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DISASTER MITIGATION MEASURES (FLOOD) FOR THE RIVER INDUS & NALLAHS IN LEH TOWN, J&K

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ABSTRACT

India is one of the most disaster prone countries of the world. It has had some of the world's most severe draughts, floods, famines, cyclones, earthquakes, avalanches, chemical disasters, mid-air head-on air collisions, rail accidents, and road accidents.

Mountainous regions in India, particularly the Himalayas which are the youngest, tallest and the most fragile mountain ranges in the world, are disaster prone because of topographical conditions.

Due to geo-climatic conditions and geographic location, the historic town of Leh, in Ladakh Region of Jammu and Kashmir, is highly prone to natural hazards, which often converts into disasters, sometimes of unprecedented nature. One such disaster was faced by the town of Leh on August 5, 2010 in terms of flashflood resulting due to cloud burst in the region. The damage was more in Leh because mountains are highly disintegrated and made up of loose rock /soil/boulders. At the time of flash flood gusting water along with lot of mud, stones & rocks erodes the ground & choked the houses, deposited on the roads & devastated buildings. The impact of disaster was very severe in the region due to exceptional floods and lack of preparedness and mitigation measures to handle such situations. The disaster resulted in huge devastation in terms of human lives lost and damage and destruction of physical infrastructure.

The Indus River is the lifeline of the Ladakh Region, which originates from a point near the Mount Kailash and joined by a number of streams and rivulets forming overall hydrological character of the this Region. It flows south of Leh town, from east to west. Its water is used for drinking, irrigation and generation of power. In the north of Leh town, rivulet namely Leh Nallah (Gangles Tokpo) with its tributary streams form the natural drainage system with their own valley formation. The Leh town has been growing in the Gangles valley.

Due to cloudburst, very high discharge in the tune of 584 cum/sec was observed in the Leh Nallah. The observed velocity of gushing water was observed in the range of 7 – 20 m/s. The highest flood level (HFL) in the Leh Nallah was GL+ 0.6 - 1.1 m along the various sections with average scour depth varying from 1.1 - 2.9 m in habited areas. High quantities of water entering the Nallah with a very high speed resulted in devastating flash flood, which swept away everything in its path. [21]

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To meet the challenge of flash floods in expending town of Leh, a number of mitigation measures are proposed to be taken up. This paper includes design of protection bunds to train the river & nallahs based on calculation of design discharge for 100 year return period with the help of extreme value distribution function. Besides, the paper highlights other flood risk mitigation measures which includes channelization of the Nallah and water storages to collect additional amount of water during flashfloods.

1.0 INTRODUCTION

Leh, situated at an altitude ranging from 2900m to 5900m [7] is the most elevated & habituated district of the earth. It is on the high Tibetan plateau between India and the Himalayan Mountains to the south, China and the Karakorum Mountains to the north, & Indian Kashmir to the west. Location of Leh can be seen in figure 1. Leh, Ladakh region is consisting of two districts Leh and Kargil. Leh with an area of 45110 Sq Kms [1] makes it second largest district in the country in terms of area. Leh is connected to the main land through two roads namely Leh-Srinagar highway (NH-1D) (422 Kms) and Leh-Manali highway (NH-21) (479Kms)[1] These two roads remains closed for more than 7 months during winters due to closure of the passes (Zojila, Rotang, Baralacha, Changla) [1]

The Airport namely Kushok Bakula Rimpochee, at Leh provides all weather accessibility to Leh by Air.

1.1 CLIMATE

Leh has a cold, arid climate with long, harsh winters from October to early March, with minimum temperatures well below freezing for most of the winter. The town gets occasional snowfall during winter. The weather in the remaining months is generally fine. Air is very dry & relative humidity ranges from 45.62 % to 78.80 %. [8]

Figure 1: Jammu & Kashmir

1.1.1 TEMPERATURE

The town enjoys extreme type of climate with wide diurnal and seasonal fluctuations in temperature with -40°C in winter and +35°C in summer. [1] Due to extreme cold climatic conditions town should be better prepared to cope with increased frequencies of disasters. So the mitigation work will include some extra measures to work under extreme cold climate such as:

- Effective emergency management (emergency preparedness and response capacity) such as sufficient power supplies, food distribution systems and shelter provision.

- Implementation of early warning systems to reduce damages against floods.

1.1.2 RAINFALL

The annual average precipitation is very low being 100mm only which is mainly in the form of snow, making the town climate devoid of humidity. [1]

1.2 FLORA OF LADAKH

The entire area of Ladakh is a cold desert & devoid of any natural vegetation however the sporadic flora is available mainly along rivers/streams. The alpine, desert and oasitic elements are the representative feature of the flora of Ladakh, dominated by annual and perennial herbs, followed by few stunted shrubs and bushes. The main trees are the willow and poplar and they meet the requirement for fuel and timber. Easy to grow and maintain, they provide a good yield of fodder for the animals and twigs for baskets. Fragrant juniper (Shukpa) grows everywhere, and is used for ceremonial and religious purposes. [10]

The most prevalent flow impediment during flashfloods is vegetation. So the plantation should be away from rivers/streams flood plain to avoid obstructions during flashflood. This will help in increasing carrying capacity of channels.

1.3 GEOLOGY

The soil of Leh town could broadly be classified into four broad categories:
Sandy Soil: The sandy soil is generally found near/on the foot hills of different mountains. These areas are devoid of any vegetation and green cover.
Sandy Loam: Sandy loam is found near river basin and around the rivulets these areas form rich and fertile agricultural areas and are full of willow and poplar trees.
Exposed Rocky: The exposed rocky soils consist mainly of mountain with rugged and steep topography.
Boulder Sandy: Boulder sandy areas are concentrated mostly towards the Choglamsar and Agling.

In Recent cloudburst disaster of Leh huge amount of mud came along with rainwater which caused more damage to life and property. The solution to this problem is to relocate the population in vulnerable areas to higher and firm mountains i.e. on Stok side.

1.4 LANDUSE PATTERN

Recent development in Leh town has been haphazard and unplanned. Mostly development can be seen near the river/nallah sides. Many houses, Guest Houses, Hotels and other premises have come up along the nallah bank. Being the higher cost of land in the town, some habitants encroached upon the nallah land. New buildings coming up in town should follow an architectural code, and should have thermal retentive capacity.
For reducing the damages from disaster, Leh town is to develop along the lines of a zonal town-planning model. Relocation & Rehabilitation of encroachments on a nallahs is required. Other important adaptive measures to

reduce the health and hazard risks include land use regulations, such as limiting floodplain development, and upgrading water and wastewater treatment facilities.

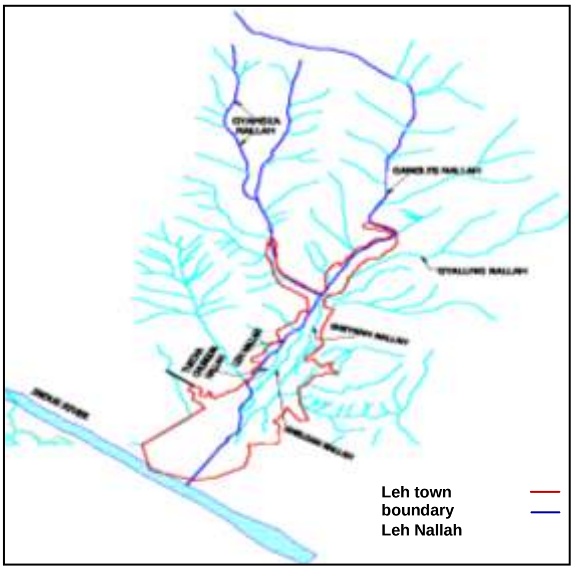


Figure 2: Drainage Pattern in Leh

1.5 NATURAL DRAINAGE IN LEH

River Indus flows south of the town of Leh from east to west. In the north of Leh town towards Gangles, rivulet namely Leh Nallah (Gangles Tokpo) with its tributary streams namely Gyulang Tokpo and Togar Tokpo form the natural drainage system with their own valley formation. These two streams meet the Gangles Topko at Horzey. The Leh town has been growing in the Gangles valley.

Another tributary of Gangles Tokpo comes from north-west side of the Gangles Topko namely Gyamtsa Tokpo from the side of the Gyamtsa and meets Gangles Topko in Khakshal & Sangto-Tokpo form the natural drainage whose water is used for domestic and irrigation purposes. Gyamtsa Topko has formed its own valley where the Leh town has taken its course of growth.

The Gangles Topko in its down ward journey has acquired the name of Leh Topko after its confluence with Gyamtsa Topko and other streams which splits into a no. of branches and sub branches- Tukcha Topko, Sheldan Topko and Sheynam Topko. Drainage Pattern is shown in figure 2.

Leh Nallah originates from snowy peaks of Khurdungla ranges and passes through the Leh Town. Many houses, Guest Houses, Hotels and other premises have come up along the nallah bank, nallah no doubt is a small nallah but whenever melting of snow takes place and some cloud burst occurs in its catchment, flashflood occurs in the nallah resulting in corroding banks, damaging houses, orchards and other properties. Relocation & Rehabilitation of encroachments on a nallahs is required.

The department has done spot treatment works at some places out of District plan by providing crate, revetments along nallah Banks. Since District funds are not sufficient, therefore this project has been framed to protect the nallah Banks from eroding at vulnerable spots from Gangless to Spituk within municipal limits of Leh town to safe guard life and property of people.

1.6 CONSTRUCTION PRACTICES IN LEH

The houses in Leh are built in traditional Ladakhi fashion using sun baked mud bricks and wooden beams made of poplar and willow. Over the centuries these houses have allowed Ladakhi's to lead a self-sufficient and comfortable life with limited local resources. The two main reasons for the damage to houses are.

1. The excessive lateral force exerted by the rushing mixture of water, mud and rocks
2. Use of mud as the only material for walls. Mud loses it ability to bind and eventually dissolves once it comes in contact with water.

The houses have been damaged to varying degrees and forms depending upon the location and the techniques and material used. The damage suffered can be broadly classified into three categories:

a) Damage to the corners of the house: This was due to the absence of any lateral load resisting features in the house

b) Complete failure of walls: This was due to the excessive outward pressure exerted by the rushing mass of mud, rocks and water on the plain mud walls.

c) Damaged openings: Due to the force of rushing mud, rocks and water funneled through small openings.

d) Complete failure of some RCC frame buildings: Lack of know-how and absence of quality control led to poor construction, which caved in under the extra stress exerted by flood waters.

e) Excessive damage to schools and other community buildings.

There are structural damages due to poor strength of material and absence of resistant technologies to face disasters of such magnitude. Construction materials and technologies have to be thus improved.

1.7 SOCIO-ECONOMIC CHARACTERISTICS

The total population of Leh town as per the Census 2001 is 28639 [10]. The Census population from 1911 to 2001 has been listed in table 1 & population trend in figure-3 below:

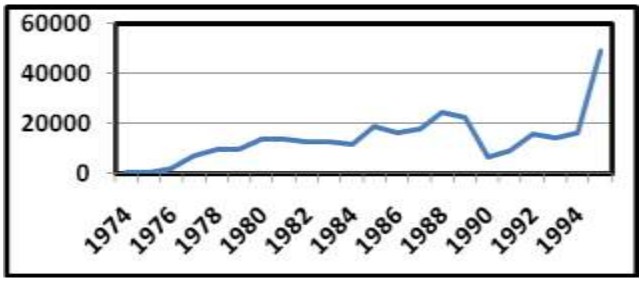
Table 1: Population for Leh town as per Census

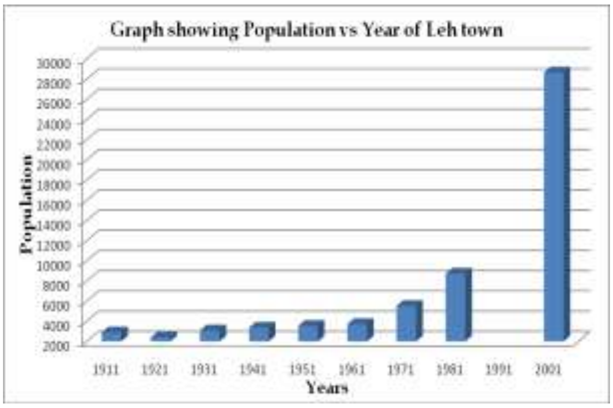
Year	Population
1911	2895
1921	2401
1931	3093
1941	3372
1951	3546

1961	3720
1971	5519
1981	8718
1991	-
2001	28639

Figure 3: Population Increase Trend of Leh Town

Figure 4: Domestic and Foreign tourist arrival in Leh 1974 – June 2009





Source: Jammu& Kashmir, X-A, town directory

1.8 TOURISM: Tourism has emerged as one of the dominant components of the current Ladakhi economy. It provides jobs to people in the thousands today, and is easily the biggest source of money for the locals after the government sector. [15].Tourist arrival for last 37 years is shown in figure 4.

In order to increase the tourism we need to focus on strong structure of flood mitigation measures which can combat with disasters like the cloudburst that happened in August 2010. Due to this kind of disasters huge loss of life & property will cause panic & may decrease tourist population in the town.

1.9 ADMINISTRATION:

Ladakh Autonomous Hill Development Council (LAHDC) governs the administration in Leh since 1995. In Leh there is no particular Disaster Management authority in Place. The Flood Mitigation Measures includes formation of Disaster Management Authority/Cell which would be involved in policy/decisions making, resource and budget allocation and monitoring through the State Emergency Operations Centre. Further authority will also be responsible for following activities with local participation:

- Hazard and vulnerability assessment.
- Training, education, awareness & preparedness.

- Disaster risk management planning.
- Community and local level programming.
- Multi-hazard early warning system.
- Mainstreaming disaster risk reduction into development.
- Emergency response system, and
- Capacity development for post disaster recovery.

2.0 HAZARD & VULNERABILITY ANALYSIS

The major calamities, which the Ladakh is facing, are cloud bursts, flash floods, earthquakes & snow avalanches in upper reaches have been discussed below:

2.1 SEISMIC SETTING

The Ladakh Region of the Himalayas is situated in seismic zone IV close to Karakoram fault zone, Eastern Karakoram, Ladakh which is highly prone to earthquakes.

In fact the whole of the Himalayas are the seismic effective zones and experience frequent sub-terranian tectonic disturbances causing earthquakes of severe intensity which are the cause of huge loss of life and property.

As many as six earthquakes have been recorded in the last century of magnitude 6.0 and above on the Richter Scale as below:

- May 17, 1917 of 6.0 magnitude,34.20N & 77.50 E
- Nov. 11, 1921 of magnitude 6.0, 34.20N & 77.50 E
- Nov. 15, 1937 in Northern Ladakh along the Indo-China Border region of magnitude 6.0, 35.1 N & 78.10 E
- June 22, 1965 of magnitude 6.1, 36.30 N & 77.70 E
- April 28, 1975 in Aksai Chin of magnitude 6.3, 35.054 N & 72.870
- Nov. 19, 1996 in Aksai Chin of magnitude 6.9, 35.345 N & 78.133 E

2.2 FLASH FLOODS

Flashfloods are frequent in Leh Region. It occurs due to following reasons:

- Cloud burst
- Excessive melting of snow in the upper reaches of glaciers
- Sudden removal of cloud cover / long sunny days after a period of sustained snow fall

In flash floods water starts flowing at unprecedented rates and the problems are multiplied by movement of slush / mud slide / boulder movement, culminating into movement of debris and local mass in the drainage channel resulting into flash floods.

Since the drainage channel in hilly areas are extremely steep with gradients higher than 10%, so the total warning time is very less. The required safety measures cannot be taken to prevent or mitigate loss of life and property in such an event unless an early warning / prediction system is designed & established.

Recent Floods in Leh Nallah

Year	**Cause**
June 2005	Snow Melting
August 2006	Cloud Burst
August 2010	Cloud Burst

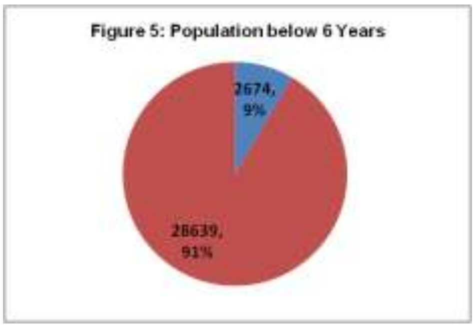
In June 2005 Leh experience floods because of melting of snow, in August 2006 & August 2010 because of cloud burst.

2.3 SNOW AVALANCHE

The snow avalanche, a common occurrence in snow covered mountainous regions, is a slide of snow mass down a mountainside. Humans have been exposed to the threat of sliding snow for as long as they have inhabited mountainous regions. This is a rapid down slope movement of a large detached mass of snow, ice, and associated debris such as rocks and vegetation. Small avalanches, or sluffs, occur in large numbers, while large avalanches occur infrequently but cause most of the damage. A large avalanche can run for many kilometers, and result in massive destruction of forests and anything else that comes in its way. For prevention of such disaster various early warning system are to be adopted.

In the context of human vulnerability to disasters, the economically and socially weaker segments of the population are the ones that are most seriously affected. Within the vulnerable groups, elderly persons above 60), women, children (0-6 years), especially women rendered destitute, children orphaned on account of disasters and differently abled persons are exposed to higher risks. Out of total population of 28639 (as per census 2001), 2674 are below 6 Years which are highly vulnerable during disasters & can be seen in figure 5.

Vulnerability assessment deals with the physical vulnerability and socio-economic vulnerability. Physical vulnerability depends on physical location of people & element at risk i.e. buildings & infrastructure. Vulnerability varies according to construction techniques, material used & location.



3.0 RECENT FLOOD DISASTER OF AUGUST 2010 [2] [17]

A Leh flood that has been occurred on August 5, 2010 (night) was the huge disaster. At least 193 people died (official reports suggested five foreign tourists were killed), and thousands were injured as heavy rains overnight caused flash floods and mudslides. Thousands more were rendered homeless according to government officials. 200 people were still missing following the floods. Origin of flashfloods can be seen in figure 6.

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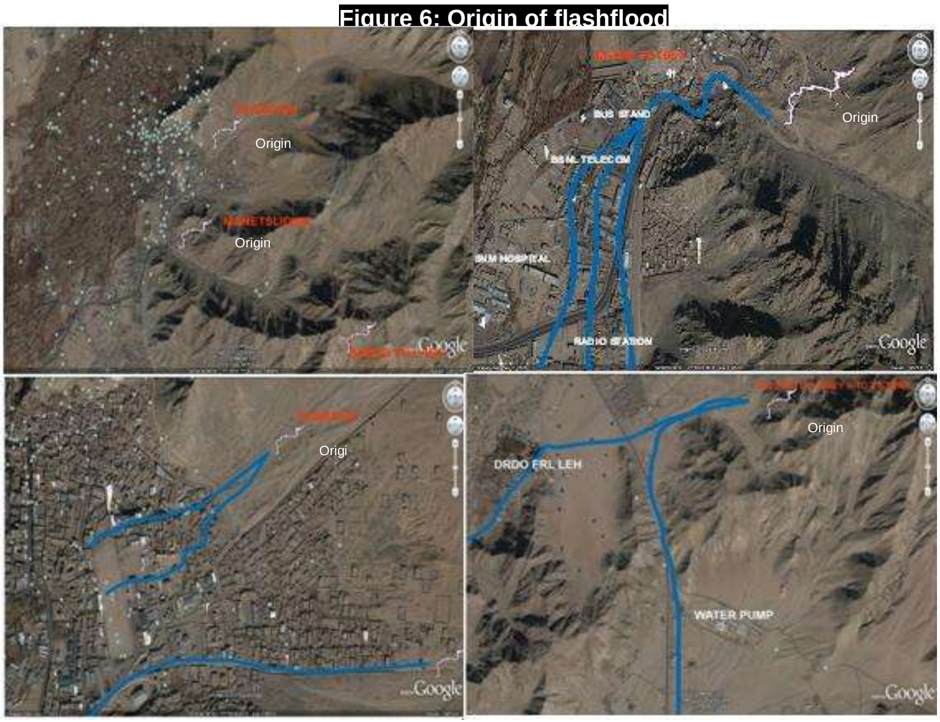
Figure 6: Origin of flashflood



The flash floods happened after a night of heavy downpour. The rains came after midnight and surprised everyone. Many buildings were destroyed including Hospitals, bus terminals, radio station transmitter, telephone exchange and mobile-phone towers, even the BSNL communication systems were fully destroyed, the communication was then restored by the Indian Army.

The local bus station was damaged and some of the buses were carried more than a mile by the mud. The city's airport was damaged but this was repaired and relief flights were expected to come in the following day. The village of Choglamsar on the outskirts of the city was particularly badly hit. All of the estimated 3000 tourists in the area including 1000 foreigners were safe according to local officials.

Lives Lost: 234 (207 civilians, 6 foreigners, 26 army personnel
No. of Injuries: 424 (20 grievous injuries)
No. of Missing: 64 (52 Civil inclusive of 2 foreigners, 12 Army (2 are porters)
Area of Impact in the Leh District: 52 Villages Affected
Population Affected: 9000 persons (approx)
Total No. of Houses Damaged: 1440 Houses
Estimated Value of Damage to Public Utilities: 158.02 Cr
Estimated Value of Damage to Houses: 40.03 Cr
Total Cropped Land Area Affected: 660 Hectares
No of Animals Lost: 1329

3.1 ASSESSMENT OF DAMAGE [2] [17]

Damage to Infrastructure (Public)

Damages to the Hospital and Health Department Infrastructure

- Damages to Operation Theatre, Surgical Ward No. 1 and 2, Gynecology Ward, Blood Bank, Medical Wards 1 and 2, Labor Room, OPD and C.T Scan
- Heating System at SNM Hospital Destroyed
- DG Set Destroyed
- Restoration of Health Department Buildings in villages and completion of E-Block at the SNM Hospital is urgently needed
- Cost of restoration of F-Block and completion of E-block estimated at 8.91 Crores
- Works being carried out by the PWD on a credit basis

Damages to Roads and Bridges

- 26 different roadways inclusive of link roads, airport road and internal roads have had major impact (under PWD)
- 688.80 km damaged out of 1722 km maintained by PWD
- Breaches at stretches: 66.46 km
- 622.34 km was totally under flood water, heavy sludge, slips/slides accompanied with heavy boulders
- 3 major link roads under PMGSY damaged
- 29 bridges damaged out of which 10 have been completely washed away
- 6 Nos. of Bailey Bridges have to be installed/launched at vulnerable sites on an emergency basis (Yurtung and Phyang Bridges have been installed

Bridges Washed Away

- 80 Metre Span Bailey: Mankhang Phyang
- 70 Metre Foot Suspension Bridge: Phey
- 15 Metre Steel Girder Bridge: Phyang Phulung
- 6 Metre Culvert: Shamba Airport Road
- 6 Metre Culvert: Manley Bagh to Airport
- 10 Metre Culvert: Tunglung Chamba Road
- 2 Nos. 6 Metre Culvert: Nimoo Drukpa Road
- 8 Metre Culvert: Nimoo Tsaldung Road
- 6 Metre Culvert: Nurla Temisgam Road
- 65 Metre Foot Suspension Brigde at Tar
- 3 Nos. 6 Metre Culverts: Saboo-Pullu Road

Damage to Canals/Khuls

- Headworks of most Zamindari Khuls/Canals were destroyed in the flash floods

- Heavy damages to irrigation khuls and footbridges under Rural Development Dept.
- Protection works on the banks of the Indus, Siachen, and Shayok Rivers were also damaged
- Medium Irrigation Igoo-Phey Canal – sludge and boulders at stretches as well as damages at various sections
- Temporary Restoration has been carried out, however funds are need for permanent restoration

Damage is more because in Leh because there is lack of Disaster Mitigation Plan in Place. So the proposed Disaster Mitigation Plan will be a strong structure to overcome the high damages.

3.2 REASONS FOR LEH CLOUDBURST

Cloud burst is natural calamity; it occurs when during the thunderstorms, the air mass that goes up from the lower level carries a certain amount of water in it. Sometimes that air current abruptly stops moving and the water mass falls down forcefully on the surface of earth which causes cloudburst.

In fact, cloudbursts fall from a very high altitude. That is why the force of cloudbursts is so strong.

The primary reason behind cloudburst is the rapid concentration of the pieces of clouds in the sky. The result of cloudbursts sometimes causes great harm to the certain place it appears.

Cloudburst in Leh area was a natural calamity as similar events happened in the surrounding areas however some more reasons might have contributed for the same:

- Prolonged winters which may be due to climate change.
- Increased plantation of trees in the region.

4.0 THE RECOMMEND FLOOD CONTROL MEASURES

During flashfloods very high discharges in the tune of 584 cum/sec are observed in the Nala. Also velocity in the Floods is observed to be 7m/s to 14m/s at certain sections it goes up to 20m/s also. The highest flood level (HFL) of Gangless Nala is varies from GL + 0.6 m to GL+1.1 m along the various section & The Average Scour depth varies from 1.1 m to 2.3 m in habited area and at some locations it is observed to be as high as 2.9 m. Foundation depth of the structures is designed based on the scour depth. Some other recommendations are[21]:

1. **Construction of Embankments near inhabited areas along River Indus & various Nallahs.**

It has been proposed to construct embankments on vulnerable spots in stretches at river & nallahs. With the help of discharge data of River Indus (procured from Irrigation & Flood Control department, Leh), design discharge is calculated for return period of 100 Yrs. Using the 100 yrs design discharge value an embankment is designed as below:

Gumbels Extreme Value Distribution Function

Table 1.1: Data available is of 5 years 2004 - 2008,

Years	Peak Discharge (m^3/sec)
2004	96.065
2005	319.501
2006	492.00
2007	157.00
2008	162.331

Mean X =245.3794, Standard Deviation Sx =160.7159

$$y = a\,(x - xf)$$

Where, y is the reduced variate and can be estimated as:

$$y = \ -0.830432 - 2.3 \log 10 \log 10 \ (\frac{Tr}{Tr-1})$$

Where, Tr = Return Period

a & xf are the parameters of the distribution and x is the design discharge. The values of a & xf can be calculated as:

$$xf = \overline{x} - 0.45005\ sx$$

$$a = \frac{1.28255}{Sx}$$

Where, x is the mean of the data and Sx is the standard deviation of data series

$$Xf = x - 0.45000Sx$$

$$Xf = 245.3794 - 0.45005\, x\ 160.7159$$

$$Xf = 173.0492$$

$$a = \frac{1.28255}{Sx}$$

$$a = \frac{1.28255}{160.7159}$$

= 7.980 x 10^{-3}

Y100 = - 0.830432 – 2.3 log10 log10 x {T_r / (T_{r-1})}

Y100 = - 0.830432 – 2.3 log10 log10 x {100/(100-1)}

Y100 = - 0.830432 – 2.3 log10 log10 x (100/99)

Y100 = - 0.830432 – 2.3 log10 log10 x 1.010

Y100 = - 0.830432 – 2.3 x (-2.3643)

Y100 = - 0.830432 + 5.438

Y100 = 4.60

$Y100 = a (X_{100} – X_f)$

$Y100 = a \times 100 – a \times f$

$a \times 100 = Y_{100} + a \times f$

$$Y_{100} = a \times (Y_{100} - xf)$$

$4.60 = (7.980 \times 10^{-3}) (Y_{100} – 173.0492)$

$576.44 = Y100 – 173.0492$

$Y_{100} = 576.44 + 173.0492$

$Y_{100} = 749.48 = 750m^3/sec$

Design Discharge for return period (100 years) is coming out to be 750 m^3/sec.

Embankment Design for design discharge of 750 m^3/sec

Length of Embankment for inhabited area to be protected: 250m

Invert Levels: 3260, 3259m

Slope is: (3260 – 3259) / 250

Slope =0.004

Using Manning's equation, calculating water depth

$$Q = \frac{1}{\eta} AR^{2/3} S^{\frac{1}{2}}$$

Where Q = discharge

A = Wetted Area;

P = Wetted Perimeter:

n = manning's roughness coefficient, 0.025 for earth in ordinary condition

S =slope

For trapezoidal channel:

Area = (b+2 h) h

Perimeter = (b+ 2√5 h)

Clear water way can be calculated with the help of Lacey's equation: P = 4.75√Q = 4.75√750 = 130 m

$$\frac{Q \times \eta}{S^{\frac{1}{2}}} = A \times \left(\frac{A}{P}\right)^{2/3}$$

$$\boldsymbol{h = 1.65}$$

The length of guide bund u/s

L = 1.25 b

$$l = 1.25 \times 130 = 162.5m$$

$\boldsymbol{l = 162.5m}$

The length of guide bund d/s

L = 0.25 b

$l = 0.25 \; x \; 130$

$\boldsymbol{l = 32.5m}$

The radius of curved head

(upstream portion)

= 0.45 b

$= 0.45 \; x \; 130 \; = 58.5m$

$\boldsymbol{l = 58.5m}$

Cross Section of Guide bund

Height of embankment = Water depth + free board =1.65 + 1.5 = 3.15m

Assuming the top width of bund as 5m & side slopes as 2:1.

$Gl = 3261$

R.L of top embankment = 3259.5 + 3015 = 3262.65m

Assuming width bund 5m with side slopes 2:1

Design of stone pitching and apron

t = 0.06 Q 1/3

$t = 0.06 \; \times (750) \; 1/3$

$t = 0.06 \; \times 9.0835 \; = 0.54m$

The thickness of apron is given by:

$= 1.9 \; \times t = 1.9 \; \times (0.55)$

$= 1.045 = 1.05m$

The length of apron is given by 1.5D, where D for the straight reaches of the guide bund

$$= 1.25 \; R - y$$

Where, $R \; = 0.47 \; \left(\frac{Q}{F}\right) \frac{1}{3}$

Where f is the lacey's silt factor given by:

$f \; = 1.76 \sqrt{dmm}$

Where, dmm is the average particle dia in mm

$= 1.76\sqrt{0.10} \; = 0.556$

$R \; = 0.47 \; \left(\frac{750}{0.556}\right) \frac{1}{3}$

$= 5.19m$

$y = 1.65\ (water\ depth)$

$D = 1.25\, R - y$

$D = (1.25\ \times 5.19) - \ 1.65$

$D = 4.83\, m$

Length of apron = $1.5D\ = 1.5\ \times 4.85$

$= 7.275 = 7.3m$

Proposed embankment section can be seen in figure 7

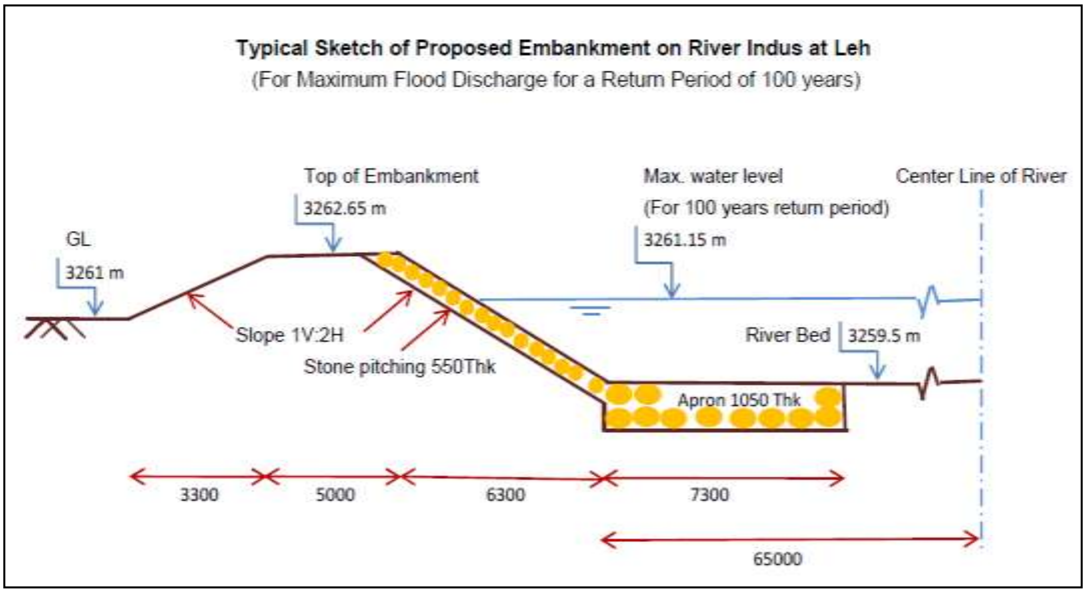


Figure 7: Proposed Embankment Section

2. **Wire Crate / Gabion walls / Bunds in Giamtsa, Gyalong and Shenam Nallah**

Wire Crate / Gabion walls are proposed for lining in the upper reaches and in the base it is proposed to use cascade type energy dissipating structures all along the Nala. In the urban areas where the land is not available in suitable width CC Walls at vulnerable spots are proposed in urban areas of Leh and in Giamtsa, Gyalong and Shenam Nallah.

3. **Check Dams across the Nallah.**

It has been proposed to lay crate check bunds along nallah to prevent erosion of nallah bed at vulnerable spots from Ganglas to spituk.

4. **Channelization of Nallah at Places.**

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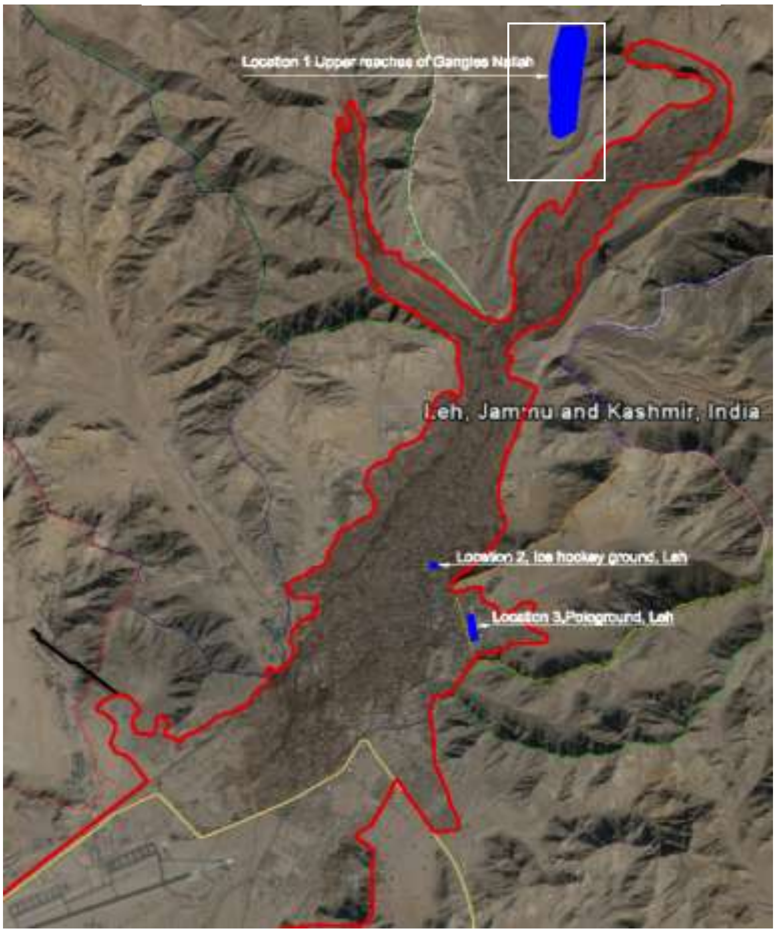
Channelization of the nala can be done in certain reaches to accommodate full discharge in the flood periods of around 600cum/sec. The purpose of this measure is to increase the flow-carrying capacity of the channel. Types of channelization include channel lining, excavation, bypasses, and levees.

Figure 8: Locations of Detention basin



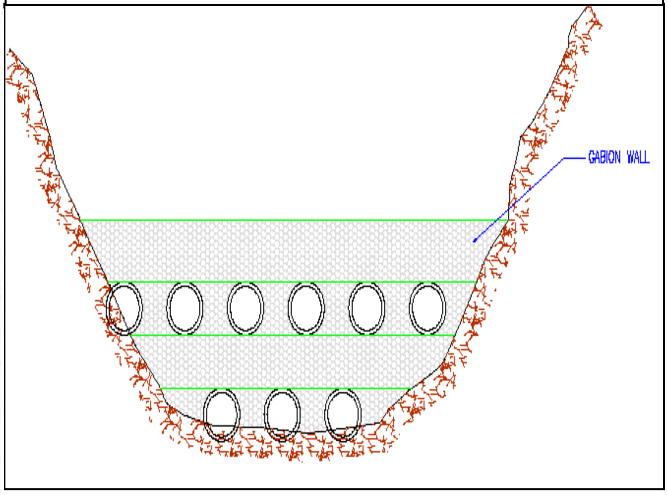
5. Detention basins: Flood damage reduction through attenuation of flood flows (reduction in peak discharges) can be provided by detention basins. Basins temporarily store a portion of the total runoff from a storm event until the event ends, when the stored water can be released into the downstream channel at a rate that is less than or equal to the channel's capacity. Basins typically require large areas of open space, in which the use of the land must be restricted to those that are compatible with periodic inundation.

For Leh town flood control solution consisting of three detention basin complexes, one Detention Basin in the upper reaches of Gangless, second at polo ground & third one at ice hockey ground which will receive the diverted additional water of the Flash Flood through a tunnel and finally spreads in the detention basin (see figure 8)

At outlet point of detention basin a gabion structure with suitable diameter RCC pipes for controlled release of water shall be provided. Early warning system should be implemented so that alarm/signals can be raised in any eventuality of raising the water level in Nallahs. Plan of Detention basin can be seen in figure 9 & Gabions section in figure 10.

Figure 9: Plan of Detention Basin at upper reaches of Gangles Nallah

Figure 10: Gabions for Controlled Release of



6. Removal of Impediment to flow:

Objects in the channel impede flow, in effect decreasing channel capacity and increasing the frequency and severity of flooding. The most prevalent flow impediments found in this watershed are vegetation, boulders, mud/ silt deposits & narrow culverts. Removal of flow impediments is required to increase the carrying capacity of Nallahs during the flood.

7. Relocation:

As described earlier many houses, guest houses, hotels and other premises have encroached /come up along the nallah banks, whenever flood occurs in the nallah it results in croding banks, damaging houses, orchards and other properties. So Evacuation & Relocation is required at these places to reduce the damages.

Also proper Preparedness i.e. Establishment of the Control Rooms, Communication System, Training for Disaster Management Team Members, Organization of Mock Drills, Community Awareness on Various Disasters etc instantly helps to respond a disaster in time. So disaster wise preparedness and mitigation is highly required. These are normal time activities. A prepared community is the best community to minimize the loss and damage caused by the disasters. Mitigation focuses on various ways and means of reducing the impacts of disasters on the communities through damage prevention. The most important measure is to reduce vulnerability is through capacity building.

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