Design of Urban Storm Water Drainage System using GIS and SWMM Software

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Abstract: The rapid growth of villages and towns affecting natural drainage channels. Inundation of low-lying areas is a common phenomenon especially during rainy seasons in many localities of Narsapur town. Narsapur is considered a census town as well as a municipality situated in Medak district, Telangana State. With the increased demand for a proper drainage system, the Municipal Authorities decided to re-design the Stormwater Drainage System starting with mapping the existing road network and drains. The Narsapur town has 15 revenue wards. Considering the Topography of the town, the entire town was divided into six zones. In this study, the Central Zone of town covering 4 Wards (13, 14, 15, and 8 Partly) is considered for investigation and design of stormwater drainage systems. The entire zone is completely urbanized, and frequent inundation is observed during moderate to heavy rainfall events due to congested and improper drainage disposal system. The study is carried out in five phases viz. Mapping of Road Network, Obtaining Elevations, Mapping Drainage Network, Computation of Peak Discharge, and Design of Stormwater Drainage System. In this study, EPA-SWMM Software is used to build a Hydraulic and Hydrologic Model to analyze the existing drainage system and re-design the stormwater drains to safely discharge flood water without causing inundation in low-lying areas. To validate the results, Manning’s Flow Equation is used to compute the flow carrying capacity of drainage channels.

Keywords: GIS Mapping, Hydrologic Modelling, Storm Water Drainage Design, Manning’s Flow Equation, SWMM Software.

1. Introduction
Narsapur Municipality is located in the Medak district of Telangana state, with a population of 18,338 (Census 2011), comprising of 4,376 households, 15 wards, and an area of 28.82 sq. km. Narsapur was made 1st-grade Municipality within the year 2019. Due to the lack of proper planning and drainage system, frequent inundation of low-lying areas is observed in many areas. To resolve the issue, considering the Topography of the town, the entire town was divided into six zones. In this study, the Central Zone of town covering 4 Wards (13, 14, 15, and 8 Partly) is taken up for study.

The main aim of this study is to Design Stormwater Drainage System to dispose of floodwater without causing inundation in low-lying areas. At present, the entire flow from Central Zone is going to a Pond near Bus Stand which doesn’t have any disposal system. Due to sedimentation and improper maintenance, the storage capacity of the Pond is reduced drastically and causing inundation in low-lying areas when it overflows. To overcome this problem, a bye-pass
channel is proposed to divert the floodwater to tail-end North Zone through an existing Culvert on the Sangareddy-Toopran highway as shown in Figures 1 and 2.

Figure 1. Narsapur Municipality Map (with Central Zone)

Figure 2. Proposed Drainage System near Pond in Central Zone
2. Literature Survey
The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model that estimates runoff quantity and quality from primarily urban areas. The runoff component of SWMM works on a set of sub-catchment areas that receive precipitation and generate runoff and pollutant loads. SWMM channels the quantity and quality of runoff generated in each sub-catchment and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps (US-EPA, 2009).

3. Methodology
The study is carried out in five phases. In the 1st phase, Land Surveying work is carried using GPS, DGPS, and Total Station equipment. Identification of existing road network and drainage system was done with the help of base maps prepared using Google Earth Satellite Images. In the 2nd phase, Levelling work is carried out to find the Elevations of all road junctions and drainage flow direction. In the 3rd phase, mapping the Roads and Drainage network was done using ArcGIS Software and identified 4 sub-catchments. In the 4th phase, Catchment Delineation is done using ArcGIS software. In the final phase, Peak Discharge is computed using EPA-SWMM Software, and capacity of drainage channels is validated using Manning’s Flow Equation.

![Figure 3. Methodology](image-url)
3.1 Data:
- Ward Boundary Maps acquired from Municipal Authorities.
- CartoDEM data collected from ISRO Bhuvan Website to prepare Terrain Map.
- Satellite Images are downloaded from Google Earth Pro to prepare Base Map which is used for Land Surveying and Levelling.
- Rainfall Data collected from Telangana State Development Planning Society (TSDPS) and is used in Rainfall-Runoff Simulation using EPA-SWMM Software.

3.2 Software
- Google Earth Pro to download Satellite Image of Narsapur Town
- ArcGIS Software to prepare Base Maps like Roads, Drains, Catchment, etc.,
- EPA-SWMM Software to Analyze and Design Stormwater Drains

4. Results and Discussion
Land Surveying work is carried out using GPS/ DGPS instruments and prepared existing roads and drainage network map as shown in Figure 4. Google Earth Satellite Images are used to prepare Base Maps to take up Field Survey.

![Figure 4. Road Network Map of Central Zone (Red color indicates Proposed Roads)](image)

Levelling work is carried out to find the Elevations of all road junctions to identify flow direction map as shown in Figure 5. The main objective of this study to dispose floodwater from Point 1 to 2. Due to the lack of a proper drainage system, the colonies near Point 2 are under inundation frequently during moderate to heavy rains.
Figure 5. Existing Drainage Map with Drainage Outlets 1 & 2

Peak Discharge is computed for the Catchment shown in Figure 6 using EPA-SWMM software. Rainfall of 175mm in 24 hours interval on 13-Oct-2020 as shown in Figure 7 is used for Rainfall-Runoff Simulation.

Figure 6. Catchment Map with Flood Disposal Route
From the Simulation, it is observed that a Peak Discharge of 1.82 cumec is observed at Catchment Outlet as shown in Figure 8.
However, the discharge observed is causing inundation in surrounding areas at Point 2. To avoid flooding, a major portion of flood flow is diverted to Pond near Bus Stand as shown in Figure 9 after considering the Flood Discharge Capacity of Culvert at Point 2.

**Figure 9.** Flow Diverted to Pond near Bus Stand

After diversion of Flood Discharge of 1.02 Cumec into Pond, the balance flow of 0.8 Cumec is directed to Point 2 as shown in Figure 10, 11 and 12.

**Figure 10.** Flow Routed to Outlet (at the end of Central Zone)
Figure 11. Proposed Stormwater Drainage System

Peak Discharge: 0.50 Cumec
600mm dia. RCC Pipe
Peak Discharge: 0.30 Cumec
800mm dia. RCC Pipe
1m x 1m Rectangular Channel
Peak Discharge: 1.02 Cumec
Peak Discharge: 1.82 Cumec

Figure 12. Flow Distribution for Smooth Discharge of Flood Water

| Outfall Node | Flow Freq. Pcnt. | Avg. Flow CMS | Max. Flow CMS | Total Volume $10^6$ ltr |
|--------------|------------------|---------------|---------------|------------------------|
| O2           | 21.78            | 0.461         | 1.020         | 8.315                  |
| O3           | 40.54            | 0.345         | 0.500         | 11.597                 |
| O4           | 89.89            | 0.170         | 0.300         | 12.638                 |
5. Conclusions
In this study, an attempt is made to design a Stormwater Drainage System for the Central Zone of Narsapur Municipality. The main objective of this study is to safely discharge the flood water without causing inundation of low-lying areas and colonies near Central Zone outlet which is caused due to overflow of Pond.

From Hydrology & Hydraulic modeling and Rainfall-Runoff Simulation using EPA-SWMM Software, a Peak Discharge of 1.82 Cumec is observed on 13-Oct-2020 for a Rainfall of 175mm. Considering the capacity of Culvert at Outlet, a proposal is made to divert floodwater about 0.8 cumec through 800 mm dia. RCC Pipe. The balance of 1.02 cumec is routed to the existing Pond. To validate Flow Carrying Capacity of proposed 800mm dia. RCC Pipe drain, Manning’s Flow Equation is used and results are found satisfactory.

Further study will be taken up to Estimate of Storage Capacity of the Pond and Design a System for Safe Disposal of Surplus water from the Pond.

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