STORM WATER MANAGEMENT – Case study of Karumkulam Panchayat

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Abstract - *Storm water is a major cause for urban flooding. The increased rainfall rates and rapid urbanization without proper planning, leads to frequent localized flooding across the country. In certain coastal areas, there is an issue of ponding of storm water runoff, draining from the higher grounds in large volumes affecting the community significantly. Karumkulam, a panchayat in Trivandrum situated near Poovar, Kerala, also face the same issue every year during the rains. The topography of the study area is such that natural draining off of the storm water is not possible. This study focuses on finding a feasible solution to the drainage and flooding problems of the storm water in this panchayat. This is done by mapping the existing drainage system available in the area, quantification of the amount of runoff reaching the low lying area, where waterlogging is prevalent, and design of suitable pump stations and culverts at appropriate locations along the affected area. It is found that a storm water pump station is the most sustainable solution for the study area, which will prevent the occurrence of flooding by pumping away large volumes of water, ensuring uninterrupted livelihood activities and a healthy environment.*

***Key Words*: storm water, coastal flooding, GIS analysis, drainage system, pump stations**

1. INTRODUCTION

India is one of the few countries in the world endowed with reasonable land and water resources. The water and sanitation sector has been accorded highest priority by the United Nations (UN). The Government of India is very much committed to transform Urban India into well informed citizen-driven, totally hygienic, healthy, smart and habitable cities and towns. Provision for the management of storm water drainage system and groundwater recharge, requiring large public investments are few among various initiatives undertaken by the Union government in this direction so as to achieve and sustain these goals. There is an urgent need for consultations amongst various stakeholders and other multidisciplinary field experts on the planning, design, execution and operation & management of storm water drainage system based on the worldwide best practices in the sector and to incorporate the same in addressing the challenges in urban storm water management in India.

1.1 Storm Water Management

In an urban situation, Storm Water Drainage is concerned with the accumulation of runoff resulting from rainfall, which needs to be conveyed to an appropriate outfall as quickly as possible, without causing inconvenience to pedestrian and vehicular traffic, damage to adjacent property. Urbanization is always accompanied by increased impervious areas in the drainage basin, resulting in increased peaks and volumes of runoff. The traditional engineering approach is to dispose the runoff quickly, but in the past three or four decades, storm water management through onsite or offsite detention storage/infiltration, etc., is being practiced in most countries.

1.2 Coastal Flooding

For coastal areas, flooding can happen in two main ways: from sustained heavy rain that doesn't drain away, or from storm surges, when storms drag the sea up and over the coastline. But when they occur together, or in close succession, the consequences can be even more severe.

2. RESULTS AND DISCUSSIONS

The study was mainly to understand the plight of the local community due to water logging issues. The existing drains were identified and the cross sectional details were collected along the drains in the entire panchayat. The study area was analyzed using ArcGIS and different thematic maps were prepared in the process. Then, the major watersheds which contributed to the water logging in the coastal area were identified and the runoff was calculated for the same. The measures proposed for relieving the water stagnation includes non-structural measures and structural measures like design of pumps and culverts.

2.1 Mapping and analysis of the existing drainage system

2.1.1 Existing drainage network map

The latitude and longitude values of different points of the present drainage system taken during field survey using GPS was made into XML format. The XML file was then converted into KML file and opened in the Google earth. The network of drain was drawn connecting the different points. The entire data was then saved as KML file. Then, in the Arc GIS platform, the KML file was converted into a layer using the Conversion Tools in the ArcToolbox.

It is seen that no particular pattern has been followed for the drains. Some of the drains are running parallel to the coastline and there are abrupt junctions where water has to deviate at right angles. As such, drains and flows are interrupted in between, making the drainage ineffective.

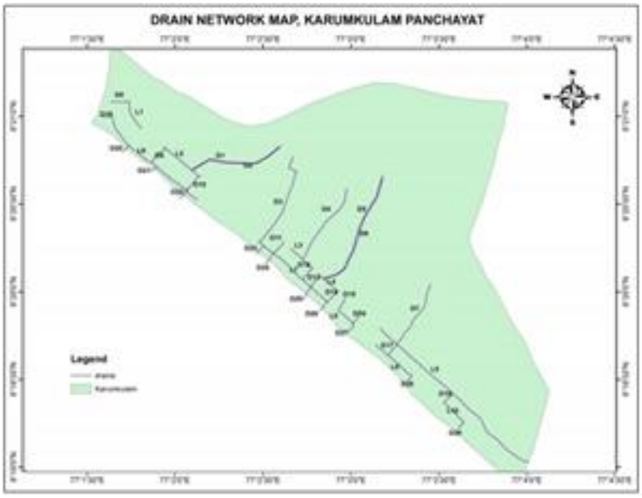

Fig-1: Existing drain network

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2.1.2 Delineation Of sub-watersheds

The sub-watersheds were obtained from the basin map. The basin map is generated using the hydrology tool in the Spatial Analyst Tools. The output of the Flow direction tool, is given as the input for the Basin tool.
The major watersheds contributing to the waterlogging in the coastal side were identified by comparing both the flow accumulation map and the basin map.

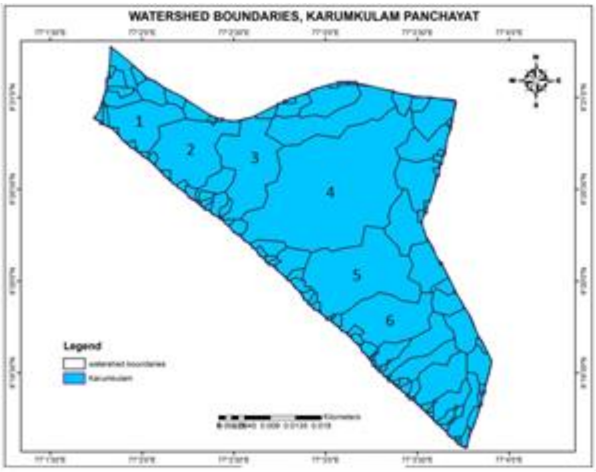

Fig-2: Sub-watersheds

The areas of different sub-watersheds are as given in the table 1.

Table -1: Watershed areas in hectares

Watershed	Area (hectare)
1	23.95
2	37.26
3	42.61
4	149.93
5	63.05
6	34.52
7	13.69
8	32.44
9	7.4
10	9.08
11	3.09
12	2.4
13	11.15
14	11.95
15	17.14
16	15.9
17	14.6
18	5.43
19	20.55
20	12.33
21	17.92
22	8.72
23	8.2

In the table given above, the watersheds from 1 to 6 are the major contributors of the runoff towards the coastal side.

2.1.3 Watershed hydrology

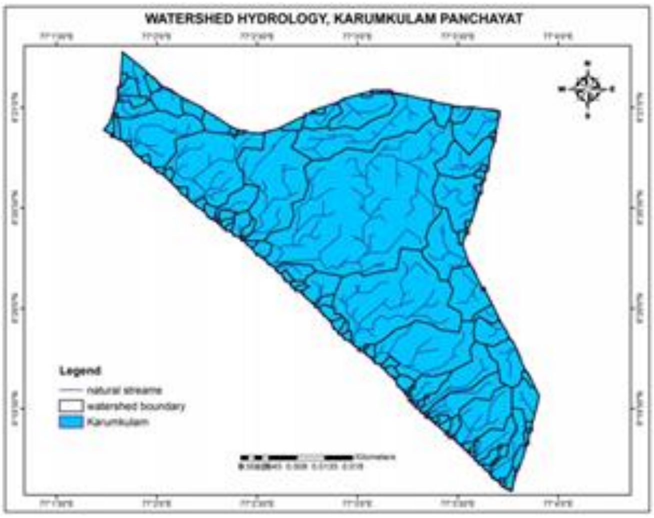

Fig-3: Watershed hydrology

The map given in Fig-3 represents the natural hydrology pattern for the study area. This has been generated using the hydrology tools in ArcGIS. The Stream order and Stream to feature tools in the Spatial Analyst tool facilitates the generation of natural stream pattern.

The map gives an idea about the natural flow patterns in different sub-watersheds.

2.1.4 Flow accumulation

The flow accumulation according to the DEM for the study area, is estimated using the hydrology tools in ArcGIS. The highest accumulation value is indicated by red color.

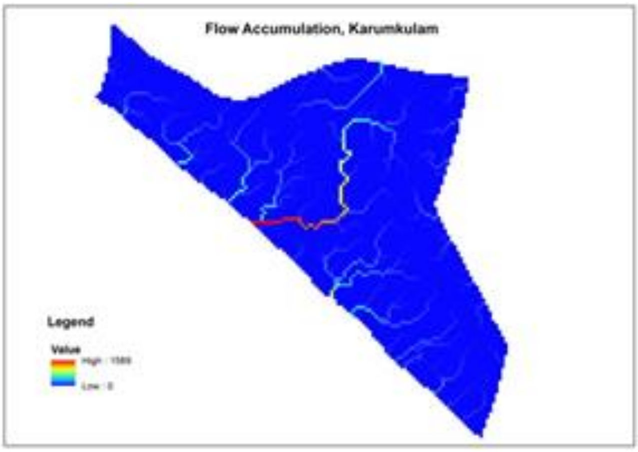

Fig -4: Flow accumulation map

2.2 Hydrologic analysis

The purpose of hydrologic analysis in storm water drainage design is mainly to obtain reasonable estimates of peak flows for the acceptable selected design return periods of rainfall intensity for the location. These flows are then used in the hydraulic analysis for designing the size and slope and scope of storm drains to convey the runoff efficiently, or for flood protection works, culvert / bridge vent-way calculations, etc. Since the catchment area is less than 1000 ha, Rational Method is used for rainfall analysis.

2.2.1 Calculation of discharge

The runoffs from the major contributing watersheds are calculated using the rational method.

$$Runoff = CIA / 360$$

where, C = Runoff coefficient
I = Rainfall intensity
A = Area in hectares

Table-2: Calculated runoff

Watershed	Area (hectare)	Rainfall intensity(mm/hr)	Runoff coefficient	Runoff (m3/s)
1	23.95	71.3	0.55	2.61
2	37.26	71.3	0.55	4.06
3	42.61	71.3	0.55	4.64
4	149.93	71.3	0.55	16.33
5	63.05	71.3	0.55	6.87
6	34.52	71.3	0.55	3.76

2.2.2 Existing drain capacity

The capacity of the drains reaching the coastline is calculated using the Manning's formula,

$$Q=V*A$$
$$V=(1/N)*(R^{2/3})*(S^{1/2})$$

Table-3: Drain capacity

Drain	Length (m)	Slope	Width (m)	Depth (m)	Capacity(m^3/s)
D19	82.7	0.1	0.58	0.51	2.02
D20	82.8	0.1	0.58	0.51	2.02
D21	77.4	0.06	0.56	0.51	1.49
D22	97.6	0.1	0.58	0.35	1.25
D23	101	0.1	0.56	0.51	1.92
D24	124	0.1	0.58	0.48	1.88
D25	137	0.08	0.53	0.48	1.48
D26	112	0.08	0.53	0.48	1.48
D27	85.5	0.1	0.99	1	9.99
D28	86	0.1	0.35	0.38	0.68
D29	76.8	0.1	0.58	0.51	2.02
			Total capacity		26.23

The total runoff from the water sheds are calculated as 38.27 m^3/sec using rational method and the total capacity of the drains are calculated as 26.23 m^3/sec using Manning's formula. So, clearly the drain capacity is not sufficient for this particular area. Since the drains are passing through heavily build-up area, it will be difficult to widen the drains and so, the drains shall be deepened wherever possible.

2.2.3 Map showing critical points

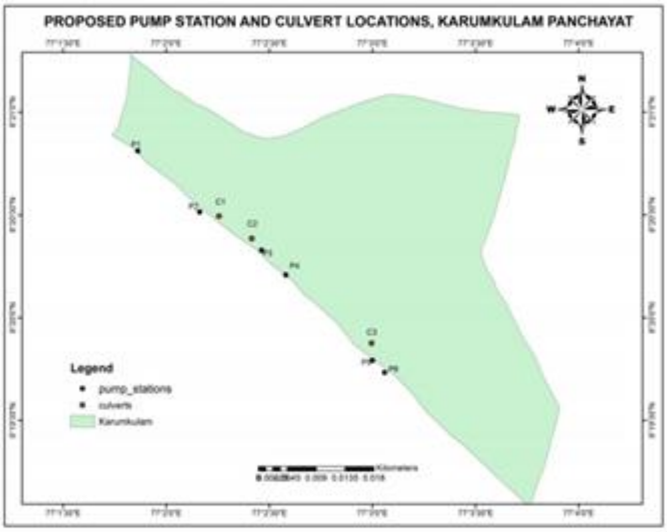

Fig -5: Critical points

The above map shows the critical points in the panchayat from the above analysis, where culverts and pump stations are proposed to relieve water stagnation.

2.3 Measures proposed for relieving water stagnation

In the process of relieving water logging in the panchayat, both structural and non-structural measures need to be taken. The non-structural measures should be carried out as a periodic process since, any shortcoming in this will make the structural measures also ineffective.

2.3.1 Non-structural measures

These measures will be effective only if the community themselves actively participate in the process.

i. Desilting of the existing drains
ii. Removal of solid waste
iii. Community awareness camps

2.3.2 Structural measures

i. Design of pumps-

The pumps are designed for draining the runoff from six major sub-watersheds in the panchayat. The aim is to drain off the water within a limited duration, before it affects the community severely. The pumps are designed at the Beach Road at different critical locations.

Table-4: Pump capacity

Sl.No.	Pumping Station	Ward No.	Capacity (cumecs)	Motor capacity (HP)
1	Kochupalli	18	2.61	35
2	Pulluvila	16	4.06	55
3	Pallom	14	4.64	65
4	Puthiyathura	11	16.33	220
5	Kochuthura	9	6.87	100
6	Karumkulam	8	3.76	50

ii. Design of culverts-

The area between the Poovar-Vizhinjam road and Gothambu road gets inundated creating difficulties to the inhabitants during rains. A proper path is absent for the surface runoff to reach the other side of the road. Therefore, three severely affected points are identified along the Gothambu road for the construction of culverts. Ward no. 15 is the most affected region due to water logging. So the first culvert is designed at Erayimmenthura. The second culvert is designed at Pallom which is ward no. 14 and last culvert is designed for the ground near the St. Antonnies Church at Kochuthura.

Table-5: Comparison of culverts

	Culvert 1				Culvert 2				Culvert 3			
Component	Top slab		Vertical slab		Top slab		Vertical slab		Top slab		Vertical slab	
Location	Erayimmenthura				Pallam				Kochuthura			
Ward	15				14				9			
Diameter of bars (mm)	12		8		12		8		12		18	
Overall depth(mm)	200		200		200		200		200		200	
Live Load (KN/m)	250		300		250		300		250		300	
Effective span (m)	0.979		0.6		0.779		0.65		1.379		0.8	
Main reinforcement bars	lateral	longitudinal	lateral	longitudinal	lateral	longitudinal	lateral	longitudinal	lateral	longitudinal	lateral	longitudinal
No. of bars	8	25	5	24	5	16	7	29	15	35	11	44
Spacing (mm)	142	140	150	145	200	225	108	120	100	102	80	80
Quantity of concrete (mm^3)	3.948				1.768				2.644			

3. CONCLUSIONS

A study was conducted to design an effective storm water drainage system for the coastal panchayat of Karumkulam. The existing drainage network of the panchayat was mapped along with their cross sectional details. The capacities of the drains were found insufficient compared to the total runoff of the watershed. Since space availability for widening the drains are very less, the depth of the drains can be increased accordingly. The design of pumps are done for the six major watersheds and the pumping stations are found to be the most sustainable option for relieving water in this area. The culverts are provided at most critical areas considering the severity of previous events and field observations. Community participation in the process of maintenance of drains, waste collection, and the monitoring of pump stations will be ensured through workshops and awareness camps.

There is scope for further improvement in this study. The Digital Elevation Model is prepared using the ASTER DEM data which has a resolution of only 30m. For a detailed study of storm water drains, total station survey of the entire area can be done; the rainfall data of the station nearest to the study area is used for hydrologic analysis. For more precise study, rainfall data from the study area can be analyzed by setting up a temporary rainfall station; the study includes the design of capacity of the pumps for different watershed regions but the pumping station consists of different electrical as well as mechanical components and this can also be done at a later stage.

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REFERENCES

[1] Needhidasan. S, "Design of Storm Water Drains by Rational Method-an approach to Storm Water Management for Environmental Protection," International Journal of Engineering and Technology (IJET), Vol 5 No 4, 3203, 2013.

[2] J.B. Ellis, "Multi-criteria decision approach to support sustainable options for the treatment of highway and urban runoff", Science of the Total Environment, 251-260, 2004.

[3] Haifeng Jia, "Development of a multi-criteria index ranking system for urban runoff best management practices (BMPs) selection, Environmental Monitoring and Assessment, 10661-013-3144-0, 2013.

[4] A.C Taylor, "'Triple-bottom-line' assessment of urban storm water projects", 10th International Conference on Urban Drainages, Copenhagen/Denmark, 2005.

[5] Chan Kin-Kwong, Integrated Planning And Design Of A Flood Relief Project For Sheung Wan Low-Lying Area, 2009.

[6] Kerala State Urban Development Project, Storm water drainage-Thiruvananthapuram.

[7] David Butler and John W Davies, Urban drainage, Spon Press, 2nd Edition, 2004.

[8] Dr. R.K Bansal, Fluid Mechanics and Hydraulic Machines, Laxmi Publications Ltd., 9th edition, 2008.

[9] IS 456-2000, Code of practice for Plain and Reinforced Cement Concrete, Bureau of Indian Standards.