INTEGRATED ENGINEERING FRAMEWORK FOR WASTEWATER NETWORK MANAGEMENT

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ABSTRACT

Wastewater utility networks are complicated systems that must be managed carefully to maintain effective operation and environmental protection. This study proposed an integrated engineering framework that combines Geographical Information System (GIS), Closed Circuit Television (CCTV), and hydraulic modeling to improve wastewater network management. The framework addressed the disadvantages of using each method alone by combining their strengths. Geographical Information System (GIS) provides a spatial framework for organizing and analyzing data, while Closed Circuit Television (CCTV) and hydraulic modeling provide real-time information about the condition and performance of the network. The proposed approach can help to improve the efficiency and sustainability of the networks. The study was applied to the Zamalek region in Egypt, where Closed Circuit Television (CCTV) was used to recode 12,900 m, with a total of 21,500 m. It was found that there were cracks and fractures in some parts of the network that were filmed at a length of 6,450 m. The interior was treated and repaired by injection or lining for approximately 650 m, as well as changing 325 m by digging. The hydraulic study also showed the presence of some inverted branches, which required rehabilitation. A Geographic Information System (GIS) was used to provide integrated data on the region's network, such as the number of manholes (2600) and 5 expulsion lines, determining the locations of stations serving the region, and calculating the actual behavior of the network. This led to an increase in the design capabilities of the stations. The study also showed that the integrated engineering framework can be used to manage sewerage networks effectively.

Keywords: Geographical Information System (GIS), Closed Circuit Television (CCTV), Hydraulic Model, Engineering Framework, Wastewater Networks

INTRODUCTION

In order to ensure efficient operation and environmental protection, wastewater utility networks are intricate systems that require careful management (Metcalf & Eddy, 2003; Koukoulakis *et al.*, 2020). There are several disadvantages to manual inspections and hydraulic modeling, two popular conventional methods for managing wastewater networks (Ashley *et al.,* 2010; EPA, 2006). According to Shariati et al. (2023), manual inspections are

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labor- and time-intensive, and might not discover every network problem. Hydraulic modeling represents an effective tool for understanding wastewater network behavior, but it requires the proper data on the network's operational conditions and physical characteristics. The integration of Geographical Information System (GIS), Closed Circuit Television (CCTV), and hydraulic modeling can be used to improve wastewater network management (Zamorano *et al.*, 2009). The framework solves the disadvantages of using each approach alone by combining their strengths. Geographical Information System (GIS) offers a geographical framework for data organization and analysis, whilst Closed Circuit Television (CCTV) and hydraulic modeling give real-time status and performance information on the network (ESRI, 2022; Patel & Sinha, 2019). The suggested framework is expected to boost the efficiency and sustainability of wastewater networks by giving a comprehensive view of the network's status and performance. This can lead to better maintenance and repair choices, as well as new infrastructure design (Butler & Davies, 2004; Deletic & Fletcher, 2006). The integration of Geographical Information Systems (GIS), Closed-Circuit Television (CCTV), and hydraulic modeling has emerged as a promising approach to wastewater management, offering a comprehensive and data-driven approach to understanding, monitoring, and managing wastewater systems (Zhang *et al.*, 2022). This integrated framework overcomes the limitations of traditional methods such as manual inspections and hydraulic modeling. Case studies from various regions, including Regional Utility Authority XYZ, Dublin, Ireland; Daegu Metropolitan City, South Korea, and Saudi Arabia, have demonstrated the effectiveness of this integrated framework in optimizing wastewater infrastructure management, reducing overflows, and improving flood risk assessment (Martínez *et al.*, 2020; Neto *et al.*, 2023). One of the key benefits of the proposed framework is the ability to integrate data from several sources. The framework is now being implemented on Egypt's wastewater network in the Zamalek district, and the case study findings are intended to provide useful insights into the framework's performance and its potential to improve wastewater network management in other places.

Field Description

The Zamalek area is considered one of the distinctive areas in Cairo, as it is an island located in the middle of the Nile with an area estimated 2.7 Km^2, and it has many important buildings. This makes it an excellent prototype for implementing an integrated engineering framework that uses Geographical Information System (GIS), Closed Circuit Television (CCTV), and hydraulic analysis to manage water and sanitation networks. The Zamalek region is served by a sewage network implemented for approximately 60 years, with diameters [9, 12, 18, 24] inch and a length of 21,500 meters, in addition to 4 lifting stations to receive this water. Greater Cairo Sanitary Drainage Company (GCSDC) performs periodic maintenance of the current sewage network to increase its lifespan, especially since the rate of water consumption increases with increasing population density, as some villas were demolished, and residential buildings were built instead. This adds a burden and increases the consumption of the current sewage network. Four small lifting stations service Zamalek: Al-Zohria station, which has a design capacity of 21,600 liters/second and an actual capacity of 4,900 liters/second; Al-Zamalek Al-Qibliya station, which has a design capacity of 9,000 liters/second and an actual capacity of 2,500 liters/second; Taha Hussein station, which has a capacity of 25,920 liters/second and an actual capacity of 6,500 liters/second. The actual capacity of the Omar El-Khaym station is 2,000 liters/second compared to a design capacity of 14,000 liters per second. The locations of Sanitation pumping stations in the research region are represented in Figure 1.

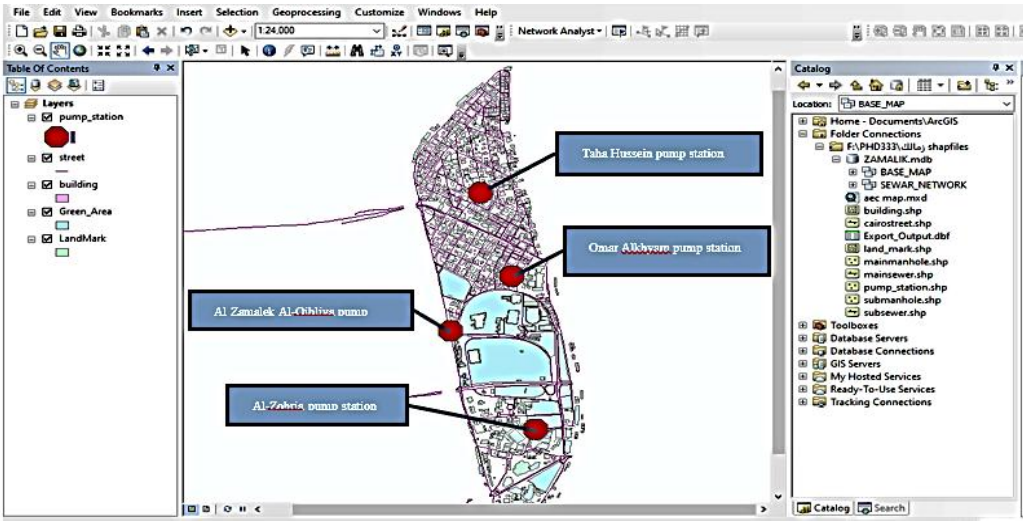

Figure 1 Sanitation pumping stations in Al-Zamalek

The Zamalek area's wastewater facility network is facing issues as a result of growing development and aging infrastructure. These issues necessitate innovative solutions. Population expansion puts more strain on the wastewater network. This might endanger the ecosystem. Leaks and inefficiency are caused by aging pipelines, pumps, and manholes, necessitating regular repairs and replacements, which raise expenses. Traditional maintenance is imprecise, resulting in squandered resources that may not reach essential locations. The lack of a data-driven strategy impedes informed management, reform, and resource allocation decisions, which rely on assumptions rather than evidence. The purpose of this study is to use an integrated engineering approach that uses Geographic Information Systems (GIS), closed circuit television (CCTV) inspection, and hydraulic modeling to address wastewater network problems in Al-Zamalek. Increased output, proactive maintenance in high-risk regions, and decision-making based on previous data are among the goals. Using Geographical Information System (GIS), modeling, and Closed-Circuit Television (CCTV) data together gives decision-makers precise information for allocating resources, setting priorities, and handling emergencies. The strategy locates sources of untreated discharge, hotspots for pollution, and encourages mitigating techniques. The approach improves network resilience and makes contingency planning easier. Beyond Al-Zamalek, the study provides a template for sustainable wastewater system, enhancing the quality of the utility sewage network in Al-Zamalek district.

METHODOLOGY

To obtain relevant data, combine base map data and sewer network information (e.g., pumping station data, pipelines, and manhole data) from the As-built drawings the (CAD) files extracted from AutoCAD 2000. To develop a geodatabase, the first step is to create a geographical database, which is separated into spatial data and network data. The geographical data is separated into shapefiles and indicates the names of streets as shown in table 1, the positions of dwellings, and notable landmarks in the region, as well as the locations of structures. Figure 2 depicts a data table example for landmarks in ARC GIS. From a shapefile comprising pipeline data, force pipelines, manholes, sub manholes, and pump stations, a network database was generated. Figure 3 depicts sewage station and main pressure lines.

Table 1 street data

AStreet_Na	EStr	Last_U	Label	Cond	Locat	Fro	To_	Mat	Mai	Wat	Dia	Dia	Dow	Dow	UpSt	UpSt	Slop	CCTV	Ages	Notes
حسن عاصم		<Null>	2951	1		2950		Unkn			3	0	20.7	22.98	20.96	22.96	0.18	1	6	
الشيخ المرصفي		<Null>	3116	1		3123	3116	Unkn			5	0	18.1	22.53	18.48	22.58	0.35		6	
كمال خليل		<Null>	3099	1		3100	3099	Unkn			3	0	21.0	23.08	21.56	23.96	0.53		6	
شفيق منصور		<Null>	3066	1		3065	3066	Unkn			3	0	18.8	22.4	19.19	23.39	0.35		6	
شفيق منصور		<Null>	3064	1		3036	3064	Unkn			3	0	19.3	22.32	19.57	22.27	0.25		6	
شفيق منصور		<Null>	3065	1		3064	3065	Unkn			3	0	19.1	23.39	19.32	22.32	0.13		6	
		<Null>	3041	1		3042	3041	Unkn			1	0	20.4	22.64	20.63	22.93	0.19		6	
يحى ابراهيم		<Null>	3040	1		3041	3040	Unkn			1	0	20.0	22.6	20.44	22.64	0.39		6	
يحى ابراهيم		<Null>	3039	1		3040	3039	Unkn			1	0	19.5	22.4	20.05	22.6	0.55		6	
بهاء الدين		<Null>	3018	1		3017	3018	Unkn			3	0	20.9	22.84	21.08	22.83	0.09		6	
بهاء الدين		<Null>	3045	1		3019	3045	Unkn			3	0	20.6	22.78	20.84	22.74	0.21		6	
بهاء الدين		<Null>	3019	1		3018	3019	Unkn			3	0	20.8	22.74	20.99	22.84	0.15		6	
حسن صبرى		<Null>	3044	1		3045	3044	Unkn			3	0	20.2	22.96	20.63	22.78	0.42		6	
اسماعيل محمد		<Null>		1		2861	2848	Unkn			3	0	18.6	23.13	20.96	23.06	2.33		6	
		<Null>		1		2862	2861	Unkn			3	0	20.9	23.06	21.07	23.07	0.11		6	
الصالح ايوب		<Null>	2997	1		3000	2997	Unkn			3	0	19.8	22.72	21.34	23.34	1.47		6	
طه حسين		<Null>		1							225	0	19.3	22.58	19.47	22.59	0.1		1	أصلاح هبوط
طه حسين		<Null>		1							225	0	19.4	22.59	19.57	22.65	0.1		1	أصلاح هبوط
		<Null>		1							225	0	18.1	22.62	19.37	22.58	1.25			
طه حسين		<Null>		2							3	0	0	0	18.18	22.78	0			

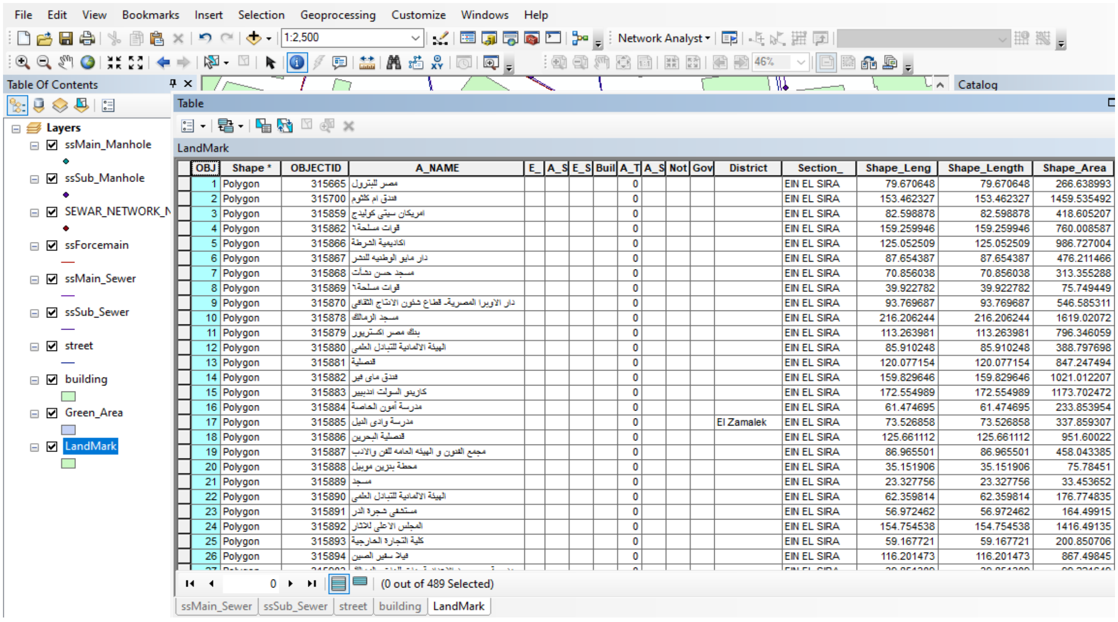

Figure 2 land mark data talbe in ARC (GIS)

Geographical Information System (GIS)-Based Network Mapping

Geographical Information System (GIS) is used to construct a detailed geographical representation of the wastewater sewerage network using ARC Geographical Information System (GIS) version 10.2. Pipes, pumps, manholes, and treatment facilities must all be mapped. Geographical Information System (GIS) spatial analysis techniques aid in the identification of susceptible sites, congested regions, and probable pollution sources. Figure 4 represents the Al-Zamalek Geodatabase after it has been created and implemented in ARC.

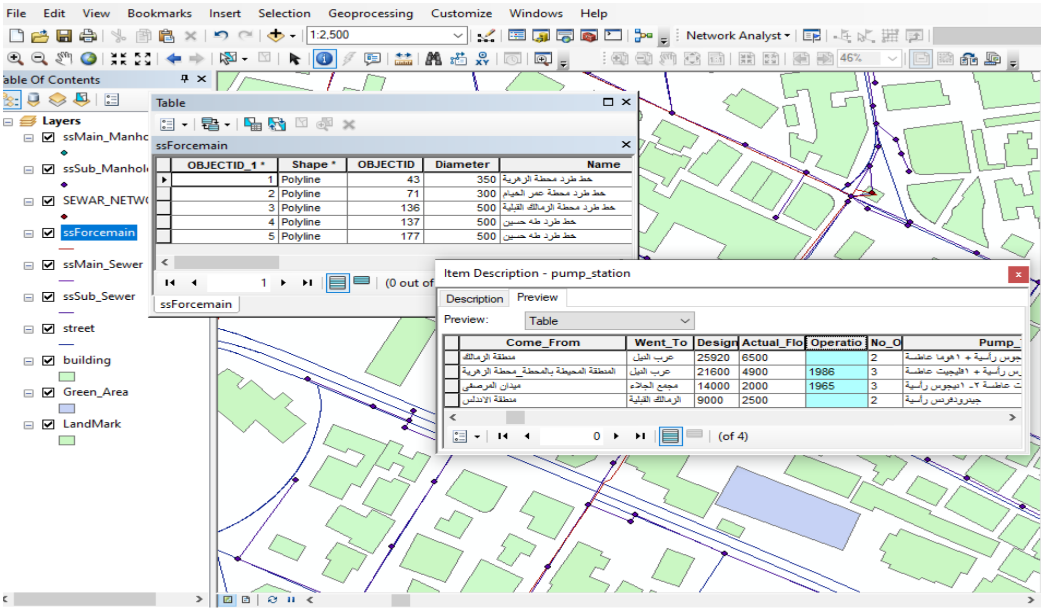

Figure 3 pumpstation and Main forceline

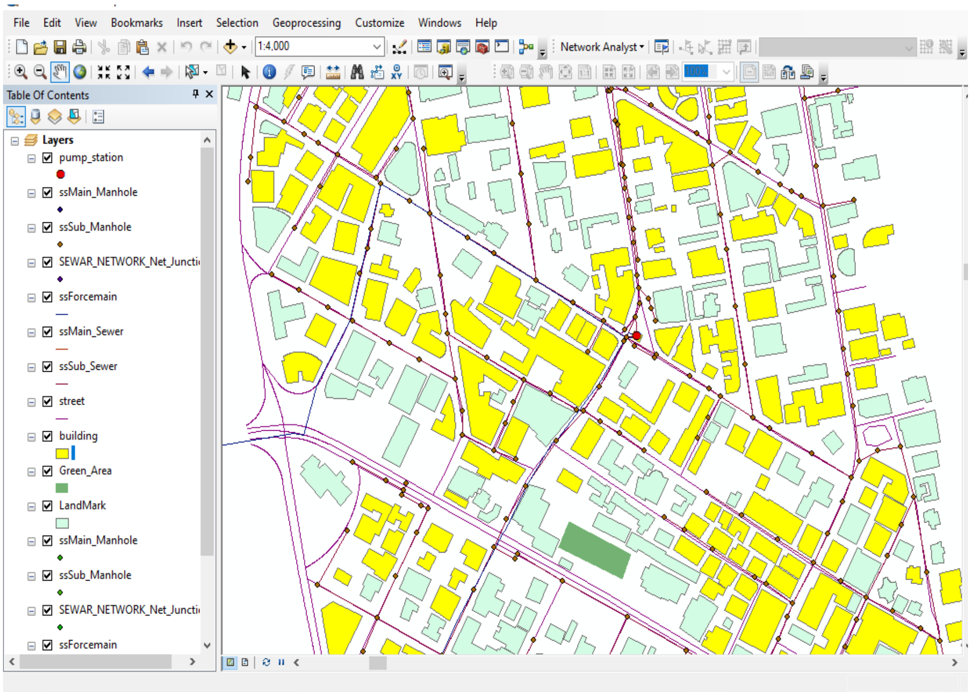

Figure 4 Al-Zamalek Geodatabase

Hydraulic Modeling and Simulation:

Hydraulic modeling tool like Sewar GEMS V.8 employed to simulate flow dynamics within the wastewater network. The hydraulic model is supported by integrated Geographical Information System (GIS) data, allowing for reliable modeling of flow patterns, pressure changes, and capacity restrictions. Various scenarios are simulated to evaluate network reactions to various situations. SewerGEMS Connected Edition Ver. 2 software designed conduits according to given sanitary load. We get all designed data through flex table presented in tables 2 and 3.

Table 2 Flex table of Manholes

ID	Label	Start Node	Set Invert to Start?	Invert (Start) (m)	Stop Node	Set Invert to Stop?	Invert (Stop) (m)	Has User Defined Length?	Length (User Defined) (m)	Length (Scaled) (m)	Slope (Calculated) (m/m)
651	996988	165906	☑	18.00	48558	☑	18.50	☐		3.4	-0.147
652	176385	165904	☑	19.00	48558	☑	18.50	☐		4.4	0.115
653	41444	48772	☑	18.13	49271	☑	18.03	☐		4.3	0.023
654	621524	587587	☑	18.70	48548	☑	18.63	☐		4.7	0.015
655	996989	48497	☑	21.89	48495	☑	19.66	☐		5.1	0.440
656	41562	49360	☑	18.92	49329	☑	17.50	☐		5.7	0.251
657	38645	48356	☑	19.30	48355	☑	19.24	☐		5.7	0.010
658	41516	49315	☑	18.00	49337	☑	17.06	☐		5.7	0.164
659	176387	165907	☑	0.00	48559	☑	0.00	☐		5.8	0.000
660	267367	256496	☑	17.62	49331	☑	17.20	☐		5.9	0.071
661	38712	48362	☑	20.85	48358	☑	20.80	☐		6.0	0.008
662	41443	48773	☑	19.00	48772	☑	18.13	☐		6.2	0.139
663	40890	48779	☑	18.34	48778	☑	18.20	☐		6.8	0.021
664	40588	48481	☑	22.04	48492	☑	20.04	☐		7.0	0.285
665	38693	48361	☑	21.40	48362	☑	20.85	☐		7.6	0.073
666	41469	46598	☑	20.71	49288	☑	19.00	☐		7.8	0.218
667	40679	48566	☑	20.00	48531	☑	19.80	☐		8.0	0.025
668	40730	48596	☑	20.79	48597	☑	19.01	☐		8.0	0.221
669	41479	49301	☑	18.39	102202	☑	18.36	☐		8.3	0.004
670	41517	49336	☑	17.31	49337	☑	17.06	☐		8.4	0.030
671	40724	48610	☑	20.92	48609	☑	20.81	☐		8.6	0.013
672	41478	104654	☑	18.56	49301	☑	18.39	☐		8.8	0.019
673	38068	48347	☑	19.77	48344	☑	19.28	☐		8.8	0.056
674	38860	48359	☑	20.70	48360	☑	20.60	☐		8.8	0.011
675	38520	48346	☑	20.43	48350	☑	20.40	☐		9.0	0.003
676	621526	587589	☑	21.55	48710	☑	21.30	☐		9.0	0.028
677	40963	48845	☑	20.50	48350	☑	20.40	☐		9.1	0.011
678	40896	48752	☑	22.69	48753	☑	21.66	☐		9.4	0.110
679	40608	100745	☑	22.27	48525	☑	21.87	☐		9.9	0.040
680	40611	48523	☑	21.45	48522	☑	21.35	☐		10.1	0.010
681	41475	49304	☑	21.46	49303	☑	21.43	☐		10.3	0.003

Table 3 Flex table of condiuts (pipelines)

ID	Label	Elevation (Ground) (m)	Set Rim to Ground Elevation?	Elevation (Rim) (m)	Bolted Cover?	Elevation (Invert) (m)	Inflow (Wet) Collection	Flow (Total In) (m^3/day)	Flow (Total Out) (m^3/day)	Depth (Out) (m)	Hydraulic Grade Line (Out) (m)
480	49294	24.97	☑	24.97	☐	22.07	<Collection:	0.00	190.00	0.04	22.11
481	49295	24.82	☑	24.82	☐	21.92	<Collection:	190.00	380.00	0.15	22.07
482	49296	24.85	☑	24.85	☐	21.85	<Collection:	380.00	570.00	0.21	22.06
483	49297	24.02	☑	24.02	☐	21.87	<Collection:	2,470.00	2,660.00	0.19	22.06
484	49298	24.04	☑	24.04	☐	21.74	<Collection:	2,660.00	2,850.00	0.14	21.88
485	49299	24.32	☑	24.32	☐	20.82	<Collection:	3,040.00	3,230.00	0.15	20.97
486	49300	23.17	☑	23.17	☐	19.17	<Collection:	3,230.00	3,420.00	0.15	19.32
487	49301	22.59	☑	22.59	☐	18.39	<Collection:	3,990.00	4,180.00	0.20	18.59
488	49302	22.53	☑	22.53	☐	18.23	<Collection:	4,940.00	5,130.00	0.17	18.40
489	49303	22.63	☑	22.63	☐	21.43	<Collection:	380.00	570.00	0.07	21.50
490	49304	22.86	☑	22.86	☐	21.46	<Collection:	190.00	380.00	0.07	21.53
491	49305	23.15	☑	23.15	☐	21.65	<Collection:	0.00	190.00	0.04	21.69
492	49306	22.49	☑	22.49	☐	21.19	<Collection:	190.00	380.00	0.06	21.25
493	49307	22.49	☑	22.49	☐	21.29	<Collection:	0.00	190.00	0.05	21.34
494	49308	24.28	☑	24.28	☐	21.48	<Collection:	2,850.00	3,040.00	0.14	21.62
495	49309	24.96	☑	24.96	☐	22.06	<Collection:	1,710.00	1,900.00	0.13	22.19
496	49310	25.03	☑	25.03	☐	23.33	<Collection:	190.00	380.00	0.06	23.39
497	49311	25.05	☑	25.05	☐	22.35	<Collection:	1,140.00	1,330.00	0.11	22.46
498	49312	25.14	☑	25.14	☐	23.74	<Collection:	0.00	190.00	0.04	23.78
499	49313	25.07	☑	25.07	☐	22.42	<Collection:	950.00	1,140.00	0.12	22.54
500	49314	25.21	☑	25.21	☐	22.61	<Collection:	760.00	950.00	0.09	22.70
501	49315	22.60	☑	22.60	☐	18.00	<Collection:	7,980.00	8,170.00	0.21	18.21
502	49316	23.00	☑	23.00	☐	19.00	<Collection:	2,280.00	2,470.00	0.15	19.15
503	49317	23.50	☑	23.50	☐	19.50	<Collection:	2,090.00	2,280.00	0.14	19.64

Data import and preparation come first. Firstly, the wastewater network shapefile was imported into SewerGEMS Connected Edition Ver. 2 using ARC(GIS)V10.8. Verify that the imported data has pipe dimensions, connections, junctions, and other relevant properties. Data verification and quality assurance by check the imported data for completeness and correctness. Fixing any inconsistencies, omissions, or mistakes in the dataset. Take care of topological problems to guarantee a fluid hydraulic model.

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Model configuration and setup using SewerGEMS Connected Edition VER 2, start a new project. Begin by defining the network components, such as pipes, junctions, and boundary conditions, for the hydraulic model. Assign suitable material properties, pipe roughness, and boundary conditions (for example, inflow and outflow points). Merge Geographical Information System (GIS) data obtained from ARC(GIS) V10.8. into the hydraulic model. Link the geographical information, such as pipe locations and elevations, this ensures an accurate representation of the physical layout of the wastewater network. Figure 5 represented a model for main pipeline towards AlZohria sanitation pump station.

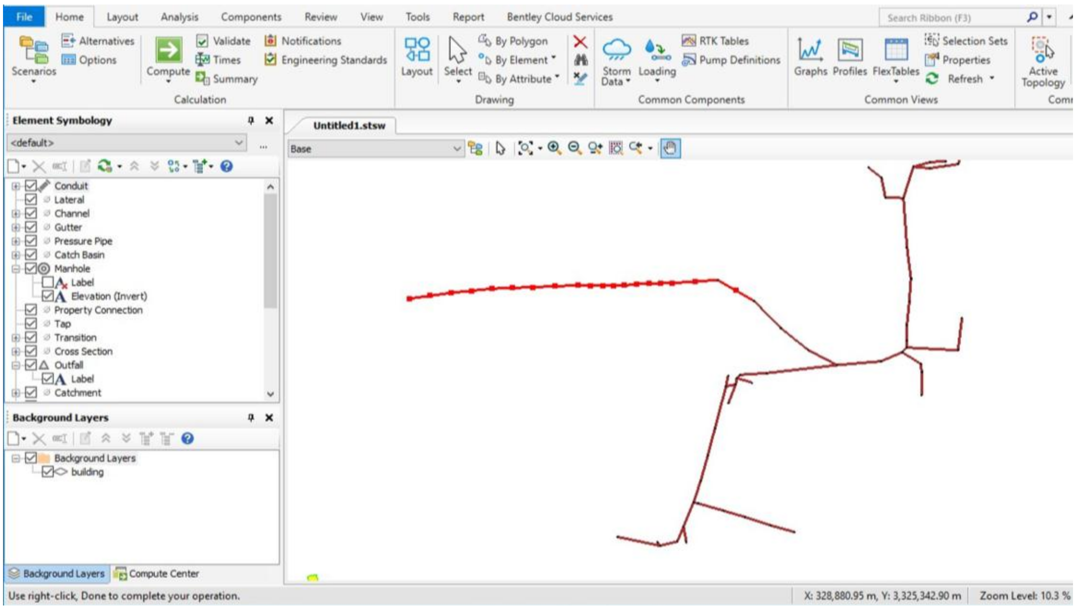

Figure 5 model for main pipeline towards AlZohria sanitation pump station

During this phase, the research will define simulation scenarios that are congruent with its aims. These scenarios include flow rate fluctuations, seasonal changes, and emergency circumstances. The accuracy of the model is evaluated in the study by comparing its predictions to real-world data when feasible. Model parameters such as pipe roughness coefficients and pump settings are adjusted to improve accuracy. The flow dynamics in the wastewater network are then analyzed using SewerGEMS Connected Edition Ver.2 simulations. This entails investigating pressure changes, flow patterns, and capacity constraints in a variety of settings. The research assessed the network's reaction to shifting flow rates and circumstances. Figure 6 represented the pipeline engineering profile, while Figure 7 displayed the elevation profile and Figure 8 shows the elevation and hydraulic profile.

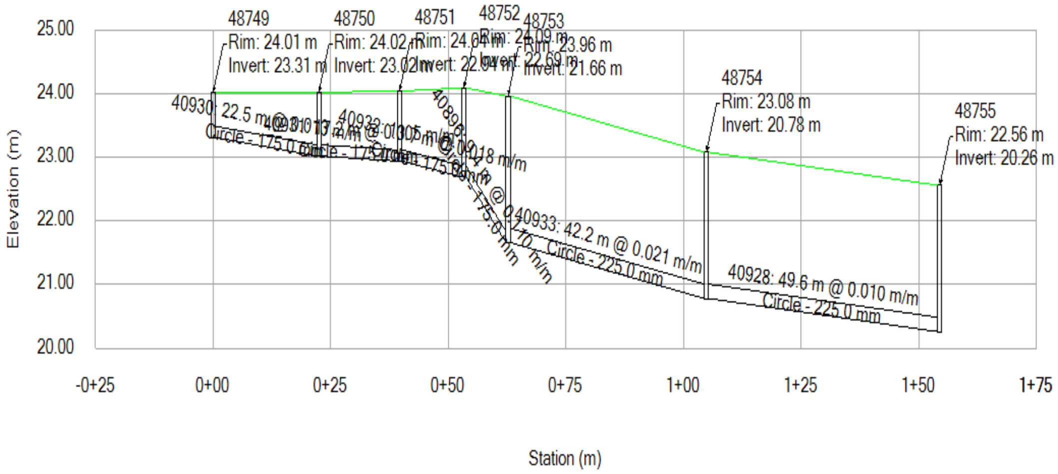

Figure 6 pipe line enginnering profile 1

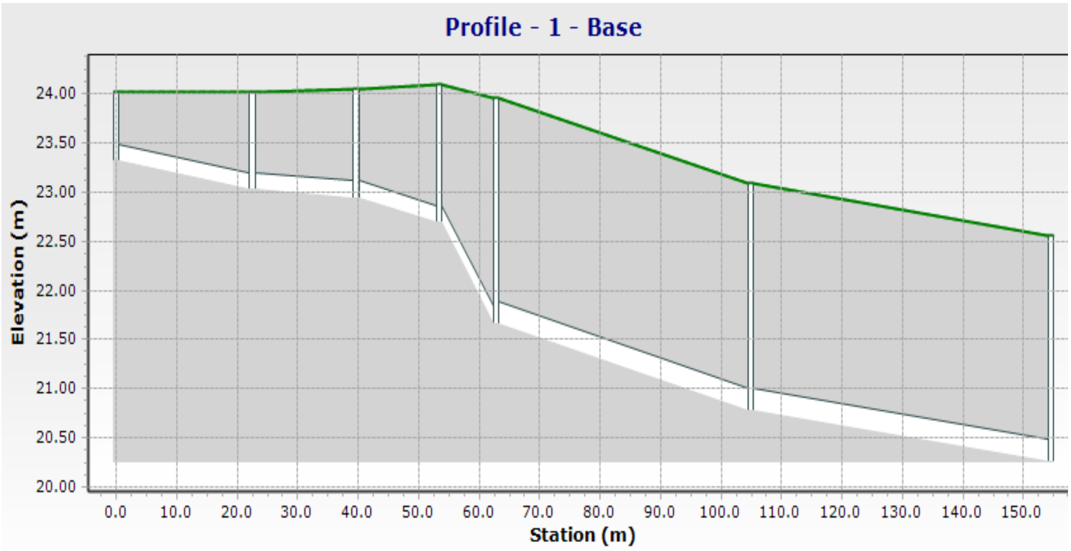

Figure 7 elevation profile

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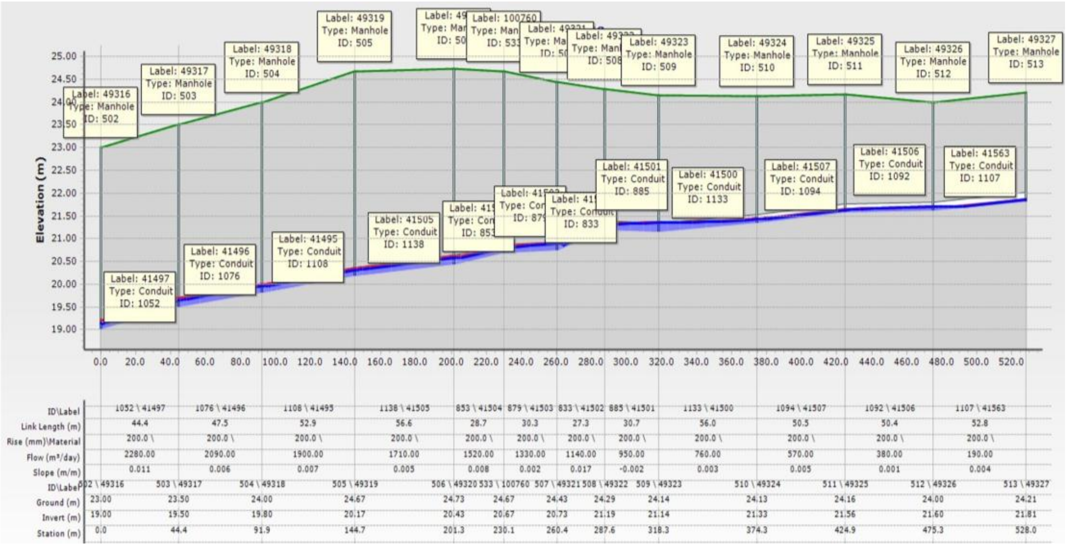

Figure 8 elevation and hydraulic profile

In the network inspection stage through Closed Circuit Television (CCTV) and visual assessment, inspections are performed to visually assess the condition of the network. Specialized remote-controlled cameras are used and placed on a tow truck so that its movement in the pipeline is controlled, taking into account that the smallest diameter of the pipe being examined is 8 inches. Some precautions are also taken, such as completely emptying the drainpipe and locking the branch in both directions so that it is easy to control during the inspection of the internal parts of the pipes, blockages, leaks, structural problems, and signs of deterioration are identified. The collected data is then integrated into a Geographical Information System (GIS) database to obtain a comprehensive view as shown in Figure 9 Closed Circuit Television (CCTV) inspection findings highlight potential pipeline problems such as breakage in picture 4, obstruction in picture 3, leakage in picture 2, or cut in the Coupling picture 1. Closed Circuit Television (CCTV) van provided with a chemical injection unit to carry out the treatment of cracks and fissures in damaged pipes that were discovered as a result of video record to treat the problem at a time without digging due to the difficulty of digging in some places as a result of many different reasons, including high population density, continuous work in the area, or security reasons due to the presence of agencies, governmental institutions or foreign embassies

Figure 9 CLOSED CIRCUT TELEVISION (CCTV) inspection results

RESULTS

After obtaining spatial data from Geographical Information System (GIS) and exporting it to carry out the hydraulic analysis process, it was found that there were some pipes suffering from problems in the level, as they are in the opposite inclination to the natural inclination of the ground, which leads to problems in flow within the network. Figure 10 showed the streets in selected in cyan blue which problems were found.

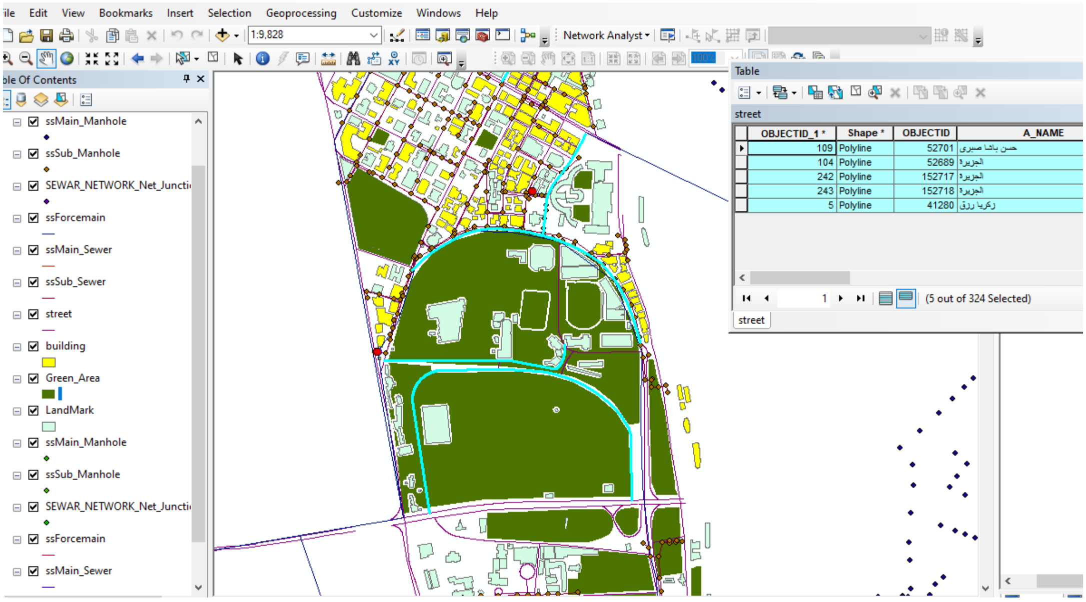

Figure 10 A (GIS) map of the streets where problems emerged from the hydrualic analysis

When the hydraulic model study applied to the Zamalek region, it revealed the presence of several upside-down branches that require drilling. The branches are located on Hassan Sabry Street, Al-Zahria Street, Al-Jazeera Street, and Zakaria Rizk Street, as depicted in the elevation profile in figures 11-14.

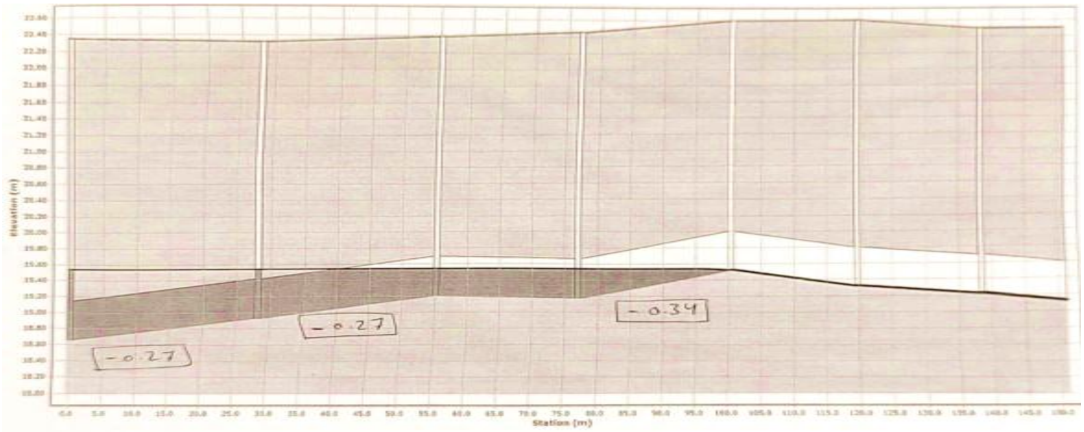

Figure 11 Al Jazeera street profile

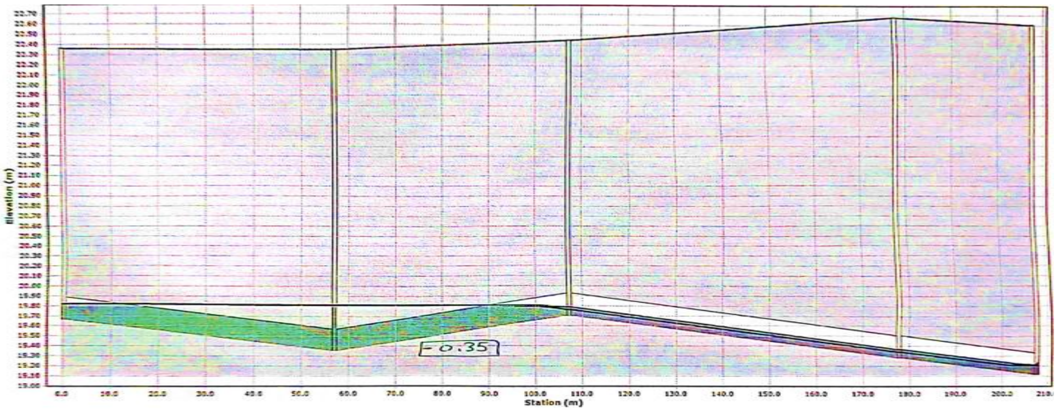

Figure 13 Zakria Rezek street profile

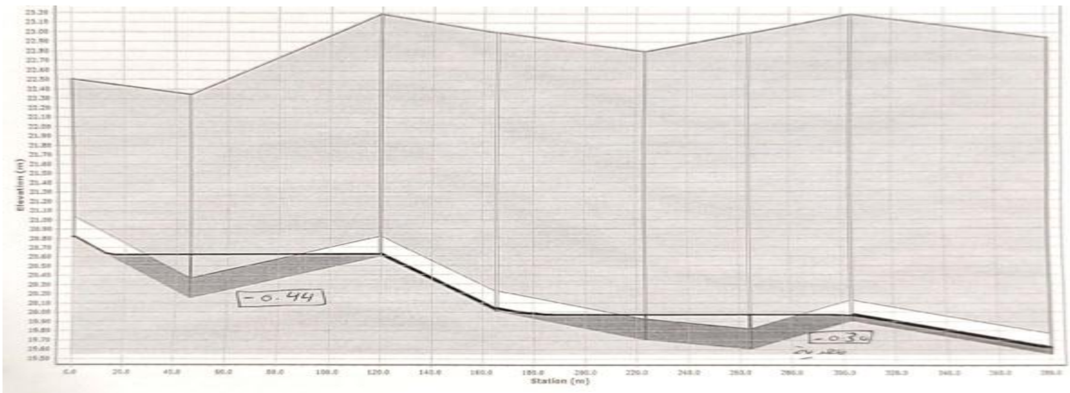

Figure 15 Hassen Sabry st profile

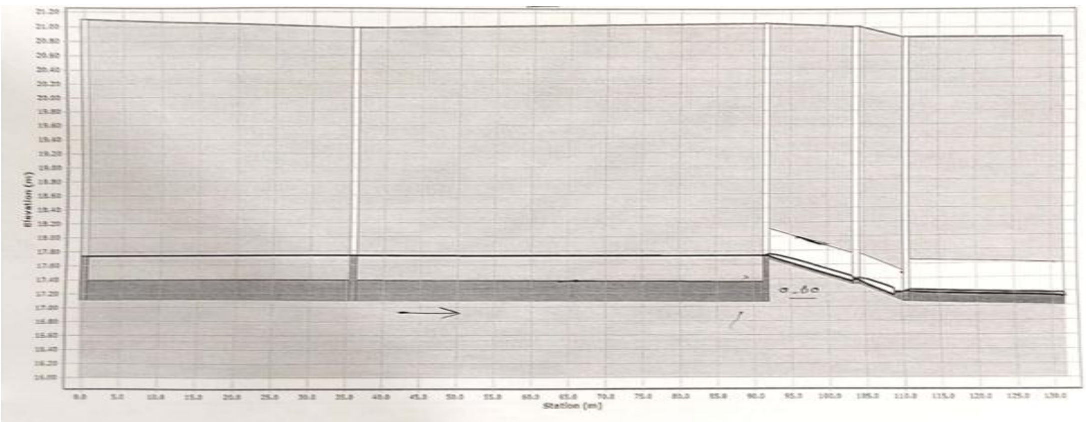

Figure 14 Zohria et profile

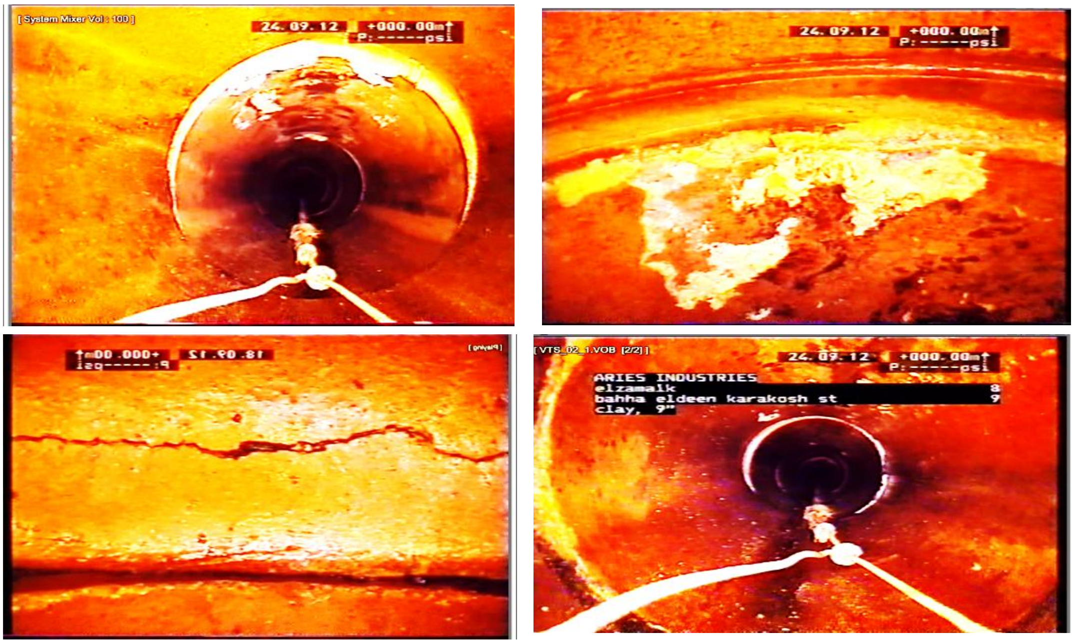

Figure 15 CCTV inspaction for Karakosh pipeline

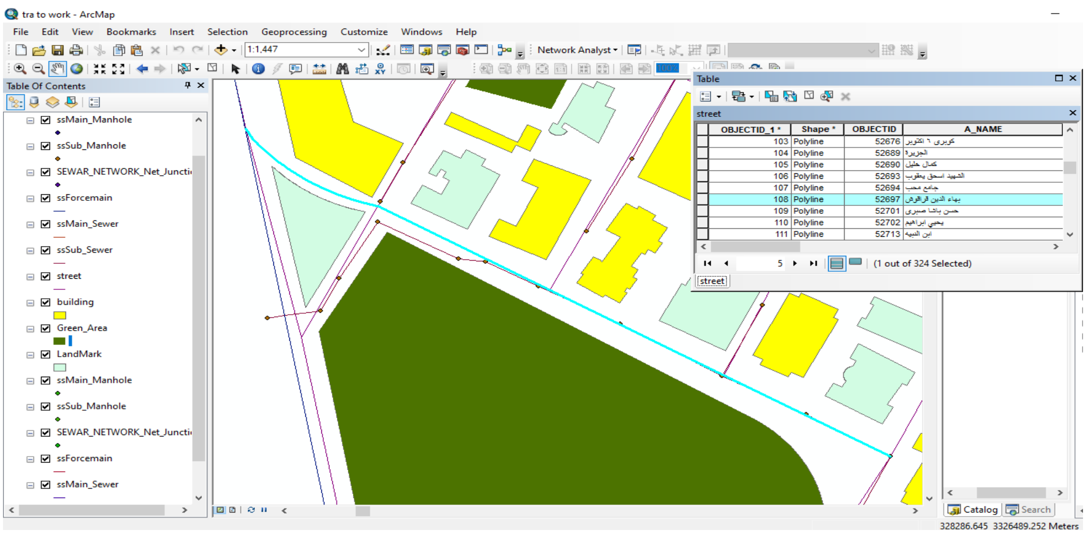

Figure 16 the (GIS) Map for (CCTV) problem in Bahaa Eldeen Karakosh St,

The study using Closed Circuit Television (CCTV) was applied to the Zamalek area, where surveillance cameras were used to record 12,900 m for a total of 21,500 m. It was found that there were cracks and fractures in some parts of the network that were photographed at a length of 64 metres. The interior has been treated and repaired by grouting or lining for approximately 650 metres, in addition to replacing 325 meters by excavation. Figure 16 shows the location of Bahaa Edeen Karakosh street, on the Geographical Information System (GIS) map and Figure 15 shows some inspection of pipes on Bahaa Edeen Karakosh street, showing the cracks and cracks in the pipeline.

DISCUSSION

Findings of the present study, which originated from hydraulic modeling, Geographic Information Systems (GIS), and Closed-Circuit Television (CCTV) inspections, identified important problems in Al-Zamalek's wastewater network. As seen in Figure 15 and the related Geographical Information System (GIS) map Figure 10, Geographical Information System (GIS) spatial data revealed pipes with incorrect inclinations that impeded flow. Drilling was required when hydraulic modeling revealed upside-down branches on Hassan Sabry Street, Al-Zahria Street, Al-Jazeera Street, and Zakaria Rizk Street Figures (11–14). Closed Circuit Television (CCTV) examinations covering 12,900 of the 21,500 meters found fractures and cracks; 64 meters needed to be treated and repaired using lining or grout. Figure 15 shows pipeline fractures found during inspections on Baha Eldin Karakosh Street. This research shows integrated engineering framework for managing wastewater sewerage networks, incorporating Geographic Information Systems (GIS), Closed-Circuit Television (CCTV) inspections, and hydraulic modeling. The study demonstrates that the integration of Geographical Information System (GIS), Closed Circuit Television (CCTV), and hydraulic modeling can significantly enhance the management of wastewater networks. According to the implementation of Geographical Information System (GIS) in wastewater management has resulted in improved data accessibility and streamlined decision-making processes (Berrezal et al., 2022), Geographical Information System (GIS) provides a comprehensive perspective on the network by offering a geographical framework for organizing and analyzing data. In this context, the importance of this spatial perspective in network research, planning, and decision-making was emphasized. The inclusion of Closed-Circuit Television (CCTV) enables real-time assessment of the network status, facilitating the timely identification of issues such as cracks, fractures, and blockages, in alignment with the findings of Ashley et al. (2010). The study conducted in the Zamalek area showcases the improved operational efficiency brought about by the integrated framework. The proactive maintenance procedures recommended by Langeveld and Clemens (2001) align with the identification and repair of faults discovered during Closed Circuit Television (CCTV) inspections, contributing to a reduction in operational interruptions, maintenance costs, and environmental hazards. It was emphasized the critical role of the hydraulic modeling component in understanding network dynamics, enabling informed decisions on capacity expansion, pipeline repair, and pump station upgrades through scenario simulation and network response evaluation. The methodology underscores the significance of data integration, aligning with the principles of data interoperability highlighted in the field of geographic information systems (ESRI, 2022). Seamless integration of data from various sources is imperative for the success of the integrated framework. The study reveals disparities between design and actual capacity in pump stations, emphasizing the importance of addressing such issues for network reliability and performance (Shariati et al., 2013). The utilization of advanced technology, such as remote-controlled Closed-Circuit Television (CCTV) inspections, underscores the need for technological innovations in wastewater management, contributing to more efficient and cost-effective network assessments. While the study provides valuable insights, it acknowledges limitations, suggesting long-term monitoring and evaluation of the framework's performance in the Zamalek region, and proposing future enhancements with predictive analytics and artificial intelligence.

CONCLUSION AND RECOMMENDATION

Based on Geographic Information Systems (GIS), Closed-Circuit Television (CCTV) inspections, and hydraulic modeling, our study asserts that the proposed integrated engineering framework effectively addresses key issues in Al-Zamalek's wastewater network. This integrated approach significantly boosts operational efficiency, aligning with proactive maintenance recommendations. The conclusion is rooted in observed results, emphasizing tangible improvements over highlighting advantages. Long-term monitoring and potential advancements like predictive analytics and artificial intelligence are suggested for further enhancement. This ensures a robust, evidence-based conclusion, demonstrating practical success in wastewater network management in Zamalek. The successful implementation of the integrated engineering framework in the Zamalek region showed the potential to improve operational efficiency, reliability, and performance. Advantages include a comprehensive network view, proactive maintenance, real-time status evaluation, and scenario simulation capabilities. The framework offers a promising approach to enhance wastewater network management efficiency, sustainability, and resilience. Future research should focus on creating a new smart system for combining GIS, CCTV, and hydraulic modeling data, analyzing the framework's suitability for various sewerage networks, and assessing its long-term performance. It is highly recommended to implement an integrated engineering framework for wastewater management, utilizing GIS, CCTV inspection, and hydraulic modeling for a comprehensive network overview. Continuous monitoring and evaluation to enhance performance and efficiency, providing insights for future capacity design should be emphasized. Upgrading existing systems by incorporating new cameras and portable flow meters for accurate measurements and continuous data updates, ensuring an up-to-date network status should be adopted. Integration of preventive maintenance programs with spatial data for streamlined network management, offering regular reports to senior management for resource optimization and cost reduction must be considered. Establishment of continuous interaction between devices and technologies, conducting regular assessments for maximum benefit, and direct integrated reports to senior management for informed decision-making and best practices is of utmost importance.

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الإطار الهندسي المتكامل لإدارة شبكات الصرف الصحي

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المستخلص

تعد شبكات مرافق مياه الصرف الصحي أنظمة معقدة يجب إدارتها بعناية للحفاظ على التشغيل الفعال وحماية البيئة. اقترحت هذه الدراسة إطارًا هندسيًا متكاملاً يجمع بين نظم المعلومات الجغرافية وكاميرات المراقبة والنمذجة الهيدروليكية لتحسين إدارة شبكة الصرف الصحي. يعالج الإطار عيوب استخدام كل طريقة على حدة من خلال الجمع بين نقاط قوتها. يوفر نظام المعلومات الجغرافية إطارًا مكانيًا لتنظيم وتحليل البيانات، بينما توفر الدوائر التلفزيونية المغلقة والنمذجة الهيدروليكية معلومات في الوقت الفعلي حول حالة الشبكة وأدائها. يمكن للنهج المقترح أن يساعد في تحسين كفاءة الشبكات واستدامتها. تم تطبيق الدراسة على منطقة الزمالك في مصر، حيث تم استخدام كاميرات المراقبة لتسجيل 12,900 م، بإجمالي 21,500 م. وتبين وجود شقوق وكسور في بعض أجزاء الشبكة التي تم تصويرها بطول 6450 م. تمت معالجة وإصلاح الجزء الداخلي عن طريق الحقن أو التبطين لمسافة 650 مترًا تقريبًا، بالإضافة إلى تغيير 325 مترًا عن طريق الحفر. كما أظهرت الدراسة الهيدروليكية وجود بعض الفروع المقلوبة والتي تتطلب إعادة الحفر تم استخدام نظم المعلومات الجغرافية لتوفير بيانات متكاملة عن شبكة المنطقة مثل عدد غرف التفتيش (2600) وعدد 5 خطوط طرد وتحديد مواقع المحطات وخدمات الصرف الصحي التي تخدم المنطقة وحساب السلوك الفعلي للشبكة مما أدى إلى زيادة القدرة التصميمية للمحطات. وقد نجحت الدراسة في إظهار إمكانية استخدام الإطار الهندسي المتكامل لإدارة شبكات الصرف الصحي بشكل فعال.

الكلمات المفتاحية: نظم المعلومات الجغرافية، الإطار الهندسي للإدارة، التحليل الهيدروليكي، التصوير التلفزيوني، شبكات الصرف الصحي.