Flash flood and its Preventive Measures in Hilly Areas

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Abstract— Flash floods generally occur suddenly caused by heavy rainfall due to cloudburst, damage to infrastructure (buildings, roads etc.) and life. In the India flash flood occurs only in monsoon season (i.e. June to Sept). Flooding contributes to more than 100 deaths each year across India with most deaths due to flash flooding. The main causes of flash flood in hilly areas are cloudburst or stationary rainfall, heavy rainfall and rapid snow melt in high mountain areas, glacial lake outburst, failure of dams built-up by landslide, rock falls or debris flows and overspill following the failure of water reservoir dams. Most flash floods occur due to intense rainfall caused by cloudburst, the magnitude of a flash flood is dramatically affected by pre-existing physical factors such as ground cover, topography and soil moisture. This study looks at flood prevention and mitigation in India and guiding principles with regard to flash flood are presented here and also looks at the relationship between the number of flash flood events and rainfall within that year in hilly areas such as Uttarakhand, Himachal Pradesh and Jammu& Kashmir. Results showed that with increasing the number of cloudburst and snow melting there is an increase in the average annual number of flash flood events. A composite factor was developed to account for both cloudburst and heavy rainfall together. This factor when compared to the average annual number of flash flood events indicates that densely populated areas within hilly to high terrain are the most susceptible to flash flooding. It is the hope that these results will highlight hydro logically vulnerable areas that are prone to flash flooding in the northeast India. With this improved understanding, Central Water Commission (CWC) forecaster situational awareness will increase, leading to more accurate and timely flash flood warning.

Key words: Flash Flood causes, Flash Flood Occurrences, Flood Prevention

I. INTRODUCTION

A flash flood can be defined as "a flood that rises and falls quite rapidly with little or no prior warning, usually as a result of snow melt and intense rainfall caused by cloudburst over a relatively small area". The flash floods generally occurs after heavy rainfalls caused by cloudburst often in mountainous areas. The available time to predict flash flood is very limited. Flash floods frequently induce landslides and debris flow leading to severe damage and casualties in hilly areas. Flash flood prevention is a worldwide problem that is posing a great challenge and many countries and flood prone regions fasten a great importance to the work of flash flood control.

Flash Floods frequently occur in hilly parts of India and may cause of loss of lives and huge damage of infrastructure in the hilly areas due to flash flood caused by cloudburst and snowmelt. Every year flash flood causes the loss of a great number of lives as well as great damage to public property and infrastructure. This causes a larger economic impact thus affecting growth. The main impact of flash flood is undercutting of check dams, the collapse of river banks, debris, debris flows, debris deposits, river damming by debris, river bank erosion, and channel displacement, clogging bridges, scour and inundations. After studied several cases of flash flood in hilly areas the various expert committee observed the problems caused by flash flood and proposed various mitigation measures for flood management to the government.

II. CHARACTERISTICS OF FLASH FLOOD

- **Depth of water-** Building foundations and vegetation will have different degrees of tolerance to bring inundated water.
- **Duration** – Damage to structures, infrastructure vegetation related to duration of time with water inundation.
- **Velocity** – High velocities of flow create erosive forces, hydrodynamic pressure, which destroy foundation supports and may occur on floodplains or in the main river channel.
- **Frequency of occurrence** – The frequency of occurrence measured over period of time determines types of construction or agricultural activities on the floodplain.
- **Seasonality** – Flooding during a growing season destroy crops while cold weather, floods seriously affect the community.

III. CAUSES OF FLASH FLOODS

Flash floods can occur under various types of conditions. Flash floods have occurred after eruptions, in areas on or near volcanoes, when glaciers have been melted due to global warming. Flash floods generally occur in the hilly areas. The various causes of flash floods are listed as below-

A. INTENSE RAINFALL

Intense rainfall is the most ordinary cause of flash flood in the hilly areas. A high rainfall event may only last for a few hours at most, but can cause petrifying and destructive floods. Their impact can be affected by a wide range factors such as the location and intensity of the rainfall, steepness of the catchment it falls on and the shape, how much sediment is moved by the water and the vulnerability of the communities in the path of flood.

B. CLOUDBURSTS

The cloudburst is a localized weather phenomena representing highly concentrated rainfall over a small area lasting for few hours. The cloudburst is sudden copious rainfall and leads to flash floods/ landslides, house collapse, dislocation of traffic and human casualties on large scale. The rainfall at rate greater than 100 mm per hour is termed

as cloudburst. The result of cloudburst can be disastrous and responsible for flash flood.

C. OUTBURST OF LANDSLIDE DAMS

The hilly regions are prone to frequent and disastrous landslides because the slopes of hills are both steep and unstable. The earthquakes and heavy rainfall can cause the slopes to landslide. The debris flow and the landslides may cause to form temporary dams across river banks, impounding huge volume of water. A landslide dam outburst flood can occur when these temporary dams are overtopped or water breaks through.

D. OUTBURST OF GLACIAL LAKES

Glacial lake outbursts are the main cause of flash floods in the hilly areas. Glacial lakes form as glaciers decline, and their formation is directly related to climate change due to global warming. When glaciers decline they leave behind large voids that are filled with melt-water; these are moraine-dammed glacial lakes. Moraine dams are structurally weak and internally unstable; they undergo constant changes due to slope failures, slumping, and other such effects Glacial lakes can also burst due to external triggers such as earthquakes and rock or ice avalanches. Therefore main causes of GOLF are avalanches and earthquakes.

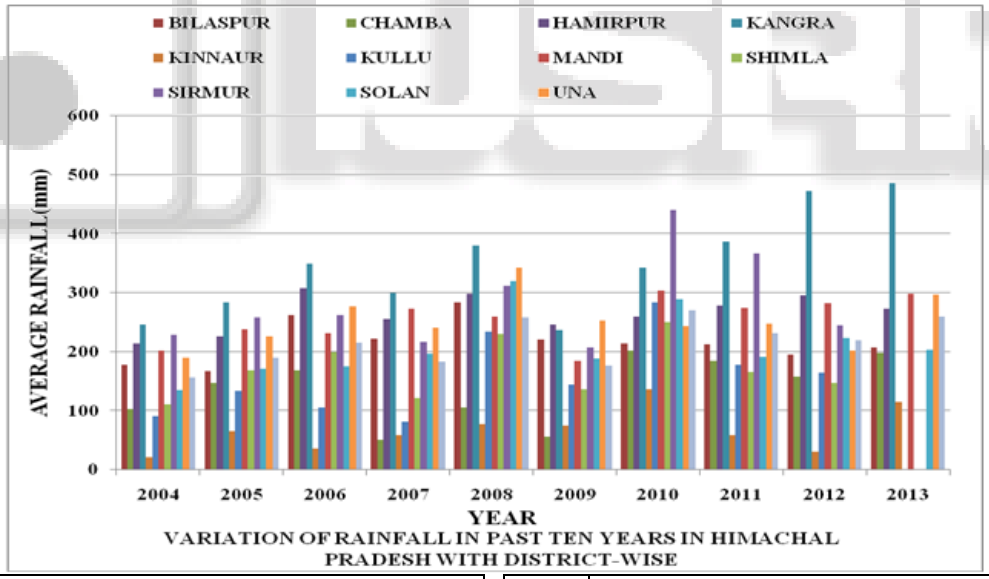
E. SNOWMELT

Because of global warming, the temperature is increasing per year. The ice caps melt in spring, and the water goes into the river and makes the river level rise. When river level rises, flooding may occur.

IV. FLASH FLOOD OCCURANCES

YEAR	LOCATION	CAUSE
1975	Spiti Valley	Earthquake
1988	Soldang Khad	Cloudburst
1997	Shimla, Mandi, Kinnaur, Chamba, Kullu And Una	Earthquake
2000	Satluj valley	Unprecedented rise in the water level of satluj river
2001	Kullu and kangra	Cloudburst
2003	Kullu	Cloudburst
2005	Shimla, Mandi, Kinnaur, Kullu And Simaur	Unprecedented rise in the water level of satluj river

Table 1: Past flash floods and their causes in Himachal Pradesh



VARIATION OF RAINFALL IN PAST TEN YEARS IN HIMACHAL PRADESH WITH DISTRICT-WISE

Year	Heavy Rainfall in the month of June
2002	June : NIL
2003	June 2:Tehri-7, Pantnagar-7 June 25 : Haripur-7 June 27 :Banbasa-7
2004	June 14:Dehradun-10 June 17 :Dehradun-8 June 18:Dehradun-12 June 20:Uttarkashi-12, Banbasa-7
2005	June 26:Hardwar-8
	June 29:Didihat-9 June 30:Didihat-7
2006	June 30:Srinagar-11
2007	June 12:Kotdwar-10 June 14:Didihat-7 June 15:Kosani-10 June 25:Nainital-18 June 26: Uttarkashi-17 June 28:Pantnagar-9
2008	June 4: Nainital-7

	June 10:Pantnagar-9 June 13:Dehradun12, Roorkee-7 June 15:Dehradun-7 June 16 :Kalagarh-9 June 17:Bambasa-8,Uttarkashi-7 June 19: Didihat-10 June 20: Hardwar-13, Marora-7 June21:Rishikesh-7 June 22:Dehradun-9 June 25 :Hardwar-7 June27:Bosan-13, Marora-10, Rishikesh-9 June 28:Kalagarh-10 June30: Rishikesh-9, Srinagar-8, Bosan-7, Hardwar-7.
2009	28 June :Uttarkashi-12, 29 June :Banbasa-17, Khatima-11, Marora-8
2010	June 21 : Dunda-9, Uttarkashi-7
2011	June 17 :Pithoragarh-7 June 26 :Rudraprayag-7 June27:Bambasa-7 June 28: Uttar kashi-7 June 29: Champawat-11, Uttarkashi- 9,Nainital-7,Landsdown7, June 30 : Chamoli-8, Uttarkashi -8,Mussoorie-7, Nainital-7
2012	June 25 Rudraprayag-7
2013	June 11 :Bambasa-8, Landsdown-8, Haldwani-7, Mussoorie-7, June12: Chamoli-7 June 14:Dehra Dun-9, June 15:Dunda-8, Jakholi-7,Kashipur-7 **June 16** Dehra Dun-22, Purola-17, Deoprayag-13, Uttar Kashi-13,Tehri (CWC)-12, Tehri-12, Uttar Kashi (CWC)-12, Dunda-12, Barkot-11, Hardwar-11, Jakholi-11, Haldwani-9, Rudraprayag-9, Karnaprayag-9, Mukteshwar-8,
	Kotdwara-7 **June 17** Dehra Dun-37, Mukteshwar-24, Hardwar-22, Uttar Kashi(CWC)-21, Kosani-21, Haldwani-20, Nainital-18, Tharali-17, Tehri-17, Tehri (CWC)-17, Deoprayag-16, Bageshwar-16, Mussoorie-15, Roorkee-15, Joshimath-11, Jakholi-11, Champawat-10, Keertinagar-10, Rudraprayag-9, Karnaprayag-9, Almora-9, Pithoragarh-9, Chamoli-8 **June 18** Haldwani-28, Champawat-22, Mukteshwar-18, Nainital-17,Ranikhet-12, Pithoragarh-12, Pantnagar-11, Almora-10,Chamoli-10, Kosani-8, Karnaprayag-8, Tharali-8, Joshimath-8, Deoprayag-7, Keertinagar-7, Jakholi-7

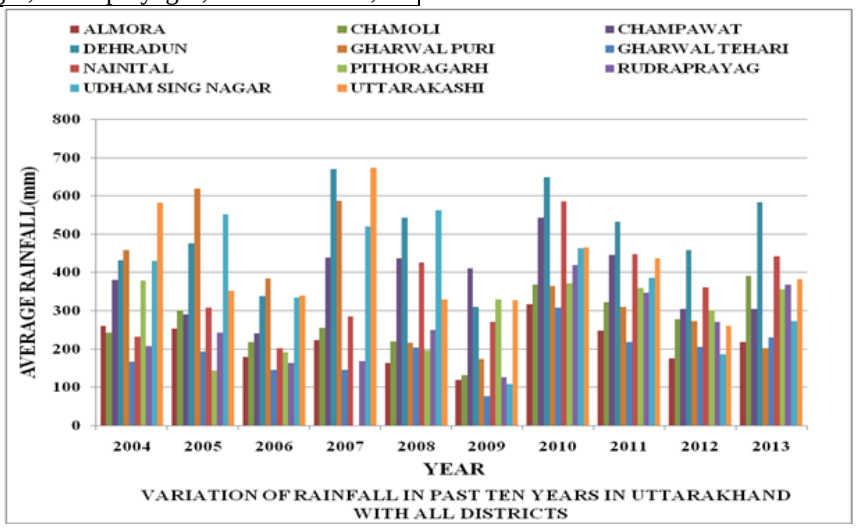
Table 2: Heavy rainfall reported over Uttarakhand during the period 2002-2013

V. PREVENTION AND MITIGATION

Prevention is an important aspect of flood management. Several measures have been adopted to minimize the flash flood damages and to protect the hilly habitation. Depending upon the nature work, Flood prevention and flood mitigation measures may be broadly classified as under:

- Engineering / Structural Measures
- Administrative / Non-Structural Measures

Structural measures are termed as physical measures in the nature and used to modify the floods while non-structural measures are termed as planning phase and used to modify the losses due to floods. In the structural measure we keep the water away from people while in non-structural measures is a procedure to keep the people away from water.



A. ENGINEERING /STRUCTURAL MEASURES

The engineering measures are the mitigation measures which are taken to protect people and public property from the flash flood event in order to minimize the hazard or to influence the course or probability of occurrence of the event. Different aspects of some of the important measures for flood management are illustrated as below:

1) RESERVOIRS

Dams and reservoirs can be of both types i.e. natural and manmade. These are the effective means for reducing flood peak in rivers. These reservoirs play an important role in flood prevention and mitigation. Reservoirs and dams are designed to aid in flood protection and mitigation in hilly areas. People issues involve in the case of reservoirs and dams are evacuated and re-habitation of humans in the reservoir area, environmental impacts increase in population and development activities. Large dams have flood control reservoir is keep a certain elevation before onset of the rainy floodwater can fill. The result of dam failure can damage to ecological system in downstream and people encroachment on the flood plains. Therefore, security provided by dams is also too take into account. The effect is on its surrounding environment and on the settlements in the downstream areas to take into account.

2) EMBANKMENTS

The constructions of embankment are the most basic and generally form of mitigation measures to provide immediate relief from floods and flash floods. These are generally quick, cheap and the most popular method of the flood control and mitigation and have been constructed at large scale in the ancient. This report is to given remarkable protection at relatively low costs, especially in to the let down to arrive of the large rivers. Dams are constructed and design to control against the flash floods of a certain magnitude and frequency or against the maximum recorded floods depending upon the location prevented and their economic explanation. The raising and strengthening of present dams is to take in to multiple of the flood prone areas. In order to the work is necessary to take up the flood frequency in their re-design, taking into account the data of past floods and flash floods, which is now available. This is constructing with easily available earth in nearby location. Dams of the pre-independence period and this come later independence by plans are the protection to ecological system is living in flood plains.

3) CHANNEL IMPROVEMENT

This is an important method of flood mitigation and prevention and helps in improving the channel by improving the hydraulic structure of the river channels. And it is done by removing of suspended silt from the water stream, dredging, lining etc. to allow the river to transport its pours at lower levels or within its edge has been generally supported but accommodated on a very limited size because of its high cost and other critical situations or conditions. It is economically justifiable method for flood or flash flood mitigation measure where navigation is involved.

4) DRAINAGE IMPROVEMENT

Surface water drainage congestion due to lack of natural or manmade drainage channels to carry the rain or flood water discharge within a reasonable period causes extensive damages. It is usually difficult to discriminate between flood and drainage congestion situations. This situation is rather critical in hilly areas. Therefore, improvement of drainage channel by constructing new channels or improving the discharge capacity of the present drainage system is approved as an intrinsic part of the flood and flash flood management projects in the hilly areas. The acceptability of present sliding gates and drainage system should be investigated in areas drainage congestion. If the capabilities of present a sliding gate in embankments and drainage channels are not adequate, this should be improved by increasing the inlet/outlet and improving outfall conditions of river.

5) DIVERSION OF FLOOD WATERS

Diversion of flood waters involves diverting all or a part of the flood discharge into natural or artificial constructed channels or basin which may be within or outside to the flood plain where it could be stored for succeeding release.

B. ADMINISTRATIVE / NON-STRUCTURAL MEASURES

The administrative or non-structural methods can be considered as set of mitigate or adoption that do not make use of traditional structural measures. The flood damages can be reduced by providing timely evacuation of the people and shifting of their portable property to safer grounds by having prior warning of incoming flood.

1) FLOOD PLAIN ZONING

Flood plain zoning is an important non-structural prevention and mitigation measure which is used in flood mitigation. The basic concept behind food plain management is to synchronize the land use flood plains in order to reduce the damage due to flood and flash floods. This phenomenon is done by examining the locations that are affected by floods and flash floods of various intensities and to develop that area in such manner so the damages can be reduced in case of flood and flash flood. Flood plain zoning is useful for both in case of floods and flash floods by heavy rainfall due to cloudburst and in minimizing damages caused by drainage congestion and drainage of rain water mainly in hilly areas where drainage system is not designed for worst possible conditions that may occur in monsoon season.

2) FLOOD PROOFING

Flood proofing measures generally used in the mitigation of flood and flash flood and provide instant relief to the population in flood prone areas. The combination of structural change and emergency action, not involving any evacuation is called flood proofing. The techniques acquired consist of providing raised platforms for flood shelter for cattle and people and raising the public utility installations above flood levels and other prerequisites to make various essential services flood proof so that the miseries of people can be reduced to minimum even when flooding occurs.

3) FLOOD FORECASTING AND WARNING

Flood forecasting and flood warning in India activated in the year 1958 in New Delhi with the foundation of a unit in

Central water commissions (CWC). Flood Forecasting & Warning System plays an important role in reducing the damage to public property and the loss of life and during flash floods. Central water commissions (CWC) has established nationwide flood forecasting and warning system. Nationwide flood forecasting and warning system initiative has also been supplemented by states that make special facilities for strategically important locations in their states. The forecasts can be of several types such as area to be submerged (inundation forecast) and forecast for water level i.e. stage forecast, flow forecast. When the forecast fetches definite risk information is called flood warning. The flood forecasting services includes collection of meteorological data such as rainfall and hydrological data such as gauge discharge etc.

VI. CONCLUSIONS

After the study of several case study of flash flood in hilly areas such as Uttarakhand, Himachal Pradesh and Jammu and Kashmir it is found that the main causes of flash flood in hilly areas are snow melting due to climate change and sudden and frequent heavy rainfall due to cloudburst in monsoon. Because of these the rivers in hilly areas overflows and the flash flood occur. It is apparent that the number of flash flood events occurred in the hilly areas i.e. Uttarakhand Himachal Pradesh and Jammu and Kashmir, caused by both cloudburst and intense rainfall. In these three floods prone hilly areas rainfall remains the most suspected cause of flooding due to cloudburst and snow melting. Flooding has been shown to have various effects on the human activities on one hand and the environment on the other hand. It is essential that structural measures, particularly bioengineering works be complemented with non-structural measures. Only their joint implementation can secure the adequate use of prevention and mitigation strategies.

In addition, non-structural measures need to be effectively consolidated and implemented within a legal framework so that such strategies can be sustainable for the future.

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