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RESEARCH ARTICLE

CAUSES AND IMPACT OF URBAN FLOODING IN DEHRADUN

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ABSTRACT

Disasters like flooding have changed their dimensions in urban areas. The urban flooding in cities is mainly in the form of flash floods and water logging of streets due to high intensity short spell rainfall. But the extents of damage to these disasters have increased over time in the urban areas because of increased rainfall runoff volume and due to greater exposure of people and assets because of concentration of resources. But it is clearly evident that different level of exposure and different extents of flood hazard characteristics vary the 'urban flood risk' nature from city to city. In order to be able to quantify the present and potential flood risk, an understanding of the causes of urban flooding, vulnerability and exposure is mandatory. These may be seen as -causing and impacting factors of flood risk, which may be specific to a given area. In this context a study is conducted to identify the reasons of flooding in the city of Dehradun, (the capital of Uttarakhand State), where these factors are studied as- (a) causes of flooding factors and (b) impact due to flooding factors, for Dehradun. River flooding and water logging of streets is one of the major problem of the area during monsoon period. The urban floods in the city causes great amount of destruction and inconvenience; causes heavy traffic jam due to street water logging, paralyzes day to day activities, damage the urban infrastructure viz, roads, bridges, electric poles etc causing severe economic damage. Therefore this evidence based study is taken up, where review of flooding incidents of last 5 years (2009-2013), highlighted the significant factors of causes and impacts of flooding where as primary survey and visual survey has also been conducted which helped in identifying the people's perception of risk and the experts are also interviewed to get most accurate information.

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INTRODUCTION

Flooding causes extensive destruction, economic damages, and loss of human lives (**World Disaster Report, 2009**) (**Knight 2011**). Urban areas are at a higher risk to flooding because of increased rainfall runoff volume and due to greater exposure of people and assets because of concentration of resources (Sato 2006). The historical evidences indicate statistics of huge destructions and losses, which testifies this fact. In order to be able to quantify the present and potential flood risk, an understanding of the causes of urban flooding, vulnerability and exposure, is needed (**Genovese 2006**). These are dependent on the flood characteristics, level of exposure and socio economic structure of the people, which may vary from place to place. Therefore it is important to identify the indicators of flood risk which affects the phenomenon and variability of urban flooding. These are derived from the factors that cause and impact the flooding in an area. Dehradun city is located in Doon Valley region of Uttarakhand. It is politically significant as it is the newly formed state capital of

Uttarakhand state (in the year 2000) and with respect to disaster management, it experiences multiple hazards. Flooding and water logging of roads are a major problem of the area during monsoon period. The urban floods in the city causes great amount of destruction and inconvenience; causes heavy traffic jam due to street water logging, paralyzes day to day activities, high intensity rains damage the urban infrastructure viz, roads, bridges, electric poles etc causing severe economic damage. A review of such various incidents is being attempted in this paper on the basis of last 5 years of flooding events. Therefore this study aims to identify the factors of causes and the factors that impound the impact of flooding.

Study Area

The Dehradun city is located in south central part of Dehradun district. Dehradun city lies at 30° 19' N and 78° 20' E. Figure 1, shows the location map of Dehradun city. The city lies in Doon Valley which has the Himalayas to its north, the Shivalik range to its south, the sacred river Ganga to its east and the river Yamuna to its west. The physical limit of Dehradun city is marked by two intermittent streams namely Rispana River in the eastern part and Bindal River in the western part.

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Figure 1. Location Map of Dehradun City

Dehradun is surrounded by dense forest all around and number of streams and canals dissect the city in the north-south direction. The high hills in the east and north and Sivaliks in the south give an interesting topographical setting to the city. The city area is administered by Dehradun Municipal Corporation. The Dehradun city consists of 60 wards as per 2011 Census. Two intermittent streams viz. Rispana River and Bindal river, on the east and west respectively mark the physical limits of Dehradun Municipality. The city is located at an altitude of 640 m above MSL. The lowest altitude is 600 m in the southern part and the highest altitude is 1000 m in the northern part. The city slopes gently from north to south and south west and is heavily dissected by a number of seasonal streams and nallas. The drainage of the city is borne by the rivers Bindal and Rispana.

Urban Flooding Scenario

Urban flooding is a relatively serious problem in the city, especially in the dense parts of the city and in the areas located along the river flood plains. Dehradun is majorly affected by water logging of streets and seasonal river flooding. The city has many large and small drains, but it is mainly drained by two rivers, namely Bindal and Rispana. These rivers remain out of water throughout the year except for the monsoons when water level reaches the nearby low-lying areas. Each year more and more localities are being affected due to water logging of streets in Dehradun. For instance, the localities that were worst hit in 2013 rains were Guru Tegh Bahadur Road, Balbir Road, Purn Balmiki Basti, Nai Basti, Nimi Road, Mahatma Gandhi Basti, Nai Basti, Rajesh Rawat Colony, Karan Pur, DL Road, Arya Nagar, Bhagat Singh, Shanti Vihar, Indira colony, Chukku Mohalla and Kanwali Road; are also the most frequently affected every year. This is the situation year after year and it is getting worse with the increase in intensity in rainfall which is mainly anticipated due to climate change. The high intensity rainfalls for short durations are primary cause of such flash floods. These urban floods bring stress in people's life and cause and increase "everyday risk" in the city. These have been evidenced in various incidents of urban flooding in the city and are discussed in the later section. It has been observed that due to flooding, roads get blocked; people are unable to commute to work or to schools; the economic damages are seen to be heavy in terms of housing damage, household contents being flooded and sometimes the kuccha houses collapse partially or completely due to intense rains. Not only this but the roads also gets damage due to long hours of water retention and infrastructure services like electricity and water supply gets disrupted. Though there is no high number of death casualties but the economic loss impact is irreparable especially to poor people as recovery in most cases takes away everything from them or in some cases recovery is not even possible. These people lose all hopes of surviving the everyday challenges of life.

The Lack of public awareness and lack of preventive measures at household level and by city officials, leads to failure of flood management in the city. The District Administration, Dehradun Municipal Corporation and State Disaster Control Room of Disaster Mitigation and Management Centre (DMMC), have a very big role to play after and during the floods, but it seems inspite of their efforts, the problem has

gained monstrous dimensions. Therefore there is a need to strategize the mitigation and pre preparedness activities in Dehradun based on flood risk assessment. Based on the available and accessible literature, it has been identified that there has been no research carried out for Dehradun city on urban flooding. Thus there is a need to study and analyze the causes of urban flooding in Dehradun. These can then be used to formulate quantifiable indicators to measure the urban flood risk. This will help the city planners and policy makers to take necessary actions to mitigate and prevent the flooding situation. There is also a need of detailed micro level study to understand the drainage system. Thus the next section describes the factors of urban flooding in Dehradun in terms of (1) causes of flooding and (2) impacts impounding factors.

MATERIALS AND METHODS

The study identifies examples from the historical evidences of disaster impacts of flooding, which are based to conclude to the factors causing and multiplying the flooding impact. Therefore this study is evidence based where review of flooding incidents of 5 years (2009-2013) is done which help in highlighting the significant factors of causes and impacts of flooding in Dehradun city. Also 1800 primary household surveys randomly stratify in in 60 wards, and visual survey is conducted, which helped in identifying the people's perception of risk and the local level issues during disasters. The experts of DMMC, Dehradun Municipal Corporation are also interviewed to get most accurate information from their view point. These identified factors may later be converted into measurable indicators using appropriate tools and techniques for indicator based risk approach in further studies. The identified factors are discussed under two sections- (a) *Causative factors* and (b) *Impact impounding factors*. Both these categories may include factors that indicate the hazard, physical social economic character responsible for flooding. In the later section, these factors are regrouped into three categories- (1) factors of flooding hazard, (2) flooding exposure (physical elements) and (3) flooding vulnerability (social elements).

Urban Flood Risk Factors

As discussed in the previous section, there are numerous reasons which cause and aggravate the flooding and water logging in the city. We try to list them here and understand the gravity of their contribution in urban flooding in case of Dehradun.

Causative Factors

These are those factors which may be primarily become the reason of flooding in any area. These may include physical factors such are topography, elevation etc.; vulnerability factors like the inefficient urban drainage, inefficiently planned areas responsible for water logging of streets, etc. Thus 7 factors that are primarily 'causing' flooding in Dehradun are identified and discussed below under this category.

Topography (Slope and Elevation)

The elevation of the city ranges in between 550m to 1000m above mean sea level. The earlier study of elevation map

derived from Digital Elevation Model(DEM) indicates that the contours are at closer intervals at the higher elevations, where as they are at greater distances in the lower part of the city indicating that central part of the city is majorly a low lying area with gentle slope. The influence of topography can be evidenced in many incidents. For example Ward No. 12 (upper central part of the city) residents complain about the rain water entering their premises due to down slope where resident Amar Singh, who owns a tailor shop in Green Valley, said “he faced a lot of trouble during rainy days as water entered his shop every year” (The Tribune, Dehradun Plus 2013a). Thus the variation in steepness of the slope is responsible for water accumulation as runoff moves slowly in low lying areas creating problems in parts of the city. Thus it is an important consideration while assessing the causes of flooding.

Excessive Rainfall

Dehradun is surrounded by Himalayan ranges on the north and Sal forests in the south. The high hills in the east and north and Siwaliks in the south, offering an interesting topographical setting to the city. Dehradun experiences heavy to moderate showers during late June to mid August. Most of the annual rainfall (about 2000 mm) is received during the months from June to September, July and August being the rainiest months of the season. The rainfall data of past 14 years of Dehradun city during the rainy months of June to September show that there is a general trend of increase in rainfall amount (Figure 2). This can be associated with many factors like climate change, Global warming etc. This rise in rainfall quantity does not get way through the city as the city storm water drains are not prepared for the increase in surface runoff due. This causes urban flooding.

Increasing in runoff volume

There has been greater runoff generated due to two reasons, first increase in rainfall (discussed before) and second, land use changes in the past few decades due to high urbanization. This has resulted in more built up areas and reduced permeable surfaces and open spaces. This has been evidenced from the growth rate and increase in built-up statistics. The population of the city registered a growth of about 114% during the last two decades from 1991 to 2011 (Singh et al., 2013). As per a study carried out the change and increase in urban build area over the past two decades in terms of built up density per/ 1000 persons increased from 41 ha in 1986, 62 ha in 1998 to 104 ha in 2011 (Singh et al., 2013). Thus the surface runoff due to rains has increased considerably as the impervious layer has increased. Inabilities to deal with increased runoff have been one of the causes of increasing urban floods.

Encroachments on river beds

The encroachments along seasonal rivers and drains are common in Dehradun. These places prove to be easily available to slums. Estimates show as much of 70 per cent of the MC land along the riverbeds is under encroachment as per City Development Plan 2007 (Jawaharlal Nehru National Urban Renewal Mission, 2007). Bindal and Rispana are the two main seasonal rivers draining the city which get flooded only during monsoons.

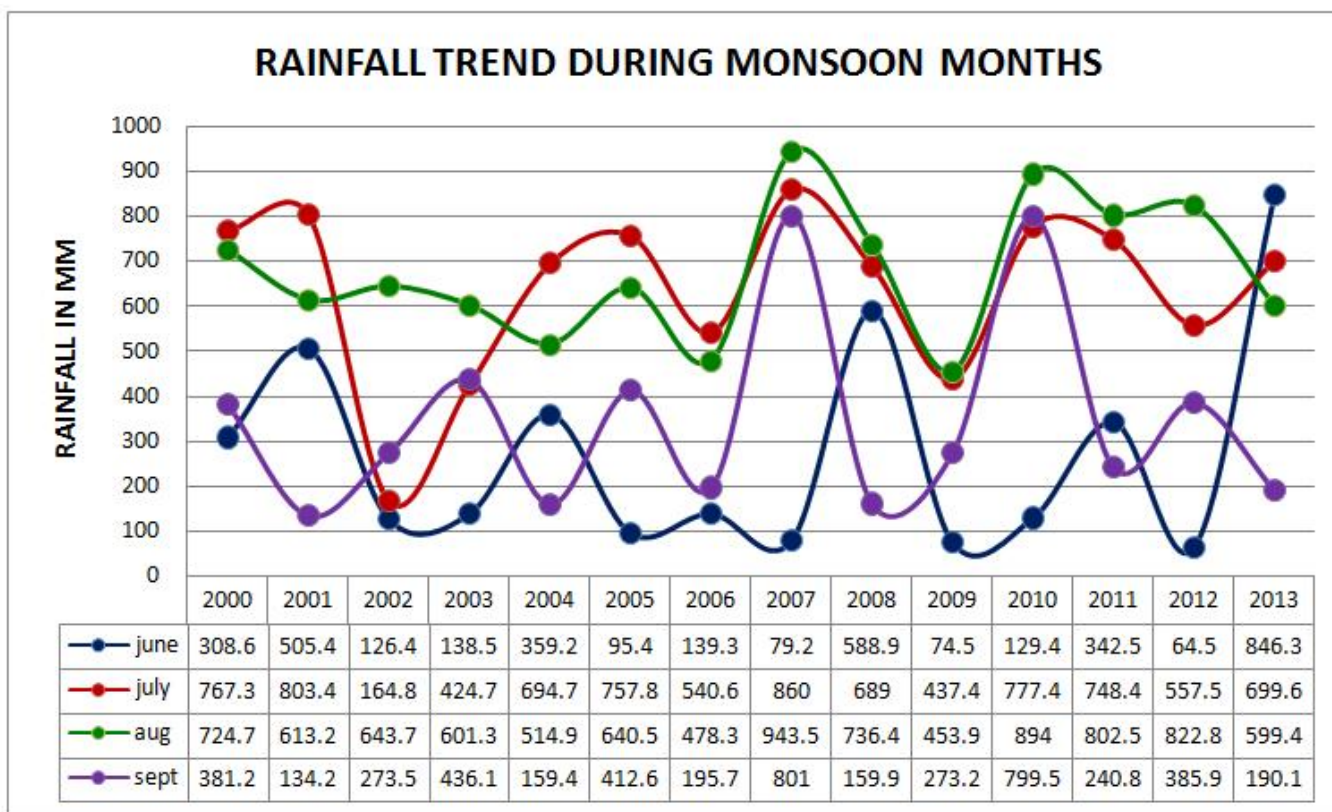


Figure 2. Rainfall trend from 1997-2008 in the rainiest months of the year

Their water level never reaches the danger mark, but it is the encroachment on the river beds that ends up being affected during monsoons. It has been notified by DMC that over 6000 encroachments are there on the Bindal River, and it is just not the slums but rich and powerful people encroaching the river bed too. The evidence of encroached people being affected can be noted in an incident, where in a rainfall event on June 2013, hundreds of slum dwellers living on and near the banks of Bindal and Rispana rivers were worst affected. Several houses (600) got washed away and many others suffered damage in continuous three days rainfall. Thus it can be concluded that encroachment causes flooding. Figure 3 (a) and (b) shows the pathetically vulnerable slum encroachments on Rispana and Bindal rivers.

Embankments Failure/ damaged embankment

Most parts of the embankments provided at various locations in Rispana and Bindal rivers cannot sustain the tremendous pressure of increasing rain water and they get washed away every year. The district administration and Dehradun Municipal Corporation (DMC) try to rescue, but in general they are unprepared to meet the challenge thrown by the natural disaster ([The Tribune, Dehradun Plus, 2013a](#)).

The evidence of embankment failure causing flooding can be evidenced in many incidences. In one of the rain incidents in 2012, Anil Kumar, resident of Sanjay Colony Basti, reported that nearly one dozen embankments which were built quite recently got washed away in one spell of rain and water entered the houses ([The Tribune, Dehradun plus, 2012a](#)). Similarly Nirmala Rani, who lived near Bindalpul said, complained embankment failure and thereafter water entering their houses on June 18 2012 ([The Tribune, Dehradun Plus, 2012d](#)). Thus embankment failure causes flooding in areas along riverbed which could otherwise be prevented.

Urban Storm Water drains

The primary and visual survey indicated that at most of the places the capacity of storm water drains are smaller than the rainfall volume generated each year, secondly in some areas they are broken and not been repaired. Whereas in some areas the drains are not regularly cleaned and solid waste remains dumped in them by people and ironically by the sweepers also. As a result the choked drains overflow the rain water on the roads. Figure 4 (b) below shows the pathetic state of drains in Rajpur area of the city. As the storm water drainage system is incapable of draining the rain water it causes flooding and other associated problems such as inconvenience, damage to roads and spread and deposit the solid waste on roads and other places.



(a)



(b)

Figure 3. (a) Slums along Rispana river bedside on July 5, 2013 in Dehradun, India; (b) Damaged embankment along the



(a)



(b)

Figure 4. (a) A choked drain in Ward No. 54, Dehradun. A Tribune photograph; (b) A waterlogged rajpur road following heavy rain in Dehradun on July 14, 2012

Evidences of flooding due to incapable storm water drainage system can be noted widely throughout the city. For example: Due to insufficient drain capacity, the water enters houses in most localities as in Chander Road, Nayee Basti, majara, clementown, shastri nagar, Nehru gram etc every year([The Tribune, Dehradun Plus, 2011b](#)).

Another example is of Dalanwala (north) area, which is one of the oldest residential colonies is facing many problems due to the absence of drainage system. Owing to choked drains, water remains stagnated outside houses, thus causing flooding and inconvenience to people in this area. ([The Tribune, Dehradun Plus, 2011a](#)). It is just not the insufficient drains but the encroachment of drains in commercial areas that cause flooding. For instance, the road near Paltan Bazaar (CBD of the city) often gets knee deep waterlogged in rains. "It is common knowledge that encroachments by shopkeepers have covered the roadside drains in Paltan Bazaar and other areas of the city", says The Daily Pioneer in their State editions. Figure 4 (a) shows A choked drain in Ward No. 54, Dehradun.

Narrow Streets

A narrow road causes and aggravates the flooding of the streets and roads for hours during rains. Specially when narrow streets lack urban drainage infrastructure they act as land locked spaces. As the streets are denser and narrower in the city centre and in the high population density areas, it causes severe water logging in these areas. The Figure 5 (a) and (b) shows the spate of two narrow streets in Dehradun. It is evidenced in many instances where the residents complain of water logging in areas with narrow streets due to associated problems.

For example- A resident of Morowala area, complained water logging problem due narrow road with blocked drains. The most problem areas that have narrow road network along with broken roads and drains, due to which these areas get soaked each time monsoon arrives are Prince Chowk, Budha Park, Lohiya Road and Bhagat Singh Colony and parts of Alaknanda, Dronapuri, Brahampuri, Panditwari and the ISBT; says The Tribune in their edition on 3rd July 2010 ([The Tribune, Dehradun Plus, 2010c](#)). The conflict of power among various authorities is said to be the cause of such state of roads; as talking to "The Tribune news paper" on 3rd July 2010, the then Mayor of the city said.

Impact Impounding factors

These are the factors which show the impact of the flooding or the factors indicating impact aggravation of urban flooding on elements of the city. These elements may be physical infrastructure or social or economic aspects. There are 11 such factors identified which have been discussed below.

Pollution of river bed

The encroachments of river beds not only pose danger but they cause great deal of pollution to the river beds and these become breeding grounds of diseases and causes monumental damages especially health problems. Figure 6 (a) and (b) shows the pollution state of the two rivers. Every year government spends lacks and lacks in cleaning of this river, but it is futile as it is not followed by any law to forbid people from again polluting it. "One of the dirtiest and the most polluted Chota Bindal river crossing is the Chabel Bagh, Govindgarh locality in the city, which speaks volumes and volumes about the incompetence and laid-back attitude of the administration" says one of The Tribune news paper personnel. It further says, that in Chabel Bagh area even after spending an approximate Rs 2 lakh on cleaning the dry riverbed of Rispana Under the project called "Clean rivers," a Project by Uttarakhand Chief Minister and backed by the Mussoorie Dehradun Development Authority (MDDA), in the last 10 days, the scenario remains unchanged([The Tribune, Dehradun plus, 2013b](#)).

Vulnerable Urban Services

The vulnerable services in different parts of the city such as, hanging electrical wires, choked drains, broken water supply lines, damaged roads are highly responsible for aggravating the damage due to urban floods. These contribute greater problems during rains. It is also very shocking to see, that it is not only the development of colonies but some infrastructure services are being provided in the middle of the Rispana river bed which are vulnerable by their origin only. These are bound to destruction even in shorter spells of rains. Evidence of this is the instance where electricity towers have been constructed on Rispana river beds which are also dangerously very near the settlements.



(a)

(b)

Figure 5. (a) A waterlogged street after a heavy downpour in Dehradun on Wednesday, August 1, 2013; (b) A dilapidated road in ward number 9 does not have drainage line also, May 9, 2011



(a)



(b)

Figure 6. (a) The garbage spilled in Risapna riverbed in Ward No.10 in Dehradun. May 16, 2011; (b) The polluted Bindal river and vulnerable services in the centre of the river bed, 2009



(a)



(b)

Figure 7. (a) A house damaged by rainwater in the Suman Nagar area and (right) August 1, 2010; (b) the boundary wall of houses collapses in heavy rains at Saraswati Vihar, June 17, 2013

This can be seen in Figure 6 (b). In another instance under the DMC, the electric poles were installed by the then Counsellor of Chukhu area, just in the middle of the Bindal river area.

Vulnerable building material and construction

The poor housing stock in terms of materials and construction makes it vulnerable to incessant rains in the city. In many examples, it is the poor building stock that has led to collapse of houses. In the city such instance can be seen, where boundary walls of a number of houses collapsed on Rajpur Canal road area leading to rain water rushing inside houses on June 18, 2012. Figure 7 (a) shows- A house damaged by rainwater in the Suman Nagar area in Dehradun, on August 1, 2010 ([The Tribune, Dehradun Plus, 2010c](#)). In other instances, one person died, four houses were completely damaged while 11 got partially damaged and 53 houses were flooded due to rain over the two days rains in Morowala area of Dehradun, on September 9, 2010. Thus it is clearly evident from the figures that the poor constructions were unable to sustain pressure of rains and the building material of poor quality and the

construction type are incapable of resisting any type of disaster. Figure 7(b) shows The boundary wall of a houses collapse in heavy rains at Saraswati Vihar area of Dehradun on, June 17, 2013.

Socio- economic vulnerability

The children and old people are most affected in terms of socially vulnerable groups. These two sections of society lack mobility and suffer in terms of life loss. The slum people are next most affected ones due to their poor living conditions and due to their inability to recover physically and economically. These are many instances where children have been washed away due to rains; old people are unable to rescue themselves against rains. Evidences of economically weaker and poor people being affected extremely are clearly recorded. For example: In an incident four persons, including a child, died at various places in the city in June 2012 due to the incessant rains. The areas majorly occupied by low income group people, or slums are noted to be the ones with maximum Damages in terms of structures, life loss and urban service breakdown year after year. The main localities with this kind

of vulnerability are Indira Gandhi Marg, Kashmiri Colony, Brahampri Chowk, Kargi Chowk, Shakti Vihar, Banjarawala Tea Estate Bhagirathipuram, Jogiwala Badrishpur Colony, University Road, Indra Enclave, Vasant Vihar, Vani Vihar, Raipur, Mehuwala, Aadarsh Vihar, Kherigauv, Premnagar, Majra and Gandhi Gram (The Tribune, Dehradun Plus, 2010d). Figure 8(a) and (b) shows two such incidents where the structures collapsed.

Aged buildings and Older constructions

Older constructions of the city are more vulnerable during heavy rains. There are various examples where due to age of the building the buildings have collapsed in rains. The denser areas are generally the older parts of the city settled along some water body or near river. These areas are also physically vulnerable in terms of building fabric, age of the buildings and denser road networks. Example: 'Lal Pul', an old bridge in Patel Nagar area of Dehradun, collapsed due to heavy rains on Friday August 29, 2009 due its age and vulnerable construction Figure 9(a) and (b) shows two such incidents where the structures collapsed due to age vulnerability.

Damage to Infrastructure

Heavy rains not only cause damage to houses but severely damage the urban infrastructure like roads, electric poles and damage and disrupt services like water supply and sewerage lines temporarily. The extent of infrastructure damage is especially high in cities due to concentration of infrastructure. The evidences indicate that the impact of flooding is very high especially in places where the infrastructure is below standard in construction and services that are in dilapidated state. Evidence of damaging impact of flooding can be noted in several instances year after year. For instance: an incident of storm followed by heavy rains disrupted normal life, by damaging electricity wires, disrupting power supply; Traffic was obstructed with uprooted trees blocking the roads and damaging cars and properties on June 26, 2012. The most affected areas were Chandan Nagar, Rajpur Road, Balbir Road, New Road, Sahastradhara Road, EC Road, Cross Road,

Lensdown and Budha Crossing ([The Tribune, Dehradun Plus, 2012b](#)). In another rainfall event on June 17, 2013, a road near the Rispana bridge was damaged and an electric poll fell down on the DL road. Figures 10(a) and (b) show access road to LDA area, filled with mud after rains June 2013, A view of uprooted electric poles after a dust storm and heavy rain on the Rajpur Road respectively.



(a)



(b)

Figure 8. (a) Owners try to repair a damaged tin roof of their shop, June 22, 2010; rain fury; (b) The boundary wall of a house collapsed due to heavy rains in Dehradun, August 5, 2012



(a)



(b)

Figure 9. (a) Lal Pul, an old bridge in Patel Nagar area, collapsed due to heavy rains on August 29, 2009; (b) A house damaged on the Neshville Road in Dehradun on September 20, 2010



Figure 10. (a) Access road to LDA, filled with mud, June 2013; (b) A view of uprooted electric poles after a dust storm and heavy rain on the Rajpur Road in Dehradun on, June 23, 2010 (The Tribune, Dehradun Plus, 2010b)



Figure 11. (a) Two girls wade through knee-deep water in the Clementtown area, June 2013; (b) at Nehru Gram and submerged cars in a workshop in Dehradun on July 13, 2013

Different flooding water Depth

The different parts of the city get water logged due to heavy rains, but the water does not reach premises everywhere. It is the low lying areas or areas with narrow roads where water enters the buildings causing greater and longer damage. Thus varying flood levels can be seen during the rains, which vary from 15cm on road to 100 cm water inside the houses. Evidences of different flooding depth are shown here in Figures 11(a), and (b). Examples of this can be seen in rains on July 17, 2013 the localities that are the worst hit were Guru Tegh Bahadur Road, Balbir Road, Purn Balmiki Basti, Nai Basti, Nimi Road, Mahatma Gandhi Basti, Nai Basti, Rajesh Rawat Colony, Karan Pur, DL Road, Arya Nagar, Bhagat Singh, Shanti Vihar, Indira colony, Chukku Mohalla and Kanwali Road where water entered the houses upto 30 cm in different places inside the houses.

Besides this, areas around the ISBT and Clementtown are also completely waterlogged where Cars, autos and two-wheelers could be seen partially submerged with knee deep water above road level. Gandhi Gram, JMS Road, Saraswati Vihar, Panditwadi, Gobindgarh, Teachers' colony and Yamuna Colony were some the worst hit areas where water level was upto 60 cm above road level on July 17, 2013.

Life Loss and Property Loss

As the rain water enters into the houses and shops it causes loss of property and movable goods inside and structural damage to the houses. This can be clearly evidenced in various incidents. For example- In the continuous torrential rains for more than 24 hours on September 19, 2010, life inside the houses got worse. People reported that -"Household things pickied up fungus and clothes started smelling and getting a

grayish tinge due to fungus” ([The Tribune, Dehradun Plus, 2010d](#)). In another incidence in august 2010 rains, water entered low-lying residential areas at Mahatma Gandhi Basti, Nai Basti at Nemi Road, Balmiki Road, Sanjay Colony and many other areas causing problems for the people and household goods. Gandhi Gram, JMS Road, Saraswati Vhar, Panditwadi, Gobindgarh, Teachers’ colony and Yamuna Colony were the worst hit in terms of damage.

[Tribune, Dehradun Plus, 2009a](#)). A severe traffic jam is seen throughout the city during monsoon period especially due to stagnant water and due to broken infrastructure. Some instances are: on June 26, 2012 due to high intensity rains, on two places vehicle movement was diverted due to severe damage to infrastructure which created traffic jam.



Figure 12. (a) Rainwater enters a house in the Shastri Nagar area of Dehradun, June 17, 2013; (b) Morowala area Workers take out water from their shop, July 15, 2011



Figure 13. (a) Traffic came to a halt following heavy rain in Dehradun on august 15, 2012; (b) A traffic jam at the Clock Tower due to heavy rain and the road got blocked on June 27, 2012

In another incident reported on august 25, 2010, people complained of – “Leakage of roofs, fungus, and inlet of sewage water through drainage holes, damage to crops and food grains and as some of the major problems. Figure 12 (a) and (b) shows 2 incidents where water severely damaged the household property and caused severe economic to people.

Severe Traffic Jam throughout the city due to floods

The roads in the city centre suffer greatly due to flooding. Most of them get unfit for travel. Almost all prominent crossings get choked and rain water and dirt lay scattered ([The](#)

Traffic came to a halt following heavy rain in Dehradun on august 15, 2012; A traffic jam due to heavy rain in Dehradun on Monday, July 20, 2010. Figure 13 (a) and (b) shows 2 incidents where traffic came to halt due to heavy rains and flooded water on streets.

Health issues due to spilling garbage

The situation with respect to pollution and health issues turns worse during the rains with overflowing drains spreading the litter onto the roads. This is seen in the Figure 14 (a), (b) which shows how in different parts of the city the garbage is spilled

due to rains during monsoons in different rainfall incidents (**The Tribune, Dehradun Plus, 2009b**). The survey indicates that corporation officials try to handle this situation by providing fogging and spray machines to check the spread of mosquitoes and other insects in the city. But still even a day in these areas can cause great deal health damage. The authorities in their intervention with the tribune - argue that they have shortage of sanitary workers. The senior health inspector expressed his concern over the fact that garbage generated is more than the DMC can handle where, He says “Dehradun Municipal Corporation limits generate an estimated 257 metric tonnes of solid waste per day and it only 155 tons per day finds way into the dump site; the rest finds way into vacant plots, into drains and ultimately seasonal rivers” (**The Tribune, Dehradun Plus, 2009b**). Figure 14 (a) and (b) shows 2 incidents where garbage spilled on the roads due to heavy rains in flooded water on streets.

DISCUSSION

A hazard becomes a disaster when it comes in contact with exposed and vulnerable elements of the city. Therefore as per **Wisner et al., 2004**, Risk is a function of Hazard and Vulnerability. Where, *vulnerability* is defined as the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (**Wisner et al., 2004**). *Hazard* is defined as a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation (**UNISDR 2004**). And *Risk* is defined as the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged)



(a)



(b)

Figure 14. (a) A waterlogged road in Dehradun following a downpour on Thursday evening May 29, 2009; (b) Heaps of garbage could be seen on roads after the rain June 24, 2012

Economic losses

The state capital suffers a great amount of economic damage due to urban flooding, where it is mainly in the form of compensation, repair of the damaged infrastructure. If this amount is used for pre disaster mitigation then probably the loss will considerably reduce. Some examples are stated here which are taken from different rain event damage losses data referred to news archives- for ex. A total of more than 900 roads in the state are believed to have been damaged in the year 2010 rains. According to state government officials, a total of 1,571 houses have been damaged out of which 137 houses totally collapsed. The government claimed that a sum for Rs 45 crore had already been spent as a relief to the affected population. The state government claimed that it was unprecedented rainfall that led to such colossal damage to life and property (**The Tribune, Dehradun Plus, 2010d**). In another incident in the year 2010, Uttarakhand SDM Giri provided an interim relief of Rs 2,000 each to 320 houses was distributed at Grant Market, Banjara, Chander Bani areas and some parts of Rampur, Badripuri (**The Tribune, Dehradun Plus, 2010d**) Such is the amount of loss every year.

resulting from interactions between natural or human-induced hazards and vulnerable conditions (**UNISDR 2004**). The researchers on urban flooding have identified indicators of urban flooding in numerous studies (**Cutter et al., 2000; Cançado et al., 2008; Mutchar and Bahar 2010; Espada et al., 2012**), but in each case the indicators and significance of each indicator varies. Therefore each specific study provides different perception of flooding risk, where the combinations of indicators define the vulnerability and risk levels.

The identification of factors in Dehradun city indicates that there are total 18 factors which are primarily significant with respect to urban flood character in the city. It is seen that, it is primarily the encroachment in case of river flooding and inefficient storm water drainage in other areas of city which is causing flooding. In experts' opinion if the storm water drainage issues are eliminated through mitigation, more than 50 percent of the flooding problem can be resolved. Further, the poor qualities of housing and dilapidated infrastructure in various parts of the city are facing most of the wrath of the flooding. These factors are highly aggravating the impacts of flooding. Therefore probably the flood proofing in most

vulnerable areas can lead to flood risk reduction. The factors which have been identified need to group in terms of hazard, and vulnerability in order to formulate indicators of flood risk assessment. These indicators when quantified and converted into a scale of measurement then the risk is can be quantified in terms of hazard, exposure and vulnerability of the elements at risk as risk is a function of hazard and vulnerability (UNISDR 2009; Trohanis et al., 2010).

Formulation of Flood Risk Indicators

The identified factors help in formulating indicators for risk assessment. The flood risk assessment would enable the administrative authorities to take necessary actions in the specific target areas. Not only this it will allow the disaster managers to identify priority action areas for pre and post disaster mitigation; it will also identify the risk sensitive land use areas which are important component of integrated land use planning. The only limitation in quantification is the data availability or accessibility. The indicators are grouped as-

Urban Flood Hazard

Rainfall return period in no of years, flood plain delineation around the rivers, measuring damaged embankment per unit length of river, measuring the rainfall runoff for a typical return period measured in m^3 ; Measuring Drainage density in a given area, measuring the slope and the elevation; will define the flood hazard characteristics.

Urban Flood Vulnerability

The vulnerability can be primary measures in two components as from the type of factors affecting the city.

Physical Vulnerability

Storm water drainage accessibility and maintenance, dwelling density; measuring the %age of commercial areas/ unit area for exposure of physical, areas with shortage of water supply, areas with poor waste management, areas with shortage of housing, areas with inefficient power supply or poor condition of power supply lines, the age of the buildings will measure their structural vulnerability, type and material used for construction will measure their vulnerability to flooding water).

Social and economic vulnerability

population density, % age of people below 5yrs and above 65 years will measure age vulnerability, % age of illiterates measures lack of awareness, % age of females measures vulnerable population, household size that is persons per household and this shall measure their capacity to cope in flooding, economic vulnerability components- income per person, number of dependents per person, number of persons with disability in a given household, expenditure per person.

Conclusion

Urban flooding is a serious problem in cities and its extent of damage is completely dependent on the extent of their own

vulnerability (Oblack 2014). It is seen from the case of Dehradun that areas which have greater physical and social vulnerability, poor housing stock are most affected. In fact the storm water drainage is a major flood causing factor, never the less to say about narrow streets and in efficient maintenance of whatever small infrastructure exists. It is seen that in case of Dehradun the low lying areas are most subjected to wrath of urban flooding especially when these people are incapable of taking pre mitigation measures for their households. It is also the encroachment in the seasonal rivers which causes maximum destruction in this case. As these few problems are specific to the city, we can conclude that flooding causes and impacts are specific to a location and geographic settings. Flood risk in general is higher in cities with a backdrop of high demographic growth, unplanned urbanization trends and impact of climate changes, which are general and most frequent causes of urban flooding. But it is observed that the causes of floods are changing their dimensions and impacts. Thus for that the Risk Assessment using indicators is very useful tool as it is easy to make changes in the system of indicators. As scope of further research the indicators may be developed for further research and urban flood risk assessment may be taken up.

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