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A Study on the Measures for Improvement of the Underground Drainage System

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Abstract: The past years have seen significant changes in the way underground drainage systems are understood, planned and designed. Underground drainage system plays a very important role in development of a country, more so in a developing country like India. Hence, its significance is very high. Infrastructure of a country or a city depends on proper drainage and road network systems. Due to poor construction quality and poor maintenance of subsurface drainage system in some regions, it is very likely that the ground water may be contaminated resulting in hostile effect on the environment. The last decade has witnessed exceptional development with respect to infrastructure development all over country. This prompted to increased movement of people from villages to towns. By 2050, it is predicted that majority of world population will be living in cities. So, development of towns occurs at a very faster rate. All this will require an efficient underground drainage system so that the health and safety of citizens is ensured and the city or town looks decent and liveable. In this paper, a suburb called Madhurawada (of the Visakhapatnam city) is selected as the study area. It is proposed to improve the existing drainage system with better and adequate discharge capacities, to cater to the needs of an ever-growing population. Manual calculations are done for analysing the existing sewer network for Madhurawada area. Preliminary data like quantity of water supply, number of wards/ zones with their population details, topography and source of sewage are collected from the local municipal body - Greater Visakhapatnam Municipal Corporation (GVMC). Using the details provided by GVMC, manual calculations are done. The results obtained are compared with the existing drainage parameters and suitable changes to the existing drainage network are suggested and a new Sewage Treatment Plant (STP) is designed.

Keywords: Underground drainage system design; Spreadsheet software; Sewer network; STP design; Vehicle load calculation.

I. INTRODUCTION

The Underground Sewerage System has been designed with a propensity of modern generation towards health and sanitation and also their hatred to foul matter and pollutants. Due to the unfriendly nature of human waste, a drainage system should be “out of vision and out of sense”. Most of the drainage systems are actually concealed from the eyes (underground). It is hence vital that it must be of superior quality and should be able to work seemingly endless amount of time without leakage or deformities. It becomes awful and expensive to address such issues that emerge in ordinary underground pipelines unexpectedly, and which may happen because of poor item quality or because of faulty construction. It is strongly suggested for structures where hygiene is an important requirement. This paper discusses about the development and implementation and an efficient underground drainage system for Madhurawada region in Visakhapatnam (India). Visakhapatnam is one of the fastest developing cities in India and has been identified by the Ministry of Urban Development (Government of India), as one of the smartest cities to be developed under the Smart Cities Mission program, proposed in 2017 in the Union Cabinet and obtained approval for implementation. Visakhapatnam is a city with population tremendously increasing due to urbanization, improved medical facilities in the form of a large number of network hospitals, education hub, presence of SML (small, medium and large scale) industrial establishments and a special economic zone (SEZ). Hence, providing water and infrastructural facilities to the people is a main concern for the urban bodies, like the GVMC. Visakhapatnam is one of the most populated and largest cities in Andhra Pradesh and it has an area of 540 square kilometers. Visakhapatnam is famously served by a port which is one of the highest revenue generating ports in the country. The city is situated in the middle of the Eastern Ghats to its West and the Bay of Bengal to its East, State of Odisha verging on the North and Vizianagaram district and East Godavari district towards the South. The city's coordinates lie between 17.6868°N, 83.2185°E. GVMC provides 460 tanker (of drinking water) trips every day to those areas which do not have a proper capable pipe network in place.

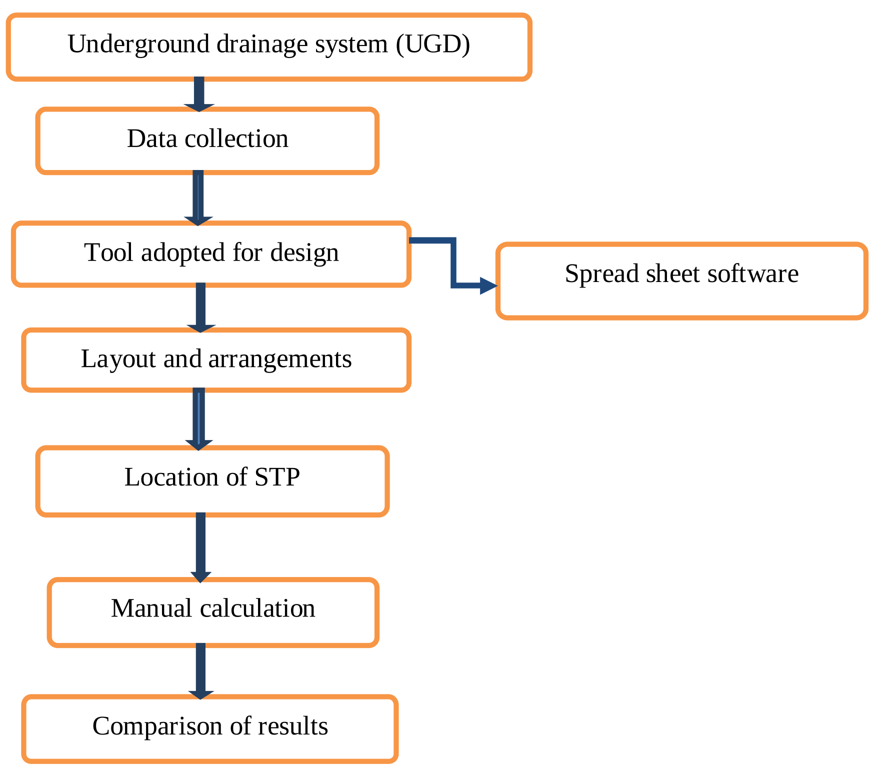
II. LITERATURE REVIEW

Manning’s formula for design of velocity was found to successfully (Patil et al., 2014) identify velocity differences along the different stages of the pipeline and led to reliable sewer solutions, as compared to the Crimp and Burge’s Formula, Chezy’s Formula and Hazen- Williams formula. In designing the collection system for Islampur(in India) town, GIS is used as a tool for mapping the collection system. Program logic control software program is used to swap the manual cleaning of drainage by a mechanical drain cleaner (Jiang and Zhang et al., 2014). For automatic control of sewage treatment, a mechanical semi-automatic drainage water cleaner was designed and implemented. It does not completely clean the sludge deposited in the drainage system. Based on a study conducted in Iran, minimum and maximum change of drainage parameters effect the change of volume of drain discharge. The volume of change in the discharge of drain for every 1% increase or decrease in each of drainage parameters was influenced by water level depth in the drain below the soil surface is equivalent to 3.0%. Depth of water level in the sewer below soil surface is introduced as the most effective parameter (Valipour et al., 2012). Mapping and Management of Sewerage System require a proper procedure for managing the sewerage system. Suggestions for ensuring the quality of drainage networks in Aurangabad (in India) were put forth, so as to improve the functional level of the drains acceptable to the users (Amol et al., 2016). Computer software X and Y are considered good to evaluate the velocities in pipes, drains and to produce the layout map for a zone in Tumkur(in India) city (Satish et al., 2015). Sewer system network, pumping station and wet/suction well were developed using Xand modelling and layout of sewerage network using Y. The individual results obtained from X software and manually calculated are compared for volume/volume percent ratio & diameter/diameter ratio. Manual on sewerage and sewage treatment by CPHEEO (Central Public Health and Environmental Engineering Organization) Manual (1993)provides objectives, planning and design of sewerage system, also shows design considerations, population estimate, design standards, limitations. It provides standard assumptions, tables, and design period for various systems. The sewer line, a basic unit in the design of a sewerage system, will change the overall cost of the sewerage system (Swameeet al., 2001). The present status of sewer line design uses linear and dynamic programming and provides the various formulae such as, diameter equation, depth equation, maximum velocity and discharge equation and optimization of the equations. Variousremedial measures are suggested based on minimum cover, self-cleansing velocity.

III. OBJECTIVES OF STUDY

The following activities have been proposed.
Design of underground sewerage system.
Design of Sewage Treatment Plant (STP).
Location of Sewage Treatment Plant (STP).

A. Methodology



B. Procedure

1) Preliminary data consists of the following

a) Geographic data

i) Population details
ii) Number ofhouseholds
iii) Boundary map of town

b) Geographical data

i) Rain fall data
ii) Water bodies information
iii) Soil conditions

c) Existing infrastructure data

i) Road networks
ii) Water supply dat
iii) Details of existing Storm Water Drain
iv) Existing underground drainage dat
v) Existing layout and zoning pattern

2) Secondary data consists of the following:

a) Potential for the development of the town
b) Problems concerning points of overflow
c) Manhole locations

C. Analysis of the Data

The analysis of the data is done for the selected area. According to the existing drainage conditions,the analysis of the remaining areasis also done. The extent to which the citizens will put to use the drainage facility effectively is studied.It is predicted that the new drainage system will be function effectively for the next35 years.

IV. STUDY AREA

Madhurawadais a major suburb of Visakhapatnam city in the Andhra Pradesh state. It is situated on the Visakhapatnam-Vizianagaram stretch of NH16 (National Highway-16)about 16km from Visakhapatnam city. Dr. Y. S. Rajasekhara Reddy ACA–VDCA cricket stadium,Visakhapatnam is also located in this suburb. This area consists of many well-developed areas like Pothinamallayya Palem, Mithilapuri VUDA colony, Revallapalem, Ganesh Nagar and Port colony. Madhurawada is one of the fastest developing areas in the city. Design of underground drainage is done for Vambay colony, Rajiv Gruhakalpa, Carpenters colony, Sivasakthinagar, APHB layout, Krishna nagar and Priyadarshini colony.

A. The parameters considered in the design are given below

1) Population : The population is a very important parameter because water supply quantity is a main element in the plan and design of underground drainage system.

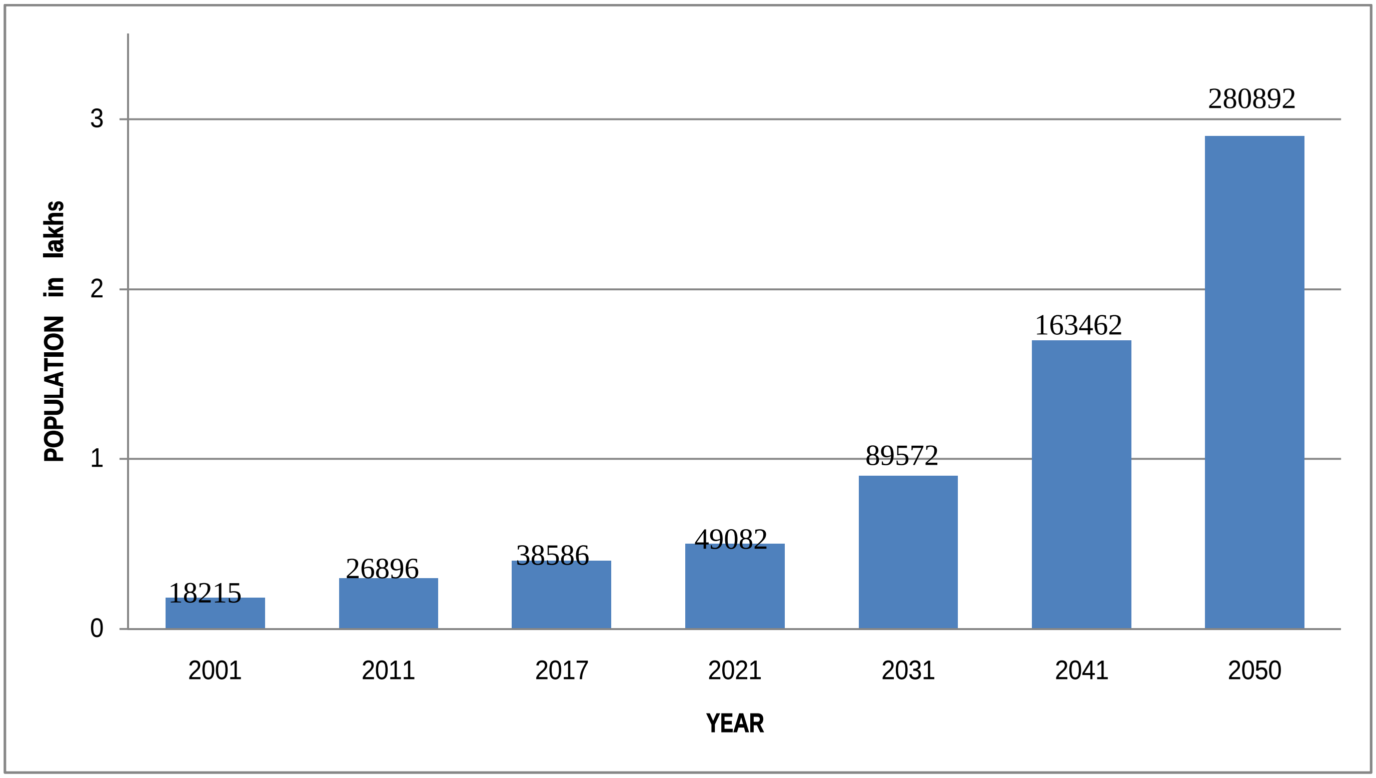


Fig. 1.Population forecast of Madhurawada area

2) *Rate of Water Supply:* Wastewater quantity may be assumed to be 80% of the quantity (Punmia et al., 2009)of water supply. The drains must be designed for a minimum of 180 lpcd.
3) *Slope/Gradient :*Slope depends upon the topography of ground and levels. Slope is also another important parameter because the rate of flow depends upon the amount of slope.

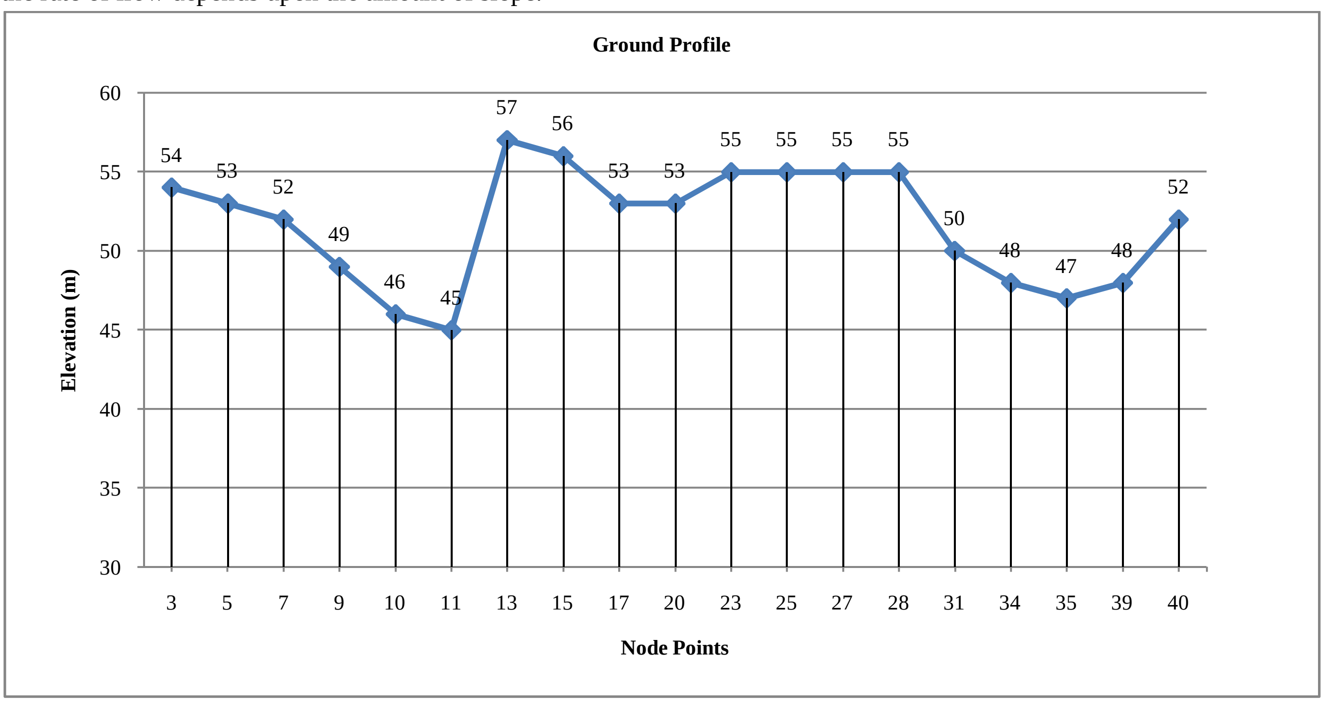


Fig. 2.Ground profile of Vambey colony

4) *Peak Factor: In* India, the CPHEEO (1991) has recommended following standards of peak factor based on population (Table. 1) for the design of water distribution system. The peak factor or the ratio of maximum to average flow depends upon the contributory population and the recommended values are given in Table 1. These peak factors will be applied to the estimated population for the design year considering an average wastewater flow based on allocation.

TABLE1. Peak Factor Table

S.No.	Population	Peak factor
1	Up to 20000	3.5
2	20000 to 50000	2.5
3	50000 to 750000	2.25
4	Above 750000	2.0

5) *Velocity:* The sanitary sewer is designed to achieve acceptable cleaning velocities at the average or at least at the maximum flow stream at the beginning of the design period for a given flow and slope. Velocity is slightly influenced by pipe diameter. A minimum velocity of 0.75 m/sec and maximum velocity of 3.00 m/sec is recommended.
6) *Pipe Size: The* pipe size should be decided on the basis of ultimate design peak flow and the allowable depth of flow. The minimum diameter of public sewer may be 150 mm. In hilly areas, where extreme slopes are prevalent, sewer size of 100 mm is also considered.
7) *Depth of Cover :*The cover on the pipeline is normally sufficient to protect the pipelines from external damage.
8) *Manholes:*Manhole is a small covered opening in a paved area allowing access beneath, especially one leading to a sewer. Manholes are used to build connections and junction chambers.

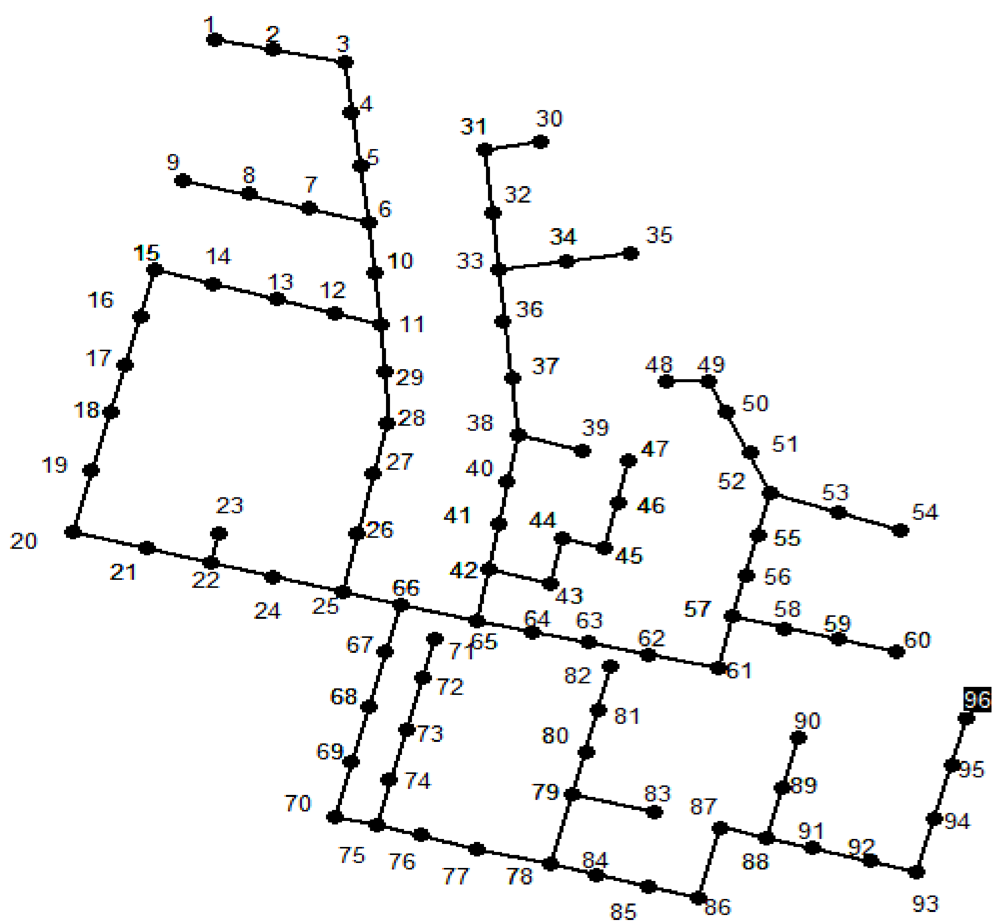


Fig. 3.Vambey colony manhole locations and numbers

V. VARIOUS POPULATION FORECASTING TECHNIQUES

There aremanymethods for the population forecasting, suitableforthetown.9

A. Geometric Progression Method

In this method the rate increment is assumed to be the rate of growth and the average of the percentage increase is used to find out future increment in population. This expansion has to be done carefully and it requires huge experience and decision-making ability. This technique gives significantly higher values and mostly applicable for growing towns and cities having vast scope for expansion.

The formula used in this method is given below:

$P_n = P_1 \times (1 + (i/100))^n$

where,

P_n= Population in the n^{th}decade

P_1=Populationinthelatestdecade

n=Number ofdecades

i = Average percentage increment per decade

B. SampleCalculation (using the data from the current study)

P_n=2051,P_1=163462,n=1, i = 73.28andP_n=?

$P_n = 1{,}63{,}462 \times (1+73.28/100)^1$

P_n= 2,84,064

VI. HYDRAULIC DESIGN

Manning's equation is used most commonly for the design of sanitary sewers as it is efficient and popular. The values obtained from the Manning's formula agree well with the experimental results of the current work.

The Manning's Equation is given by,**$V = (1/n) \times R^{(2/3)} \times S^{(1/2)}$**

where,

V = Velocity in m/s

n = Friction Factor

= 0.011 (for Plastic smooth pipe)

= 0.013 (for Cement-concrete pipe)

R = Hydraulic Radius in metre (c/s area of flow in sq. m)

S = Slope of Energy Grade Line

Wastewater = 80 % of water supply per person

Sample Calculation (using the data from the current study)

Considering one primary line of sewer line of sewer,

A. Data

Population (P)=5325,

Peak Factor (PF)=3.5,

Slope (S)= (56-53) /63.12 = 0.0476,

Wastewater Quantity= 80%

Design Flow (Q_d) and Velocity of Flow (V) =?

Q_d=5325 x3.5 x 180 x 0.8 = 0.008875m^3/sec

Q_{full}=0.0310625m^3/sec

Q_{full}= V x A

$= (1/n) \times (D/4)^{(2/3)} \times S^{(1/2)} \times (\pi/4) \times D^2$

D= 0.154m (or 200 mm is provided)

V =1.661 m/sec

VII. SEWER NETWORK LAYOUT PATTERN OF VAMBEY COLONY

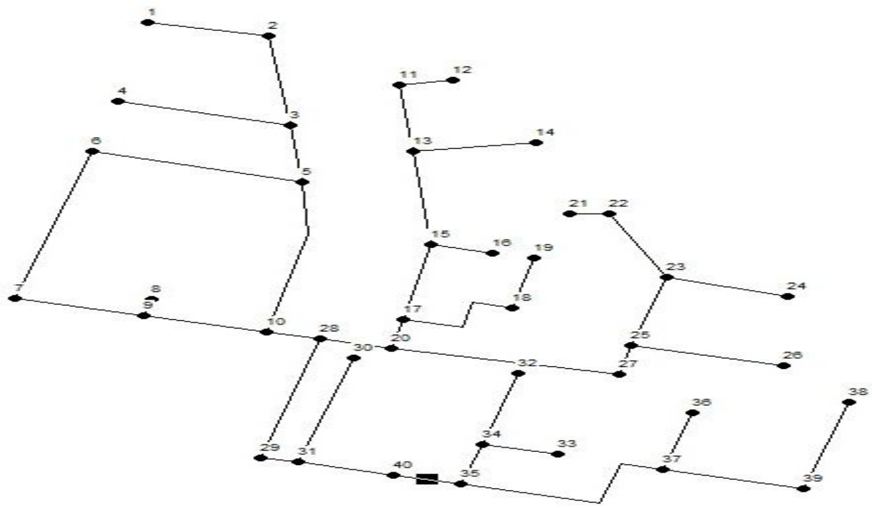


Fig. 4.Sewer network pattern of Vambey colony

Same procedure and calculations of other lines of the network and all these lines of calculated values are shown in Table 2.

TABLE 2. Velocity and discharge calculations

Sewer line	From	To	U/s RL(m)	D/s RL (m)	Population	Length (m)	Q (cu. m/sec)	Diameter (mm)	Velocity (m/sec)	Slope	PF
1-2	1	2	54	53	5323	65.04	0.005	200	1.661	0.0476	3.5
4-3	4	3	53	51	7925	94.17	0.0075	200	1.572	0.03157	3.5
6-5	6	5	52	49	10647	114.27	0.01	250	1.613	0.02777	3.5
6-7	6	7	49	45	23957	161.49	0.022	300	1.738	0.02469	2.5
8-9	8	9	46	46	15971	18.28	0.015	350	1.188	0.00937	3.5
2-10	2	10	54	48	23957	318.53	0.0225	300	1.577	0.01904	2.5
7-28	7	28	45	48	63885	175.43	0.0595	400	1.922	0.018	2.25
12-11	12	11	57	55	2661	26.06	0.0025	150	1.101	0.02528	3.5
14-13	14	13	56	54	5323	64.16	0.005	200	1.410	0.03076	3.5
16-15	16	15	53	53	5323	32.19	0.005	250	0.784	0.00644	3.5
19-17	19	17	53	50	6654	129.45	0.006	200	1.338	0.02307	3.5
11-20	11	20	55	48	19964	282.29	0.018	300	1.813	0.02491	3.5
24-23	24	23	55	54	7925	65.58	0.0075	250	1.133	0.01315	3.5
26-25	26	25	54	51	2661	81.08	0.0025	150	1.183	0.03061	3.5
21-22	21	22	55	55	2661	19.71	0.0025	150	1.118	0.02631	3.5
22-27	22	27	55	50	18633	178.91	0.017	300	1.852	0.02762	3.5
27-28	27	28	50	48	38597	148.99	0.035	400	1.517	0.0125	2.5
30-31	30	31	48	44	13309	115.98	0.0125	250	1.844	0.03418	3.5
33-34	33	34	47	46	1330	40.28	0.0015	150	0.922	0.025	3.5
32-35	32	35	48	45	7925	122.74	0.0075	250	1.204	0.01549	3.5
28-29	28	29	48	44	107806	131.93	0.1	500	2.678	0.03076	2.25

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38-39	38	39	55	52	13309	94.62	0.0125	250	1.731	0.02884	3.5
36-37	36	37	52	50	6654	63.48	0.0075	250	1.777	0.04918	3.5
39-40	39	40	52	45	29280	237.13	0.027	300	1.881	0.02666	2.5
29-40	29	40	44	45	121116	84.43	0.09166	500	2.139	0.01562	2.25

VIII. VEHICLE LOAD CALCULATION

$W_{sd}=C_s \times p \times B_c \times I_e$

where

W_{sd}= load on conduit (t/m)

P= intensity of uniform distributed load(kg/m^2)

I_e= impact factor = 1.5 for highway traffic and air-filled taxiways

B_c= outside width of conduit= D+2t

C_s= load efficient, which is a function of B_c/2H and L/2H

H = height of surface over the top of conduit

Width of trench,B_d=1.5 m

As per IRC (Indian Roads Congress) under critical case wheel load of 6.25 tons (and wheel area of 300mm x 150mm) is given

$P = 6.25/(0.3 \times 0.15) = 138.89$ t/m^2

Depth= 3 m

Outside width of conduit, B_c= D+2t =500+160= 660 mm =0.660m

H = 3-0.66 = 2.34 m

$B_c/2H = 0.66/(2 \times 2.34) = 0.141$

L/2H= 1/2.34 = 0.42

$C_S = 0.067$

Impact factor I_e=1.5

Load on conduit,

$$W_{sd} = C_s \times P \times B_c \times I_e$$
$$= 0.067 \times 138.89 \times 0.66 \times 1.5$$
$$= 9.219 \text{ t/m}$$

IX. SEWAGE TREATMENT PLANT

Sewage treatment plant consist of physical, chemical, and biological procedures to remove these pollutants and impurities and produce environmentally safe treated wastewater. The plant is designed so well to meet the future development for the next 35 years. The plant designed with all the components of STP from receiving chamber, screening chamber, grit chamber, skimming tank, sedimentation tank, secondary clarifier, aeration tank and sludge drying beds. Capacity of STP to be provided is 30.4 MLD

TABLE 3.STP dimensions

Component	Numbers	Dimensions (FB = freeboard)
Receiving chamber	1	6.6 m x 3.3m x 3m + 0.5m(FB)
Coarse screen	2	1.3m x 0.7m + 0.5m(FB)
Grit chamber	2	6.4m x 6m x 3m + 0.5m(FB)
Skimming tank	1	1.5m x 1m x 3m + 0.5m(FB)
Primary sedimentation tank	1	60m x 14m x 4.5m + 0.5m(FB)
Aeration tank	2	68m x 4.5m x 10m + 0.5m(FB)
Secondary sedimentation tank	1	37.2m Ø x 3.5m + 0.5m(FB)
Sludge drying beds	5	12m x 6m

X. RESULTS

In this paper, one part of the work is design of sewerlines and another part is STP design and its location. The main purpose of this paper is to design an underground drainage system for Madhurawada, along with sewage treatment plant for treatment of collected sewage. The total length of sewerline is 18 km. The range of diameters of sewerlines is about 150 – 600mm. The capacity of sewage treatment plant is 30.4 MLD (million litres per day).

XI. CONCLUSIONS

A. From the available population data of Madhurawada from year 1971 to 2011, the population growth rate is 6.2% and forecasted population in 2051 is nearly 2,84,064.

B. Total length of sewerline obtained is 18 km.

C. The proposed new underground sewerage system is badly required due to increasingpopulation, as the existing drainage system is inadequate. With most of the existing drains being open drains, more often than not, sewage overflows, creating unsightly conditions and diseases. Hence, as per analysis and design, the total sewage generated by all STPs is about 30.4 MLD.

D. One STP is proposed for collection of wastewater and is to be provided near the sea for easy disposal of treated waste and water.

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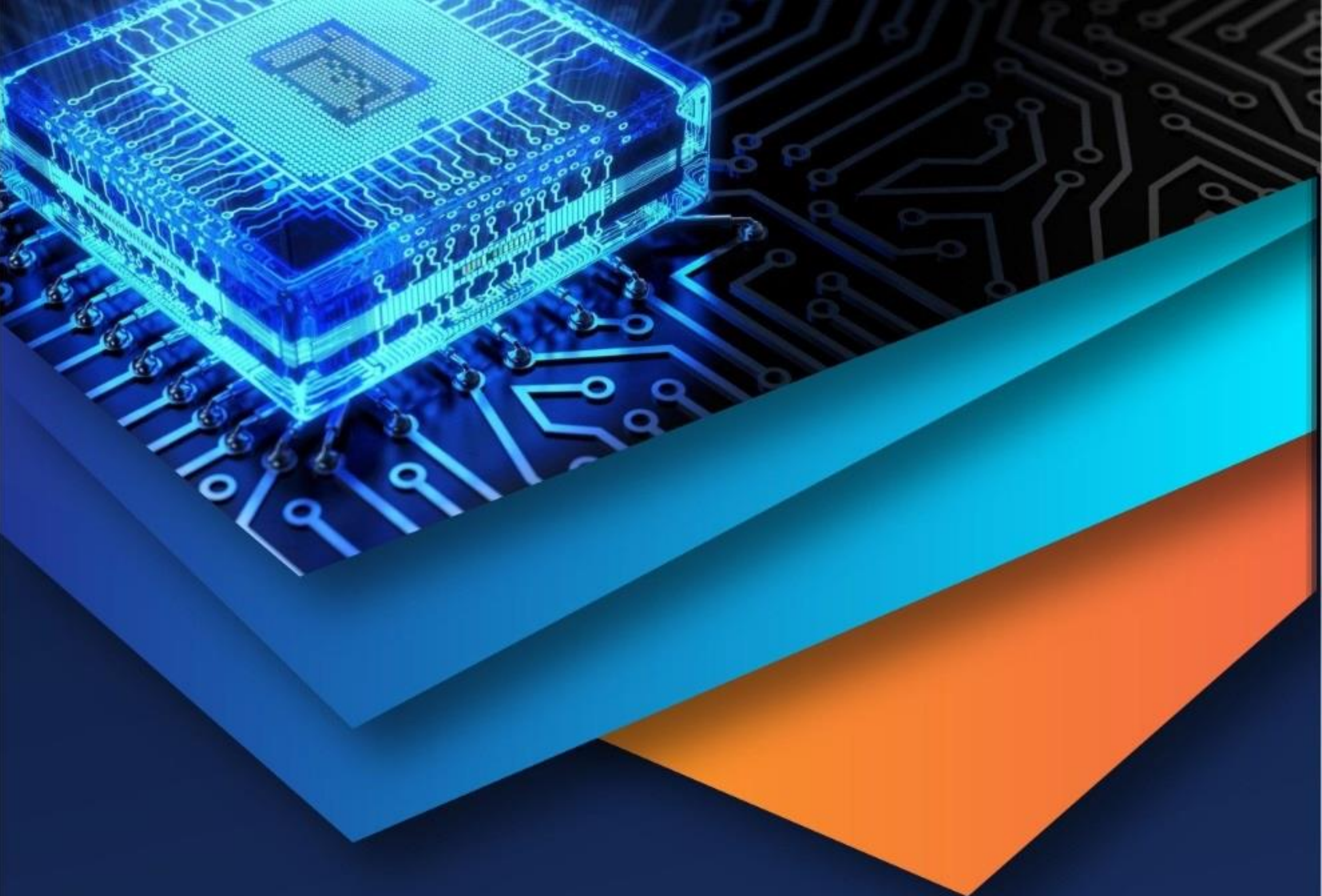

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