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Hydraulic Design & Analysis of Underground Drainage System: for a Zone in Tumkur City

Shruthi S Kannur[1], Santosh Patil[2], Satish S Kannur[3]

[1] *Research Scholar, Environmental Engineering, K.L.E. Dr M S Sheshagiri College of Engineering & Technology, Belagavi, Karnataka, India*
[2] *Senior Project Manager, Royal Hoskoning DHV, Bengaluru, Karnataka, India*
[3] *Project Consultant, Royal Hoskoning DHV, Bengaluru, Karnataka, India*

Abstract –

During early years of designing conveyance system, manual calculations were practiced which was laborious to handle the data and results. Now a days, specific softwares are developed to minimize the time for calculation and improved environments for documentation and presentations. One of such software is given by Bentley's products named 'SewerGEMS'. The environment of 'SewerGEMS' software emphasis on creating set of sewer networks alignments, alternatives such as physical alternative, design alternative etc. The computation of design and analysis for different scenarios is possible by adopting 'SewerGEMS' Software. In the proposed paper, the 'SewerGEMS' software is used as a design tool to have amicable results for analyzing sewer network for a Zone in Tumkur city. Initial data was provided by city municipality, comprised of parameters related to water supply, number of wards with their population distributions, topography and source of sewage. The sewer network is designed by considering the local statutory body regulations along with the commercially available materials. Utilizing these data, analysis was performed to simulate hydraulic conditions of sewers. In order to assess compatibility to accept the outputs of the software results; manual calculations are carried out with the aid of 'Microsoft Excel'. The variations of the output parameters are analyzed and compared with manual calculations. The results are found in similar nature with slight variations in physical values. Proposed work benefits academics and practitioners (municipal engineers, consultants and contractors) to prioritize plans for forth coming localities which are in need of underground drainage system.

Keywords: *Underground drainage system, SewerGEMS, Microsoft Excel, Sewer Network, Pumping station and Wet well/Suction well*

1. INTRODUCTION

Since earlier times, manual design of conveyance system was practiced and from the recent past, it has switched to advanced design practices adopting well organized computer aided design tool named 'SEWER'. Among the latest technologies, 'InfoSewer' is a powerful ArcGIS – based computer program used for the planning, design, analysis & expansion of sanitary, storm & combined sewer collection system. Also, another software which has been widely used currently is 'SewerGEMS' developed by Bentley's products. Out of the latest technologies, in the present study, focus has been made on 'SewerGEMS'. In the proposed paper, 'SewerGEMS' software is adopted for the design & analysis of underground drainage system, alternatives of designs and analysis with different scenarios [1]. The initial data was gathered from City Municipal Corporation [2]. The design attributes considered were - diameter of the pipes, depth of excavation, slopes to achieve desired self cleansing velocity and commercially available sewer attributes. The design was taken up to satisfy the set of design constrains prescribed by local statutory bodies & regulations. Thus considering all these parameters, an underground drainage system was design and analyzed.

1.1 Need for proposed work

Newly developed layouts and twenty three numbers of surrounding villages have added to the Tumkur city limits which do not have the underground drainage facilities. The terrain is crisscrossed between river valley tributaries of Krishna & Kaveri and series of hills intersects the land for about 4000 feet (1200 meters) from North to South directions. The land also consists plain flat terrain with rock outcrops & fertile soils, when the soils are mixed in certain proportions, impacts the infiltration of water to the groundwater system [3]. Thus the land terrain gives a challenging task to take up the vigorous engineered design & analysis of underground drainage system for a zone in the Tumkur city.

1.2 Background

The proposed study area is a small part in the Tumkur city which is a district headquarters of Tumakuru district. It has total area of 10,598 m^2 situated at latitude of 13°19′0″ N, longitude of 77°5′ E, elevated at about 860 meters from sea level with annual rainfall of 670 mm and has the maximum temperature of 31°C to 40°C during summer and

16˚C to 30˚C during winter. It has two major canals for water supply in the city with 240 km long with 1429 cusecs capacity and 78.50 km long and 890 cusecs of capacity [3]. The figure below displays the proposed study area.

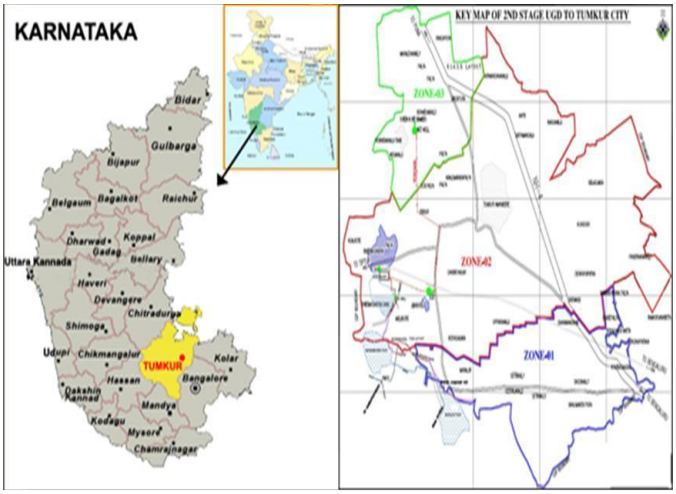
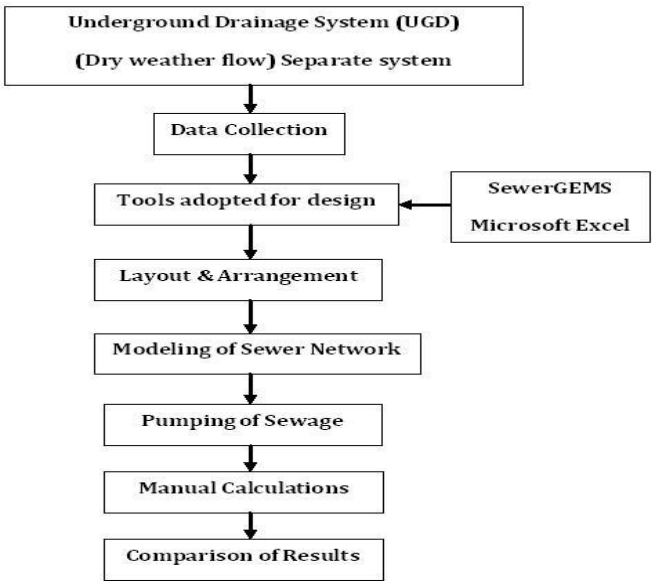


Fig -1: Project Layout of a Zone in Tumakuru city [3]

2. MATERIALS & METHODOLOGY

In the flowchart of methodology given below, describes the systematic procedure of the proposed work.



Flowchart-1: Methodology for proposed work

2.1 UGD SYSTEM

In the proposed work, much focus is on the design of underground drainage system for a zone in Tumkur city with the area of 10,598 m² [3] that lack the sewerage conveyance system. Separate Conveyance system for DWF (Dry weather Flow) is adopted in the design of underground drainage system. The system is designed as per the CPHEEO (Central Public Health & Environmental Engineering Organization) guidelines which involves the design parameters that are practiced for Indian conditions.

2.2 DATA COLLECTION

The data was collected from city municipality and the preliminary studies were carried out. Contour maps, land use, ward wise population distribution, sources of water & sewage generation and trends in the population variations data were collected. Data pertaining existing sewerage and treatment facilities were gathered. Location of roads and adjacent areas likely to be merged were studied. Topography or elevation difference, required for design of sewers and location of outfall or disposal point were visualized. Troubles faced for maintenance of present sewers were known.

2.3 TOOLS ADOPTED FOR DESIGN

For the design of sewer network/ (UGD), a computer aided design tool named 'SewerGEMS' software was utilized along with 'Microsoft Excel' for the manual calculations. The details of the design tools adopted are as described below-

SewerGEMS

Well organized design software named 'SewerGEMS' is given by 'Bentley systems' in collaboration with 'Haestad Methods Solution Center'[1]. SewerGEMS can perform multiple design iterations by creating plans and profile sheets that will meet a set of constraints given by the client. The fundamental components of the software are as given below –

- Menu & sub menu for the choice of a specific unit for design are made available in the software environment.
- Hydraulic configuration methods as indicated by standard references & regulatory bodies.
- A caution notification alert system, if estimation of any parameter is out of design parameters or missing the range from usual practice.

Microsoft Excel

The manual calculations were carried out adopting 'Microsoft Excel' spread sheet for the design of sewer attributes such as - full discharge, velocity at peak flow conditions and d/D ratio by utilizing various design formulae and design constraints as approved by CPHEEO guidelines. Further comparison was done for the software results & Excel results. For the result comparison, the basic data for slope, diameter & flows were taken from 'SewerGEMS' results.

2.4 Layout & Arrangement

The framework of the layout & arrangement for sewer design is as in the following steps:

(a) Selection of an outlet or disposal point.
(b) Specified limits to the drainage valley or Zonal Boundaries.
(c) The fundamentals of local bye-laws were known.
(d) Location of different services such as - position, depth and size of all other pipes, mains or different services in the proposed region were considered.
(e) Location of Trunk and Main Sewers were determined.
(f) Location of Pumping Stations was visualized.

The layout of sewer lines are arranged by joining sewer lines of every building in every road already existing or likely to come up in future.

2.5 Modeling of Sewer Network

For modeling of Sewer Network, initial study was conducted on the land area. As per the study conducted, the ground levels conformed three distinct terrains draining at 3 different directions thus for the better conception the region is classified as Zone – A, Zone- B and Zone -C. A synchronized AutoCAD & Google map of the land was prepared by downloading Google images and importing it to AutoCAD software. Using the 'Scale' command of AutoCAD, scaling of every image was performed by considering single reference point on the CAD drawing & co-inside the same point on the Google image. The scaling of map was done for 1: 1000. This synchronized AutoCAD & Google map prepared is imported to the 'SewerGEMS' environment and is considered as the base reference for the modeling of Sewer Network. The figure below shows the synchronized map of the proposed Zone.

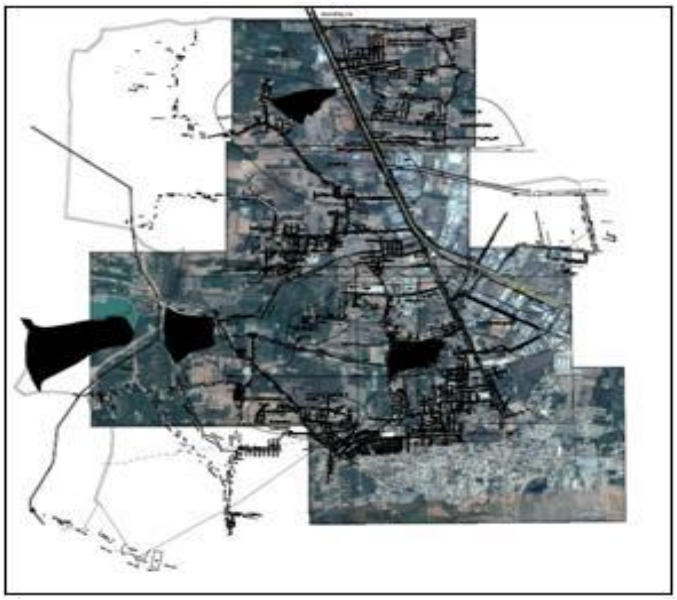


Fig -2: Synchronized AutoCAD & Google map.

Steps for Modeling of Sewer Network [1]

1. Obtained regulatory design guidelines, set design criteria & other related data were collected.
2. Identified regions to be served & divided total territory into subareas to develop design flow rates for each section & design flow was estimated.
3. Data was collected with respect to alignment & elevations of existing and proposed services.
4. Performed hydraulic design by choosing pipe sizes, slopes and inverts from the conduit catalog of the software.
5. Review design and assumptions. Change the design if vital.

In the proposed work, 'Unit count load' population is considered for the design and 'Hazen & William's method' along with 'Manning's formula' is adopted for the analysis of Sewer Network.

2.6 Pumping of Sewage

Since there exists, 3 zones draining at 3 different directions, a provision is made to combine two zones at a low lying area and a sewage storage structure called wet well/suction well & a set of pumping stations are provided. In the proposed work, the rate of water supply for the city is 135 lpcd (liters / Capita / Day) and 80 % is sewage contribution [4]. Thus per capita sewage production is 108 lpcd. The infiltration is about 2 % [2] therefore the rate of wastewater return is 110.70 lpcd. The pumping stations & wet wells are provided at two locations one at MH (Manhole) 1333 & other at MH 1473 in the sewer network. The pumping stations & wet wells are designed for average flow conditions. The following tables provide the details of pumping stations and wet wells.

Table -1: Pumping Stations Details

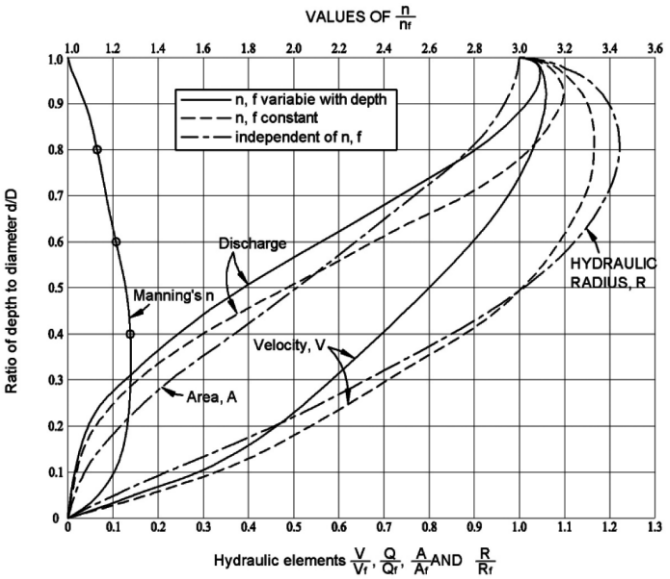
Sl. No	Design Parameters	units	MH-1333 to Ridge manhole MH-2	MH-1473 to Ridge manhole MH-67
1	Population	Numbers	1611	6320
2	Sewage generated	MLD	0.20	0.70
		l/s	2	8
		m^3/s	0.002	0.008
		m^3/hr	7.2	28.8
3	Diameter of raising main	mm	100	150
4	Pipe material		Ductile Iron	
5	Length of pumping main	m	200	250
6	Station losses	m	1	1
7	Total frictional loss	m	0.22	0.55
8	Total pumping head	m	15.98	21.17
9	Residual head	m	2	2
10	velocity	m/s	0.250	0.47
11	Required HP of pump	HP	0.71	3.76
12	Provided HP of pump	HP	2	6
13	Efficiency	%	60	60
14	Delivery level (G.L)/Ridge level	m	810.36	813.60
15	Bottom level of wet well	m	797.60	795.98

Table -2: Details of Suction well / Wet wells

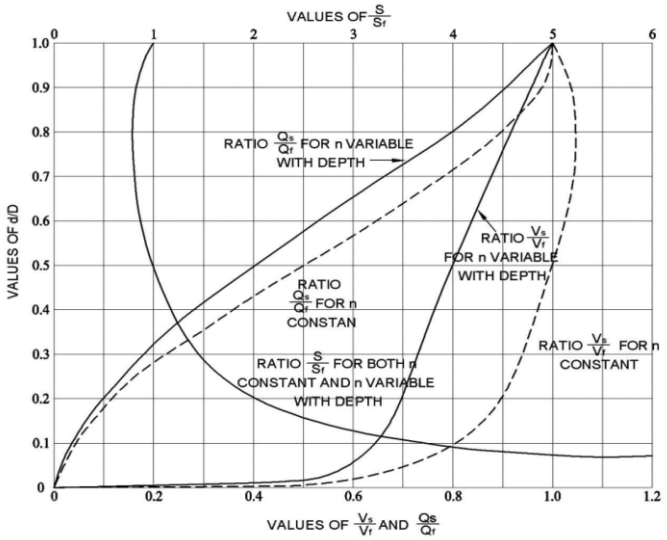
Sl. No	Design Parameters	units	MH-1333	MH-1473
1	Capacity	MLD	0.33	1.25
2	Diameter of sump	m	3.50	4.50
3	Effective depth	m	0.3	0.65
4	Free fall	m	0.30	0.30
5	Maximum water level (MWL)	m	798.810	797.560
6	Low water level (LWL)	m	798.510	796.910
7	Bed level	m	797.610	796.010
8	Ground level at wet well site	m	801.25	802.98
9	Submersible depth of pump	m	0.90	0.90
10	Height of floor above G.L	m	0.45	0.45
11	Roof level	m	801.7	808.980
12	Height of pump house above floor level	m	6	6
13	R.L of pump house below roof level	m	807.250	808.980

2.7 Manual Calculations

Manual calculations were done considering the design parameters such as self cleansing velocity, minimum size of sewer, minimum depth of cover, maximum depth of sewer invert, flow characteristics, hydraulic design consideration & slope of Sewers. For the design of Sewer Network, circular closed conduits with 60 % partial full conditions are adopted with the self cleansing velocity ranging from 0.60 m/s to 0.80 m/s. But minimum velocity of 0.40 m/s is acceptable by the regulatory guidelines [5]. Minimum diameter of pipe size considered in the design is 150 mm; minimum invert depth provided to avoid silting in the sewers is 1 m & the maximum cover provided is 6 m in the design. The slopes are determined by adopting hydraulic graphs as given below. The pipe materials adopted are Galvanized Stoneware pipes (GSW) & Reinforced Cement Concrete pipes (RCC) with manning's co-efficient for pipes as 0.0012 & 0.0013 respectively.



Graph 1: Hydraulic – Element graph for circular sewers [5]



Graph 2: Circular sewers having equal self-cleansing properties at all depths [5]

Difficulties during design of Sewer Network/UGD

- Maintaining a proper depth/ rise ratio and self cleaning velocity was very difficult.
- The software works on the values defined by the user, results ended up with infeasibility in implementation.
- Tracking the errors and satisfied corrections of error notifications for the smooth run of design engine was tedious.

3 RESULTS & DISCUSIIONS

The analysis of underground drainage system has been done as per the design considerations prescribed by CPHEEO guidelines. The results derived from 'SewerGEMS' are compared with manual calculations. Since there exists,

initial manhole points with the self cleansing velocities less than minimum values, at such points flushing manholes are provided to boost up the velocity of the flow in the sewers. Thus the results derived are well within the design parameters and they are in satisfactory manner so as to easily employ in the field without much complicatedness. The abstract of the results are as follows–

Table -3: Abstract of underground drainage system for the Zone of Tumkur city

Parameters	Units	Total
Area of Zone	m^2	10,598
Total Manholes	Numbers	1,958
Total Length of Sewer line	m	52,846.7
No of Flushing tanks	Numbers	300

The complete plan of the underground drainage system for the zone is displayed in the figure below –

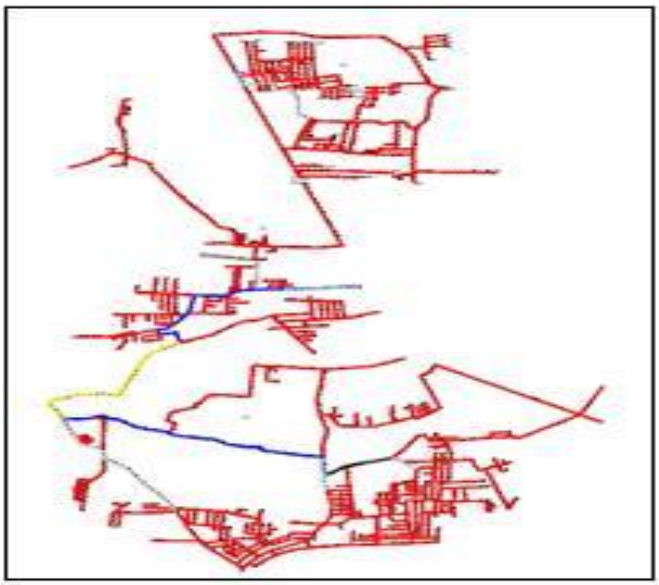


Fig-3: Complete Underground drainage system for the Zone

3.1 COMPARISON OF RESULTS

The software results obtained are compared with manual calculations. The individual results obtained from 'SewerGEMS' software & manually calculated are compared for v/V ratio & d/D ratio.

Table -4: Comparison of d/D Ratio of software & Manual results

d/D Ratio	Software results of MH	Manual results of MH	Software Percentage	Manual Percentage
< 10 (Low flow)	828	698	42%	36%
10 -25 (Moderate flow)	539	535	28%	27%
25 -50 (Average flow)	538	367	27%	19%
>50 <80 (Good flow)	53	358	3%	18%
Total	1958	1958	100%	100%

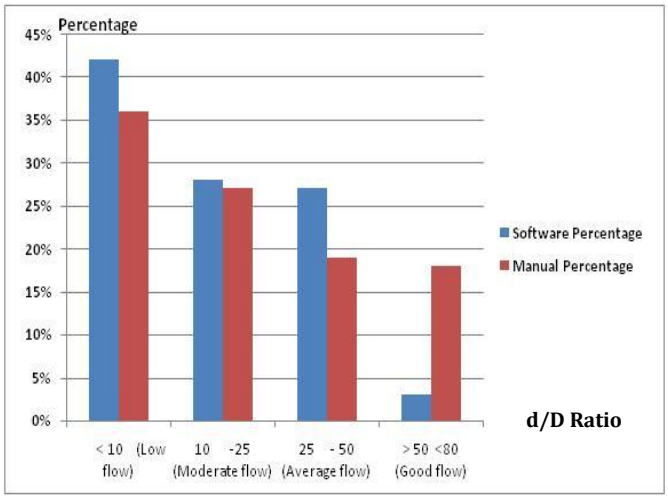


Chart -1: Percentage Variation of comparison for d/D Ratio

From above chart, it is understood that, there is 6 % variation of d/D ratio for low flows & there shows 15 % variations in good flow conditions. But the variation is comparatively within the limits. Hence there wouldn't be much problem in implementation. Thus the design is acceptable.

Table -5: Comparison of v/V Ratio of software & Manual results

v/V Ratio	Software results of MH	Manual results of MH	Software Percentage	Manual Percentage
< 0.30	383	252	20%	13%
0.30 - 0.60	1055	1160	54%	59%
0.60 - 1.00	469	490	24%	25%
1.00 - 1.50	51	56	3%	3%
Total	1958	1958	100%	100%

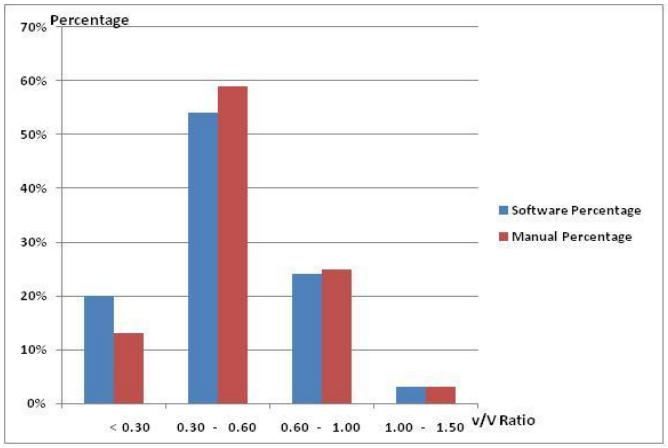


Chart -2: Percentage Variation of comparison for v/V Ratio

From the above chart, v/V ratio has varied 7 % & rest variation percentage is very slight. Thus, the comparison of the results shows similar nature except slight variations in the percentage.

4. CONCLUSIONS

An underground drainage system for 'Dry weather flow' with separate conveyance system was designed for a unit zone of Tumkur city (Karnataka, India) with the design population of 45,673 and sewage generation of about 110 lpcd when water supply for the city is 135 lpcd. The design period was considered for 30 years. The results were obtained from 'SewerGEMS' software & from 'Microsoft Excel' spread sheet. The individual results were compared. The following are the conclusions derived from the comparison.

- ✓ About 74 % of velocities in the sewer lines fall below 0.60 m/s due to the minimum diameter of 150 mm. Hence flushing of initial manholes is recommended to increase self cleansing velocity.
- ✓ 80 % of velocity in sewer lines falls in more than 0.30 m/s, considering execution point of view, hence it is presently acceptable.
- ✓ Similar natures of results were obtained by software & manual calculations, but with slight percentage variations.
- ✓ 'SewerGEMS' software consumes lesser time for analysis and design compared to 'Microsoft Excel'. Once the model is ready, within short period, the system can be analyzed with different alternatives and scenarios using 'SewerGEMS'. But 'Microsoft Excel' consumes lot of time.

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BIOGRAPHIES

Ms. Shruthi S Kannur
Fellow Post Graduate
Mtech(Env Engg), BE (Civil Engg)
K.L.E. Dr M S Sheshagiri College of Engineering & Technology,
Belagavi, Karnataka, India.

Er. Santosh Patil
Senior Project Manager,
Royal Hoskoning DHV,
Cavery Bhavan, Bengaluru,
Karnataka, India.

Er. Satish S Kannur
Project Consultant,
Royal Hoskoning DHV,
Cavery Bhavan, Bengaluru,
Karnataka, India.