

Design of Underground Drainage System in Rural Area Using SewerGEMS Software

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Abstract-The aim of this paper is to understand the designing of underground sewerage network using SewerGEMS and different components of a sewerage network. Other objectives include basic knowledge of a rural sewerage scheme from its base i.e study of a Rural Underground Scheme. In the proposed research paper, a study on the same topic has been made.

Keywords: Sewage, Design, Efficiency, Network, Waste Water.

Introduction-The two basic essential amenities for a healthy living are Safe Water Supply and Hygienic Sanitation Facilities. The provision of safe drinking water precedes when talking about providing basic amenities to community. Although, the importance of hygienic sanitation facilities that are effective and low-cost on-site sanitation, cannot be allowed to lag behind. This can be done through practicing and following the conventional sewerage and sewage treatment techniques. A proper knowledge about sewerage system is hence important looking at the high percentage of domestic water that is considered as sewerage while designing any sewerage system i.e 80% of the gross domestic water supplied for drinking purpose. If this huge quantity of water, that is already polluted and hazardous for human and animal health, is let into open streams without any prior treatment can cause heavy damages to human health as well as to environment. Hence a proper network for carrying this sewage from its source to a Sewerage Treatment Plant, where it can be treated and then disposed-off safely, without harming the environment is very important to be designed. To achieve above objective, the study involving designing of a sewerage network with the help of SewerGEMS software is being proposed.

The Underground Sewerage System are Infrastructures that plays an important role in any society. Underground Drainage is the term given to the systems of pipes and fittings that are installed below ground level for transporting foul drainage or runoff to a sewage treatment facility or, in the case of rainwater, a soak away or water course.

LITERATURE REVIEW

Following is the study for Underground Sewerage Scheme for Deori.

DESIGN DATA

Design Period of the Scheme

Design period of this scheme is taken as 30 years. It is planned that scheme will be commissioned by 2021 and thus design is taken as 2051. The water supply scheme is recently prepared and under augmentation considering design year as 2036.

LAYOUT OF SEWER NETWORK

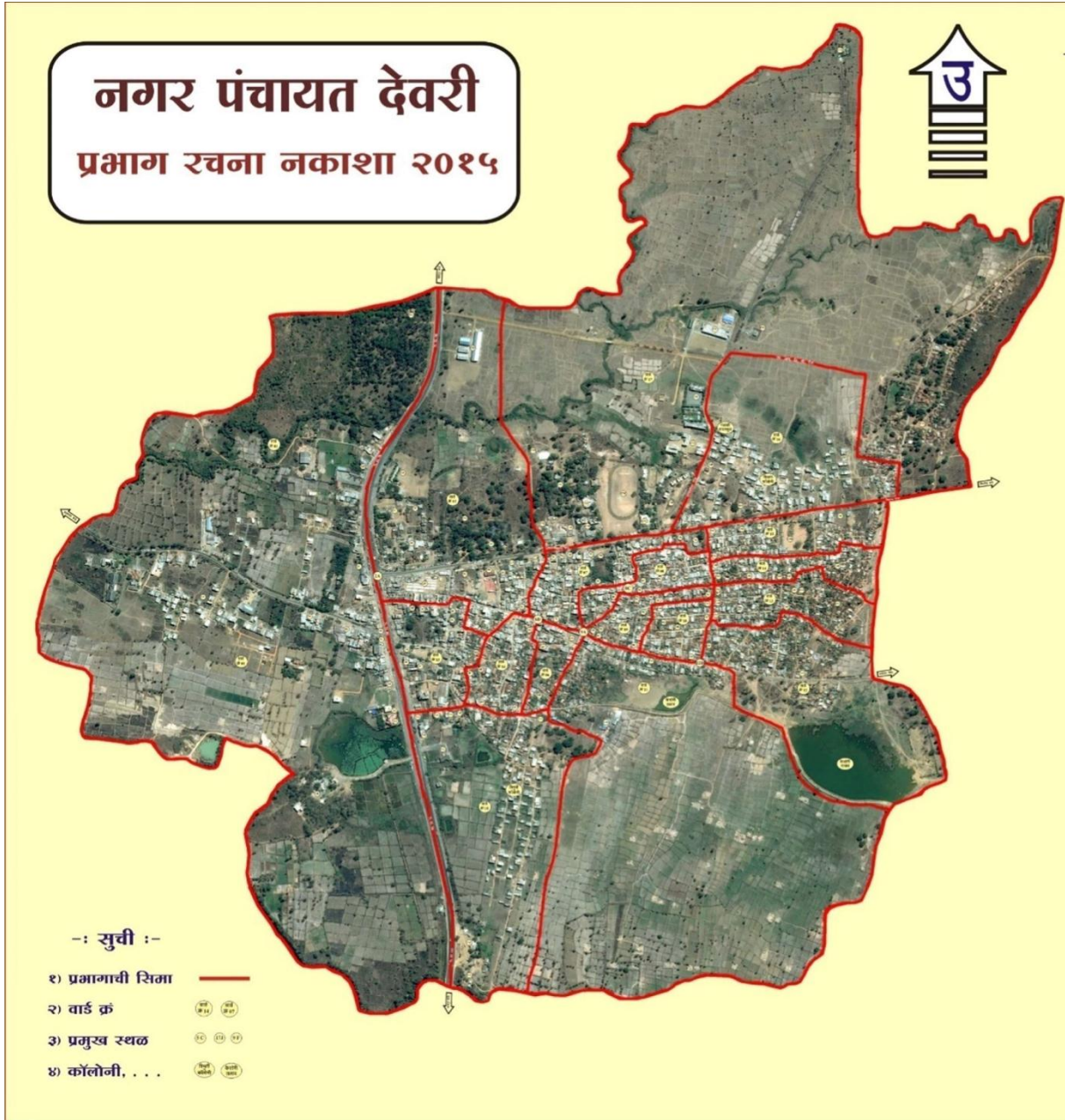
Considering the topography, street pattern and railway track, the entire area is divided into two zones – zone 1 and zone 2. North Sector predominantly covers area on the north side of highway. South Sector is on south side of highway. These zones are further divided into wards. First zone consists of ward no. 1; and second zone is divided into 16 wards as shown in drawing 1 and described below.

Zone 1: Zone 1 comprises ward 1 fully. Sewage from this ward is proposed to be collected at manhole number 1404 (MH1404) by gravity as shown in Drawing 1.

Zone 2: Zone 2 comprises wards 2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17. MH 186 of Zone 1 is the starting manhole, in this Zone. Gravity flow continues in this zone and sewage from Zone is proposed to be collected at a point (PS2) by gravity. Wet

well of fifteen minutes capacity is provided. Sewage from wet well is proposed to be pumped to STP for treatment and disposal.

Availability of vacant land for construction of pumping stations PS1 and PS2 for sewage treatment plants has been checked and verified by Puranik Brothers Consulting Engineers



DESIGN CRITERIA

Design criteria that are given by CPHEEO and some other norms of MJP are taken in consideration for design of underground sewage system. Important criteria are listed below.

1. The Pumping machinery for a wastewater is always designed for 15 years of time period. For this study the pumping machinery was designed for intermediate period which is 2036.

2. Collection systems, Sumps and Wet well, Sewage treatment plant are proposed for 30 years period. For this study this design is done for projected population of the year 2051.
3. Sewage flow i.e quantity is taken as 80% of the domestic water supply (CPHEEO Manual page 39), i.e $0.8 \times 135 = 108$ Lpcd. The minimum wastewater flow that is taken for design of sewers is 100 Lpcd (CPHEEO Manual page 39).
4. Ground water infiltration is taken as 5 % of flow. Thus, the quantity of flow in sewers is $108 \times 1.05 = 113.4$ Lpcd, say 120 Lpcd.
5. As per CPHEEO manual the peak factor for trunk/main sewers is taken as 2.25 for contributory population between 50,000 - 7,50,000 (Page 39 of Manual). All these peak factors are taken keeping in view the density of population in that particular zone/area.

Higher peak factors – 3.5 (for contributory population up to 20,000), and 2.5 (for contributory population between 20,000 to 50,000) – have been suggested. In the optimal design of sewer network, an average peak factor of 3.0 & 2.5 is considered. The same is adopted for design of pumping mains for this study.

6. Manning's formula is used for calculation of velocity in sewers. Talking about the Manning's roughness coefficient for RCC pipes with collar joints is taken as 0.013 (CPHEEO Manual – Page 47 Table 3.4)
7. For ultimate flow recommended minimum self-cleansing velocity in sewer is always taken as 0.6 m/s. This assures a minimum self-cleansing velocity of 0.6 m/s for present peak flow within the network. (CPHEEO Manual Page 52). But for avoiding steeper slopes in initial stretches, lower velocities are tolerated but with provision of flushing tanks (CPHEEO Manual Page 53). In upper stretches, a minimum of 0.3 m/s is assured.
8. DWC & RCC non pressure pipes of class- II is considered for gravity sewers. However, pumping mains is considered to be of HDPE pipes.
9. Maximum velocity in RCC sewers networks is always limited to 3.00 m/s and not more than that (CPHEEO Manual Page 53).
10. Minimum diameter for DWC sewer is 150 mm and for RCC sewers the minimum diameter is 300 mm. In the study of this design, only laterals, branch and main sewers are considered. Hence, minimum diameter for them is considered as 150 mm.
11. The Maximum depth of flow in sewers having diameter upto 400 mm can be three-fourth ($3/4^{\text{th}}$) of its diameter.
12. Manholes are considered at every junction where change in direction is observed and at 30 m c/c on straight lines.
13. Minimum cover is considered as 1.0 m.
14. The Maximum depth of excavation for laying of sewer is limited to 5.0 m below ground level considering groundwater table.
15. Sewage network is designed in such a manner that depth of excavation is minimized, i.e. sewers will be laid parallel to ground surface wherever possible.
16. Capacity calculations for Sewage treatment plants are provided. Conventional treatment plants are suggested to meet effluent standards for disposal into inland water bodies, i.e. BOD less than 30 mg/L and Suspended Solids less than 50 mg/L.

PROPOSED SCHEME WORK:

The proposed study for Deori Underground Sewage Scheme consists of underground network of laterals, branch and main sewer lines within Deori Nagar Panchayat limits. The entire area is bifurcated into two zones – I and II for maintenance and construction purposes. Sewage from Zone I would be collected by gravity at PS1. It does not require any intermediate pumping. Sewage from to STP. Sewage would be treated to produce effluent of desired quality which would be disposed in river.

The entire system hence now consists of:

1. Underground sewers for Zones 1 and
2. Wet wells at PS1 and PS2.
3. Pumps and pumping mains.
 - (a) Pumps for maximum and average discharge at PS1.
 - (b) Pumping main from PS1 to STP.
 - (c) Pumps for maximum and average discharge at PS2.
 - (d) Pumping main from PS2 to STP.
4. Sewage treatment plant.

Methodology:

SewerGEMS:

SewerGEMS makes the modeling process much easier, so that we get more time to solve wastewater engineering problems, like improving capacity and limiting sewer overflows, which ultimately enable utilities to comply with sewer regulations set by regulatory agencies.

SewerGEMS has provided the professionals with the advanced engineering tool to plan things up, design them, maintain and operate sanitary sewer systems which includes following

- Decision guidance tools: Leverage SewerGEMS what-if scenario management tools to understand the behavior of your wastewater system, improving decision making and response time in a better manner.
- Improved model accuracy: A well calibrated model will decrease the risk of making poor decisions and ensures that the model uses the best available data that is fed into it. SewerGEMS calibration tools such as SCADA integration enable us professionals to rely on our model results.
- Increased information mobility: SewerGEMS' full GIS, CAD, and SCADA interoperability enables the cost-effective sharing and flow of information between utilities' design, engineering, GIS, and operation departments, and their consultants. You can leverage the data that the utility invested in once and reuse across departments.

From urban sewer planning to overflow remediation analysis to optimized best management practices design, SewerGEMS provides an easy-to-use environment for engineers to analyze, design, and operate sanitary or combined conveyance sewer systems, using built-in hydraulic and hydrology capabilities, and a variety of wet weather calibration methods. SewerGEMS takes advantage of Bentley CONNECT services by associating a hydraulic model with a CONNECT project. This enables all team members to have easy sharing access to the model.

Superior Interoperability

With SewerGEMS, the designer working with this platform can choose model from within four platforms, while accessing a single, shared, project data source. These platforms include:

- Window stand alone for ease of use, accessibility and performance
- ArcGIS for GIS integration, thematic mapping, and publishing
- Microstation for bridging geospatial planning and engineering design environment

- AutoCAD for convenient CAD layout and drafting

The design engineers can leverage their skills from different departments, and they can hence flatten learning curves by choosing the environment they already know and provide results that can be visualized on multiple platforms.

Required Data:

- Shapefiles of pipeline, elevation, road, demand and manholes marked on pipeline.
- Type of flow
- Minimum and maximum velocity permitted
- Minimum and maximum slope feasible for the available terrain
- Minimum and maximum cover
- Available diameter of pipes (internal and external) referred from IS:458.2003
- d/D ratio(80%)
- Manning's constant (n=0.013, RCC NP2 pipes)

Shapefile:

Shapefiles of Pipeline, road, and elevation were prepared on AutoCAD MAP 3D and that of demand was prepared using ArcGIS, where were then exported to Sewer Gems.

Procedure for creating shapefiles:

- In civil 3D first click on Map, in map click on tools, from tools to drawing cleanup
- Select layer of pipeline, click on next, from next to delete duplicate.
- From delete duplicate click on break crossing objects.
- Next click on extend undershoot.
- Dissolve Pseudo-nodes.
- Next convert all select objects.
- Finish. Creating Topology.
- Click on map then topology.
- Click create then on network name.
- Create name topology.
- Next Select manually, select drawing, enter and then finish. Topology created successfully. Attributes are added.
- Click on map, then object data and then define object data

- Create new table, name the table, fill table with diameter, material and node.
- Again, click on map then object data.
- Attach/detach object data.
- From table select the required file.
- Attach to object, select drawing and enter
- From map select tools and export the file.
- Name the exported file.
- Click on selection, line and select layer.
- Click on data, select attribute, object data and on file name.

Shapefile is created. By the above given procedure, create shapefiles of Pipeline, Road, zone boundary and elevation.

In sewerGEMS, using model builder application shapefile of pipeline is uploaded. Manholes are marked on the pipeline at a distance of 30m. At the end where Sewage Treatment plant is located mark that end as outfall.

Shapefile of elevation is loaded using TRex application and shapefile of road is loaded in background.

- Select data source type, then click on ESRI and select pipeline shapefile.
- Change the units to meters.
- In key field select label.
- In property select length for pipe.
- For diameter, select diameter.
- For material, select materials.
- For nodes, select nodes.
- Click on next and then finish.

Elevation:

- From zoom extends, click onTrex.
- Select data source type as ESRI shapefile
- Select elevation shapefile.
- From this select text ring click on next and then finish.

Demand:

- Click on home, loading, inflow control centre and select yes.
- On left hand corner click on new, then initialize pattern loads for all elements.
- In table on the right side click on base inflow, then base inflow value ranging from 250-500 litre/day and press okay.
- Click on tools, select Theissen polygon, select the complete drawing.
- Now click on pressure junction at all elements, select the current location, include active elements and click next.
- Click on polygon boundary layers, select zone boundary (from new shapefile folder),select layer, open, click okay.
- Click on next, output file created, name that output file as TP in the same shapefile folder, click on finish and then okay.
- Now, click on tools, load builder, new the non area load data then proportional distribution by area and click next.
- From the node layer browse new layer(TP).
- From flow boundary layer, browse old layer i.e. of zone boundary.
- On boundary field select layer.
- Keep unit as MLD and click on next.
- Put the demand in MLD, add peak factor and click okay.

Conduit table:

- Add the conduit catalogue.
- Add different diameters ranging from 150 mm to 600mm.
- Add conduit description and type.
- Change conduit class.

Design Constraints:

- Minimum and maximum velocity provided is 0.6m/s and 3 m/srespectively.
- Minimum cover provided is 1m and maximum cover provided is of 5m.
- Minimum slope provided is 1 in 600 and maximum slope provided is 1 in50.
- Conduit catalogue consists of diameters 150mm, 170mm, 200mm, 250mm, 300mm, 350mm, 400mm, 450mm, 500mm and600mm.
- Diameters of 150mm, 170mm, 200mm and 250mm are of DWC pipes, and the rest are of RCC.
- Fordiameterrangingfrom150mmto250mmthemanningsconstant(n)istakenas0.010 and for diameter above 250mm the manning's constant (n) is taken as0.011.

- Base inflow is taken in the range of 250 L/d to 500L/d.
- Analysis type is steady state design.

After feeding complete data, the network is validated by checks. If the check gives no validation errors then the network will be proceeded for designing or else we have to again check upon the fed data and perform checks unless the there are no validation errors.

Results obtained:

- Velocity of Sewage flow through each pipe.
- Rim and Invert slope.
- Excavation depth at each node.
- Appropriate Diameter for each pipe.

The accuracy of sewer gems is higher than Sewer and the manual work for adjusting the desired outputs is reduced. Sewer Gems generates the drawing and can be directly exported as AutoCAD drawing. Sewer Gems also assigns conduit attributes and different colours to respective diameters for better appearance and recognition.

Following are the output tables that we get in the form of results from the software.

Excavation Details:

Label	Elevation Ground (Start)(m)	Elevation Ground (Stop) (m)	Invert (Start) (m)	Invert (Stop) (m)	Diameter (m)	Elevation Start Diff	Elevation Stop Diff	Average Excavation Depth	Length (Scaled) (m)	Width (m)	Depth	Quantity	Soft Soil/Soft Murrum	Hard Murrum	Hard Murrum with Boulders	Soft Rock	Hard Rock	Shoring Strata
CO-2177	346.99	346.9	345.84	345.75	150	1.15	1.15	1.15	5.4	0.755	1.15	4.69	1.9	0.5	0.5	0.94	0.94	12.42
Pipeline-203	341.44	341.4	340.24	340.25	150	1.2	1.15	1.175	7.8	0.755	1.175	6.92	2.8	0.7	0.7	1.38	1.38	18.33
CO-1894	325.68	325.63	324.43	324.38	250	1.25	1.25	1.25	8.1	0.855	1.25	8.66	3.5	0.9	0.9	1.73	1.73	20.25
CO-2151	343.46	343.34	341.6	341.51	150	1.86	1.83	1.845	8.5	1.755	1.5	22.38	9.0	2.2	2.2	4.48	4.48	25.5
CO-1786	332.73	332.68	331.48	331.43	250	1.25	1.25	1.25	9	0.855	1.25	9.62	3.9	1.0	1.0	1.92	1.92	22.5
CO-1826	330.16	330.11	328.91	328.86	250	1.25	1.25	1.25	9.6	0.855	1.25	10.26	4.1	1.0	1.0	2.05	2.05	24
Pipeline-198	341.84	341.93	340.69	340.78	150	1.15	1.15	1.15	9.8	0.755	1.15	8.51	3.4	0.9	0.9	1.7	1.7	22.54
CO-1822	330.33	330.28	329.08	329.03	250	1.25	1.25	1.25	9.9	0.855	1.25	10.58	4.2	1.1	1.1	2.12	2.12	24.75
CO-2059	340.51	340.43	339.36	339.19	150	1.15	1.24	1.195	10	0.755	1.195	9.02	3.6	0.9	0.9	1.8	1.8	23.9
Pipeline-190	341.78	341.68	340.52	340.53	150	1.26	1.15	1.205	10	0.755	1.205	9.10	3.6	0.9	0.9	1.82	1.82	24.1
CO-1772	333.53	333.48	332.28	332.23	250	1.25	1.25	1.25	10.4	0.855	1.25	11.12	4.5	1.1	1.1	2.22	2.22	26
Pipeline-196	341.73	341.81	340.58	340.66	150	1.15	1.15	1.15	10.5	0.755	1.15	9.12	3.7	0.9	0.9	1.82	1.82	24.15

REFERENCES:

1. CPHEEO manual on Sewerage and Sewage Treatment System.
2. CSR Nagpur-Amravati2018
3. PWD CSR 2018-19
4. IS 458:2003