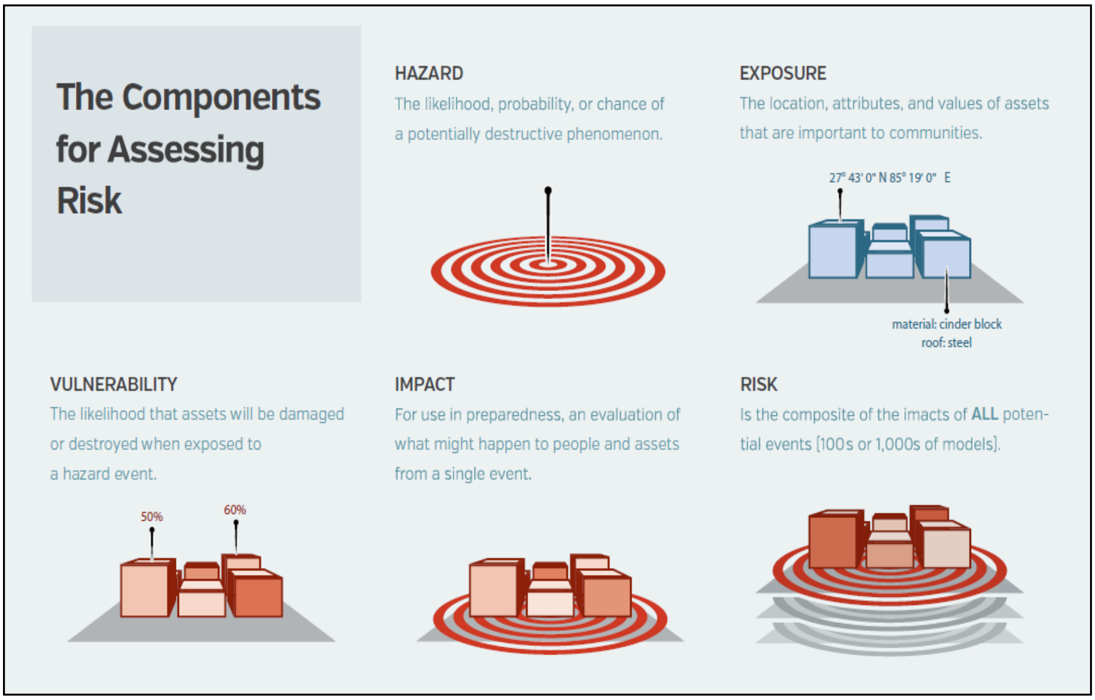

Figure 26: Example of components of risk assessment (Sourced from GFDRR report "Understanding Risk in an Evolving World", 2014)

Development of risk profile

Risk is the uncertainty of future losses – if we perfectly know a future loss, it is simply a cost, not a risk. Risk is uncertain with regard to the causative hazard event, its location, date and time of occurrence, and the degree or amount of damage to assets caused by the hazard event, and what losses accrue due to the damage.

PROBABILISTIC MODEL-BASED RISK PROFILE

Development of calibrated risk parameters

Development of the calibrated risk parameters is an important task for the risk assessment. The assessment of risk starts with the estimation of losses to various exposure elements for every historical and stochastic event for which hazard will be assessed. These will be used to generate an Event Loss Table (ELT) for every exposure type that has the total loss for that event and the associated rate of occurrence. Two most important risk parameters generated using an ELT are Average Annual Loss (AAL) as shown in figure below and the Loss Exceedance Probability Curves (LEC). LEC curves will be used to report the losses for the following return periods: 10, 20, 50, 100, 250, 500, and 1000.

AAL is calculated using the following equation:

AAL (j) = $\sum_{i=0}^{n} L(i,j) * R(i)$ Equation 1

Where:

L (I,j) = Loss for event 'I' and exposure type 'j'

R (i) = Rate of occurrence of event 'i'

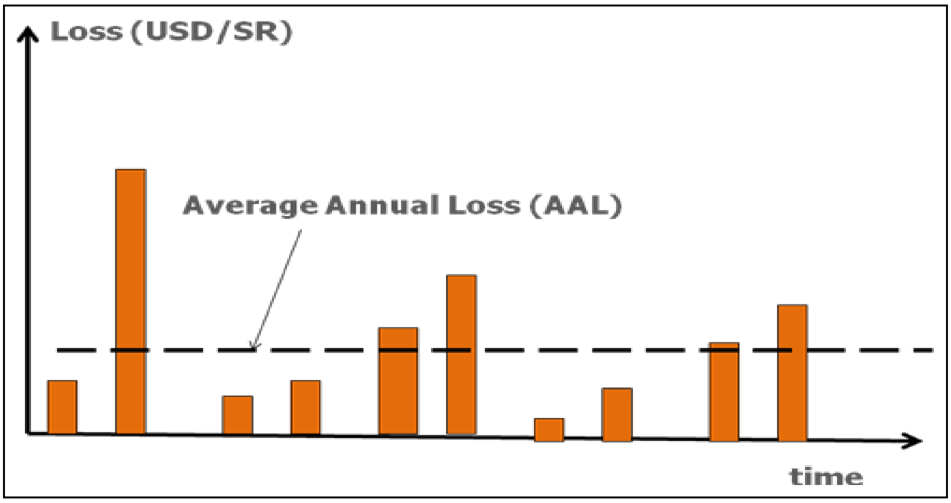

Figure 27: Sample of AAL

Since risks are uncertainty, they must be stated probabilistically, as shown in below Figure, which is expressed in terms of a Loss Exceedance Curve (LEC, also sometimes termed an Exceedance Probability, or EP curve). LEC is a graphical representation of the probability that a certain level of loss is exceeded in a given time period.

The abscissa of the LEC is loss, while the ordinate is the frequency or probability of loss (for most losses, probability and frequency are equivalent). Small losses occur frequently, and large losses occur rarely, so the curve slopes downward to the right. The probability weighted average of all possible losses is termed the Average Annual Loss, or AAL. AAL is equivalent to the average per year of all future losses. In this study, losses are presented in terms of AAL and LECs, with the emphasis on some key points on the LEC, such as the "25-year loss" or the "100-year loss". By "25-year loss" we mean a loss that will occur on average about once every 25 years, given what we know about hazards, exposure, etc. Such a "25-year loss" in actuality has a 1/25 = 0.04 probability of occurrence in any one year. Similarly, a "100-year loss" has probability per year (or "per annum", pa) of 1/100 = 0.001.

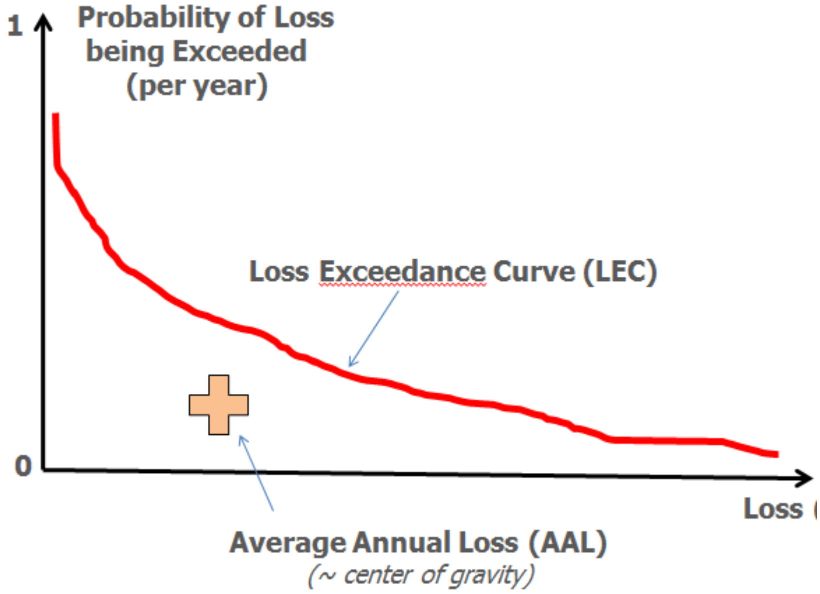

Figure 28: Loss Exceedance Curve

Estimation of economic/financial loss and damage

Risk analysis can be categorized into following two broad categories: Economic Loss and Social Impact.

Economic Loss: Economic Loss has two main components; i) Direct loss which happens due to the direct impact of the hazard on structures and crops, and ii) Social loss which is the consequential impact of the hazard.

Direct Loss: Risk is the uncertainty of future losses and loss is the decrease in asset value due to damage, typically quantified as the replacement or repair cost. Loss estimation is the last step in risk analysis.

Direct Loss is a function of the damage ratio derived in the vulnerability module translated into currency loss by multiplying the damage ratio by the value at risk.

L = MDR(j,h) * Value_At_Risk(j) Equation 2

Where:

MDR(j,h) = Mean Damage Ration for an exposure type 'j' at a specific hazard intensity 'h'

Value_At_Risk(j) = Replacement cost of the exposure type 'j'

Once the losses have been computed for every event, an ELT will be generated for every exposure type that has the total loss for the events and the associated rate of occurrence. From the ELT, financial losses will be derived for different stakeholders from different financial perspectives. This will be computed at model resolution and then aggregated to consolidated levels for each class of exposure. Using the ELT, AAL and LEC will be generated.

For crop loss, the direct losses can be computed using the MDR and crop production in terms of economic value or crop yield, acreage and current year prices.

Direct loss will be calculated for every scenario event and for all types of exposure at risk like residential, commercial, industrial buildings, essential facilities, infrastructure, and agriculture. This will be done for each asset class at each location where the treatment of location differs from cyclone and associated hazards and asset class to asset class. Losses will then be aggregated at ward level if boundary data is available.

L(i, j) = MDR(j,i,h) * Value_At_Risk(j) Equation 3

Where:

MDR (j,i,h) = Mean Damage Ration for exposure type ‘j’ at a hazard intensity ‘h’ for event i

Value_At_Risk(j) = Replacement cost of the exposure type ‘j’

Determining risk for different exposure elements

Based on the above approach, losses will be computed for all the exposure elements discussed in the exposure section. These elements are categorized into two broad categories, namely, Aggregated Exposure and Site Specific Exposure.

Aggregated Exposure: Aggregated exposure will be treated differently for different hazards. The reason for differentiation is that earthquake is a regional hazard whereas hazards like flood, landslides are site specific hazards. Therefore, for estimation of losses for earthquakes having exposure aggregated at administrative level will suffice, whereas for flood and landslide it is important to know in which part of the study area the exposure lies. For this purpose, the aggregated exposure will be further disaggregated into built up clusters of various types of exposure elements.

The losses will be estimated at the built up area clusters for various exposure types based on the area overlap of the cluster with the hazard grid. The losses will be estimated only on the area of the built up cluster that is impacted.

The losses will be estimated at the built up area clusters for various exposure types based on the area overlap of the cluster with the hazard grid. Figure below depicts how the area overlap will be estimated. The polygons with violet outline represent the built up cluster and the filled polygons represent the flood depth grid. The losses will be estimated only on the area of the built up cluster that is under the depth grid.

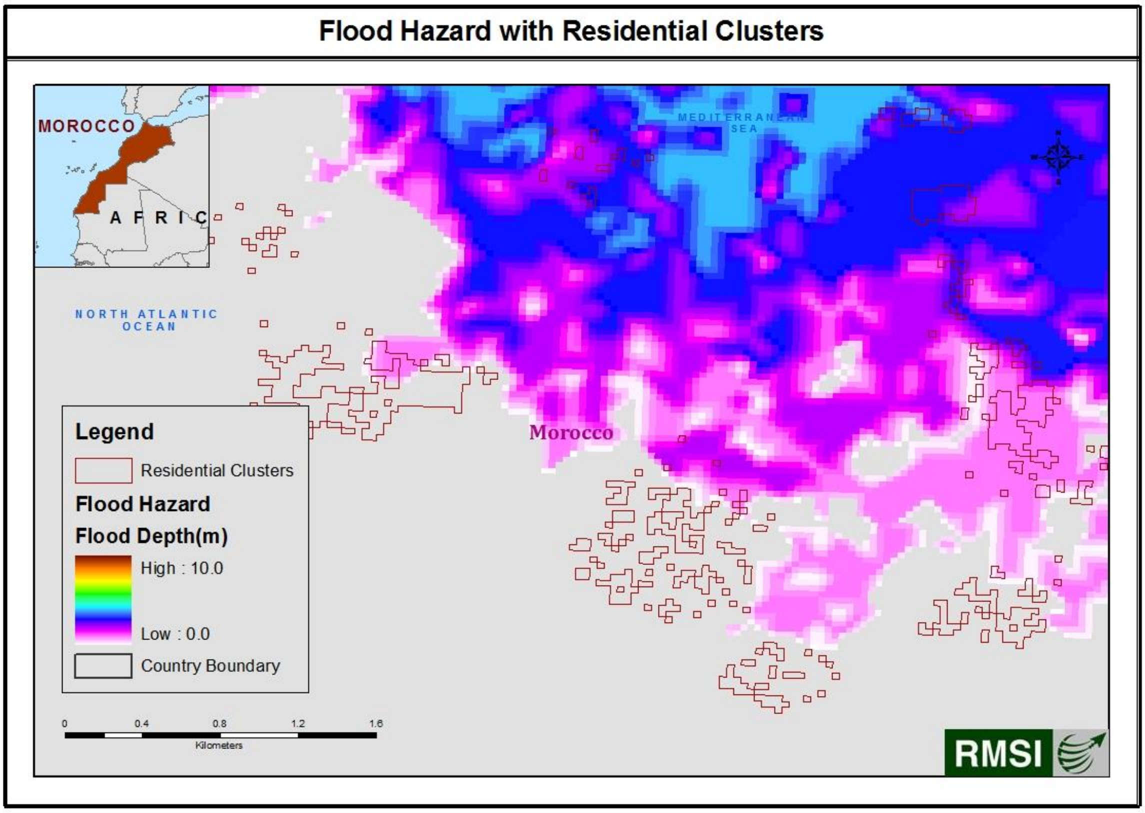

Figure 29: Example of residential clusters overlap with flood hazard

Site specific exposure: Site-specific exposure will be further divided into two types – point location type exposures like airports, ports, electric power stations, bridges, railway stations, etc. and line type exposure like roads, railway lines, electric transmission lines, pipelines, etc.

Point Type Exposure: For point type exposure elements the loss computation will be done at the point location level based on the hazard intensity estimated at the location for various stochastic events. AAL will be computed for every location of the exposure element. Therefore, loss for these elements will be available at location level as well as aggregated at various administrative levels. The generic equations for loss and AAL for point type exposure elements are presented below:

L (i, j, k) = MDR(j,i,h) * Value_At_Risk(j,k) Equation 5

Where:

L (i, j, k) = The loss from event 'I' for exposure type 'j' and location 'k'

MDR (j,i,h) = Mean Damage Ration for exposure type 'j' at a hazard intensity 'h' for event i

Value_At_Risk(j,k) = Replacement cost of the exposure type 'j' and location 'k'

AAL at any location will be calculated using the following equation:

AAL (j, k) = $\sum_{i=0}^{n} L(i,j,k) * R(i)$ Equation 6

Where:

AAL (j, k) = AAL for exposure type 'j' and line element 'k'

L (I,j,k) = Loss for event 'i' and exposure type 'j' and location 'k'

R (i) = Rate of occurrence of event 'i'

Line Type Exposure: The treatment for line type exposure will be different from point type exposure. Since line type exposure elements are spread over a long area, so a single hazard value cannot be used to estimate the losses to them. Since a line type exposure element is made of a set of smaller segments, so the loss will be estimated at the centroid of every segment. The losses of all the segments will be summed up to estimate the loss to the line exposure element. Figure below shows an example of the segments for Railways lines at which the losses are estimated.

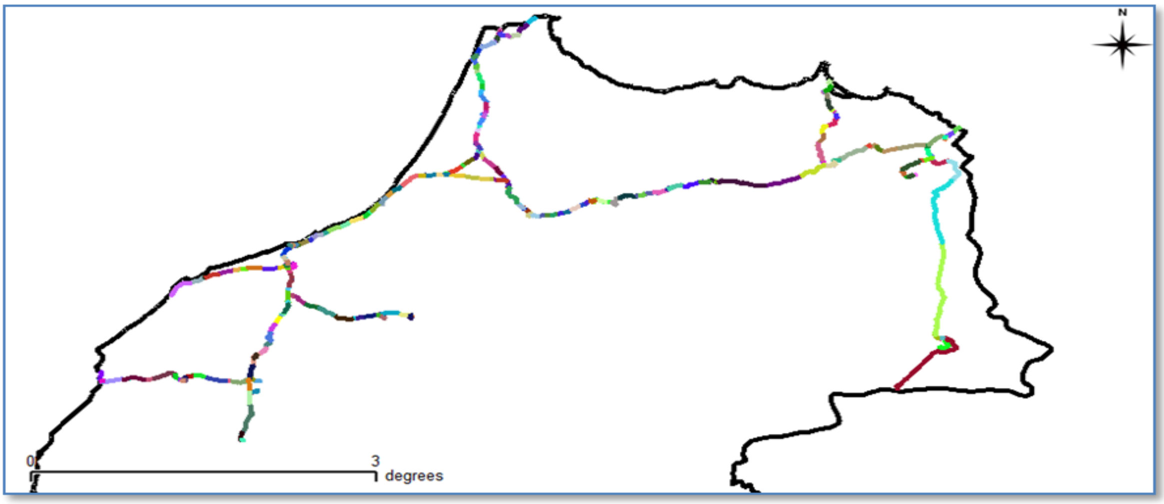

Figure 30: Example of loss estimations for line-type exposure

The generic equations for loss and AAL computation for line type exposure elements takes the following form:

L (i, j, k) = $\sum_{l=0}^{m} MDR(j,i,h) * Value\_At\_Risk(j,k,l)$ Equation 7

Where:

L (i, j, k) = The loss from event 'I' for exposure type 'j' and line element 'k'

MDR (j,i,h) = Mean Damage Ratio for exposure type 'j' at a hazard intensity 'h' for event i

Value_At_Risk(j,k,l) = Replacement cost of the exposure type 'j' and line element 'k' and segment 'l'

AAL at any location will be calculated using the following equation:

AAL (j, k) = $\sum_{i=0}^{n} L(i,j,k) * R(i)$ Equation 8

Where:

AAL (j, k) = AAL for exposure type 'j' and line element 'k'

L (I,j,k) = Loss for event 'i' and exposure type 'j' and line element 'k'

R (i) = Rate of occurrence of event 'i'

Susceptibility based risk profile

For the hazards where hazard susceptibility maps are created, an exposure overlay analysis will be performed to identify the exposure elements that are at higher risk. Risk maps will be created for every exposure element based on this overlay analysis. These risk maps will provide the population, buildings and infrastructure at various risk levels starting from extreme to low.

Social Impacts

Risk Assessment (Social-casualties, shelter needs, subsistence requirements)

Social impact is the quantification of susceptibility of population to mortality and injuries, and needs like shelter, food, rescue/evacuation, contingency planning, etc. in the event of a disaster. Potential mortality and injury scenario will be generated for key hazards. For this, adequate number of hazard events and mortality and injury information at state, district, and tehsil levels is required.

Casualty

This risk model will combine the output from the building damage assessment with building inventory, and demographic data to quantify casualty status in the region. The output of the casualty model will contain estimates of four classes by general occupancy and time of the event. The casualty severities will range from "Severity 1: First aid level injuries not requiring hospitalization" to "Severity 4: Instantaneous death or mortal injury."

Casualty rates for all hazards will be generated based on the recent data from disasters in J&K State. Available casualty data from various national and international sources will be reviewed to assess the types and causes of both human and livestock casualties due to various hazards in the country. During the review of the data we will try to capture casualties that are primarily due to a single hazard. For example, in case of floods the data review will include both only flood events and heavy rainfall events that cause significant inland flooding. For heavy rainfall events, rainfall-related casualties will be distinguished from flood-related casualties by causes, such as deaths caused by tree fall will be considered rainfall-related, while drowning will be generally flood-related. Moreover, the review will try to identify the people trapped in damaged or undamaged buildings.

All the casualty information will be organized by casualty type (human/livestock), hazard, entrapment, gender, age, and casualty level. This information will be used to develop the casualty rates for various hazards and casualty type (human/livestock) by casualty levels, gender, age and entrapment. If enough data is not available to build casualty rates, then data for the state from other countries similar to J&K state will be used for developing casualty rates. These rates will also be validated against the casualty rates used in other open models like HAZUS.

The casualty estimates will be aggregated at different administrative levels. This will help governments at various administrative levels to plan for saving lives. It is important to consider gender and age factors for any preparedness plan for the community. Using risk assessment outputs on physical and social losses, RMSI team will identify probable threats that may need timely and coordinated response to protect lives, property, infrastructure and environment. The estimation of response and rehabilitation needs particular focus on people who need food, shelter, rescue/evacuation and first aid, etc. RMSI team will also provide intervention requirement that will help the disaster management authorities for implementation in near future.

Subsistence Requirements

Subsistence requirements arising during disaster events are driven by displaced households. Displaced households are a function of damage to residential building stock and utility service outage (electric power and potable water). The utility service outage will be estimated based on the restoration of the electric sub-stations and potable water pipelines from the indirect loss model.

Shelter, Food and Water Needs Assessment

The dilapidated household estimates when combined with demographic data and social behaviors will give a quantification of the number and composition of the population requiring both short-term and long term shelter. The methodology for short and long term shelter needs will be based on statistics from recent events in the J&K state with similar infrastructures and demographic patterns.

Population and demographic data will be reviewed to understand the distribution of the population across genders and various ethnic, age and income groups. In addition to this, data available from recent disasters will also be reviewed to understand the socio-economic and behavioral factors that define how people respond to disasters differently-when they seek shelter and when not, who would seek shelter and who would not, etc. This will help in the development of weights for various groupings of population. The weights would be validated against similar weights used in other open models like HAZUS. These weights when applied to the number of displaced households will give an estimate of the number of people looking for short and long term shelter.

Estimation of indirect economic losses:

Indirect losses of disasters are losses resulting from the consequences of physical destruction. Indirect losses are incurred as a result of interruption of business in the codependent sectors (sectors that are dependent on agriculture, and allied sectors, industry and service sector), relocation of population and resources brought about by the droughts, etc.

Often the largest loss following a natural disaster is business interruption. Business interruption is not only important for immediate financial reasons but also for more intangible considerations as ongoing stakeholder confidence, reputation, brand value, etc. The methodology discussed here calculates Business Interruption as a function of damage to buildings and infrastructures. The following time dependent losses will be calculated: Relocation expenses that estimate the expenses that occur due a business not able to operate in is pre-disaster location, Loss of proprietor's income estimates the loss that the businesses have due to non-operation, and Loss of rental income estimates the losses to commercial complexes that are vacated due to the disaster event.

To calculate these, it will be important to capture the building recovery time and loss of function. Recovery time is a function of availability of resources and labor to carry out repairs. The Time Element vulnerability function will help in the estimation of these. Effort will also be made to account for various types of variations by identifying the key resources required for recovery and trying to find some values for them based on historical information coupled with expert judgment and inputs from open source models alike HAZUS, CAPRA, etc.

Separate relations will be established between damage and repair and replacement costs, annual gross sales, contents value, relocation costs, rental costs and income by sector as all of these get impacted to a different extent for the same amount of damage. This will be done based on the study of the behavior of various sectors during historical disasters in the state of Jammu and Kashmir, coupled with expert judgment and inputs from open source models alike HAZUS, CAPRA, etc.

For infrastructural elements, restoration curves will be developed based on an approach similar to the development of vulnerability curves described above. When infrastructural damage is applied to the repair and replacement cost and associated restoration curves, an estimate of the loss to the infrastructure and the elapsed time for their restoration is obtained. These restoration curves will be compared to the corresponding curves for similar structures used in open source models like HAZUS.

The development of risk analysis for the three priority/critical sectors – agriculture and allied sectors, industry and service sector will be considering the availability and applicability of the model for the State of J&K. Based on our preliminary study, there are no separate econometric models at the State level in India that can be used to estimate the Gross State Domestic Product (GSDP). Therefore, the risk analysis for the three priority/critical sectors will use the direct results from risk models and assessment of the buildings and infrastructures as a basis for analysis, and will be combining with the economic vulnerability assessment.

Component 6: Development of a Digital Risk Database (DRDB)

The primary objective of developing this Web-GIS based DRDB for the State of J&K is to provide a mechanism for streamlining DRM and DRR activities at all levels. This will provide all state agencies with a centralized repository of hazard, exposure and risk information that could be readily used for mitigation and developmental planning as well as for risk communication.

DRDB will be developed using open source technologies on top of the Geonode platform. It will have various levels of access as well a slew of functionalities for decision making. DRDB will have Dashboard for navigation and the key components of Risk Atlas, Risk Analyzer and Hot Spot Analyzer.

Key Aspects of the DRDB

The following are the key aspects of the DRDB:

- **Centralized database**: the DRDB will ensure that the most up-to-date GIS layer based information on the hazards being modelled under this consultancy (earthquake, landslides, floods, flash floods, GLOF, avalanche, forest fires, fire hazard potential w.r.t. built environment, drought, climate variability and climate change & industrial hazards), exposure elements (including buildings, infrastructure, critical facilities, forests, tourist destinations, population and demographics etc.), and vulnerability and risk layers are available at a centralized place to enhance and facilitate DRR and DRM efforts in the state.
- **Sharing outcomes of the study:** this will ensure that stakeholders involved in DRR and DRM processes and planning such as first responders (including the SDRF/NDRF, police, home guards, fire, and security and paramilitary forces), state level policy planners and disaster management specialists along with researchers, engineers, and other non-government or quasi government entities involved in the DRM process have on the fly web-access to the GIS information discussed in the previous point so that it may be of practical help in carrying out various aspects of disaster risk mitigation, relief, planning, etc.
- Provide a **platform for deterministic/ probabilistic risk assessment** to understand the inherent and often changing risks from various hazards
- Provide **assistance in disaster planning**, preparedness, response and recovery – this is the dynamic aspect of the application that will allow users to see the impact of imminent or just occurred disasters on various assets at a State location thereby helping in response activities. The application will also provide ground truthing abilities to support recovery operations, followed by inputs for improving planning and preparedness.
- Provide a common platform for all the agencies a common data and information sharing platform to ease and enhance operation for planning preparedness and response,
- Use the DRDB for **training and decision support** where users can create different scenarios choosing different hazards and hazard-levels.

- Administrator will be able to **create partitioning subsystem** for different administrative layers to allow processing on that partition for disaster planning and mitigation. This will help in customization of the use of database depending on individual stakeholder requirement
- Provide users the option to **quickly share data and maps** with other stakeholder users.
- The proposed DRDB architecture will be **scalable and compatible** assisting in dynamic decision making.
- DRR and DRM stakeholders will be able to find and disseminate electronically **shortest routes for evacuation, availability of safe shelters,** etc. using the DRDB

KEY FEATURES OF THE WEB-GIS DRDB

Dashboard: The Dashboard provides a quick overview of the risk to a senior level administrator for his/her state/UT. It summarizes the overall risk (Figure 31) of the state using a Risk Meter and then provides an idea of total exposure and exposure at risk to the hazards including population. By clicking on any of the above summaries the user can view the details under the summary as shown in Figure 32.

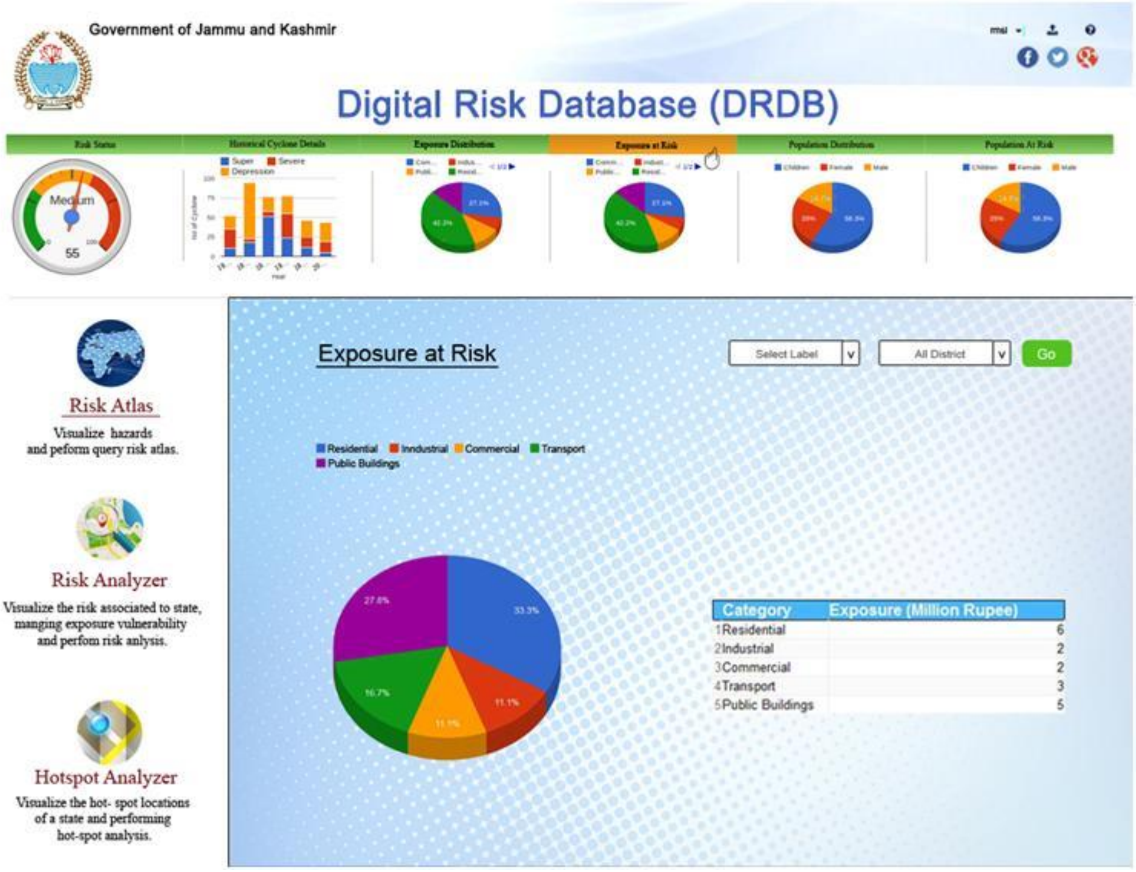

Figure 31: DRDB dashboard

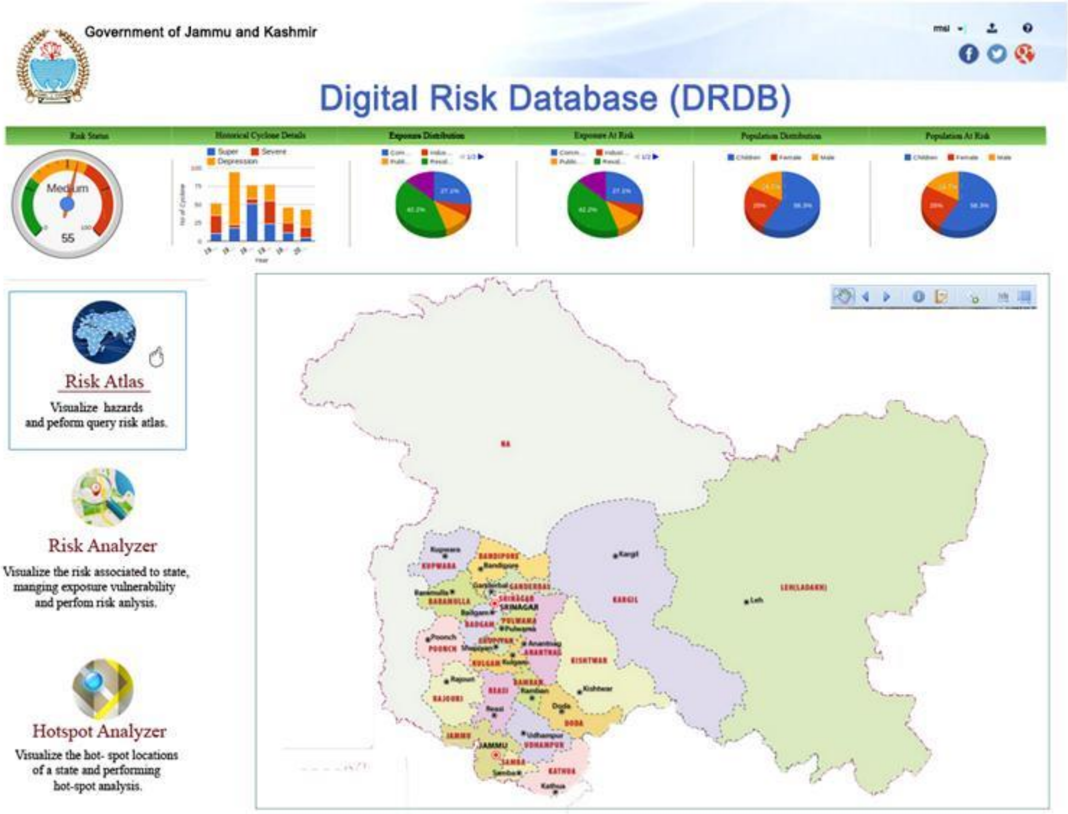

Figure 32: DRDB risk atlas view

Key Components

The three key components of DRDB are:

11. DRDB Digital Risk Atlas
12. DRDB Risk Analyzer
13. DRDB Hotspot Analysis

The precompiled DRDB Digital Risk Atlas is a ready reckoner to understand the hazards and risks in any part of the State. It provides risks in terms of population at risk, buildings and infrastructure assets at risk and estimated damage and loss from various possible hazard scenarios, both deterministic and probabilistic, for the hazards covered under this consultancy.

The DRDB Risk Analyzer (Figure 33) provides capability to decision makers to update the risk atlas and analyze state as well as district and taluka level mitigation options. Within the Risk Analyzer the functionality has been implemented to update the exposure dataset and estimation of losses to all exposure elements using the hazard and vulnerability functions. It also helps decision makers to generate Hazard, Exposure, and Risk Analysis Reports at State, District, Tehsil, City and Village levels.

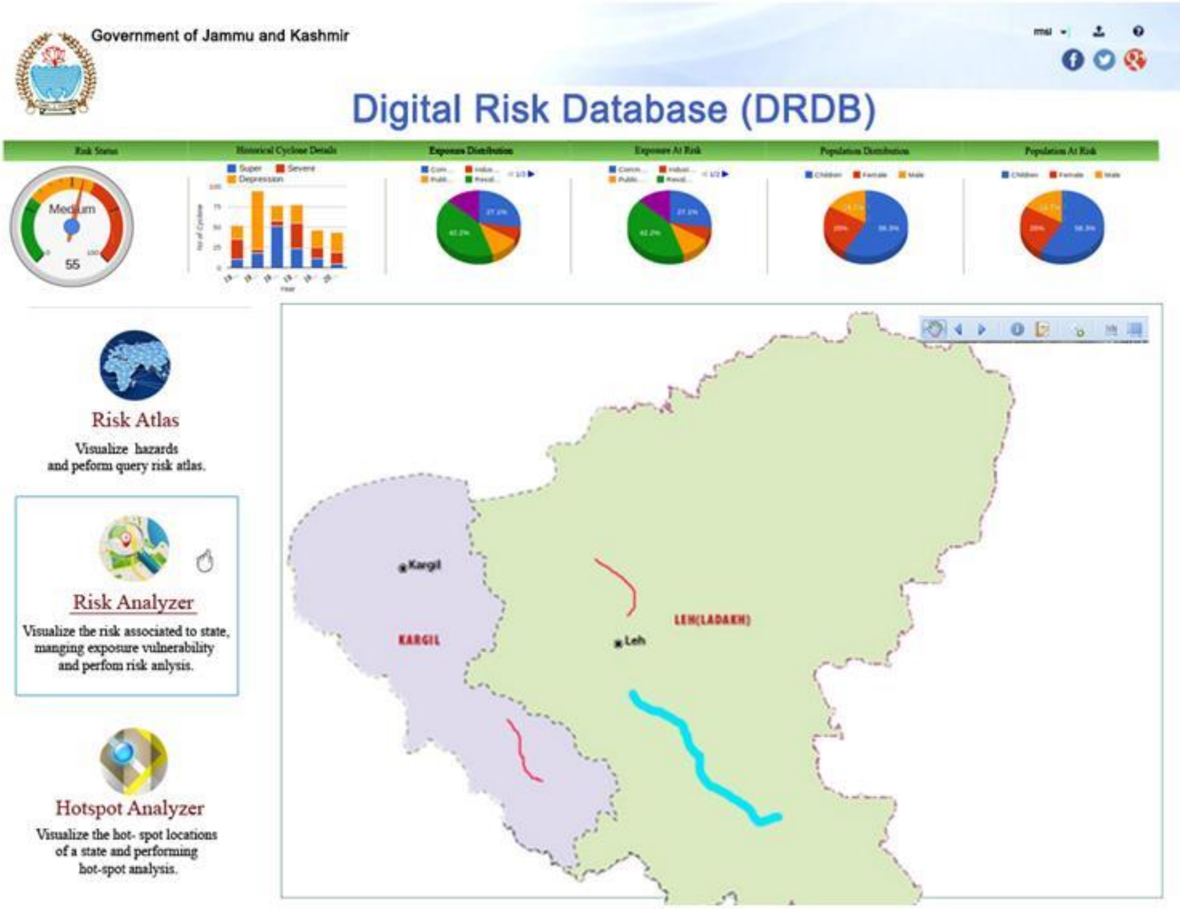

Figure 33: Risk Analyzer screen

The Hotspot Analyzer provides decision makers tools to conduct a micro-level risk analysis of tourist spots, cities, communities at high risk' at village/ward level, and other infrastructure at risk and provides options to generate "**Hotspot Risk Analysis Reports**" that help streamline risk mitigation and preparedness. This provides ability to update exposure at building level, update exposure data related to all infrastructure as well crops grown in the area of interest. Based on the risk analysis, population exposure, evacuation planning, shelter planning, evaluation of mitigation options could be performed.

Key Functionalities

Following are functionalities that will be supported by "DRDB" through the above described Key Components:

- Administrator will be able to publish and share the data
- Administrator will be able to give permissions to registered user or any other users to edit the layer
- The administrator will be able to cache the layer for better performance
- User will be able to use all mapping functionalities as given below.
    - Pan
    - Zoom in and out
    - Previous view and next view
    - Attribute Info tool
    - Measure distance, and area
    - Map search

Following are the list of layers that will be visible to the users:

- Satellite imagery as the standard base data layer by integrating either Google maps or Bhuvan maps or any other dataset suggested by the client
- State, district, tehsil administrative boundaries
- Hazard layers for earthquake, landslides, floods, flash floods, GLOF, avalanche, forest fires, fire hazard potential w.r.t. built environment, drought, climate variability and climate change & industrial hazards
- Building & infrastructure layers including building aggregated at suitable administrative level, religious places, roads, bridges, railway lines, water ways in lakes and embankments, tourism, etc.
- Critical infrastructure including hazardous material storage structure and power plant.
- Displaying locations of shelters, safe houses and evacuation routes
- Critical and high risk facility including administrative headquarters, police stations, hospitals, schools, and sensitive installations.
- Utilities including water pipelines, electricity distribution and telecommunication networks etc.
- Land use land cover
- Soil types
- Ecological data
- Social data including total population by village/block/district, density of population, population by gender, children, aged and disabled.
- Listing of social capital organizations
- Economic data based on livelihood, occupational patterns (per census classification), people below poverty lines, livestock, GDP by district (if possible) and replacement values.
- Vulnerability layers
- Risk layers
- Ability to generate various types of reports that help use the data and information available to DRDB in an easy way. This includes exposure at risk report, risk analysis report, hot spot analysis reports, benefit cost analysis reports for various mitigation options, economic risk analysis report, etc.

Tiered User Levels

While the categories of the users will be finalized in consultation with the client, broadly following types of users are expected to be accessing the DRDB.

- Administrator
- Exposure Manager
- Risk Analyzer
- Planner
- Operator
- Guest

Administrator will have privileges to upload GIS data, modify the style and publish the layer into the website as well as manage users and user levels and access rights. The administrator can also change the configurations to ensure the smooth running of the "DRDB".

Other users will have access to DRDB functionalities that are relevant to their roles. Everyone will be able to view the layers (maps) in the DRDB and can perform all the GIS functionality through simple user-friendly tools.

Proposed system design and architecture

Following are the functional and system architecture of the DRDB.

Functional Architecture

DRDB will be a web GIS-based application developed by customizing Geonode Platform. Geonode is an open source platform provided by World Bank for managing and publishing geospatial data across the web allowing users to easily modify Geonode and share interactive maps over the web.

Following are the functionalities, which make Geonode the most suitable framework for this project.

- Genode supports both the vector and raster data including ESRI shapefile, satellite imagery and Geotiff format
- It supports all popular base layers including Open Street Map, Google satellite and Bing.
- It can be installed on Linux, Windows or OSX
- Geonode look and feel can be customized based the user requirements.
- Geonode is highly secured. Guest users are only allowed to view maps. But administrator can give permission to edit the layer or to manage the layer to registered or specific users.
- Geonode internally uses the Geoserver for map rendering. Geoserver can pick the maps from the database server called postgresql. The user can take regular back of the data in postgresql and recover it in case of accidental loss of the data. The user can also implement replication on postgresql server which intern can be used load balancing.
- The Geonode supports social network. The maps can be shared using Facebook, Twitter and Google +.
- All the layers in Geonode can be cached so that layers are rendered fast to the user.

Figure 34: Geonode satellite imagery

The web based “DRDB” will be developed by customizing the Geonode framework to suit the requirements of multiple stakeholders from the State. The administrator will be able to publish both the raster and the vector data into the database.

DRDB framework will also use ajax based JavaScript libraries called Open layers and GeoExt to give additional functionality to the users. Geonode will internally connect to Geoserver and Geowebcache to render the map on the “DRDB”. The map data will be stored along with its attribute inside the PostgreSql server and inside the folder on the server. Geoserver will connect to the PostgreSql server to get the map data and returns the map to the user.

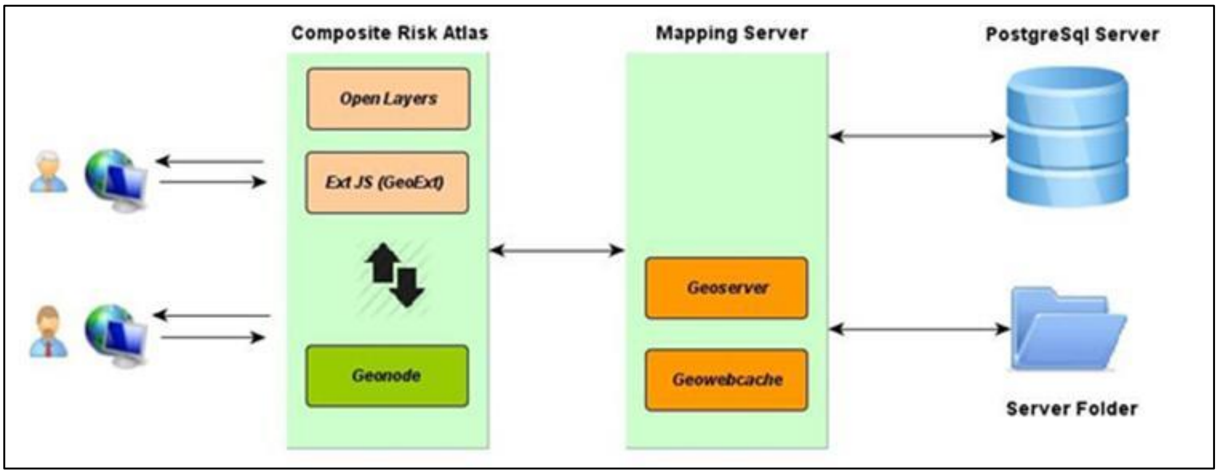

Figure 35: Functional Architecture

System Architecture

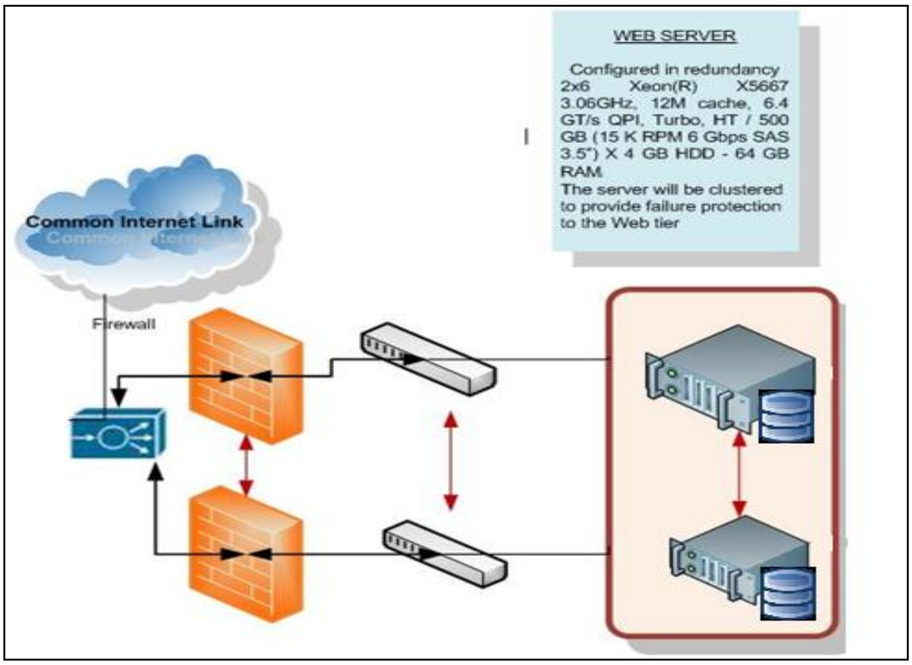

Figure 36: System Architecture

The system architecture will consist of two redundant web servers clustered to provide failure protections along with the firewall. Geonode will be installed on both these servers and data from Postgresql will be replicated in both servers.

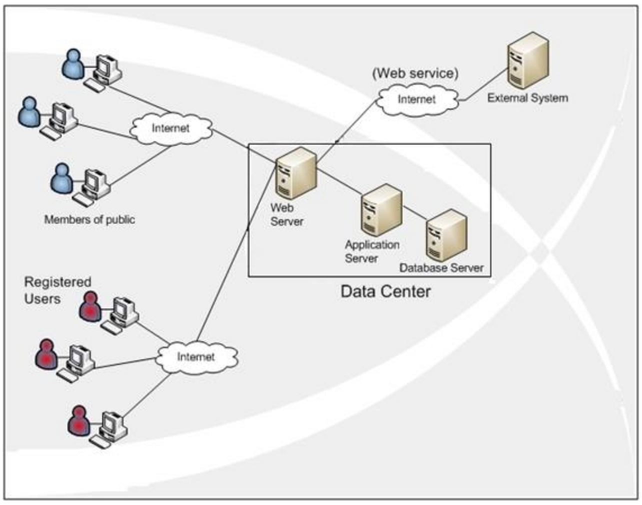

Figure 37: Network Architecture

To maintain high availability, clustering mode solution is proposed and will help in 24x7 availability of the DRDB.

High Availability

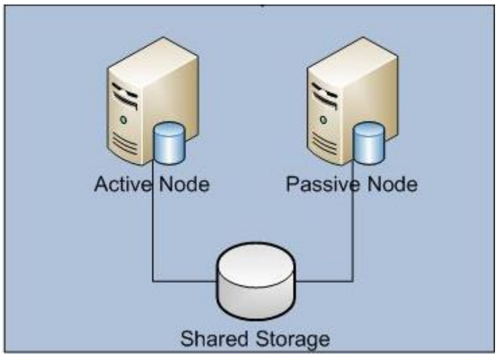

Figure 38: Redundant server

The application architecture will be a centralized and web-based application with high-availability architecture with mirrored servers at each of the tiers. Following steps will be taken to ensure the high availability of DRDB:

- **Load balancing** will be done at each tier. The application architecture provides load balancing in situations of peak load to maintain the service levels of application.
- Database Server and Web Server are configured and connected via Network Load Balancer for high availability.

High Scalability

The application architecture can be scaled up to growing future usage in terms of transactional volumes and number of users.

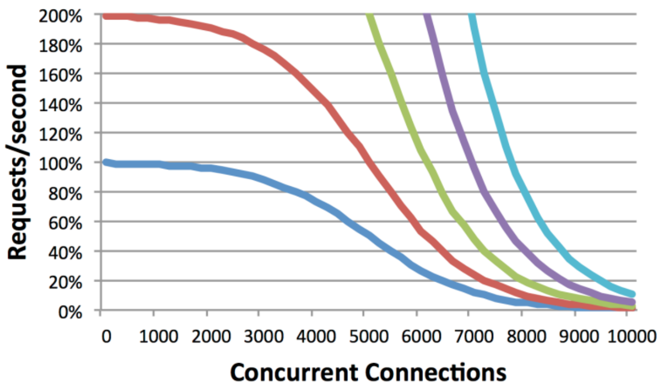

Figure 39: Load on web server

The application will support spatial data interoperability and supports multiple browsers (IE, Chrome, Safari & Mozilla Firefox)

Initial release for exposure data capture

An initial version of the DRDB with only exposure data capture and editing facilities will be made available to help the state agencies capture asset data wherever no information is available with the agency in digital format. This will help in creating the digital data for the agency assets in a centralized environment, as agency resources distributed across the state will be able to input their information from the place of their work directly into DRDB. This could only be done once the state provides database servers for DRDB installation.

For a same purpose an Exposure Data Capture Mobile App will also be made available that will help capture the data directly from the field and input it straight into DRDB. In case some agency within the state already has a similar mobile app, RMSI will integrate it into the DRDB framework.

Integration with existing systems

Due to flexible and scalable architecture, DRDB will be easy to integrate to any existing system including the State-level DSS.

Quality Assurance

Following are the quality assurance practices that will be adopted to ensure the quality of “DRDB”:

- A Quality Plan will be prepared, which will bring together in one document the different aspects related to quality that will apply throughout the project
- A Software Quality Analyst (SQA) for the project will be defined who is independent of the project management and will report to Senior Management and Quality Manager. SQA will be involved in ensuring all processes are followed as defined in the plans and all project activities are following Quality practices.
- Quality Reviews, typically artifact and code reviews will be performed to assess the products / deliverables of the phase prior to delivering products

The following tests will be run to ensure the quality delivery of the final DRDB

- Regression testing will ensure that the all the components of DRDB are integrated well and work to fulfill the requirements of the stakeholder users.
- Functional testing will ensure that the all functionalities and behavior of the website are as expected.
- Performance testing will ensure optimal response time of DRDB on higher loads.

- GUI based testing ensures all that all the user inputs are validated and appropriate messages are given to user before storing the data in the database. It will also ensure that pages are linked properly with in website.
- Security testing will ensure that DRDB is highly secure and is not prone to any known security attacks, for example, sql injection, hacking user name and password.
- User acceptance testing is the final stage of testing, which will be performed by stakeholder users to make sure that DRDB meets all their requirements and standards. This has been elaborated on further below.
- Audits, which fall into two categories – scheduled audits and snap audits will be performed as appropriate to ensure that quality standards are met. Both types of audits are formal with an audit report being produced
- Finally, regular tracking and status monitoring will be performed by RMSI team Senior Management to ensure that project deliverables are being delivered on time and as per requisite quality standards

Beta version installation

Before putting the DRDB into production environment, a beta version of the solution will be installed and tested by a team of key users nominated by client and RMSI to undergo User Acceptance testing as described in the next section.

User Acceptance Testing and Final Installation

The purpose of User Acceptance Testing is to establish whether the DRDB developed meets the expectations of the stakeholder users. This will involve carrying out of following activities: Deployment of system at the operation environment for testing by its users, Execution of user acceptance test cases by the users, and Reporting of defects/issues by users and fixing of the same by RMSI. The output of this step will be issuance of acceptance certificate by the client and will be succeeded by final installation of the DRDB.

Technical user guide and decision making guidance documents

Technical user guide: This would be a comprehensive user manual which explains all the functionalities of the risk atlas with screen shots of the applications demonstrating the task and output. The fundamental principle we will follow while developing the manual would be to ensure the demonstration and text are self-explanatory and a person with basic understanding of GIS and DRR can perform the required thematic map preparation and analysis. The user guide will have a separate section on the data inventory in the system along with details of source, attribute information, vintage. We assume that the user will have a basic understanding on concepts of GIS and computer operations and this excluded in the manual.

Considering the key objectives of DRDB, there will be a separate section to explain with illustration on building various scenario maps, and specific cases in terms of damage and loss potentials. In addition to this, the user will have the capability of carrying out economic evaluation of damages which is essential for developing appropriate mitigation measures.

This manual will also have a tutorial explaining step by step tasks to be carried out for some of the key analysis and thematic map preparations.

In addition, the manual will have separate section on Modeling the main hazards under this consultancy, physical and social vulnerability assessment, hotspot identification, shelter and evacuation planning, habitat planning and population relocation.

Decision making guidelines: This document will have fundamentals used for various decision making specific to DRR and DRM. Based on these fundamentals the document will also explain steps and guidelines for prescribing long term and short term State specific mitigation measures required for vulnerable groups. While prescribing this we will also take into consideration the existing National and State specific rules and regulation of development and conservations.

Some of the key guidelines that will be touched upon in the decision making guidance document will include processes and steps to be carried out for hazard, vulnerability and risk analysis, hot spot analysis etc. This will be explained with required charts and exercises etc.

Component 7: Development of an Integrated Operational Forecasting System

The proposed IOFS will be able to perform risk analysis for Flood, Flash Flood, Avalanche, Drought risk and will enable generation of hazard, risk and vulnerability maps for the State on real time basis. IOFS will have its own homepage and the DRDB homepage will also have a link to the IOFS so that users have a seamless experience in handling all DRR and DRM related activities.

On the backend, IOFS will share the same database with DRDB so that all updates to exposure data in DRDB are available to IOFS.

Event forecasting in IOFS is preliminarily developed based on precipitation forecast. The level of accuracy is thus a function of the accuracy of the precipitation forecast, the DEM used, and the level of details on exposed elements available in the DRDB. Therefore, IOFS forecasts will differ from the observed values due to the above mentioned factors.

Key Features

The key features of the IOFS will be.

- The solution will provide vital information of exposed elements at risk with an improved lead time for an impending disaster based on the forecasted rainfall. This will aid preparedness, and make response operations more effective at local level.
- As IOFS is a web based solution, this will aid monitoring the risk remotely, thus helping the State and Divisions to provide support to the local administration in effectively handling crisis situations
- In an extreme event, actual rainfall data can be fed into the model to generate information including maps to communicate locations (villages) that can be affected, thus aiding emergency communication for response and relief measures.
- Since cloud burst forecasts are not possible, the system will provide the user an ability to insert additional flows or excess rainfall at a specific location to simulate the potential impact once the event has happened or as a test scenario
- Early warning creation as per the Common Alerting Protocol (CAP) format and making it available for dissemination through CAP via e-mail, SMS and other means
- Building knowledge base overtime to facilitate planning and policy making based on historical events.

Real-time Flood Forecasting

There are many ways in which recently observed storm water flows and extreme rainfall data can be used for updating flood forecasts and various updating procedures are available. They differ in detail or in their mode of operation, but essentially, they provide the hydrological simulation model with feedback information from the most recently observed flows to estimate errors and thereby improve the accuracy of forecasts. The updating procedures can either be continuous, that is, they can be applied at each time step, or periodic, which will involve periodic recalibration of the model. The dynamic web-enabled flood forecasting module will be calibrated and validated against historical events and tested on the stochastic events sets for the preparation of probabilistic risk maps as described in the Flood Section in Component 2 above.

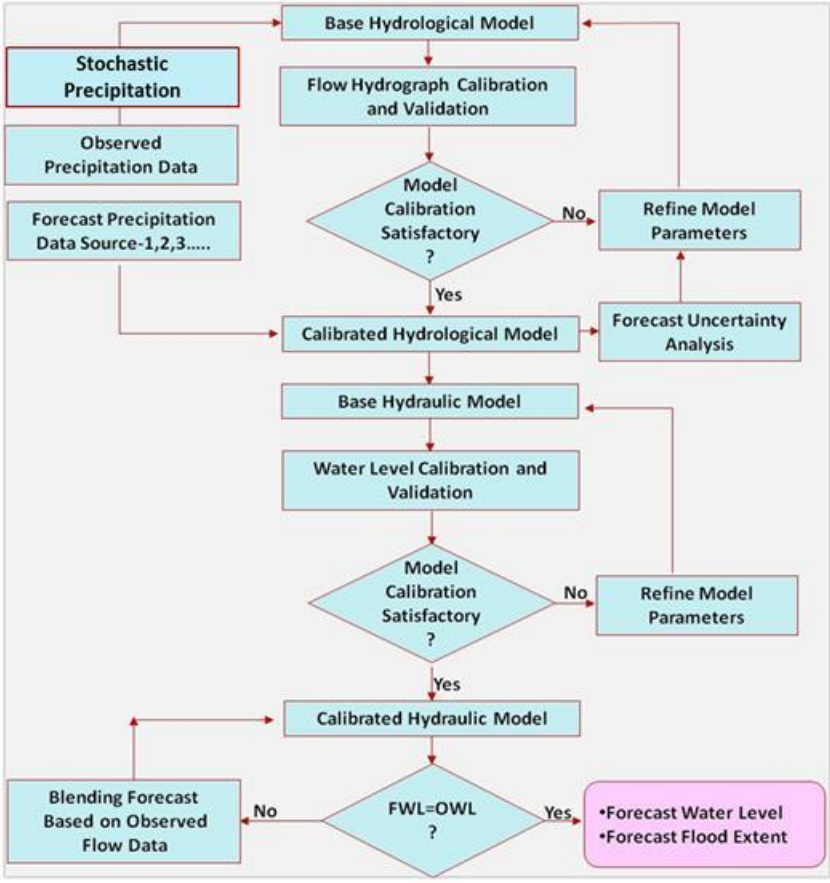

Figure 40: Flood forecasting model/components of HEC-RTS

HEC-RTS Framework

HEC-RTS is an all-inclusive system that picks up precipitation data, simulates a rainfall-runoff model, runs a hydraulic model and makes available inundation maps, stage and plots. Once the models have been calibrated and validated to reflect current hydro-meteorological conditions, they can be executed to produce forecasts of flood characteristics. That will assist the concerned agencies to evaluate the effects of their operating decisions in the near future. Reservoirs, bridges and other data from the field will be incorporated in the model to make it robust. HEC-RTS has the ability to forecast floods with a sufficient lead-time for early flood warning dissemination and to take timely protection measures.

The integrated hydrological-hydrodynamic modelling framework HEC-RTS is capable of providing probabilistic flood details using stochastically generated rainfall as well as flood forecasting.

The flowchart of the flood forecasting model has been shown in Figure 40 above. The flood forecasting model can be viewed as having following major components:

The HEC-RTS framework incorporates hydrological modelling using HEC-HMS and hydrodynamic flood modelling using HEC-RAS.

Both the key components of HEC-RTS framework, HEC-HMS and HEC-RAS, can run independently. However, in HEC-RTS they are combined to provide a comprehensive watershed forecast that includes river stages and flooding extents.

DATA INPUTS FOR FLOOD FORECASTING

For real time flood forecasting, the forecasted precipitation data, available from different sources (IMD WRF, IMD GFS, Global GFS), will be used, and the real time observed rainfall data from IMD, JAXA, and TRMM will be used. The State has Doppler Radar data since 2014 and the project team will approach IMD to collect this data. The Doppler Radar data will be validated against other available data before using this in any analysis particularly for cloud burst forecast.

The forecasted and real time observed data availability is specified in the tables below:

Table 12: Real time rainfall data

REALTIME RAINFALL			
Source	**Resolution**	**File type**	**Interval**
TRMM	0.25deg X 0.25 deg.	.tif	3hr
JAXA	0.1deg X 0.1deg.	.tif	1hr
JAXA	0.1deg X 0.1deg.	.tif	24hr
IMD	Station Data (Point Rainfall)	Excel/cvs	24hr

Table 13: Forecasted rainfall data

FORECASTED RAINFALL				
Source	**Resolution**	**File type**	**Interval**	**Forecast period**
IMD-WRF	9km X 9km	.dat	6hr/24hr	3-days
IMD-GFS	0.25deg X 0.25 deg.	.dat	24hr	7-days
Global-GFS	0.25deg X 0.25 deg.	.tif	3hr	7-days

The system will be able to forecast floods in every 3-5 hours for every rainfall forecast input to the model and generate forecasts for the next 3 days. The model will take about an hour to forecast the extents and depth.

HEC-RTS MODELLING FRAMEWORK FOR REAL TIME FLOOD MAPS GENERATION

The dynamic maps generation and flood inundation will be created at smaller scale (e.g. focus will be on exposure area) for city and tourist areas, which are densely populated. The flood discharge will be generated in HEC-HMS module utilizing real time physical and meteorological data inputs. The main dynamic real time/forecasted meteorological variable, namely rainfall, will be input to the model to generate real time/forecasted flood flows. The real time/forecasted flood flows will be the main input to the HEC-RAS module to generate flood depths and inundation maps, which will be able to illustrate the effect of extreme rainfall events. Pluvial flooding will be incorporated in the present framework by incorporating extreme rainfall events that occur with real time and forecasted precipitation data. The inundation from the pluvial impact will be assessed and then incorporated with the riverine floods. The HEC-HMS module of HEC-RTS will be updated based on pluvial and riverine floods.

Calibration and validation of a flood forecasting model requires flood extent and/or depth measurements (spatial distribution) for particular events based on the real time observed and real time flood forecasting. The real time high flood marks will be used to calibrate and validate the hydraulic model for the flood event. The real time and forecasted scenarios of flash floods and flood depth maps would be a great asset for the user prior to estimating the severity of future flash floods events. The RAS Mapper tool in HEC-RAS enables the modeler to visualize the flood inundation areas. Computed model results can be displayed dynamically on the fly. A sample RAS output flood map for the Rapti River has been shown in Figure 41 below.

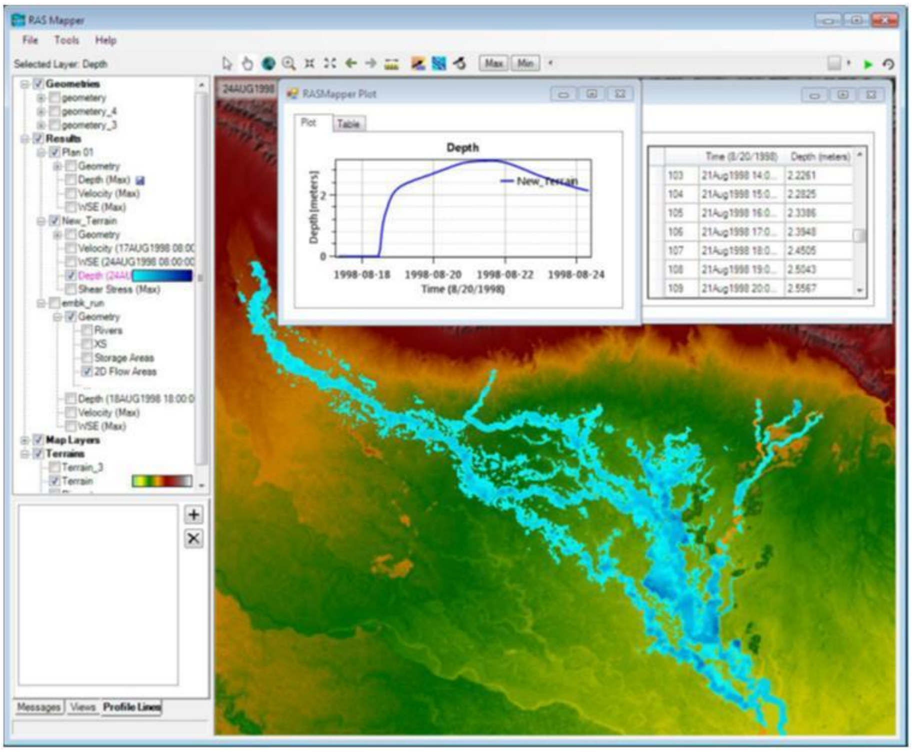

Figure 41: A sample RAS output flood map

Real-time Avalanche Forecasting

For Avalanche forecasting, the ANN-based model developed for avalanche hazard estimation as specified in section: Snow Avalanche Hazard Assessment will be used.

For analyzing the model performance, the following two accuracy measures will be considered:

- Probability of Detection (POD)
- False Alarm Rate (FAR)

Probability of Detection (POD) may be defined as the probability that the event was forecasted when it occurred. Similarly, the False Alarm Rate may be defined as the probability that event did not occurred when it was forecasted. Thus with the help of these two accuracy measures the performance of overall methodology will be analyzed that is reliable in quantitative terms. The performance accuracy measures with different threshold ANN output values will also be calculated. Finally, the validated model will be used for forecasting and output will be integrated with Operational Forecasting System. The model will also provide the total number of predicted 'Avalanche days'.

The proposed approach has potential in detecting avalanche days which were otherwise impossible through traditional method of using only the avalanche occurrence probability. Operational forecasting system will provide the information similar to given in the following sketch.

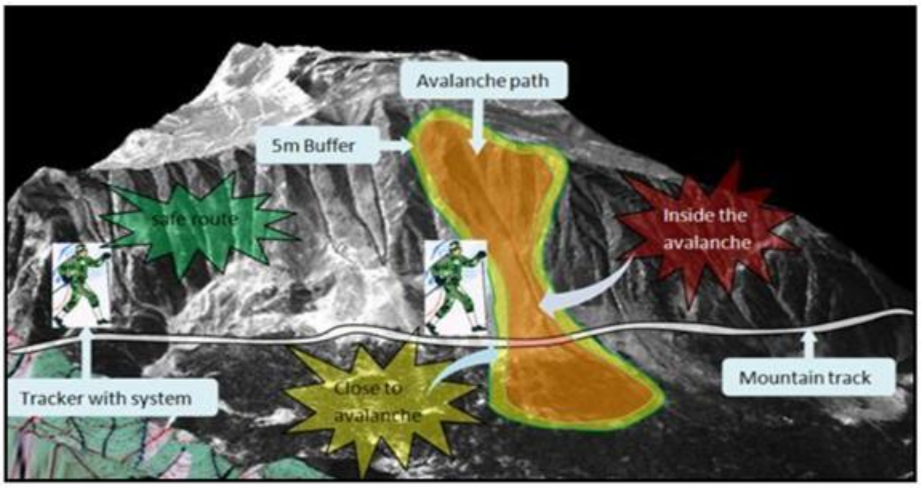

Figure 42: Operational forecasting system

Source: https://www.drdo.gov.in/drdo/labs1/SASE/English/indexnew.jsp?pg=products.jsp

Real-time Drought Forecasting

There is short, medium, and long-term drought forecasting. The terms short, medium, and long-term forecasting have been used in drought studies as indicators of lead time in months of future drought. In most of the drought forecasting, 1 to 3 months lead time is considered as short-term forecast. The medium to long-term drought forecast is lumped into one category of 4 to 12 months lead time. Forecasting of short-term drought conditions is useful for monitoring the effect of drought on agricultural systems. Under the short-term drought forecasting soil moisture and crop water stress may be defined especially during growing seasons. On the other hand, forecasting medium and long-term droughts help to comprehend the overall effect of drought on water resources at basin and regional scales. The medium to long-term forecasting is critical in water resources management. It may be used for drought risk management. The three categories of drought forecasting can be used to formulate long-term plans for sustainable management of water resources and agricultural systems.

In this study, once drought hazard modeling is established using the approach furnished in the Section “Drought Hazard Assessment” same modeling technique will be used to forecast the drought using the forecasted weather information at the required temporal resolution (i.e., short, medium, and long-term). For example, in case of PDSI index, if value is less than-0.5 then there is a chance of an incipient dry spell.

Dynamic Risk Assessment through IOFS DSS for Disaster Management

The disaster management activities initiate immediately at the onset of a disaster event such as a flood or an avalanche in terms of immediate response and slowly transitions into recovery activities, which lead to identification of mitigation measures for better preparedness. The emergency response activities can only be successful through multi-departmental coordination.

This demands for the availability of spatial and non-spatial data of various departments on a single platform. Effective emergency information management requires concerted planning, organizing, controlling, and influencing of human, material, and information resources to ensure that information is disseminated to the right decision-makers at the right time to satisfy those needs. The high level design of the proposed IOFS DSS is given the figure below.

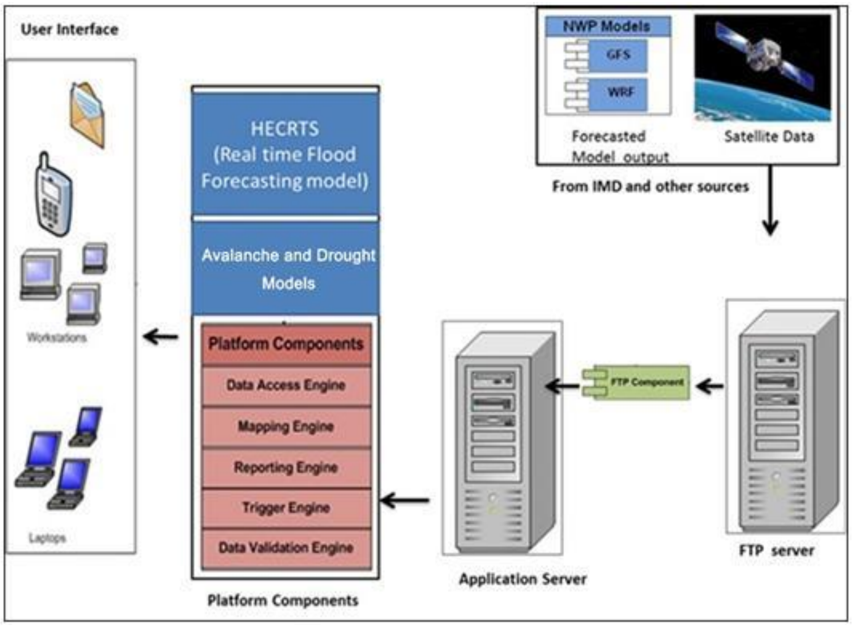

Figure 43: High level design of IOFS DSS

The proposed IOFS DSS will be open source web GIS application. It will provide information about exposure, hazards and vulnerability from impending hazards to support planning, coordination, response, guidance and decision making for emergency management personnel.

To perform this analysis on real-time basis, the IOFS DSS analysis engine will run the below mentioned tasks on automatic mode:

- Fetching input data for live events such as rainfall, snow, glacial melt etc. from IMD and other sources in automatic mode
- Running hazard models viz. – Flood, flash flood, avalanche, and drought
- Running vulnerability module
- Running loss module

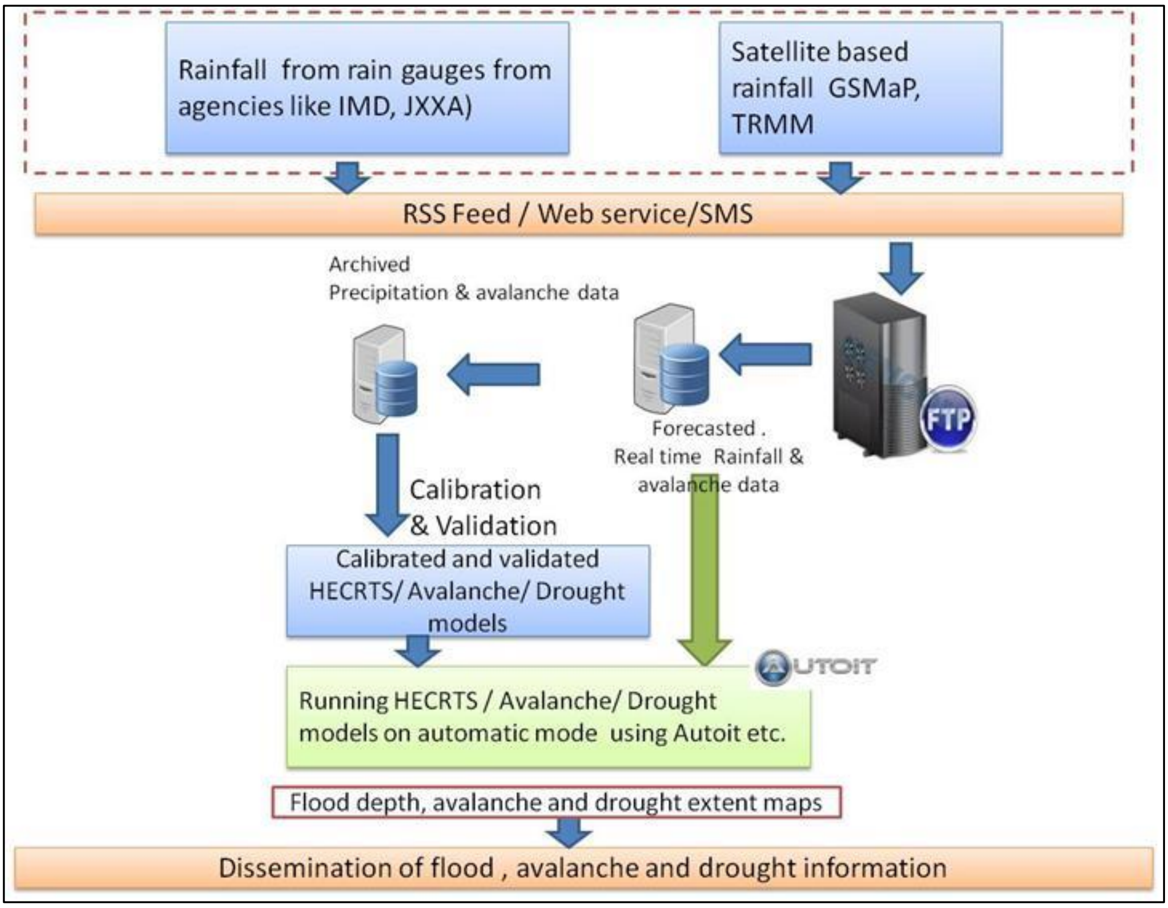

Figure 44: Process flow of IOFS DSS dynamic analysis engine

The following five are the major components that will be part of the IOFS DSS analysis engine:

Real time input data collection: This module will fetch the input data such as rainfall and drought and avalanche data from the various sources (IMD. JXXA, OpenWeatherMap, Weather Underground etc.) finalized for the model on real time basis through RSS feed, web services and SMS and store that in FTP server located at data center.

Forecasting module – Forecasting module will use HEC RTS Model to forecast flood (Convert rainfall to run off and generated flood inundation map) / ANN (for Avalanches) to Glacial melt/movement on real time basis. The AUTOIT software will be customized to run calibrated and validated model to perform forecasting tasks on real time basis. Vulnerability and loss module – This module will generate damage and loss based on hazard information generated by previous two modules and exposure information and vulnerability functions available within the IOFS DSS.

Dissemination module – This will be developed to perform dissemination of warning to decision makers and general public through websites, media and mobile SMS.

- Send event situation report to pre-defined individuals via email
- Web service to extract event related risk details to connect the IOFS DSS to any other government web-sites
- The system will generate a SMS text as per CAP format for dissemination to all mobiles in the rural areas, near airports, train stations, etc. through CAP system.
- The system will generate a SMS text as per CAP format for disseminating alerts to homes that have potential for impact on what they can do to reduce losses through CAP system
- Register missing people information

- Create a SMS alert in CAP format to be disseminated to mobiles in the area regarding missing people through CAP system
- Interface with CAP system to reporting of missing people that have been identified

The sample user interface of IOFS DSS Dashboard is shown below. The user can view results on maps, graphs or tables. The system will display the following layers by default as the application is loaded:

- River network with basin boundary
- State, district, tehsil, village, city and town, and country boundary map
- Basic GIS tools like zoom, pan, Zoom to selection, zoom to entire layer, location attribute information and calculate distance.
- Observed and forecasted flow levels from various hydrological/hydrodynamic model as table and chart in map in case of flood forecast. Similar maps and charts will be generated for Drought and Avalanches also,
- Hazard maps

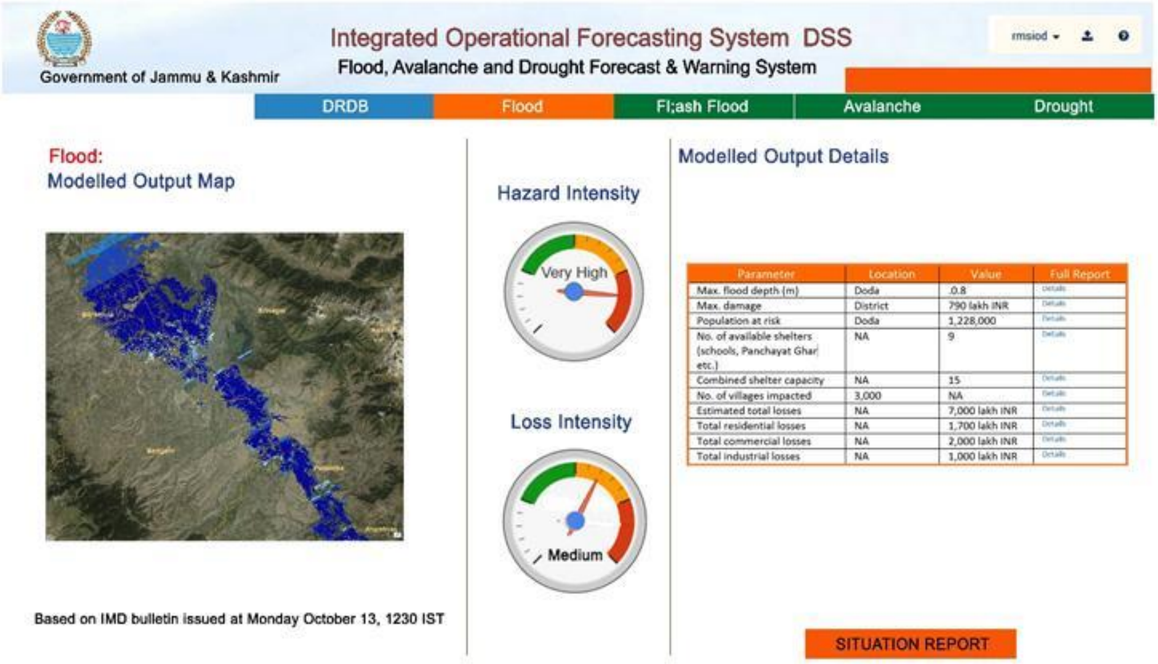

Figure 45: Sample user interface – Dashboard, IOFS DSS

Clicking the Detail hyperlink in the table (to the right in above figure) will allow users to navigate to detailed modelled results at a more granular level of the selected parameter.

The application will generate a situation report based on model output. A sample report is given below:

Flood Situation Update Report

Summary

Basin name:	Jhelum basin
Analysis name:	26julyanl6
Event name:	26july_event7
Hazard:	Flood
Scenario level:	Village
Stage:	0.20 m
Demography:	2011
Date of ocuurance:	7/26/2011

Loss Summary

Exposure Name	Total	Damaged/Loss/Affected
Paddy(Mts)	374067890	117569480.8
Buildings	199346	112395
Residential Kachcha buildings	53510	48428
Residential Masonary buildings	30590	20283
Residential Concrete buildings	83982	33271
Commercial Masonary buildings	7745	3810
Commercial Concrete buildings	20477	6000
Industrial Masonary buildings	826	284
Industrial Concrete buildings	2216	519

Figure 46: Sample situation analysis report

The information provided by this report will be updated on real time based on information received in the server through IOFS DSS App (mobile application).

As in the case of the web-GIS based DRDB, RMSI has already developed a real-time flood forecasting system and intends to use this expertise with additional inputs to develop the IOFS DSS. Details of this system are provided in the next section.

WEB-IOFS App - Android based mobile phone application

RMSI proposes a mobile-based IOFS App application that will provide below mentioned functionalities on smart-phones:

Simple registration process to receive alerts in case of an impending disaster event like SMS and pre-recorded voice alerts regarding potential for impact and what they can do to reduce losses, etc.

Figure 47: Sample user interface (Mobile application) for IOFS App

"I AM SAFE" feature: By clicking 'I AM SAFE' button the system will send SMS alert to predefined numbers. This will help the user relatives that the user is safe and a considerable effort will be reduced to search these people.

Crowd Sourcing feature to get feedback from people, who wants to submit information related to event such as:

- Status of flooding, avalanche or drought
- Damage description
- Need to be evacuated
- Need Emergency Medical help" etc.

IOFS APP will also be developed using Open Source Technologies for mobile development. Android SDK will be used as the development platform, and SQLite will be used to store data on mobile device. SQLite is an embedded SQL database engine and implements a self-contained, serverless, zero-configuration, transactional SQL database engine. The Android SDK provides the tools and APIs necessary to begin developing applications on the Android platform using the Java programming language.

The figure below depicts technical architecture of the Android platform-based mobile application.

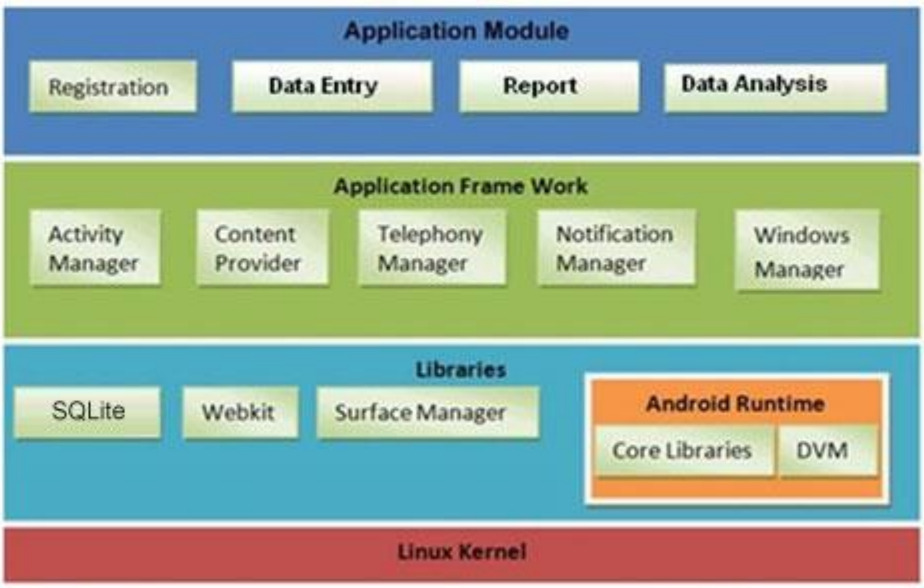

Figure 48: Android Architecture

The Android OS can be referred to as a software stack of different layers, where each layer is a group of several program components. Together it includes operating system, middleware and important applications. Each layer in the architecture provides different services to the layer just above it. Android is a Linux-based operating system for mobile devices such as smart-phones and tablet computers. The Android NDK (Native Development Kit) is a toolset that embeds components which make use of native code in the Android applications. Android applications run in the Dalvik virtual machine. The NDK allows implementing parts of the applications using native-code languages. Hence, RMSI proposes to develop modules (as shown in the above figure) on the top of the application framework.

Component 8: Engagement with the Government of J&K

> We will strategize to have continuous engagement with the GoJ&K, particularly with some of the key line departments, with the support of the PMU. RMSI will request all these key departments to depute officers who could be involved during various project activities. The idea is to have several officers with detailed understanding of DRDB and IOFS by the time this project ends so that GoJ&K can continue the usage of the two solutions without any hindrance. During the inception phase, RMSI team was introduced to the DM professionals posted in different districts and the state EOC by the Director, DM. The line departments, particularly the I&FC will play a key role in hydro meteorological warnings and has promised to depute officers who will be involved in various project activities.

Overall Strategy

Based on our understanding, the following key steps were proposed during the Inception phase/meeting as part of the engagement with GoJ&K and capacity building activities:

- Development of a training plan for imparting training during various phases of the project
- Identification of officers from different line departments with the help of PMU for the capacity building program
- Preparation of training documentation and manuals which will aid the trained officials to further train officers in their respective line departments
- Conducting short thematic trainings by different domain experts during their visits to the State.
- We will ensure that key technical aspects are explained in a simplified manner and the officials will have clarity post the thematic trainings. We propose to have half day sessions for this and any sessions which need longer duration, will be conducted in half day sessions over two consecutive days. Continuous full day training would be burdening, less effective and also will disrupt the official's routine work in their respective offices.
- In addition to this short term training we will also have formal training program at the end of the project which is detailed below.

Following will be the tentative topics to be covered during the short term training program:

1. Overview on hazard risk modeling
2. Application of GIS and Remote Sensing in exposure data development and hazard mapping
3. Hazard modeling (flood, earthquake, landslide, etc.)
4. Climate change vulnerabilities and its impact on natural hazards
5. Vulnerability analysis (physical and social vulnerability)
6. Risk Assessment and its application in disaster mitigation and risk reduction planning
7. Familiarizing DRDB database and its application
8. Hands-on experience of DRDB
9. Using DRDB for mitigation planning
10. Introduction of IOFS functionalities

11. Using IOFS for response
12. Hands-on exercise on IOFS

Comprehensive Capacity Building Program

As mentioned in the RFP and the contract document, we will carry out the following key steps under the capacity building activities:

1. Development of Technical user's guides/manuals to use the database, update the data and management of the website
2. Development of training package - including sample data, necessary hand-outs, Power Point presentations
3. Development of training package for master Trainers (ToTs) on the Multi-Hazard Risk Assessment training programs
4. Basic GIS Training including hands on sessions and basic use of web-based DRDB including uploading and managing data, creating metadata, and making maps in GIS (3-5 days)
5. Train the Trainers (ToTs) Workshop on multi-hazard probabilistic risk assessment (3-5 days)
6. Workshop on understanding, communicating and using results of risk assessments for decision makers including hands-on sessions (3-days)
7. Separate technical training to relevant staff on maintenance, administration and troubleshooting for DRDB (3-5 days)
8. As part of post-commissioning of DRDB, RMSI team has planned to conduct 3 additional trainings during Maintenance and Support period:
    a. Additional technical training to relevant staff on DRDB (5 -10 days)
    b. Additional training to relevant staff on Integrated Operational Forecasting System (IOFS) on Hydro-meteorological Hazards (5 -10 days)
    c. Additional technical training to relevant staff on maintenance, administration and troubleshooting for DRDB

Additionally, two offsite trainings will be conducted at RMSI. The PMU has to identify the officials for these training activities. These off-site trainings will be of a week's duration (5 days, Monday- Friday) for the focused trainee group of 8 - 10 persons and would be conducted in the 18^{th} month of project execution in consultation with PMU. RMSI team will formulate the comprehensive training agenda of these two specialized additional off-site trainings in consultation with PMU.

Maintenance and Support for DRDB and IOFS at Emergency Operations Centers (EOCs) at Srinagar and Jammu

One-year maintenance support will be provided for the DRDB and IOFS developed and installed at the EOCs at Srinagar and Jammu.

The maintenance activities include mainly:

- Fixing of bugs and any errors in the application
- Continuous monitoring of the IOFS to improve the forecasting accuracy and lead time
- Updating of data provided by the line departments

Three comprehensive on-job-trainings (OJTs) for 10 days each (as mentioned above) will be provided to the people who are deputed to manage/use the DRDB and IOFS.

In case any major addition of functionalities in the application or the requirement of intense field based data collection arise during the maintenance phase, this will be discussed with PMU along with the efforts required and appropriate decision will be taken with the support of PMU.

Section 3: QA procedure and peer review process

Quality Assurance

> Quality Assurance (QA) procedure will be implemented in all the phases of the assignment including data collection, data processing, development of the application and the preparation of reports.

The following procedure will be adopted as part of the QA procedure as part of the project:

1. Ensure authenticity of data source
2. Validate the collected data using methods such as cross validation using data from other sources, aggregate and disaggregate data, location specific information, remote sensing data where ever possible
3. Data cleansing to eliminate outliers and erroneous figures. Extreme values will be validated before using in the analysis
4. Error fixing at various stages of data development and application development to avoid cumulative errors
5. The software development will go through step wise QA process by independent quality team at RMSI environment before publishing beta version in client environment. These have been enumerated separately in sections dealing with DRDB (Component 6) and IOFS (Component 7).
6. We have formulated a peer review team including senior subject matter experts and technical editors who will review all the documents before delivering and reporting to PMU.

Section 4: Survey plan

Survey Plan Details

The objective of the household survey, building and infrastructure survey is to get location specific primary information related to community and exposed asset which are critical for conducting the social and physical vulnerability analysis. While household survey provides details at household level helping to capture detailed information (including community needs and perceptions) which is not available in Census data, the building and infrastructural survey help understanding of typology of structure, physical characteristics which will go in as inputs for developing fragility/damage functions of the exposed assets.

Household survey for social vulnerability analysis

SAMPLE SIZE

To start any survey, the first most important step is the estimation of a representative sample. As per RFP, 2% of population for Tehsil level sample needs to be considered for household survey. As this survey is at household level, we need to consider 2% of total households which will be 42,000 households. Assuming one person can complete 10 household surveys a day and if we deploy 40 people for conducting the survey, it will take 5 months to complete the work. This timeline is not in line with the project schedule. If we consider 95% confidence level with 1% error, the sample size required would be about 7,000. We propose to consider 21,000 HH for the survey that is in between the sample size proposed in RFP and 95% confidence level sample figure. This will take 2.5 months if we deploy 40 people for the survey.

We will devise proper sample distribution framework to ensure that the sample represents the entire state and all social groups.

SAMPLE DISTRIBUTION FRAMEWORK

While distributing the sample, we will consider the landform (geomorphic features - Floodplain, Karewa and Mountains which has high correlation to the hazard impact) and distribution of ethnic groups. We will be carrying out stratified sampling to pick the samples, confining 1% of HH at Tehsil level. While considering the ethnic groups, we will take proportional numbers based on the prevalence of that social group in the Tehsil.

DATA COLLECTION TEAM

The data collection team will comprise of subject matter experts, survey lead and a team of post graduates from relevant disciplines. While the domain experts and survey lead are part of the core team, we are in touch with the lead educational institutes of J&K and will be engaging Postgraduates in Social Sciences (Geography and Disaster Management) for conducting the HH survey. The survey team will be directly hired by RMSI, trained and engaged for the work. We will deploy minimum of two persons per district for approximately two and half months to complete the survey work.

DATA COLLECTION PROCEDURE

Following are the key steps we will follow for data collection:

- Create a survey questionnaire

- Implement this survey questionnaire in a Mobile App
- Create a web-portal that shows the status of survey at any point and displays the survey data through a map
- Implement survey data QC through the web-portal
- Subject matter experts will conduct reconnaissance survey in field and test the questionnaire through mobile app
- Mobilize the required survey team and provide training.
- Training will have following parts;
    - Initial training explaining how to conduct the survey using mobile app, stressing on key considerations and selection of households
    - In field testing of the team with subject matter experts
- Identification of gaps in the survey conducted by the team and filling that gap with additional training
- Another round of field testing with subject matter experts to ensure that the gaps have been filled
- Conduct survey, and monitor the data quality and data collection progress on a daily basis

The following are the advantages of using the mobile app and web portal for survey data collection:

1. All survey data will be geo tagged and help in monitoring the distribution of samples across the state.
2. Help monitoring of the movement of the survey team on daily basis
3. The application will have validation checks with questions to cross verify redundant responses
4. App will work offline (even without telecommunication network). Data collected will be dynamically stored into centralized system whenever there is data connectivity to ensure no loss of survey data.
5. The data will be stored with ID's of the survey person which will be used for quality verification
6. The web portal will be used to monitor the progress of the survey activities on dynamic basis avoiding any cumulative errors
7. No extra effort of data entry, which will save time as well as money. Manual data entry needs additional time and additional quality checks which is time consuming
8. The mobile app will be given to PMU and can be used for any future data collection

Building and infrastructure survey for physical vulnerability analysis

Sample size

Physical vulnerability survey will include survey of buildings, infrastructure and essential facilities. As per RFP, 1% of the buildings are suggested for the physical vulnerability survey. However, there is no mention of survey of the infrastructure. The 1% of the building sample means 30,000 buildings and if we deploy another 40-member team, assuming one person can complete 5 building surveys a day, it will take 7 months to complete the survey. This will offset the project schedule. If we consider 95% confidence level with 1% error, the sample size required would be about 10,000. We suggest a 15,000 sample size that will include about 10,000 buildings - a mix of residential, commercial and industrial, and 5,000 samples for essential facilities and infrastructure (including schools, hospitals, police station, fire station, govt. buildings, bridges, hydropower locations, communication facilities, religious places). The sample number will be proportionate to the number of buildings by occupancy type as per census. If a particular facility has more than one building, then all buildings will be surveyed as separate samples as the building type, year of construction, elevation, etc. of buildings within the same complex may vary.

SAMPLE DISTRIBUTION FRAMEWORK

Structural type and total number of buildings will be the governing factors for the selection of sample and its distribution. While floodplains have high density of population and are vulnerable to both flood and earthquake, mountains are more vulnerable to landslide but sparsely populated. Our sample distribution will also be governed by this factor. We will confine about 0.5% samples per Tehsil and will use building cluster map to distribute the sample within the Tehsils. For buildings, we will use stratified random sampling method. We will cover proportionally all structural types (traditional, masonry, RCC, shacks, etc.) as well as by building use (residential, commercial and industrial).

Since we don't have actual count of the bridges and utilities, we will go for a fixed number of samples. We propose to survey a minimum of 1 hospital, and 1 school per Tehsil and a fixed number of 1,000 bridges (different kinds) across the State.

DATA COLLECTION PROCEDURE

Similar to HH survey, we are planning to use a mobile based app for conducting the physical vulnerability survey as well. The process of the survey and the benefits are similar as mentioned above.

DATA COLLECTION TEAM

Similar to the social vulnerability survey, the survey team will comprise of domain experts and survey lead that are already part of the core team along with a team of graduates from relevant disciplines. We will be recruiting Civil Engineering and Disaster Management graduates from different educational institutes of the State and will be trained (as mentioned above) before sending them to field.

Section 5: Inception meeting

Inception Meeting Details

During the inception phase, the following stakeholders were identified by RMSI, with the support of the PMU, for further consultation:

Table 14: List of stakeholders identified for consultation during the inception meeting

S. No.	Department name
1	Indian Meteorological Department, Srinagar
2	Irrigation and Flood Control Department, J & K
3	Department of Ecology, Environment and Remote Sensing, Kashmir
4	Geological Survey of India, J & K
5	Department of Soil & Water Conservation, J&K
6	J & K State Disaster Management Department
7	Earth Science Department, Kashmir University
8	Lakes and Waterways Development Authority (LAWDA), Kashmir
9	The Directorate of Industries & Commerce, J & K
10	Fire Department, Home Department, J&K
11	Department of School Education, J & K
12	Department of Health and Medical Education, Kashmir
13	Jammu & Kashmir Police Department, Home Department, GoJ&K
14	Central Ground Water Board, J&K
15	Power Development Department, J & K
16	State Power Development Corporation, J&K
17	Public Health Engineering Department, J & K
18	Department of Telecommunications, J & K
19	ONGC, J&K
20	PWD, Government of J&K
21	Northern Railways, J & K
22	Civil Aviation Department, J & K
23	State and Central Pollution Control Board, J & K
24	Horticulture Department, Kashmir
25	Department of Agriculture, Kashmir
26	Animal Husbandry Department, J & K
27	Department of Tourism and Culture, J & K
28	Directorate of Fisheries, J & K
29	Forest Department, J & K
30	Jammu & Kashmir Geo-spatial Data Centre, Jammu, SOI
31	Census of India
32	Department of Urban Planning, J&K

S. No.	Department name
33	Economic Reconstruction Agency, J&K
34	Centre Water Commission, Jammu
35	Srinagar Development Authority
36	Rural Development Department, J & K
37	Revenue Department, J & K
38	Project Construction Corporation, J&K
39	Wular Conservation Authority J&K
For Kargil and Leh	
40	Kargil Hill Development Council
41	Leh Hill Development Council

The PMU had suggested conducting separate inception meetings in Kashmir, Jammu and Ladakh divisions. The details of the inception meetings conducted in the three regions are provided below.

Inception meeting in Kashmir Division

In Kashmir Division, we devised one to one consultations with the head of departments of various line departments and lead organizations. The consultations were pertaining to the collection of required data and information. Following are the departments/organizations consulted. The project team is continuously following up with the concerned departments/organizations for the collection of required data.

1. Irrigation and Flood Control Department, J & K
2. Department of Ecology, Environment and Remote Sensing, Kashmir
3. J & K State Disaster Management Department
4. Earth Science Department, Kashmir University
5. Lakes and Waterways Development Authority (LAWDA), Kashmir
6. The Directorate of Industries & Commerce, J & K
7. Department of School Education, J & K
8. Department of Health and Medical Education, Kashmir
9. PWD, Government of J&K
10. Horticulture Department, Kashmir
11. Department of Agriculture, Kashmir
12. Forest Department, J & K
13. Economic Reconstruction Agency, J&K
14. Srinagar Development Authority
15. Project Construction Corporation, J&K

During the meetings, the project team briefed the respective departments/organizations about the project. The discussions included project objectives, the approach RMSI is planning to adopt for delivering this assignment, the expected outcomes of the assignment (how the State and the respective department will be benefiting from the project) and the support sought (data/information and involvement). We have requested key departments like I&FC and Disaster Management to depute one or two technical officers who can continuously interact with the project team and involve in the project activities to ensure capacity building and knowledge transfer.

Inception meeting in Jammu Division

An inception workshop was organized in Jammu under the leadership of Divisional Commissioner, Jammu. All the lead line departments and organization in Jammu division were invited for the workshop. The Divisional Commissioner and CEO, JTFRR explained the relevance and importance of this project. Subsequently, RMSI presented details of the projects including the objective, expected outcomes, RMSI's approach and the support expected from various departments. Post the workshop, the team took appointments with participating departments for one to one meeting for data collection.

Inception meeting in Ladakh

Due to elections in Kargil, PMU suggested conducting the inception meeting in Ladakh region in the first week of September 2018. The development of the meetings will be communicated in the next monthly report.

Section 6: Office set-up and project management

Office Set-up and Project Management

Project Office setup

RMSI have setup its project office at Rachana Hotel which is located adjacent to the PMU office. The office is continuously manned by regular staff from RMSI. Domain experts will visit the project office and study area as per the requirements. We are also having similar arrangements in Jammu with a project coordinator based in Jammu.

The project office has the required basic facilities including computer, printer, internet connectivity, facilities to conduct discussions. As all experts use mobile phones for communication, landline phone will not be a requirement in the project office.

Project Management

RMSI has a set framework of project management practices for such multi domain consulting assignments, which is based on the principles of PMP® and PRINCE2® project management. The project management activities will be led by the team leader and will be supported by a project manager and two coordinators based in Srinagar and Jammu. We will define the project communication plan and protocol between RMSI and PMU defining the points of contact on both sides to ensure that the communication is timely and effective.

The following are the key salient aspects of our proposed project management methodology:

1. Project Initiation: This task is completed. The task accomplished under this phase includes – team mobilization, setting up of project office, detailed discussions with PMU and Bank and consultations with key stakeholders. The key objective of these consultations is to understanding the expectations of the PMU and the State and plan the project activities accordingly. The detailed project schedule defining different project activities and resources required has been prepared and is part of section: Project (activity) Plan. We will schedule the travel plans of the respective domain experts as per the activity schedule.
2. Project Status Reporting: RMSI will provide monthly project status updates in the template attached in the annex. In addition to this monthly progress report, the team will be interacting with the designated Officer of PMU to provide regular updates and to raise any issues that need the attention of the PMU.
3. Internal Project Review: Considering the project team size and diverse domain expertise, the team leader will conduct internal project meetings on a fortnightly basis to monitor project progress. The project team will further form sub-project units, which will consist of domain experts and data production team and will have a weekly meeting to plan and implement the project activities as per the project schedule.
4. Communication Plan: The project team will follow a defined communication protocol for internal communications and with PMU. Communications to PMU will be either by the team leader or the project manager keeping the other concerned in the loop. This will help us ensure prompt issue resolution, feedback gathering, monitoring and evaluation of the project against set targets, and refurbishment of the work plan/ methodologies for effective implementation.
5. Risk Management: A list of anticipated risks and their sources will be identified for different project activities and appropriate mitigation plans will be put in place after due consultations with the PMU. These risks may include delays in getting data, non-availability of data, weather issues, situations that disrupt field operation for data collection, etc. Risk mitigation plans will be communicated to the PMU to take their advice and approval before implementation.
6. Quality Assurance of Project Report and Deliverables: As mentioned in the quality assurance section, we have formulated an internal project review committee comprising of senior subject matter experts and will review all the deliverables before we submit any them to the PMU for further review and acceptance.

Section 7: Technical specifications for procurement of IT equipment/infrastructure

IT equipment/infrastructure

A minimum of three (3) servers will be required to set up the IT infrastructure for deployment of the applications. The table below gives details of these servers.

Also required will be 1 Laptop and 1 workstation for day-to-day activities like data filtering, data validation etc.

Detailed Requirements

Hardware and OS details of the above servers, workstation etc. are as follows:

A - Web server - 02

Minimum hardware requirements

- Processor: Intel Xeon 2.93Ghz,
- 4 CPU with 16 core each CPU or equivalent
- RAM: 32 GB RAM or more
- Hard Disk: 1 TB
- 250 GB free space in C drive
- Monitor
- Mouse
- Keyboard

Operating system

- Windows Server 2012 R2 64 bit or above

B - Database Server -02

- Processor: Intel Xeon 2.93Ghz, 8 CPU with 16 core each CPU or equivalent
- RAM: 128 GB RAM or more
- Hard Disk: 10 TB
- 250 GB free space in C drive
- Monitor
- Mouse
- Keyboard

Operating system

- Windows Server 2012 R2 64 bit or above

C - Modelling Server -02

- Processor: Intel Xeon 2.93Ghz, 16 CPU with 32 core each CPU or equivalent
- RAM: 128 GB RAM or more
- Hard Disk: 5 TB
- 250 GB free space in C drive
- Monitor
- Mouse
- Keyboard

Operating system

- Windows Server 2012 R2 64 bit or above

D - Workstation - 01

- Processor: Intel Core i7-7700 (Quad Core, 3.60GHz Turbo, 8MB, w/ HD Graphics 630) or equivalent
- RAM: 32GB (2x16GB) 2400MHz DDR4 UDIMM
- Hard Disk: 1 TB
- Monitor
- Mouse
- Keyboard

Operating system

- Windows 10 Pro

E - Laptop - 01

- Processor: Intel Core 7th generation i7 8650U Processor (Quad Core, 8M Cache, 1.9GHz,15W, vPro) Integrated UHD Graphics 620 or equivalent
- RAM: 16GB
- Size: 15 inch
- Mouse

Operating System

- Windows 10 Pro

Section 8: Detailed work program, schedules and milestones

Project (activity) Plan

Components and deliverables	Juy2018	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Nov-19	Dec-19	Jan-20	Feb-20
Inception phase																			
Inception Report																			
Component 1: Development of input datasets for probabilistic and deterministic hazard assessment at State, district, Tehsil level, four urban centres, four rural areas & four tourist destination risk hot spot areas for principal hazards																			
Data Inventory and data review report																			
Component 2: Development of the hazard layers at State, district and Tehsil level for principal hazards																			
Hazard Analysis Report & outputs captured in DRDB																			
(socio-economic, physical/infrastructure) at State, district and Tehsil level, four urban centres, four rural areas & four tourist destination risk hot spot areas for principal hazards																			
Exposure/Vulnerability assessment and report & outputs captured in DRDB																			
Component 4: Probabilistic and deterministic risk analysis for all principal hazards at State, district and Tehsil level, four urban centres, four rural areas & four tourist destination risk hot spot areas for principal hazards																			
Risk Assessment and Report/State Risk Atlas & output captured in DRDB																			
Component 5: Development of a Digital Risk Database (DRDB) for the State of Jammu and Kashmir																			
DRDB ready for demonstration																			
Component 6: Development of Integrated Operational Forecasting System for hydro-meteorological hazards (Flood, Flash Flood, Avalanche, Drought)																			
Operational System ready for demonstration																			
Component 7: Engagement with GoJ&K on the development of the user guide and trainers guide, risk information products, and communication of the risk results; sustainability of the initiative																			
Technical user guide and training guide																			
Non-technical summary guide for common user																			
Training programme and capacity building of key stakeholders																			
Road Map / Sustainability Plan																			
Draft Final Report / Final Report																			
Any other documents produced in the course of the study																			
Maintenance Support 19 – 30 months																			

Delivery and milestone schedule

S. No.	Deliverables	Timeline	
		Submission by consultant	Approval by PMU/WB
1.	Team mobilization	16 July 2016	-
7.	Inception report	14 Aug 2018	30 Aug 2018
8.	Component 1: Data Inventory and data review report	15 Sept 2018	01 Oct. 2018
9.	Component 2: Hazard Analysis Report & outputs captured in DRDB	15 Dec 2019	01 Jan 2019
10.	Component 3: Exposure/Vulnerability assessment and report & outputs captured in DRDB	15 Feb 2019	01 March 2019
11.	Component 4:Risk Assessment and Report/State Risk Atlas & output captured in DRDB	15 April 2019	30 April 2019
12.	Component 5: DRDB ready for demonstration	15 April 2019	30 April 2019
13.	Component 6: Operational System ready for demonstration	15 Nov 2019	30 Nov 2019
14.	Component 7:Training and capacity building (and manuals)	30 Nov 2020	15 Dec 2020
15.	Maintenance Support 19 – 30 months	Start from Jan 2020	-

Annexes

Project Management Report Format (one pager)

<table>
<tr><td rowspan="2">Project Name: Multi Hazard Risk Assessment for the State of Jammu and Kashmir</td><td>Date:</td></tr>
<tr><td>Progress Report: Month/Year</td></tr>
<tr><td colspan="2">Key Activities Accomplished this month</td></tr>
<tr><td colspan="2">Key Activities planned for next month</td></tr>
<tr><td colspan="2">Project progress Status</td></tr>
<tr><td colspan="2">Any key issues:</td></tr>
</table>

Social Vulnerability Survey Format

Multi Hazard Risk Assessment for the State of Jammu and Kashmir

Household survey questionnaire

1. Survey location details <including serial no, village, district and coordinate, and surveyor details - this will be automatically captured>

2. Building photo (photo 1: to start the survey)

3. Household profile

3.1. Head of the family: Name and phone number: (M/F) age (<25, 26-60, >61)
3.2. Ethnic group: Kashmiri, Dogra, Gujar, Bakerwal, Pahari, Dard, Bota
3.3. Caste: General/SC/ST/ OBC
3.4. Member details in the house: (M/F) age (<6, 7-17, 18 -60, >61)
3.5. Education: (how many male/female - Illiterate, 10th, Degree, PG, Others)
3.6. Occupation: (how many male/female - Govt., business, casual labour, tourism, unemployed, agriculture, or)
3.7. Family income (monthly): (0, <3000, 3001-6000, 6001-10k, 10001- 20000, >20k)
3.7.1. Household expenditure (monthly): (0, <3000, 3001-6000, 6001-10k, 10001- 20000, >20k)
3.7.2. Prevailing loan (monthly): (<30k, 30001-50k, 50001-100k, >100k)
3.7.3. Loan taken for: construction of house, education, business, agriculture, running family, marriage, death, emergency like hospital expenses, others
3.8. Source of drinking water: Pipe connection inside the house, public tap, river, public tube well, spring, others specify
3.9. Sanitation facilities: toilet inside the house (pit toilet, connected to public sanitation network, discharge to waterbody), community toilet, open space
3.10. Household assets: Car/four wheeler (number), two wheeler (number), boat, Air conditioner (number), Fridge (number), television (number), cellphone (number), cattle (number), sheep (number)

4. Access to critical infrastructure

4.1.1. How far is the govt. hospital from your house: <2 km, 2-5km, >5km
4.1.2. Specialised hospital: <5km, 5-10km, >10km
4.1.3. How far is school up to 10th standard: <2 km, 2-5km, >5km
4.1.4. How far is higher education centre (college/technical education centre): <5km, 5-10km, >10km
4.1.5. How far is the motorable road from your home: 0, <1, 1.1-3, 3.1-5, >5
4.1.6. How far is the open space/park from your home: 0, <1, 1.1-3, 3.1-5, >5

5. House type

5.1. House type (visually identify): Modern, modern with traditional design, traditional, shack
5.2. House material type
5.2.1. Floor type: wood, mud, cement, tile
5.2.2. Wall type: wood, mud, bricks, stone, cement, plastic,
5.2.3. Roof type: wood, grass, tin, concrete, plastic,
5.2.4. Number of storeys of the building: 1, 2, 3 and >3
5.2.5. Plinth height: < 2ft, 2-5 ft, >5 ft

6. House ownership: Own, rent, lease

7. Location: flood plain, side slope (steep), side slope (moderate), plains, foot hills,

8. Hazard history (events you/family experienced living in this locality during last 10 years)

8.1. Flood (year and month, duration of event in days, Number of people affected (M/F) – casualty (age), injury (age), house damaged completely (Y/N) if Y approx.. cost, house damage partially (Y/N) if Y approx.. cost, loss of household assets in Rs., agriculture loss (in Rs), number of livestock lost, number of chicken lost)

8.2. Landslide (year and month, event occurred during rainy season or dry season, Number of people affected (M/F) – casualty (age), injury (age), house damaged completely (Y/N) if Y approx.. cost, house damage partially (Y/N) if Y approx.. cost, loss of household assets in Rs., agriculture loss (in Rs), number of livestock lost, number of chicken lost)

8.3. Earthquake: (year and month, event occurred day/night, Number of people affected (M/F) – casualty (age), injury (age), house damaged completely (Y/N) if Y approx.. cost, house damage partially (Y/N) if Y approx.. cost, loss of household assets in Rs., agriculture loss (in Rs), number of livestock lost, number of chicken lost)

8.4. Forest fire: (year and month, reason according to you (human intervention/dry spell/don't know), Number of people affected (M/F) – casualty (age), injury (age), house damaged completely (Y/N) if Y approx.. cost, house damage partially (Y/N) if Y approx.. cost, loss of household assets in Rs., agriculture loss (in Rs), number of livestock lost, number of chicken lost)

8.5. Urban/household fire: (year and month, reason according to you (electric short circuit/from kitchen/don't know), Number of people affected (M/F) – casualty (age), injury (age), house damaged completely (Y/N) if Y approx.. cost, house damage partially (Y/N) if Y approx.. cost, loss of household assets in Rs., agriculture loss (in Rs), number of livestock lost, number of chicken lost)

8.6. Industrial hazard: (year and month, reason according to you (leak of inflammable-toxic gas/explosion of chemical conditioner/technical failure/don't know), Number of people affected (M/F) – casualty (age), injury (age), house damaged completely (Y/N) if Y approx.. cost, house damage partially (Y/N) if Y approx.. cost, loss of household assets in Rs., agriculture loss (in Rs), number of livestock lost, number of chicken lost)

8.7. Drought (year and month, duration of event in days, agriculture loss (in Rs), number of livestock lost, number of chicken lost)

9. Awareness and preparedness

9.1. You or your family members attended any awareness program on community disaster management: Y/N

9.2. Whether your children learn Dos/Don'ts during any disaster events (flood/Earthquake, fire, etc.) at school, or madrasa

10. Self-assessment of vulnerability

10.1. Would you consider your family vulnerable to any natural hazards? High, Medium; Low, Not at all.

10.2. If High please provide the reasons: living in the flood plain, poor construction of the house,

11. Coping mechanism

11.1. What kind of measures you have adopted to protect you and your family from any potential natural disaster (provision to pick more than one answer)? Do nothing and take risk, watch media regularly for any advisories, move family to safe location during rainy season, construct house in safe area, construct hazard resilient house, insurance for house, insurance for agriculture, plan agriculture based on weather forecast, abandoned agriculture and switch to other occupation, change agriculture crop to suit the weather change

11.2. What kind of measures community has adopted to protect the village from natural disaster (provision to pick more than one answer)? form community group to alter people, community based campaigns for preparedness, community awareness for construction of houses in safe area, community awareness to follow design standards.

11.3. What kind of measures government/ local administration is providing as part of the awareness and preparedness activities (provision to pick more than one answer)? distribute/display posters on dos and don'ts in public places, regular community awareness activities, regular awareness activities in schools, encourage madrasas to conduct awareness activities, strict building regulation, regulation of construction zones.

11.4. According to you what measures government should take to reduce hazard risk in your locality (provision to pick more than one answer)? Construct community shelter in safe area in inform communities, strict regulation of building zone and building standards, improve lead time of early warning system (particularly for flood and flash flood), conduct regular awareness activities and drill.

11.5. As per your understanding what EWS facilities are available in your locality (provision to pick more than one answer)? Regular messages in media (TV and radio), SMS on phone, EWS through community centres, not aware of any EWS.

12. Hazard risk resilient measures perception:

12.1. What would be your preferred choice if there is a flood warning in your locality? Move family to the designated shelter location, move to the roof top/upper floor of own house, move to relatives/friend's house which is in safe area, move to hotel, do nothing and pray to god.

12.2. According to you what support from the government is required to stay safe in the locality you are living (provision to pick more than one answer)? Government should regulate the flow of water in the river, avoid road construction in steep slope to avoid landslide, provide awareness on preparedness, effective weather forecasting and EWS, nothing can be done.

Building photo (photo 2: to close and save the survey form)

Physical Vulnerability Survey Format

Multi Hazard Risk Assessment for the State of Jammu and Kashmir

Building survey questionnaire (RVS method)

General	**Date:**		
ID: Location:		Road No:	
Name of the Owner:		Block No:	
Surveyor Name:		Sign:	
Supervisor Name:		Sign:	
Building Details			
Structural Type Code:		No of Floors:	
Occupancy Class:			
Number of Occupants:	a) Day:	b) Night:	
Construction Year: or Age years	(<10 years	10-30 Years	>30 years)
Existence of Shear Wall[1])	a) Yes	b) No	
Vulnerability Factors			
First Soft/Weak Storey:	a) Yes	b) No	
Heavy Overhangs and Cantilever:	a) Yes	b) No	
Shape of Building in Plan:	a) Rectangular	b) Narrow Rect.	c) Irregular
Shape in Elevation:	a) Regular	b) Setback	c) Narrow tall
Poundings Possibility	a) Yes	b) No	
Building in Slope Land	a) Yes	b) No	
There is visible ground settlement	a) Yes	b) No	
Short Columns:	a) Identified	b) Not Identified	
Visible Physical Condition			
a) Poor b) Average	c) Good		

Photograph Number:	
Comments:	

1 Please circle "Yes" for all structures with shear wall (lift core and shear wall). The purpose of this item is to distinguish buildings with shear walls that are not intentionally designed to resist lateral force from those buildings with shear wall as a primary lateral force resisting system.

Configuration	**ID:**		
Torsional Irregularity	a) Non-rectangular shape (L/U/T/E/H Others)		
b) Unsymmetrical Infill	c) Unsymmetrical Shear wall		
Short Column: a) Less than 25% of Floor Height	b) 25-50% of Floor Height		
c) More than 50% of Floor Height			
Diaphragm Discontinuity	a) Mezzanine floor (Open area sq ft)		
b) Floor Opening if courtyard Building (Area sq ft, No of Storey)			c) No
Slab System	a) Cast insitu	b) Pre-cast	c) N/A
Dimensions			
Storey Height: ft	Overhanging Length: ft		
Typical Slab Thickness:	inch		
Plan Dimension:	x	=	sq ft
Typical Column Size:	x	inch	
No of bays	x		
Typical Span Length	x	ft	
Shear Wall Type a) Concrete		x	= sq ft
b) Masonry		x	= sq ft
Only for Masonry Buildings			
Typical Wall Thickness:	inch		
Maximum Unsupported length of wall:		ft	
Corner Separation	a) Yes	b) No	
Anchorage of Wall to Floor	a) Yes	b) No	

Anchorage of Roof with Wall		a) Yes	b) No	
Wall to wall anchorage		a) Yes	b) No	
Bracing of flexible Floor/roof		a) Yes	b) No	
Existence of Gable Wall		a) Yes	b) No	
Horizontal Band (Lintel/ Floor/Roof)		a) Yes	b) No	
Vertical Post/reinforcement		a) Yes	b) No	
Defects	a) Diagonal Cracks		Width:	mm
	b) Vertical/Horizontal Cracks		Width:	mm
	c) Bulging of wall			
	d) Tilting of wall			
	e) Dampness			

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