PREVENTION OF FLASH FLOODS IN THE TOWN OF KOKRAJHAR THROUGH EFFICIENT DRAINAGE NETWORK DESIGN

Sagar Basumatary[*], Debshri Swargiary[**], Rajashekar Hubballi[*]

[*] Central Institute of Technology, Department of Civil Engineering, Kokrajhar, India
[**] National Institute of Technology, Department of Civil Engineering, Jamshedpur, India

corresponding author: Rajashekar Hubballi, e-mail: rajashekar.iith@gmail.com

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ABSTRACT

Flash floods are common in the town of Kokrajhar in north-eastern Indian state of Assam. Many areas in the town of Kokrajhar are submerged in water almost every year due to floods during rainy season. These floods cause heavy damage to roads, agricultural production and halt the progress of major infrastructural development projects. Hence, prevention of floods has become an important concern in the town of Kokrajhar. This study investigated the causes of floods and offered a solution for their elimination. The investigation showed that inadequate and inefficient network of storm drains was the reason for the flash floods. A new drainage network for the town of Kokrajhar has resulted from studying the shortcomings of the existing network of storm drains. The new network is designed in accordance with the recommendations stated in the “Manual on storm water drainage systems” prepared by the Central Public Health and Environmental Engineering Organization in 2019.

Keywords: *flooding, drainage network, runoff coefficient, storm water, flash floods*

INTRODUCTION

The town of Kokrajhar in the Kokrajhar district of Assam state has witnessed many flash floods in the recent years due to increasing urbanization and inefficient storm water drainage network [1 - 5]. It is located in the lower part of Assam in north-eastern India at the foothills of Bhutan, as shown in Figure 1. Kokrajhar district lies between 89.46’ East to 90.38’ East longitude and 26.19’ Nort to 26.54’ North latitude. The average annual rainfall of the district is 1715.7 mm. The town of Kokrajhar is bounded by two small rivers, Gourang and the Tarang. Brahmaputra is a major river in Assam. The drainage area of the Brahmaputra and Swrmanga rivers (in Bhutan) has very steep hill slopes with coarse-grained soils and unstable land mass. This results in the large instantaneous runoff and heavy deposition of the silt in the tributaries, as well as in the channels passing through the town. The district is inundated almost every year by flash floods during monsoon season. The drainage system overflows due to silting, clogging with solid waste, and encroachment

[6, 7]. Effective drainage systems are needed to protect roads and vital structures from erosion [8]. Therefore, it is important to study the condition of the drainage system for the prevention of floods, since the entire drainage system of the town needs to be re-established. For this purpose, the existing drainage network of the entire the town of Kokrajhar has been investigated. The estimation of the maximum possible flood in the town has been made. New drainage network is designed to discharge the maximum flood, using the existing drainage network. The proposed drainage network is designed in a scientific way to be efficient even in case of maximum floods. It also uses the existing drains, making it more economical. Since the drains are designed based on the concept of most economical channel sections, this results in lower construction cost.

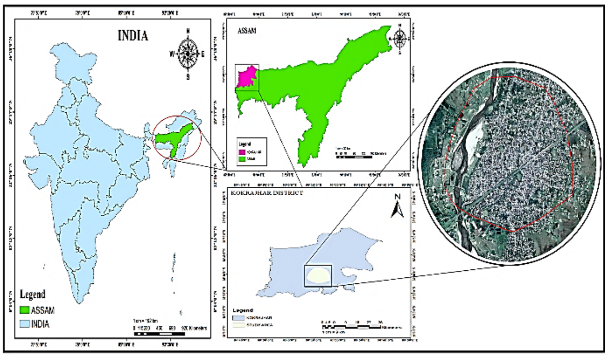

Figure 1. Geographical location of the town of Kokrajhar

STUDY OF EXISTING DRAINAGE NETWORK

A physical survey of the town of Kokrajhar has been conducted to study the layout and condition of the existing drainage network. Figure 2 shows the layout of the existing drainage network. In figure 2, it can be seen that the main canal of the Kokrajhar town collects the storm water from the surrounding area and discharges it into Gourang and Tarang rivers. It can also be seen in the Figure 2 that the town's drainage network is incomplete and that there is a lack of drain continuity in many places.

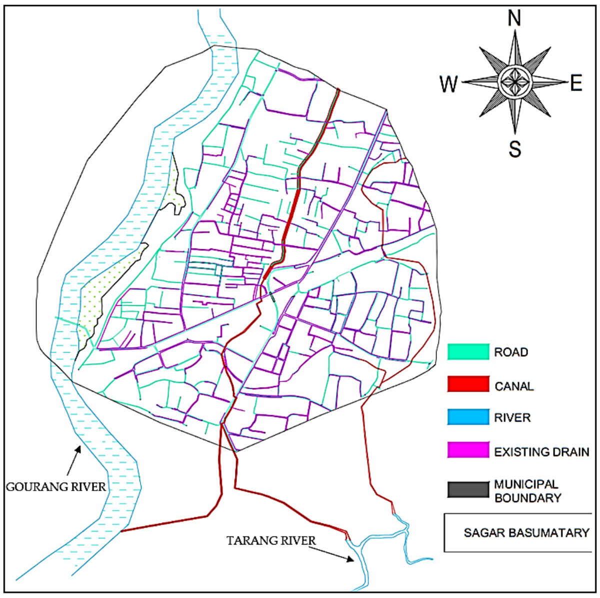

Figure 2. Existing drainage network of the town of Kokrajhar

Figure 3 shows that drains are not built in certain locations. In certain areas, there is an encroachment of drains. The existing density of the storm water drains is insufficient, which is one of the reasons for floods in the region. This gives an overall picture of the existing storm water drainage network of the town of Kokrajhar. It can be concluded that the drainage network in Kokrajhar is not efficient or fully operational which resulted in flooding of the town of Kokrajhar. Further sections of this paper discuss the design of efficient drainage network suitable for Kokrajhar.

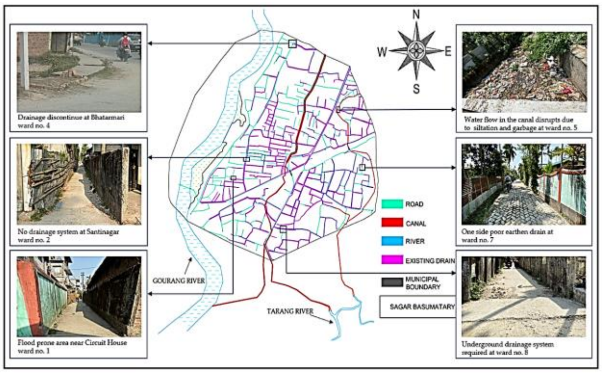

Figure 3. State of existing drainage network of the town of Kokrajhar

ESTIMATION OF MAXIMUM RUNOFF

Design of efficient drainage network requires the correctly estimated maximum flood. To estimate maximum flood, the following parameters are needed: area of precipitation, maximum intensity of rainfall and runoff coefficient for the area. Determination of these parameters is discussed in the following sections.

Determination of runoff coefficient

Runoff coefficient depends on the extent of permeability of catchment areas. Impervious areas have a high runoff coefficient and pervious areas have a low runoff coefficient value. As the town of Kokrajhar has surfaces with different runoff coefficients, the entire area is divided into nine polygons and those nine polygons are further divided into sub-polygons, as shown in Figure 4. Areas of these polygons are determined using ArcGIS and are shown in Table 1. Runoff coefficient for each sub-polygon is determined by an ArcGIS function called image classification. Based on the two different colours of the image pixel, catchment areas were classified as impervious and pervious surfaces, as shown in Figure 5. Runoff coefficient is calculated after obtaining the value from ArcGIS attribute table. Based on the recommended values for different surfaces [9], the runoff coefficient is determined for each sub-polygon and is shown in Table 1.

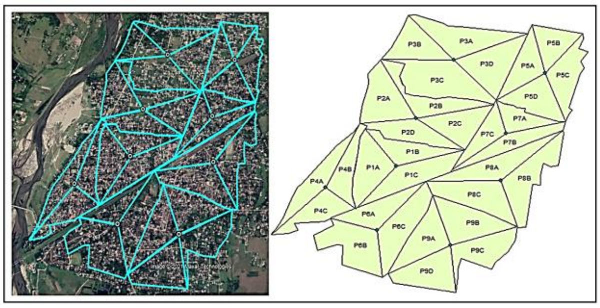

Figure 4. Division of the studied area into polygons and sub-polygons on Google Earth Pro and ArcGIS

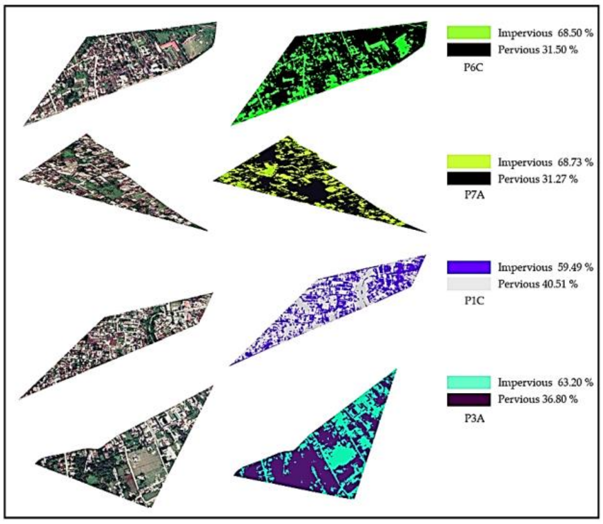

Figure 5. Image classification of the studied area in ArcGIS

Determination of time of concentration

Time of concentration is the time required for water to travel from the farthest point in a watershed to the watershed outlet. It is the sum of two components, as given in the following equation [10]:

$$t_c = t_o + t_f \quad (1)$$

where t_0 is the time required for the surface flow to reach the inlet and t_f is the time to flow through the storm drainage system to the point of consideration. These times are calculated using equations (2) and (3), and velocity of flow is calculated using equation (4) [10]:

$$t_o = \frac{0.218(1.1\text{-}C)L^{0.5}}{S^{0.333}} \quad (2)$$

where t_o is time of surface flow (min.), C is rational method runoff coefficient, L is length of surface flow (m) and S is surface slope (%),

$$t_f = \frac{L_{\text{drain}}}{V} \quad (3)$$

$$V = \frac{1}{n} R^{0.67} S^{0.5} \quad (4)$$

where V is velocity of flow (m/sec), t_f is time of travel (min.), n is Manning's roughness coefficient, R is hydraulic radius (m) and S is longitudinal slope.

Time of concentration is calculated using equations (1) - (4) and is shown in Table 1.

Table 1. Runoff coefficient and time of concentration for different polygonal areas

Polygon	Area (km^2)	Impervious surface (%)	Runoff coefficient C_i	Time of surface flow t_o	Time of flow t_f	Time of concentration (min.)
P1A	0.17	65.69	0.65	15.24	3.61	18.85
P1B	0.13	68.59	0.66	18.53	4.19	22.72
P1C	0.19	59.49	0.63	18.58	4.01	22.59
P2A	0.19	65.24	0.65	10.63	2.83	13.46
P2B	0.15	72.52	0.67	20.71	4.59	25.30
P2C	0.15	66.05	0.65	16.43	3.80	20.23
P2D	0.14	65.56	0.65	13.86	3.39	17.25
P3A	0.20	63.20	0.64	20.01	4.28	24.29
P3B	0.15	77.23	0.68	21.13	4.73	25.85
P3C	0.27	70.55	0.66	17.53	4.03	21.57
P3D	0.20	65.23	0.65	21.17	4.52	25.69
P4A	0.15	59.99	0.63	21.93	4.49	26.42
P4B	0.12	63.79	0.64	14.80	3.49	18.29
P4C	0.13	62.57	0.64	16.95	3.83	20.78
P5A	0.13	59.34	0.63	23.29	4.68	27.97
P5B	0.11	62.49	0.64	12.96	3.19	16.15
P5C	0.15	73.19	0.67	7.57	2.32	9.89
P5D	0.15	69.13	0.66	7.18	2.20	9.38
P6A	0.14	71.81	0.67	17.69	4.12	21.82
P6B	0.22	71.52	0.66	15.34	3.68	19.02
P6C	0.21	68.50	0.66	21.36	4.61	25.97
P7A	0.09	68.73	0.66	16.47	3.87	20.34
P7B	0.13	69.26	0.66	23.42	4.91	28.34
P7C	0.10	60.75	0.63	19.48	4.14	23.62
P8A	0.18	59.29	0.63	10.92	2.80	13.71
P8B	0.21	64.65	0.64	17.18	3.86	21.04
P8C	0.21	58.04	0.62	12.76	3.06	15.83
P9A	0.17	63.26	0.64	18.89	4.12	23.01
P9B	0.19	64.18	0.64	17.11	3.85	20.96
P9C	0.16	64.18	0.64	22.59	4.65	27.24
P9D	0.17	71.96	0.67	23.21	4.96	28.17

Determination of rainfall intensity

Assuming that Kokrajhar is hydrometeorologically similar to Guwahati, the following equation is used to calculate the rainfall intensity [11]:

$$i = \frac{KT^x}{(t_c + a)^n} \quad (5)$$

where T is return period (years; in India it takes as many as 10 years) [9], K, x, a, n are coefficients, whose values are taken according to reference [11] for Guwahati region. Calculated rainfall intensities are shown in Table 2.

Calculation of discharge

The stormwater discharge is calculated using the following equation [7]:

$$Q_p = \frac{1}{3.6} C_i \, i \, A_i \quad (6)$$

where Q_p is peak discharge (m^3/s), C_i is runoff coefficient, i is rainfall intensity (mm/h) and A_i is catchment area (km^2). Discharge from different polygonal areas is calculated using equation (6) and is shown in Table 2.

Table 2. Calculated rainfall intensity and discharge for different polygonal areas

Polygon	Area (km^2)	Runoff coefficient C_i	Rainfall intensity (mm/h)	Discharge (m^3/s)
P1A	0.17	0.65	8.87	0.28
P1B	0.13	0.66	8.39	0.20
P1C	0.19	0.63	8.40	0.27
P2A	0.19	0.65	9.63	0.33
P2B	0.15	0.67	8.10	0.22
P2C	0.15	0.65	8.69	0.24
P2D	0.14	0.65	9.08	0.23
P3A	0.20	0.64	8.21	0.29
P3B	0.15	0.68	8.04	0.23
P3C	0.27	0.66	8.53	0.43
P3D	0.20	0.65	8.06	0.29
P4A	0.15	0.63	7.98	0.21
P4B	0.12	0.64	8.94	0.19
P4C	0.13	0.64	8.62	0.20
P5A	0.13	0.63	7.82	0.18
P5B	0.11	0.64	9.24	0.19
P5C	0.15	0.67	10.22	0.29
P5D	0.15	0.66	10.31	0.29
P6A	0.14	0.67	8.50	0.22
P6B	0.22	0.66	8.84	0.36
P6C	0.21	0.66	8.03	0.30
P7A	0.09	0.66	8.68	0.15
P7B	0.13	0.66	7.78	0.19
P7C	0.10	0.63	8.28	0.15
P8A	0.18	0.63	9.60	0.30
P8B	0.21	0.64	8.59	0.31
P8C	0.21	0.62	9.28	0.33
P9A	0.17	0.64	8.36	0.25
P9B	0.19	0.64	8.60	0.29
P9C	0.16	0.64	7.89	0.23
P9D	0.17	0.67	7.80	0.24

IDENTIFICATION OF DRAINS IN CATCHMENT AREAS

The map of the town of Kokrajhar is divided into five zones marked as A, B, C, D and E for easier identification of drains. Within a zone, drains are identified by a unique number, as shown in Figure 6. The discharge design for each drain depends on the number of polygonal areas through which the drain passes.

The drain is designed for optimal discharge using the concept of the most economical rectangular cross-section of the channel. Geometrical and flow parameters for all the drains in the network are shown in Table 3. The proposed drainage network for the town of Kokrajhar is shown in Figure 6.

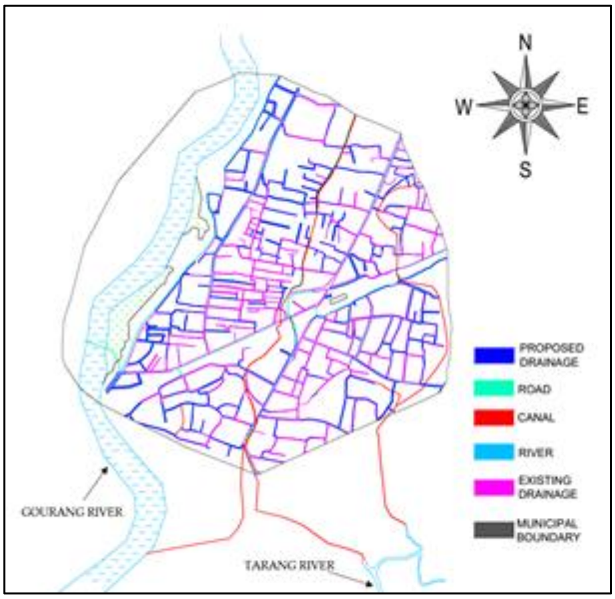

Figure 6. Proposed drainage network for the town of Kokrajhar

CONCLUSION

The town of Kokrajhar can be made flood free by implementing the drainage network proposed in this study. However, the following precautions should be practiced to maintain the full discharging capacity of drains: prevent the entry and deposition of silt into the drains, prevent the local residents from throwing garbage into the drains, clean clogged drains before the start of the rainy season, prevent the discharge of domestic wastewater into stormwater drains, and avoid encroachment of stormwater drains. Similarly, research work can be carried out to design the efficient drainage network for other flood prone areas in Assam.

Table 3. Geometrical and flow parameters for drains

Drain no.	Drain length (m)	Flow depth (m)	Width of channel (m)	Hydraulic radius (m)	Velocity of flow (m/s)	Design discharge (cumec)
A1	273	0.63	1.3	0.31	0.76	0.59
A2	196	0.48	1.0	0.24	0.64	0.30
A3	380	0.63	1.3	0.31	0.76	0.59
A4	125	0.48	1.0	0.24	0.64	0.30
A5	310	0.51	1.0	0.26	0.67	0.35
A6	169	0.56	1.1	0.28	0.70	0.44
A7	161	0.56	1.1	0.28	0.70	0.44
A8	151	0.56	1.1	0.28	0.71	0.44
A9	141	0.68	1.4	0.34	0.80	0.74
A10	239	0.68	1.4	0.34	0.80	0.74
A11	297	0.56	1.1	0.28	0.70	0.44
A12	154	0.44	0.9	0.22	0.60	0.23
A13	345	0.48	1.0	0.24	0.64	0.30
A14	335	0.60	1.2	0.30	0.74	0.53
A15	610	0.44	0.9	0.22	0.60	0.23
A16	574	0.65	1.3	0.32	0.77	0.64
A17	345.5	0.63	1.3	0.31	0.76	0.59
A18	199	0.63	1.3	0.31	0.76	0.59
A19	226	0.48	1.0	0.24	0.64	0.30
A20	457	0.66	1.3	0.33	0.78	0.67
A21	277	0.56	1.1	0.28	0.70	0.44
A22	268	0.68	1.4	0.34	0.80	0.74
A23	489	0.77	1.5	0.38	0.87	1.01
A24	506	0.66	1.3	0.33	0.78	0.67
A25	593	0.69	1.4	0.35	0.81	0.78
A26	284	0.69	1.4	0.35	0.81	0.78
A27	496	0.69	1.4	0.35	0.81	0.78
A28	571	0.62	1.2	0.31	0.75	0.57
A29	42.7	0.66	1.3	0.33	0.78	0.67
A30	87	0.62	1.2	0.31	0.75	0.58
A31	225	0.56	1.1	0.28	0.70	0.44
A32	114	0.62	1.2	0.31	0.75	0.57
A33	251	0.56	1.1	0.28	0.70	0.44
A34	75.4	0.66	1.3	0.33	0.78	0.67
A35	94.5	0.44	0.9	0.22	0.60	0.23
B1	52.2	0.42	0.8	0.21	0.58	0.20
B2	179	0.48	1.0	0.24	0.63	0.29
B3	51	0.58	1.2	0.29	0.72	0.48
B4	312	0.58	1.2	0.29	0.72	0.48
B5	244	0.58	1.2	0.29	0.72	0.48
B6	115	0.60	1.2	0.30	0.73	0.52
B7	209	0.58	1.2	0.29	0.72	0.48
B8	188	0.48	1.0	0.24	0.63	0.29
B9	102	0.58	1.2	0.29	0.72	0.48
B10	92	0.58	1.2	0.29	0.72	0.48
B11	272	0.48	1.0	0.24	0.63	0.29
B12	223	0.54	1.1	0.27	0.69	0.41
B13	389	0.54	1.1	0.27	0.69	0.41
B14	470	0.67	1.3	0.33	0.79	0.69
B15	575	0.43	0.9	0.21	0.59	0.21

Table 3. Geometrical and flow parameters for drains (continued)

B16	375.5	0.55	1.1	0.28	0.70	0.42
B17	180	0.43	0.9	0.21	0.59	0.21
B18	296	0.43	0.9	0.21	0.59	0.21
B19	380	0.43	0.9	0.21	0.59	0.21
B20	486	0.43	0.9	0.21	0.59	0.21
B21	508	0.54	1.1	0.27	0.69	0.41
B22	387	0.55	1.1	0.28	0.70	0.42
C1	84.7	0.41	0.8	0.20	0.57	0.19
C2	628	0.41	0.8	0.20	0.57	0.19
C3	94	0.49	1.0	0.24	0.64	0.30
C4	281	0.41	0.8	0.21	0.58	0.19
C5	289	0.41	0.8	0.21	0.58	0.19
C6	196	0.41	0.8	0.21	0.58	0.19
C7	190	0.41	0.8	0.21	0.58	0.19
C8	374	0.53	1.1	0.27	0.68	0.38
C9	396	0.41	0.8	0.21	0.58	0.19
C10	128	0.41	0.8	0.20	0.57	0.19
C11	50	0.41	0.8	0.21	0.58	0.19
C12	43	0.41	0.8	0.20	0.57	0.19
C13	50	0.41	0.8	0.21	0.58	0.19
D1	175	0.46	0.9	0.23	0.62	0.26
D2	144	0.51	1.0	0.26	0.66	0.34
D3	65	0.45	0.9	0.23	0.61	0.25
D4	305	0.59	1.2	0.30	0.73	0.51
D5	408	0.51	1.0	0.26	0.66	0.34
D6	256	0.44	0.9	0.22	0.60	0.23
D7	357	0.44	0.9	0.22	0.60	0.23
D8	339	0.44	0.9	0.22	0.60	0.23
D9	118	0.58	1.2	0.29	0.72	0.48
D10	102	0.65	1.3	0.32	0.78	0.65
D11	39	0.67	1.3	0.34	0.79	0.71
D12	249	0.44	0.9	0.22	0.60	0.23
D13	373	0.49	1.0	0.25	0.65	0.31
D14	564	0.51	1.0	0.26	0.66	0.34
D15	310	0.60	1.2	0.30	0.74	0.53
D16	361	0.48	1.0	0.24	0.64	0.29
D17	205	0.65	1.3	0.32	0.78	0.65
D18	439	0.49	1.0	0.25	0.65	0.31
D19	499	0.49	1.0	0.25	0.65	0.31
D20	351	0.51	1.0	0.26	0.66	0.34
D21	167	0.62	1.2	0.31	0.75	0.57
D22	219	0.51	1.0	0.26	0.66	0.34
D23	296	0.51	1.0	0.26	0.66	0.34
D24	400	0.64	1.3	0.32	0.78	0.65
E1	150	0.52	1.0	0.26	0.67	0.37
E2	293	0.52	1.0	0.26	0.67	0.37
E3	346	0.67	1.3	0.34	0.79	0.71
E4	314	0.62	1.2	0.31	0.75	0.57
E5	359	0.65	1.3	0.32	0.78	0.65

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