

Hydraulic Modelling and Capacity Optimization of The Yawal Municipal Council Sanitary Sewer Network.

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ABSTRACT

Rapid urbanization in small to medium Indian towns has placed mounting stress on existing sanitary infrastructure, frequently built without long-term hydraulic planning. Yawal Municipal Council in Maharashtra presents a representative case: its sewer network suffers from undersized conduits, irregular flow distribution, infiltration/inflow (I/I) intrusions and capacity deficits attributable to decades of ad hoc expansion. This study undertakes a systematic hydraulic assessment and capacity optimization of that network with the objective of restoring reliable, self-cleansing flow conditions across all design horizons.

Ward wise population forecasts and sewage generation estimates were derived using CPHEEO-prescribed norms, with three projection stages (2028, 2043 and 2058) establishing the hydraulic loading envelope. Bentley Sewer GEMS was employed to build and calibrate a network model that replicates observed flow behaviour, while QGIS provided the geospatial framework for network delineation, manhole georeferencing and catchment boundary mapping.

Model diagnostics pinpointed conduits prone to surcharging and sections with sub-critical self-cleansing velocities. Targeted remediation measures—pipe upsizing, slope correction and network realignment—were evaluated through successive simulation runs and the resulting optimized configuration confirmed hydraulic compliance under ultimate-stage loading. The findings demonstrate that an integrated Sewer GEMS–QGIS workflow, anchored in CPHEEO design standards, offers a replicable and cost-effective methodology for upgrading sanitation infrastructure in growing Indian municipalities.

Keywords: Sewer System, Hydraulic Modelling, Optimization, Sewer GEMS, CPHEEO guidelines.

I. INTRODUCTION

Yawal Municipal Council, located in the Jalgaon District of Maharashtra's East Khandesh region, has undergone notable physical expansion over the past two decades, with land use shifting from predominantly residential to mixed residential-commercial-institutional. This growth has

progressively overloaded a sewerage network that was originally dimensioned for a far smaller population. During peak discharge events and the monsoon season, the system operates beyond its hydraulic capacity, resulting in backflow at low-lying junctions, overflowing manholes, surcharged trunk sewers and the direct discharge of raw or partially diluted sewage into the Kapur Nallah, Ghat Nallah and other local surface drains.

Across Indian urban centres, the combination of accelerating population growth and unplanned spatial expansion has exposed a chronic infrastructure gap in sewage collection and conveyance. Adequate sewerage provision—encompassing collection, transmission and treatment—underpins public health, environmental protection and urban resilience. This gap is particularly acute in secondary and tertiary towns such as Yawal Municipal Council, where hydraulic monitoring of sewerage infrastructure is either absent or rudimentary and where network extensions have historically been undertaken without reference to a master plan or hydraulic model.

Hydraulic modelling provides a quantitative, simulation-based framework for diagnosing flow deficiencies and evaluating corrective interventions before any capital expenditure is committed. By replicating the physical behaviour of gravity sewers and pressure mains under varying loading scenarios, such models enable engineers to locate hydraulic constraints, quantify surcharge risk and test improvement options at a fraction of the cost of field experimentation. The Yawal network conveys flow through a combination of gravity sewers and rising mains located in low-lying reaches, all ultimately discharging toward the Sewage Treatment Plant (STP) or designated diversion points. Critical problem nodes include the Kapur Nallah and Ghat Nallah corridors, which currently receive inadequately treated effluent and warrant priority attention in any rehabilitation programme.

II. LITERATURE REVIEW

Functional sewerage infrastructure is a prerequisite for safeguarding public health and preventing environmental degradation in urban settings; yet a substantial proportion of networks across Indian towns operate below design intent, largely because original designs did not anticipate the pace of population growth or the absence of subsequent hydraulic audits. Published literature confirms that computer-aided hydraulic modelling is among the most reliable tools for diagnosing such deficiencies and evaluating remediation pathways in a resource-efficient manner. Optimization of pipe sizing, slope assignments and network layout has further been shown to deliver measurable improvements in flow velocity, self-cleansing performance and long-term capital economy. The following studies, directly relevant to the design context of this paper, were examined to inform the methodological choices adopted herein:

- 1) **Ms. Harsha S. Bhavimani & Dr. Anand V. Shivapur (2017)** Bhavimani and Shivapur outlined a structured procedure for sanitary sewer network planning for Zone 10 of Belagavi city, integrating population forecasting, peak factor determination and flow calculations in

conformity with CPHEEO norms. Pipe diameter and slope selection were validated against minimum self-cleansing velocity criteria. The study is notable for its disciplined application of codal provisions, though the authors themselves acknowledge that incorporation of simulation-based hydraulic tools would have strengthened the analytical depth. The framework presented is directly transferable to comparable Indian urban settings and has informed the design sequencing adopted in the present study. [3]

- 2) **Pooja Singh, et. al, (2019)** Singh et al. extended conventional sewerage design methodology to linear, infrastructure-dominated corridors—a spatial typology rarely addressed in mainstream urban sanitation research. Their work applied standard hydraulic design principles while emphasising the value of local context in determining layout priorities, slope assignments and pipe schedules. Although the study predates widespread adoption of simulation-based tools, its contribution lies in demonstrating that context-sensitive planning substantially improves design outcomes in spatially constrained development corridors, an insight applicable to the nallah-adjacent reaches of the Yawal network. [4]
- 3) **Natalia Duque, Daniel Duque (2020)** Duque and Duque addressed a long-standing gap in the sewer planning literature by treating network layout selection and hydraulic design as a single, co-optimised problem rather than two sequential tasks. Their mathematical optimisation framework, drawing on linear programming and metaheuristic search, produced designs that were demonstrably more cost-efficient than those yielded by conventional stage-wise approaches. The study underscores the quantitative value of formalised optimisation in infrastructure planning and has influenced the pipe-up sizing and slope-correction strategy applied in the present work. [5]
- 4) **Pramila K. Gajre1, Dr. D.G. Regulwar (2024)** Gajre and Regulwar presented a case-study application of established sewerage design norms to a specific Indian municipal context, reinforcing the practical value of CPHEEO-based computation in situations where sophisticated modelling resources are limited. The study is noteworthy for translating codal guidelines into a step-by-step design process that practitioners in smaller municipalities can replicate. Its acknowledged limitation—limited engagement with optimisation techniques and smart-infrastructure concepts—highlights precisely the methodological gap that the present study seeks to address through the adoption of Sewer GEMS. [6]
- 5) **Ajay Livingston, et. al (2020)**, Livingston et al. tackled sewerage planning challenges in small and peri-urban settlements—a category that receives comparatively little attention in research dominated by metropolitan case studies. By documenting the public health and environmental consequences of sewerage deficits in such communities, the study builds a compelling case for proactive infrastructure investment. Its critique of the absence of contemporary modelling or

sustainability frameworks in similar settlement-scale projects is noted; nevertheless, the paper provides grounding evidence for the infrastructure priorities pursued in the Yawal context. [7]

III. STUDY AREA

Yawal City Located in the Jalgaon district of Maharashtra's East Khandesh region, Yawal is a small town with a history that is quiet yet significant, as indicated by its ancient fort that has been associated with Nimbalkar kingdom and later the British regime. The town is also significant in that it boasts a rich culture and religion, as indicated by the presence of the Ved Maharshi Vyas Temple along the Sur River and the Tarkeshwar Mandir. The fact that the town is connected to State Highway SH-4 and rail heads such as Bhusawal means that Yawal is increasingly becoming a market center as facilities such as schools, hospitals and residential areas continue to spread in the region.

The Yawal Municipal Council, established in 1884, is classified as a 'C' class council administering approximately 5,379 hectares. Governance is exercised through elected ward members supported by standing committees responsible for, among other functions, sanitation and water supply. Agriculture remains the predominant economic activity, with the majority of residents engaged in cultivation or agri-allied trades within the surrounding Tapi basin hinterland. The town lies at approximately 21°5' N latitude and 75°55' E longitude, at an elevation of about 213 m above mean sea level, within the Tapi River valley near the southern flank of the Satpuda ranges. Topography is broadly flat, interrupted by localised undulation around the Hadkai-Khadkai River confluence that gives rise to the Sur River. The area experiences a tropical climate: summers are hot and dry, the south-west monsoon delivers the bulk of annual precipitation and winters are mild with temperatures falling most sharply in January. Outside the monsoon window, relative humidity remains low, limiting natural attenuation of any sewage that enters surface drainage channels.

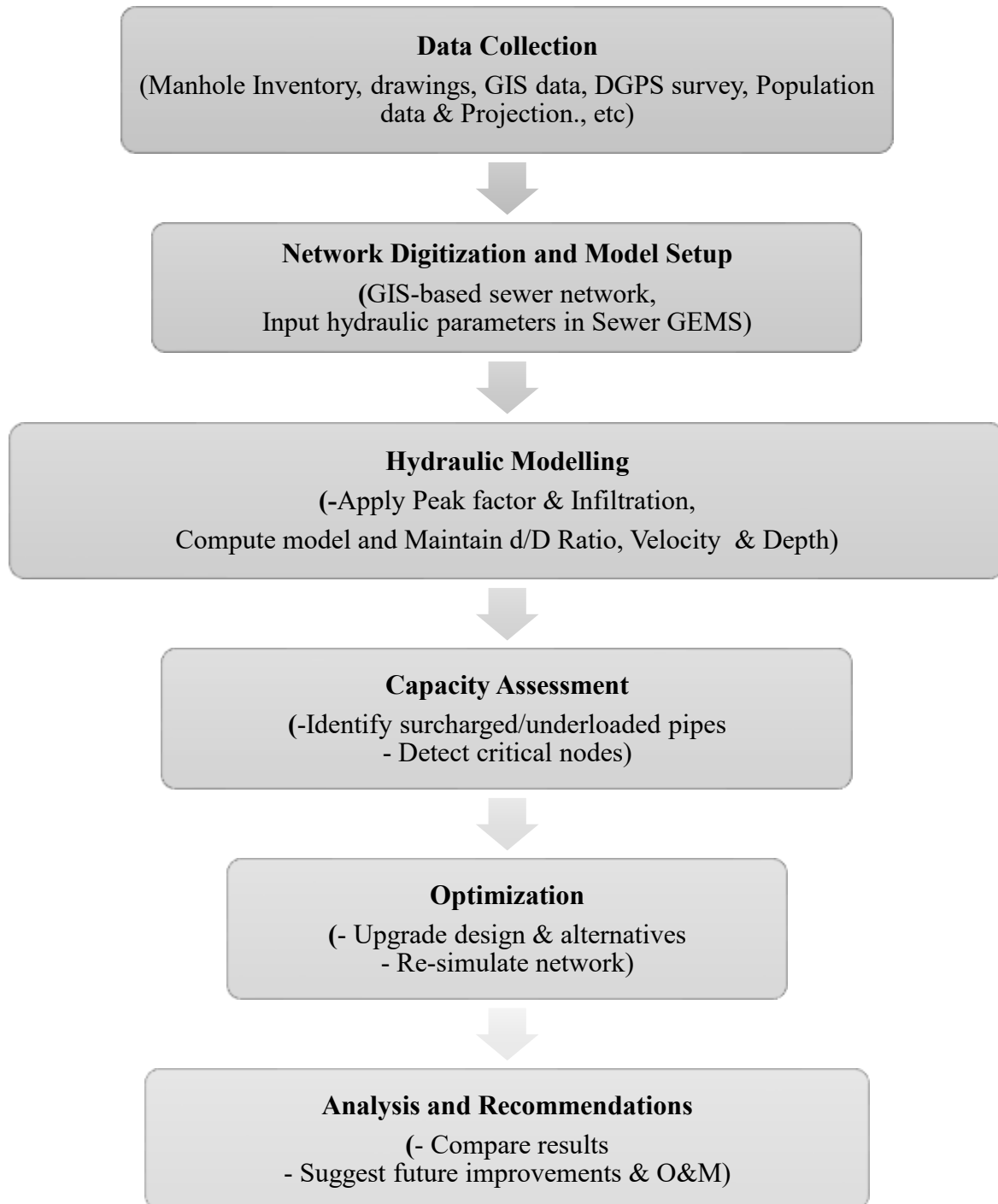
IV. EXISTING SCENARIO

The Yawal water distribution system covers three zones, served by Sane Guruji ESR, Urdu School ESR and a pure water sump. However, all are connected as one and there is no zoning, hence the supply hours and pressures vary considerably. For the sake of analysis, the zones have been hydraulically sectioned out from the network based on data and topography. The system has been developed in stages from 1978, starting with untreated canal water, carried through a simple pipeline. It has evolved to the current stage with the addition of treatment in 1986-87 and further additions in 2013-14.

The new system will be designed to meet 135 LPCD demand, drawing from the Shelgaon Barrage on the Tapi River. Key components include a fresh intake structure, a raw-water rising main, an 11 MLD automated treatment plant, pumping machinery and a distribution network of HDPE and DI pipes. A 310 KWP solar power installation will address energy efficiency. The project received technical sanction in July 2024. The existing functional components has also been incorporated into the new layout to increase the cost efficiency and performance of the system.

Currently, the town has no dedicated underground drainage infrastructure; drainage is handled through open channels that convey untreated effluent directly into adjacent natural watercourses. The progressive expansion of piped water supply, while beneficial from a potable-water perspective, proportionally increases the volume of wastewater generated, thereby heightening the environmental contamination risk. Recognising this trajectory, the Municipal Council has formally initiated design of an underground sewerage system intended to provide comprehensive sanitation coverage to all wards.

V. METHODOLOGY



5.1 Data Collection & Population Projection:

Table No. 5.1: Census Population

Sr. No.	Year	As per Census Population
1	1971	20175
2	1981	25049

3	1991	28741
4	2001	31803
5	2011	36706

Table No.5.1: Forecasted Population

Sr. No.	Year	Arithmetic Method	Incremental Increase Method	Geometric Progression Method	Average of III Method's
1	2028	43732	45141	46930	45268 Souls
2	2043	49932	54058	58293	54094 Souls
3	2058	56131	64356	72406	64298 Souls

Table No.5.2: Ward wise Area & Forecasted Population

Ward No.	Total ward area Ha	Eq. Resi. Area Ha	Pop. as per 2011 census	Density	Foreca sted Pop. for 2028	Density	Foreca sted Pop. for 2043	Density	Foreca sted Pop. for 2058	Density
1	805.0	22.2	3505	158	4557	205	5424	244	6447	290
2	442.1	13.3	3306	247	4248	318	4872	364	5791	433
3	797.2	65.6	3263	50	4568	70	5290	81	6287	96
4	10.9	10.1	3285	323	3614	356	4841	476	5754	566
5	3.2	3.1	3169	1004	3486	1105	4203	1332	4996	1583
6	5.3	4.7	3199	675	3586	757	4479	945	5324	1124
7	34.8	24.8	3149	126	4094	164	4734	190	5626	226
8	9.2	9.0	3407	378	3850	427	4519	502	5371	596
9	14.1	13.8	3031	218	3486	251	4189	301	4981	358
10	8.0	8.0	2983	369	3430	425	4396	544	5225	647
11	2747.6	64.9	4409	68	6349	98	7147	110	8496	131
Total	4877.9	240.1	36706	153	45268	188	54094	225	64298	268

Table No.5.3: Sewage Flow Estimation

Sr. No	Particulars		Projected Stage Year 2028	Intermediate Stage Year 2043	Ultimate Stage Year 2058
A)	Domestic Water Demand: -				
	1	Population (Souls)	45268	54094	64298

	2	Total Population (Souls)	45742	54094	64298
	3	Rate of Water Supply (LPCD)	135	135	135
	4	Daily Demand (M.L. Per Day)	6.111	7.303	8.68
B)		Other Water Demand: -			
	1	Floating Population (As per prev. sanctioned DPR)			
		Rate of Water Supply (LPCD)	25	25	25
			0.070	0.081	0.095
	2	Institutional Demand (As per prev. sanctioned DPR)	0.657	0.769	0.893
		Total	0.727	0.850	0.988
		Total Net Demand	6.838	8.153	9.668
D)		Sewage Flow 80% Water Supply Demand (MLD)	5.470	6.522	7.734
		Add Infiltration			
		Manhole Count	3277	3277	3277
		250 Lit/Manhole (As per CPHEEO Norms)	250	250	250
		Infiltration Flow (MLD)	0.819	0.819	0.819
E)		Total Sewage Flow (MLD)	6.290	7.342	8.554
F)		Total STP Capacity (MLD)	7.000	8.000	9.000

VI. Discussion:

The hydraulic assessment and capacity optimisation of the Yawal Municipal Council sanitary sewer network yielded a detailed characterisation of system-wide flow behaviour and the principal operational constraints limiting hydraulic performance. By coupling Sewer GEMS simulations with

geospatial data prepared in QGIS, it was possible to replicate observed flow conditions across the network with acceptable fidelity and to quantify the headroom—or lack thereof—available under projected ultimate-stage loading.

Simulation outputs identified multiple conduits operating under surcharged conditions during peak-flow events, confirming that the existing network lacks adequate hydraulic reserve to accommodate projected demand beyond the near-term horizon. Superimposed on this capacity shortfall, a significant proportion of conduits recorded flow velocities below the minimum self-cleansing threshold prescribed by CPHEEO, creating conditions conducive to sediment deposition and long-term blockage accumulation.

Three categories of optimisation intervention were evaluated within the model: selective uprating of pipe diameters, correction of adverse or insufficient invert slopes and redistribution of tributary catchments between adjacent sub-networks. Iterative simulation confirmed that the combination of these measures restored compliant hydraulic conditions throughout the network, with all modelled conduits operating within CPHEEO velocity and depth-to-diameter limits under ultimate-stage (2058) loading, thereby validating the proposed optimised configuration as the basis for detailed engineering design.

VII. RESULTS:

Table No.7.1: Outfall Summary (2058)

ID	Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (System Sanitary) (L/s)	Flow (System Wet Weather Collection) (L/s)	Population (System Sanitary) (Capita)	Flow (Total Out) (L/s)	Hydraulic Grade (m)
6887	O-1	195.00	193.50	180.838	9.887	64,298	190.725	193.71
6866	O-2	203.96	202.46	79.075	4.453	25,304	83.528	202.66

Table No.7.2: Lengthwise Velocity (2058)

Velocity (m/s)	Velocity Range		Unit	Length	%	%
Up to 0.3	0.10	0.30	M/s	18402.6	23.3	23.3
0.31-0.6	0.30	0.60	M/s	37363.9	37.3	60.7
0.61-0.9	0.60	0.90	M/s	15353.0	29.4	90.2
0.91-1.2	0.90	1.20	M/s	5107.1	6.4	96.7
1.2-3.0	1.20	3.00	M/s	2644.7	3.3	100
>3		3.00	M/s	0.0	0.0	

Table No. 7.3: Lengthwise Depth

Depth	Unit	Length	Percentage	cumm %
Up to 1.49	M	45989	58.3%	58.3%
1.5 to 2.99	M	23946	30.4%	88.7%

3.0 to 4.49	M	6708	8.5%	97.2%
4.5 to 5.99	M	2041	2.6%	99.8%
6.0 to 7.49	M	187	0.2%	00.2%
7.5 to 9.00	M	0	0.0%	0.00%

VIII. CONCLUSION:

1. A calibrated hydraulic model of the Yawal Municipal Council sewer network was built using Bentley Sewer GEMS, incorporating field-surveyed pipe data, manhole coordinates and CPHEEO-derived flow inputs.
2. The model was run under dry-weather and peak-flow conditions across all three design horizons; results exposed hydraulic deficiencies in multiple networks reaches, including surcharging, sub-cleansing velocities and under-capacity pipe sections.
3. Primary failure modes comprised sewer surcharging at peak discharge, sustained low-velocity zones promoting sediment deposition and inadequate conduit capacity relative to projected 2058 flows.
4. Targeted remediation comprising strategic pipe upsizing, slope correction and catchment redistribution was applied and verified through successive simulation iterations, restoring design-compliant hydraulic performance across the network.
5. Post-optimisation, the network demonstrated materially improved velocity distributions, markedly reduced surcharge risk at critical nodes and sustained compliance with CPHEEO depth-to-diameter and velocity thresholds.
6. The optimised design parameters provide a robust, cost-conscious foundation for future infrastructure investment, explicitly accommodating population and sewage generation growth through to 2058.
7. This study demonstrates that an integrated hydraulic modelling and GIS-based workflow constitutes a practical, scalable methodology for sewer network planning and rehabilitation in Indian municipal contexts, with direct applicability to towns of comparable size and development trajectory.

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