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Mitigation of flash floods in Kokrajhar of the state of Assam in northeast India

Mitigación de las inundaciones repentinas en Kokrajhar, estado de Assam, en el noreste de la India

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ABSTRACT

Assam, one of the northeastern states of India witnesses heavy rainfall almost every year because of its geographical location. Kokrajhar, a district of Assam witnesses flash floods at certain parts of it during rainy season. Detailed study of the reasons for occurrence of flash floods have made and presented in this paper. Incorrect estimation of maximum flood or providing undersized storm water drains are the major reasons for occurrence of flash floods. Improper construction and maintenance of storm water drains are also the reasons for flash flood occurrence. Kokrajhar, being the headquarter of Bodoland Territorial Region is coming up with large number of infrastructural development projects. However, due to flood situations, these construction projects are halted for a considerable time resulting in slower rate of completion of these projects. The present case study aims at understanding the reasons behind occurrence of flash floods at central part of Kokrajhar town and finding the appropriate preventive and remedial measures to prevent such floods. These measures will thus help in avoiding difficulties caused to the public during rainy season and also helps in the faster rate of development of the region.

Keywords: floods, storm drain, runoff, precipitation

RESUMEN

Assam, uno de los estados del noreste de la India, registra lluvias torrenciales casi todos los años debido a su situación geográfica. Kokrajhar, un distrito de Assam, en algunas partes se inunda repentinamente durante la temporada de lluvias. En este documento se presenta un estudio exhaustivo de las causas de las inundaciones repentinas. Las principales razones de la aparición de inundaciones repentinas son la estimación incorrecta de la inundación máxima o la instalación de desagües pluviales de tamaño reducido. La construcción y el mantenimiento inadecuados de los desagües pluviales son también las causas de las inundaciones repentinas. Kokrajhar, sede de la región territorial de Bodoland, está llevando a cabo un gran número de proyectos de desarrollo de infraestructuras. Sin embargo, debido a las inundaciones, estos proyectos de construcción se detienen por un tiempo considerable, lo que resulta en un ritmo de ejecución muy lento. El presente estudio de caso tiene como objetivo comprender las razones de las inundaciones repentinas en la parte central de la ciudad de Kokrajhar y encontrar las medidas preventivas y adecuadas para evitar dichas inundaciones. Estas medidas ayudarán a evitar las dificultades causadas al pueblo durante la temporada de lluvias y también contribuirán a acelerar el ritmo de desarrollo de la región.

Palabras claves: inundaciones, drenaje pluvial, escorrentía, precipitaciones

INTRODUCTION

Northeastern states of India experience frequent floods due to their geographical location. These floods not only result in the heavy damage to the property, but many times claims several lives as well. Assam is one of such north-eastern state, which has witnessed many such devastating floods. Floods in the upper Assam region has claimed the lives of forest animals in the reserved forest area of Kaziranga. Whereas flash floods are very common in the Kokrajhar area of lower Assam region. In 2010, heavy rains in Bhutan and lower Assam resulted in increase in water levels of rivers flowing through Kokrajhar. This resulted in the flooding of 199 villages in Kokrajhar [1]. In 2019, flood water submerged all the major roads in Kokrajhar town affecting road transportation. Flood water has also entered residential and commercial buildings [2]. This flood was due to release of excess water from Bhutan Kuricchu hydropower reservoir [3]. In 2020, 61 villages of Kokrajhar district were affected by flood [4]. In 2021, massive erosion was witnessed in several districts of Assam including Kokrajhar [5] In 2022, Gaurang river which passes through Kokrajhar has passed its danger level resulting in flooding. It resulted in flooding of 258 villages of Kokrajhar [7,8]. Many families were forced to take shelter in flood relief camps. It has caused the submergence of many places in Kokrajhar town. As per reference [6], addressing the flood situation, local MLA of Kokrajhar said, "Flood is not a new thing in Kokrajhar. Floods are caused due to lack of systematic drainage system and outlets in Kokrajhar." This statement stresses on the necessity of proper working drainage system to mitigate flood at Kokrajhar. This paper studies the obstructions to the proper working of drainage system and suggests suitable measures to attain free flow of storm water without causing flooding.

2. GEOGRAPHICAL CHARACTERISTICS OF AREA OF STUDY

Kokrajhar district of Assam is located on the northern part of mighty Brahmaputra River. It shares its boundaries with Chirang, Dhubri, West Bengal, Barpeta and Bhutan. It is an administrative district in Bodoland Territorial Region of Assam. It is mainly populated by Bodo tribe. As the place is in lower Brahmaputra valley, it has humid sub-tropical climate. The average temperature varies from 10º C to 35º C. The average humidity varies from 62% in winter to 87% in post monsoon. The soils of the Kokrajhar district are fertile and suitable for paddy cultivation. Because of the availability of abundant water supply, farmers of this area do paddy cultivation to a major extent. The contour survey map of Kokrajhar district obtained from Municipality authority is shown in figure 1. The location considered for the study is the portion of Kokrajhar town. The map of the area of study is shown in figure 2. This map is obtained from Google Earth Pro. The portion of Kokrajhar town considered for study starts from Bodofa Nwgwr, Dimalgao in north-east, Bhatarmari including Gaurang river in north-west, Ward no.14 including Gaurang river in west south and Narabari in south-east. The Kokrajhar town is surrounded by Champamati, Saralbhanga and the Sonkosh rivers, which flows from north to south. The river Brahmaputra along with tributaries like Gangia, Laponi, Saumukha and Lonya control the main drainage system of Kokrajhar. These rivers emerge from the Himalayan foothills and are perennial in nature. These rivers flow in north to south direction. The water that flows along natural drains and man-made canals are the main source of irrigation for agricultural fields. Kokrajhar has high drainage density and almost parallel drainage pattern. The map of area of study is shown in figure 3.

3. CAUSES FOR FLASH FLOODING

Detailed study reveals the following causes for the occurrence of flash floods at Kokrajhar town. Since last two decades, Kokrajhar has witnessed rapid urbanization. With the declaration of Kokrajhar as the headquarter of Bodoland Territorial Region, many development projects such as engineering colleges, medical colleges and airport are taken up by the central and state governments. This has led to the increase in land value and conversion of agricultural land into

residential plots. Due to urbanization, the vegetation area is replaced by impervious surfaces like concrete and asphalt surface. This has reduced the rainwater absorbing ability of ground resulting in more runoff. Urbanization has also led to the encroachment of natural water bodies. In Kokrajhar, storm water drains are not designed for maximum flood and in many places sewage drains and storm water drains are mixed up during construction. Unplanned development of residential buildings is contributing to poor drainage. Unauthorized colonies at few locations are letting sewage water into storm drains. At certain locations, storm drains do not have outlets. It has been observed that at many places the drains are not constructed on the both sides of the roads due to which there is a slow drainage of rain water and hence contributing to flooding. At many places, drains are converted into garbage dumping place as shown in figure 4. At few locations, continuity of drains is broken. The storm drains are not cleaned properly as shown in figure 5. It is very difficult to access covered drains, especially for removing settled silt. However, large lengths of covered drains in Kokrajhar do not have access points resulting in silt settlement. This settled silt has drastically reduced drain efficiency. Easy erosion of road-side silt into the storm drains is observed at many locations. The deposited silt has reduced the effective cross sectional area of drain hence reducing its discharge capacity. Wherever old houses have been demolished, it has become common practice to dump the demolition waste into nearby storm water drain. Many new houses have encroached the storm drains illegally. At certain points storm drains are discharging into sewer lines resulting in overflow of sewage and creating unhygienic conditions. Due to urbanization, many natural lakes and ponds are filled with soil and converted into sites for building construction. Especially since the last decade, many lakes and ponds have been lost to such acts. This in turn has drastically reduced natural storm water storage and detention capacity of water bodies hence building up huge pressure on the storm water drains.

Figure 1: Contour survey map of Kokrajhar (Source: Municipality authority of Kokrajhar).

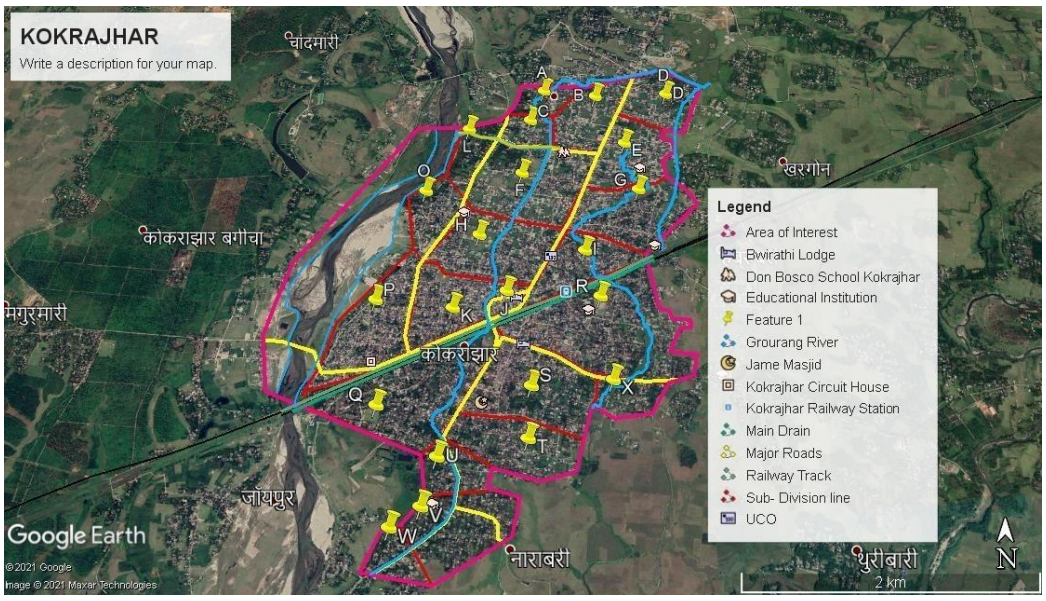

Figure 2: Map of area of study (Source: Google Earth Pro.)

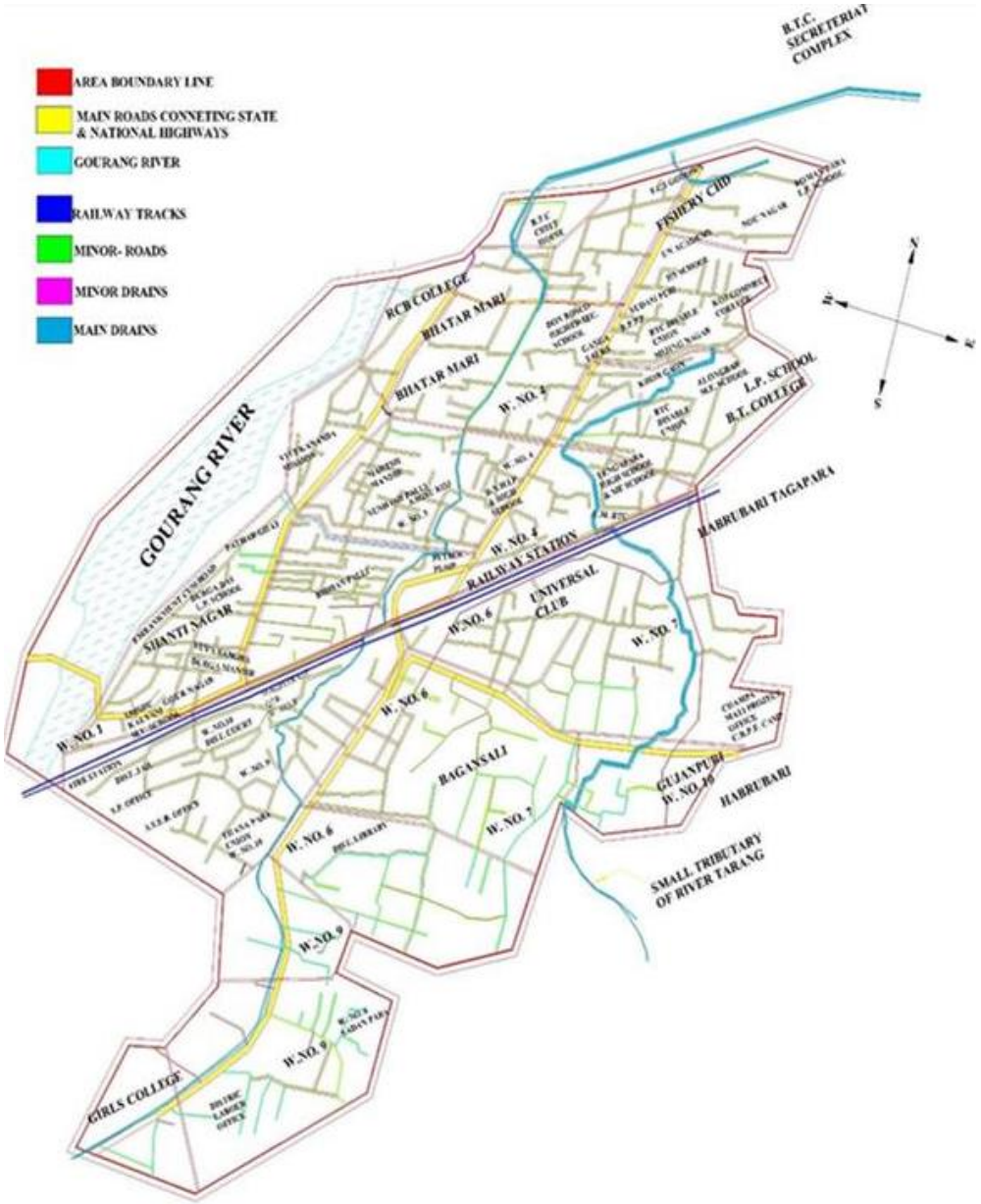

Figure 3: Map of area of study

Figure 4. Dumping of solid waste into storm drains

Figure 5: Improper cleaning of storm drains

Designing the size of storm water drain is the first and most important step in avoiding flash floods. The next section deals with the estimation of maximum flood for the area of study.

4. ESTIMATION OF MAXIMUM FLOOD

Maximum flood discharge is the product of area of precipitation, maximum intensity of rainfall and coefficient of runoff [9]. Determination of these parameters have been discussed in the following sections.

4.1. Determination of Area of Precipitation

By creating the Digital Elevation Model (DEM) of area of study, its field area has been worked out. The whole area is divided into sub-areas in the form of polygons according to the layout of drains forming the areas as shown in figure 6. These polygons are designated by the alphabets A, B, C, etc. The elevation data for the area of study were collected from Google Earth Pro. Then this data was processed in GPS elevation visualizer and for more accuracy the data was processed in UTM Geo map which is a plane coordinate grid system. Further, to create DEM of the area of study, the

data was again processed in Quick Grid Model and for more accuracy DEM is also created in Auto Cad. From the DEM so prepared, the flow direction data is obtained. 2-D and 3-D contour map of area of study are shown in figures 7 and 8 respectively. These contour maps are drawn using Municipality contour map as reference.

4.2. Determination of Rainfall Intensity

Rainfall intensity is defined as the depth of rainfall per unit time. It is generally expressed in mm/hour unit. Rainfall intensity used for peak discharge calculation is normally calculated from Intensity Duration Frequency (IDF) curves. But as hourly rainfall data is not available for Kokrajhar region, an alternative method known as Rambabu method [10] is used in maximum rainfall intensity determination. Equation (1) shows the formula suggested in this method.

$$\mathrm{i} = \frac{\mathrm{KT}^{\mathrm{x}}}{(\mathrm{t_c}+\mathrm{a})^{\mathrm{n}}} \quad (1)$$

Where i is the rainfall intensity in mm/hour, tc is the time of concentration in minutes, T is the return period in years and $\mathrm{K}, \mathrm{x}, \mathrm{a}, \mathrm{n}$ are the constants, value of which depends on the geographical location of the area. Kokrajhar falls under eastern zone, with the climatic conditions similar to Guwahati. For this region, the values adopted as per reference [10] are K = 7.206, x = 0.1157, a = 0.75 and n = 0.9401. Return period adopted for storm water drains in India is generally 10 years. Time of concentration can be determined as explained below.

4.2.1. Determination of Time of Concentration

Time of concentration is the time required for water to travel from hydraulically most distant point in the catchment to the outlet. Kirpich equation [11] is used for determining time of concentration. The equation (2) suggested by Kirpich is given below.

$$\mathrm{t_c} = 0.01947\mathrm{L}^{0.77}\mathrm{S}^{-0.385} \quad (2)$$

Where, $\mathrm{t_c}$ is the time of concentration in minutes, L is the maximum length of travel of water in meter. S is the slope of catchment, which is computed as the ratio of difference in elevation between the most remote point on the catchment and the outlet ($\Delta\mathrm{H}$) to the maximum length of travel of water (L). The length of longest channel is determined from Google Earth pro map as shown in figure 9. From the map, L is found to be 672 m, $\Delta\mathrm{H}$ to be 2 m and hence S to be 0.00298. Substituting these values in equation (2) gives the time of concentration value as 0.457 hours. Substituting this value in (1) gives the intensity of rainfall as 7.88 mm/hour for the Kokrajhar area. As Kokrajhar town is a low density residential area, runoff coefficient is taken as 0.75. Table 1 gives the area of different polygons and discharge contributed by each polygonal area.

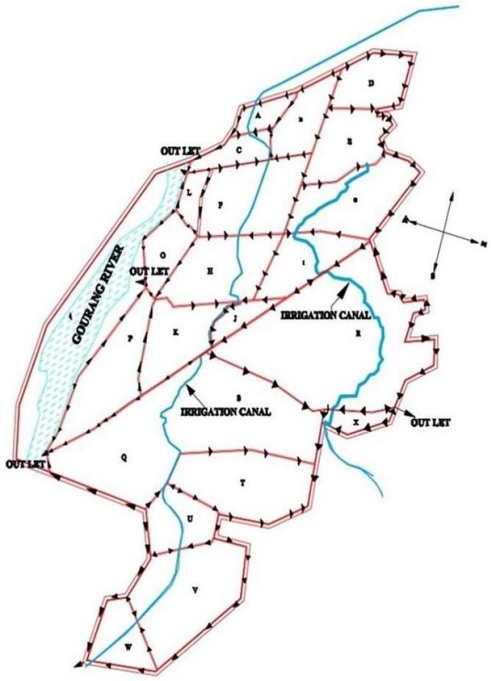

Figure 6: Division of area of study into polygons

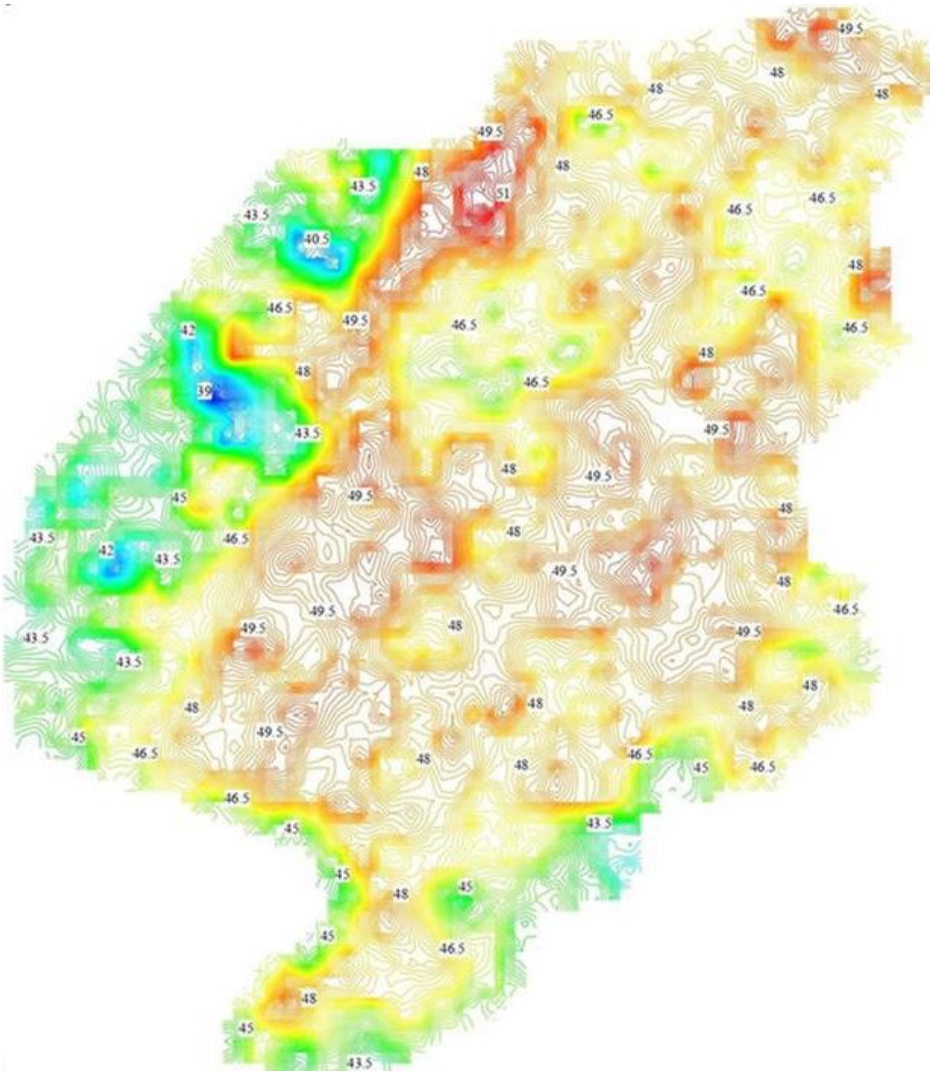

Figure 7: 2-D Contour map of area of study

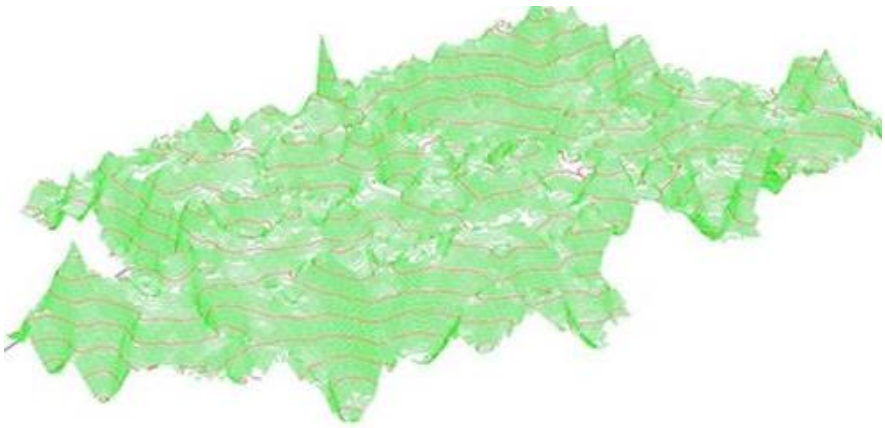

Figure 8: 3-D Contour map of area of study

Figure 9: Map showing longest channel

Table 1: Estimation of maximum flood

Sl. No.	Designated Polygon	Area in sq. km	Ares in Hectares (a)	Runoff Coefficient (c)	Rainfall intensity in mm/hr (i)	Discharge in (m^3/h) (10cia)
1	A	0.1345	13.45	0.75	7.88	794.93
2	B	0.3161	31.61	0.75	7.88	1868.20
3	C	0.1265	12.65	0.75	7.88	747.69
4	D	0.2729	27.29	0.75	7.88	1612.91
5	E	0.3578	35.78	0.75	7.88	2114.83
6	F	0.5940	59.40	0.75	7.88	3510.68
7	G	0.4489	44.89	0.75	7.88	2653.49
8	H	0.4905	49.05	0.75	7.88	2899.39
9	I	0.2946	29.46	0.75	7.88	1741.61
10	J	0.0410	4.10	0.75	7.88	242.82
11	K	0.3437	34.37	0.75	7.88	2031.74

12	L	0.1732	17.32	0.75	7.88	1022.58
13	O	0.2250	22.50	0.75	7.88	1330.16
14	P	0.4472	44.72	0.75	7.88	2643.42
15	Q	0.7132	71.32	0.75	7.88	4215.59
16	R	0.8542	85.42	0.75	7.88	5048.81
17	S	0.4818	48.18	0.75	7.88	2847.66
18	T	0.3208	32.08	0.75	7.88	1896.38
19	U	0.1383	13.83	0.75	7.88	817.44
20	V	0.3311	33.11	0.75	7.88	1957.11
21	W	0.1017	10.17	0.75	7.88	601.45
22	X	0.0120	1.20	0.75	7.88	71.28
Total Area		7.2201	722.01			42,068.72

5. STRATEGIES TO PREVENT FLASH FLOODS

The storm water drains should be designed to carry the discharge of 42068.72 cubic metre per hour. Storm drains should be aligned along the arrow lines shown in figure 6. These lines are drawn considering the contour map drawn using software with Municipality contour map as reference. The arrow represents the direction from high to low elevation. When drains are aligned as per these lines, flow through drains takes place easily under gravity. This also helps in lesser chance of settlement of solid particles, if any, inside the drain. Storm drains in Kokrajhar area should be kept free from garbage materials, whether it is natural drain or artificial drain. Blockages in storm drains should be cleared regularly. Rather than following conventional methods of manual cleaning, Storm water drainage network management authority can resort to advanced mechanical methods such as vacuum cleaning especially for clogged drains. Sewage from unauthorized residential areas should be prevented from flowing into the storm water drains by providing interceptors. While cleaning the roads, wastes from cleaning should never be thrown into the drain but transported and discarded far away from drains. Plantation should be done along the sides of the road where there are more chances of soil erosion. The roots of the plants hold the soil particles hence preventing soil erosion. All along the length of the drain at suitable intermediate distance, access points should be provided so that drains can be easily accessed, and silt can be removed without much difficulty. Storm water drains should not be used as dumping ground for solid waste. Strict action should be taken against the owners who throw construction & demolition (C&D) waste into the storm drains. It should me mandatory to transport and discard such waste at suitable locations fixed by the government authority. As storm drains are government property no encroachment should happen. However, if such encroachment is seen, immediate action should be taken, and such encroachment should be removed. Practice of discharging storm water into the sewer lines should be avoided. This practice results in overflow of sewers resulting in unhygienic conditions in the area. Individual houses should be encouraged to develop ground water recharge system. Such system reduces load on the storm water drains. Public should be controlled from diverting storm water into the sewer lines by opening manhole cover. This control can be effectively achieved by educating the people about the ill effects of overflow of sewers and creating the awareness in them. Construction of utilities inside the storm water drains should be banned. Construction of foundation pillars of flyovers or houses inside the storm drains reduces its effective discharging area. As natural water bodies like lakes and ponds act as rainwater holding sources, such sources should be monitored for encroachment. Public should be prevented

from using these sources as waste dumping areas. Regular cleaning and silt removal from ponds and lakes should be carried out to increase their water holding capacity.

CONCLUSION AND FUTURE WORK

Flash floods at the Kokrajhar area can be prevented by focusing on two aspects. The first aspect is correct estimation of maximum flood possible at Kokrajhar for the design period and designing the storm water drains accordingly. Also aligning the drains such that gravity flow occurs in drains for easy flow of storm water. According to the estimation, maximum flood that can occur at Kokrajhar town is 42068.72 cubic metre per hour. The drains can be aligned by following the contour map. The second aspect is proper construction and maintenance of storm water drains. During construction stage, sewer and storm drains should never interconnect with each other. Regular maintenance of storm water drains should be resorted to so that their full working efficiency remains throughout the year especially during rainy season. By working on these two aspects, Kokrajhar can be made flash floods free, thereby eliminating hindrance to the developmental activities. For future work, advanced model studies can be done to suggest alternative drainage networks for the Kokrajhar area.

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