

ASSESSMENT OF SUSTAINABLE WATER SOURCES FOR WATER DISTRIBUTION SYSTEM USING WATERGEMS: A CASE STUDY OF UDAYNARAYANPUR ZONE-I & ZONE-II, HOWRAH DISTRICT, WEST BENGAL

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Declaration of Originality and Compliance of Academic Ethics

I hereby declare that this thesis contains a literature survey and original research work by the undersigned candidate, as part of my **Master of Engineering in Water Resources & Hydraulic Engineering (6 Semester)** under the Faculty Council of Interdisciplinary Studies, Law and management in Jadavpur University during academic session 2023-24.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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Certificate of Recommendation

This is to certify that the thesis entitled “ASSESSMENT OF SUSTAINABLE WATER SOURCES FOR WATER DISTRIBUTION SYSTEM USING WaterGEMS: A CASE STUDY OF UDAYNARAYANPUR ZONE-I AND ZONE-II UNDER UDAYNARAYANPUR BLOCK IN HOWRAH DISTRICT, WEST BENGAL” is a bonafide work carried out by Mr. SAHANUR JAMAL MONDAL under my supervision and guidance for partial fulfillment of the requirement for the Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering (6 Semester) during the academic session 2023-24

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This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for the purpose for which it has been submitted.

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ABSTRACT

This research study addresses critical gaps in the optimization of rural water distribution systems, particularly in rapidly expanding regions like India, with a focus on adhering to CPHEEO norms and Jal Jeevan Mission guidelines. The objective is to develop a comprehensive model for gravity flow pipeline distribution networks using WaterGEMS software, analyzing factors such as velocity, flow, headloss, pressure, hydraulic grade, and pressure head at various nodes. The study emphasizes understanding trade-offs in pipe sizing, pressure, velocity, and head losses to enhance system efficiency and cost-effectiveness. Long-term performance and sustainability, including beyond intermittent water supply scenarios, are also investigated. Additionally, the study explores the integration of emerging technologies like artificial intelligence and optimization algorithms to improve network design with energy efficiency. The research identifies deficiencies in network analysis and design, particularly in addressing leakages and pressure differences. Comparisons between simulated and actual networks reveal the software's viability for accurate analysis and design improvements. The study further underscores the software's ability to handle various network problems with simplicity and accuracy and also analysis the tubewell yields under Udaynarayanpur Block. The Udaynarayanpur Zone I&II Piped Water Supply Scheme in West Bengal serves as a case study, demonstrating the practical application of WaterGEMS software for a network consisting of 984 pipes and 984 junctions. This research contributes to filling the research gap in optimizing rural water distribution systems, offering valuable insights for developing robust, economically viable, and compliant water supply systems, applicable to regions facing similar challenges.

Key Words: Jal Jeevan Mission, Hydraulic Parameters, junctions, pipes, Udaynarayanpur Block, WaterGEMS.

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Chapter 1- Introduction

1.1 Background of the study:

Water is the most precious gift of the nature. It is most crucial for sustaining life and is required in almost all the activities of mankind i.e., domestic use, industrial use, for irrigation; to meet the growing food and fiber needs, power generation, navigation, recreation etc. The common source of water mainly comprises of Rain water, Surface water, Ground water and Water obtained from reclamation.

Ancient civilization developed along rivers. Man has tried to flourish civilization beside the source of water because water provides place to hunt and fish also as the river flooded the lands around them became fertile. But it became difficult day by day for all to make residence beside the river because of population and therefore people had to start living far away from water source. So to live away from the source we have to carry water from source to the habitations. A huge development has occurred in water carriage system from ancient time. Now-a-days the whole network of water carriage and distribution system are needed to be designed. One of the main objectives to design water distribution system is minimizing the overall cost while meeting the water demand requirement at adequate pressure. However the cases of pressure drops, leakages and pollution occur during operations of water supply system and the lack of a simple tool which accurately anticipate zones of low pressures and areas where quality is compromised is the main challenge.

A water distribution system is an essential infrastructure in the supply of water for domestic as well as industrial uses. It connects consumers to sources of water, using hydraulic components, such as pipes, valves, pumps and tanks. The design of such systems is a multifarious task involving numerous interrelated factors, requiring careful consideration in the design process. Important design parameters include water demand, minimum pressure requirements, topography; system reliability, economics, piping, pumping and energy use. The primary goal of all water distribution system engineers is the delivery of water from **sustainable water source** to meet the demands on quantity and pressure. Unfortunately, as a water distribution system ages, its ability to transport water diminishes and the demands placed upon it typically increase.

Water distribution system, hydraulic infrastructure consisting of elements such as pipes, tanks, reservoirs, pumps and valves etc. is crucial to provide water to the consumers. Elements of a distribution system include distribution mains, arterial mains, storage reservoirs and system accessories (valves, hydrants, mainline meters, service connections, and backflow preventers). Distribution mains are the pipelines that make up the distribution system. Their function is to carry water from the water source or treatment works to users.

The primary task for water utilities is to deliver water of the required quantity to individual customers under sufficient pressure through a distribution network. The distribution of drinking water in distribution networks is technical challenge both in quantitative and qualitative terms. It is essential that each point of the distribution network be supplied without an invariable flow of water complying with all the qualitative and quantitative parameters. The purpose of this study is performing the hydraulic analysis of Udaynarayanpur Zone I&II Piped Water Supply Scheme in the Udaynarayanpur Development Block under the district of Howrah in the state of West Bengal, water distribution network using WaterGEMS V8i

1.2 Study area:

The proposed command area of Udaynarayanpur Zone I&II Piped Water Supply Scheme falls under Block- Udaynarayanpur, Sub-Division-Uluberia, District-Howrah, West Bengal. The Udaynarayanpur Zone I&II Piped Water Supply Scheme covers 16(sixteen) nos. of habitations in 14(four) nos. of mouzas of Block Udaynarayanpur, P.S. Udaynarayanpur under Howrah District in the state of West Bengal. The total area covered under the scheme is about 2120.6 hectare with a total population of 35066 as per 2011 census and average population density of 16.54 persons per hectare.

GPS location :22.715478°N 87.978087°E.

Udaynarayanpur Zone I&II is a PWSS, which is within 6 km radius from Block Head Quarter, 50.3 km away from Sub-Division Head Quarter, 43.5 km away from District Head Quarter and is connected with Road networks. Nearest Railway Station is Amta 23.2 km and nearest Airport is Dum Dum 58.6 km away from the Headwork site of the proposed command area.

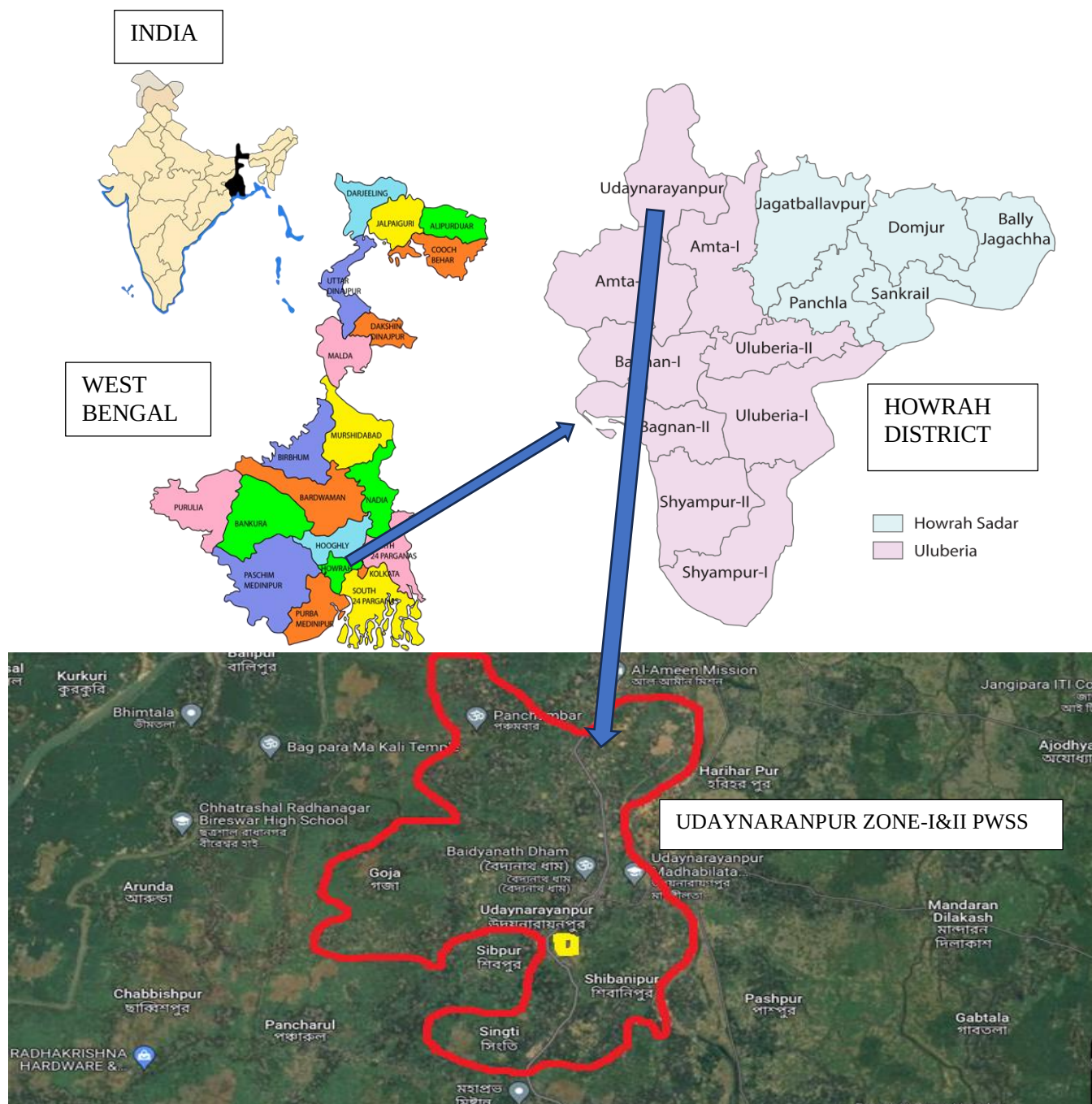


Figure 1: Index map of Study Area

1.3 Research Gap

Despite the considerable research conducted on the design and analysis of water distribution networks, a notable research gap exists in the context of optimizing rural water distribution systems while adhering to CPHEEO norms and Jal Jeevan Mission guidelines in rapidly growing regions like India. Existing studies primarily focus on software tools such as WaterGEMS, WaterCAD, LOOP, and Auto Level for network design and analysis, emphasizing factors like pipe sizing, pressure, velocity, and head losses. However, these studies lack a comprehensive investigation into the trade-offs between these factors, especially in terms of their impact on system energy-efficiency and cost-effectiveness. Additionally, while some studies analyze extended periods of simulation for intermittent water supply, there is a need for more

research into the long-term performance and sustainability of these systems. Furthermore, the application of modern hydraulic modeling and designing software, as mentioned in the literature, suggests that there is an opportunity to explore the integration of emerging technologies, such as artificial intelligence and optimization algorithms, to enhance the efficiency of water distribution network design. Addressing these research gaps would not only contribute to more robust and cost-effective rural water supply systems but also offer insights applicable to other regions facing similar challenges in meeting growing water demand while ensuring compliance with regulatory standards. So we need to focus on source of water as we are using ground water which is very limited.

1.4 Research objective:

The research objective of this study is to address critical gaps in the optimization of rural water distribution systems, particularly in the context of rapidly expanding regions like India, while adhering to CPHEEO norms and Jal Jeevan Mission guidelines and purpose of this study is to make a quantitative estimate of the available groundwater resources in the block of Udaynarayanpur for efficient utilization and management of groundwater resources. The methodology involved the investigation, drilling, lowering, collection and analysis of well data and groundwater quality as well.. This research aims to develop a comprehensive model for the design and analysis of energy-efficient gravity flow pipeline distribution networks using WaterGEMS software. Specifically, it seeks to determine the velocity, flow, head loss, pressure, hydraulic grade, and pressure head at various nodes within the network. The study will emphasize understanding the trade-offs between factors such as pipe sizing, pressure, velocity, and head losses to enhance system efficiency and cost-effectiveness. Additionally, the research will investigate the long-term performance and sustainability of these systems, extending beyond intermittent water supply scenarios. Furthermore, the study will explore the integration of emerging technologies, including artificial intelligence and optimization algorithms, to augment the efficiency of water distribution network design. By addressing these research gaps, this study aims to contribute valuable insights for the development of more robust and economically viable rural water supply systems, with potential applications in other regions facing similar challenges in meeting escalating water demand while ensuring compliance with regulatory standards.

1.5 Brief Methodology of the study:

- To study the detail about pipeline network system, following methodology was adopted:
- The layout map for the whole pipeline network in relation to Udaynarayanpur Zone I&II PWSS in Udaynarayanpur Dev. Block under Howrah district was studied.
- The available layout map of the distribution network has been modeled into the softwares named WaterGEMS. Accordingly the whole network was drawn which includes whole serve area.
- In the whole layout the hydraulic modeling is been carried out in the following process:
- The reservoir was drawn first then associated connecting links such as pipes and junction were drawn to connect the different area and the reservoir from the toolbar beside software's drawing window.
- By selecting the reservoirs, values of elevation were entered. Same input has been given to the intermediate node.
- By selecting the pipes, the values of length, diameter, material and Hazen- Williams C were entered.
- By selecting the junctions, the values of elevation, demand collection were entered.
- In this network (Udaynarayanpur Zone I&II PWSS) includes 14 mouzas which are Singti,Rajapur,sibanipur,Jangalpara belgram(50%),Senpur Dwitiya,Goja,Sitapur,Baira Kurchi,Harihar Dwitiya,Kurchi Binodbati,Pratap Chak,Udaynarayanpur,Etarai and Sultanpur.

- Reservoir exist in Udaynarayanpur Zone I&II, from this reservoir water is served in those mouzas.
- Kurchi Binodbati holds a very big area compare to other mouzas in Udaynarayanpur Zone I&II PWSS and Senpur Dwitiya holds least area.
- Then after modelling the whole network the network analysis run was done and the outputs such as pressure, hydraulic grade line in junctions and head loss, velocity, flows in pipes were saved.
- Keeping the above objective in view the investigation work was initiated with the reconnaitory traverse in the part of Udaynarayanpur area. It was assumed that since the area is Lower Gangetic Plain, it is very difficult to ascertain the characteristics of the aquifers without groundwater exploration. In this regard, exploratory tubewell having dimension 300 mm x 250 mm x 230 m depth (bgl).
- It is postulated that in order to obtain the optimum yield heavy pumping is to be
- imposed from the exploratory well in the locality so that the maximum cone of depression and
- radius of influence in the adjoining areas can be determined and thereby future scenario can be projected with reasonable accuracy.
- However, subsequently another observation well with identical dimension has also been
- constructed for the study about 230 mtr away.
- Accordingly drilling of the first main well up to 230 m depth was achieved by reverse rotary
- drilling rig. Before lowering the assembly, electrical logging, of the borehole was done. Based
- upon the study of lithological log as also the electrical log, the sub-surface disposition of the assembly pipes consisting of blank and slotted section were determined. The assembly of
- uPVC pipes were lowered for well construction purpose.
- To explore the groundwater potential of the aquifer in the area under consideration, further investigation has been resumed after thorough survey of the present site condition, a new
- well (second pumping well) (22.707669, 87.985067) was proposed to investigate further
- deep in the ground up to or below 230 m to be constructed in the study area.
- Accordingly drilling, lowering the assembly, electrical logging, lithological logs of the
- borehole of the second main well up to 230 m depth was achieved by direct rotary
- drilling rig.

1.6 Proposed outcome:

- 1 To design the distribution network considering the increase in the future population for 30 year.
- 2 To develop a model of a gravity flow pipeline distribution network from the reservoir to the consumer end using WaterGEMS software.
- 3 To determine the velocity, flow, head loss of different pipes and pressure, hydraulic grade, pressure head at different nodes of the pipeline distribution network using the software.
- 4 To evaluate the model efficacy for minimize the leakage, and to optimize the water availability to consumers.
- 5 First Phase of Hydrological Tests-First Pumping Well:

In order to adjudge various hydrological parameters as desired by PHED, pumping tests were carried out for duration of 170 and 295 minutes respectively. In the first occasion step drawdown test was conducted at variable discharges of 72, 97 and 107 m³/hr respectively. During the variable discharges, unsteady condition of aquifer was noticed. After cessation of pumping, recuperation test was also carried out in the main as also from two observation wells and the same was completed. Accordingly the piezometric level data as obtained from the main as well as the observation wells were plotted in semi-log and log-log papers as opined by various proponents in groundwater hydrology like Thiem, Cooper and Jacob and Chow. The data plots and their matching with the master curves has facilitated the determination of various aquifer parameters like hydraulic conductivity (K), Transmissivity (T), Storativity (S)/specific yield (Ss) etc. The cone of depression with respect to the maximum discharge of 107 m³/hr for which testing was

carried out in the area is found 922.4 m. The drawdowns versus yield are shown in Table.

1.7 Outline of Thesis:

The thesis is divided into 8 chapters. Chapter 2 offers a review of the literature. In the chapter 3 the detailed study about the area is described. The data analysis and methodology are presented in Chapter 4. The 5th chapter shows the governing equations as well as the significance of the numerical model WaterGEMS for the design and analysis of the distribution network. The 6th chapter depicts the research topic and technique. The outcome and discussion of the research study is presented in chapter 7. Finally, the form of conclusions and the future scope of the study is discussed in chapter 8. The dissertation concludes with a list of references

Chapter 2-Literature Review

2.1 National and International literature review

The literature review shows that in the case of simple water distribution systems, optimization is extensively used. The design of large-scale water networks has some important features like the increasing population and the topography. Some papers focus on the details of a particular master planning study or actual water distribution systems.

Ulanickiet et al. (2000) discussed about open and closed loop pressure control for leakage reduction of pipes. This paper formulates and investigates methods for planning and implementation of on-line control strategies of predictive and feedback control for areas with many pressures reducing valves and many target points. The considered methods explicitly take into account a leakage model. The results are applied to an area with three pressure reducing valves and two target points.

Engelhardt et al. (2000) discussed about rehabilitation strategies for water distribution networks: a literature review with a UK perspective. The multi-objective optimization approaches which have been developed recently have the potential to be developed into the required whole-life costing model based on the appropriate economic model and performance criteria.

Das (2006) carried out a pipe network analysis for a water treatment plant. As a case study, the total schematic drawing of the rising main for South 24 Parganas water supply scheme under Public Health Engineering Directorate, Government of West Bengal was considered. The network comprises of a clear water reservoir from which two pumps are supplying water to 24 numbers of zonal overhead reservoirs and two ground level reservoirs (for feeding 27 more overhead reservoirs) through the rising main. It was found that in this network, the time requirement taken for filling different overhead reservoir fully are not similar at all. Some of these fill up early and some other take a long duration.

Das et al. (2008) carried out a study in two phases for a water treatment plant. In the first phase, a model of pipe network based on EPANET in such a way that the modelled flow data for various zonal overhead reservoirs takes almost equal fill up times by adjusting the flow control valves (FCV) and changing some other parameters such as flow parameter of flow control valves, loss coefficient of throttle control valves (TCV), percentage of opening of pressure reducing valves (PRV) etc. In second phase, a lot of modifications have been done by adjusting different parameters of TCV, PRV and FCV for optimizing the head losses in pipes and valves in the modelled system so that the desired water inflow to the zonal overhead reservoirs is achieved. It has been found that in this network, the time requirement taken for filling different overhead reservoir fully are not similar at all.

Izquierdo et al. (2008) discussed about sensitivity analysis to assess the relative importance of pipes in water distribution networks. On the contrary, their designs are closely related to their

hydraulic performance. Recognizing the sundry and relative importance of the different pipes in a water distribution network may help in assessing their impact on the hydraulic performance of the network. This information, in turn, will be helpful in the different aspects of a water distribution network make-up, namely design, planning, control and management.

Liana and Vlad (2008) studied mathematical modelling and computer simulation which are becoming one of the most important tools for water companies in their attempt to provide their high-quality service economically for both development and operations. The available sophisticated and accessible models permit the proper evaluation of network behaviour under normal and abnormal conditions and it allows these goals to be realized more fully than ever before. The result was obtained using two softwares EPANET and INFOWORKS WS, and the results were compared among each other. The obtained results were similar to the optimal design model for water distribution systems, considering the water quality aspect reported by Vuta and Popa (2006).

Koppel and Vassiljev (2009) discussed about calibration of a model of an operational water distribution system containing pipes of different age. The aim of the paper is to demonstrate that the Levenberg–Marquardt algorithm can give successful results when operational water distribution systems are calibrated with the proper selection of parameter increment for the calculation of partial derivatives.

Jaman (2011) worked in the perspective of water and energy conservation. Many things have changed since 1940 when Roy B. Hunter's BMS65 Methods of Estimating Loads in Plumbing Systems, was published as a national standard in the United States. In the context of water conservation, which should be the primary goal in the global water- stressed scenario, designers are giving importance to using low water use (demand) fixtures. Merely recommending the use of low-water-flow fixture cannot address the issue of water conservation. Hunter's curve was based on 1940 high flow fixtures with a very high confidence level (CL) of 99%. Hunter's curve was needed to be modified in this context.

Angela and Angus (2012) discussed about correction of the EPANET 2.0 software inaccuracy in computing the efficiency of variable speed pumps. Hence the correction of the code was presented and an additional improvement of the toolkit in order to directly retrieve the efficiency was introduced.

Mukherjee (2012) studied about a pipe network design and analysis for a Water Treatment Plant. Since for proper schedule running of water treatment plant pipeline study also very necessary. As a case study, the total schematic drawing of the distribution network of Dhapa Water Treatment Plant under KMC which serves the population of Eastern Kolkata has been considered. The network comprises of clear water reservoir from which three pumps were supplied by a common header to three semi underground reservoirs (head works) situated at Anadapur, Mukundapur and Patuli. From these three head works the treated water is conveyed to sum total of 17 elevated storage reservoirs which would serve 14 KMC wards.

Mukherjee et al. (2012) carried out a comparative study about the hydraulic analysis outputs of pipeline network between EPANET and HAMMER softwares. The main objective was to model a pipeline of water distribution network and accordingly putting the inputs as required in both the softwares. The outputs mainly at junctions (i.e. hydraulic grade line and pressure), pipes (i.e. flow, unit headloss) and velocity were considered for representing the above study. The comparative study has been carried out with the help of statistical regression analysis by finding out correlation coefficient and probable error coefficient

Mukherjee et al. (2013) carried out a comparative study between hydraulic analysis outputs of

pipeline network between software EPANET and HAMMER. The main objective here was to design a pipeline of water distribution network and insert the required input in both the software accordingly. The outputs which were considered for the above study were hydraulic grade line and pressure at junctions and flow and unit head loss for pipes. The comparative study was carried out with the help of statistical regression analysis by finding out correlation coefficient and probable error coefficient.

Sumithra et al. (2013) studied to suggest measures for improvement to the distribution system. The paper represents results of analysis carried out using computer package LOOP developed by World Bank and Bentley System, 2008, Water Gems for optimal design of distribution system including cost analysis and reorganization measures needed for the design year 2044. The analysis of zone-III of the distribution network indicates that existing pipes need to be rehabilitated to cater to the demand for the year 2044 and CI/AC/PVC pipes needs replacement for the year 2044. New pipelines are to be proposed to ensure the service standards of 135 lpcd with minimum residual head of 7 m. The network analysis with rate analysis with aid of software LOOP developed by World Bank and Bentley Water Gem has been made and Bentley water Gems is found to be extremely user friendly for addressing such systems with varying demand pattern, peak factor, pipe condition, water supply modes and design horizons. In additions it has graphical interface which facilitate analyses more effective and lesser time requires to reanalyse the network.

Das et al. (2013) investigated that with the increase demand of water in an urban area it becomes necessary to increase the capacity of the water pipeline networks by keeping the pipes and valves elements unchanged as it is quite hazardous work to change those in an urban area. This paper presents a study on characteristics of mainly hammer head at increased flow demand in pipeline networks using HAMMER software. For modelling the pipeline distribution networks, the parameters of the pipes, junctions and other elements were inserted in the above software according to the layout of distribution network of Dhapa water treatment plant, Kolkata municipal Corporation (KMC). The flow capacity of the pipeline networks were increased in the order of 25%, 50%, 75% and 100% more than the existing flow capacity of the above networks and the transient analyses were done accordingly. Increasing trends of hammer head, pressure and circumferential stress with respect to increased flow demand were observed for all the zones which satisfy with vide validation with basic equation for water hammer theoretically. It was also checked whether the pipes are safe for taking the load of increased flow demand.

Mazumdar et al. (2013) incorporated low flow rates of modern fixtures, the reduced probability of a modern fixture being on at any moment, and reduced confidence level (CL) in the binomial probability function as used by Hunter. Low-flow fixtures is meaningful when the demand calculations address the issue of water conservation, and in this context, this paper's modified Hunter's curve will address optimal design of plumbing systems thereby facilitating the conservative and sustainable use of water.

Moreira and Ramos (2013) found that the majority of the life cycle costs (LCC) of a pump are related to the energy spent in pumping, with the rest being related to the purchase and maintenance of the equipment. Any optimizations in the energy efficiency of the pumps result in a considerable reduction of the total operational cost. The Fátima water supply system in Portugal was analyzed in order to minimize its operational energy costs. Different pump characteristic curves were analyzed and modelled in order to achieve the most efficient operation point. To determine the best daily pumping operational scheduling pattern, genetic algorithm (GA) optimization embedded in the modelling software was considered in contrast with a manual override (MO) approach. The main goal was to determine which pumps and what daily scheduling allowed the best economical solution. At the end of the analysis it was possible to reduce the original daily energy costs by

43.7%. This was achieved by introducing more appropriate pumps and by intelligent programming of their operation. Given the heuristic nature of GAs, different approaches were employed and the most common errors were pinpointed, whereby this investigation can be used as a reference for similar future developments.

Sarkar (2014) worked on the real life operation of Garfa Boosting Station, Garfa, under Borough XII of Kolkata Municipal Corporation (KMC). Garfa pumping station is dedicated to serve mainly four KMC wards that is ward 103, 104, 106 and 109 consisting of population above one lakh including floating ones. The operation of the above station is generally scheduled in three shifts that is morning, noon and evening. Complaints are there regarding low pressure of flow of water at various areas.

Wu et al. (2014) worked in applications where demand on a water supply system changes frequently and widely, the operating conditions of pumps always deviate from the design conditions, and this error leads to poor efficiency and reliability. For energy saving and longer service life, a parallel pump system was supplied, with the valves and rotational speed controls approximating the system's operating conditions closer to the designed conditions for different consumer loads. The developed optimization model employs a genetic algorithm (GA) aiming at the pumps' maximum efficiency. A theoretical solution based on the Lagrange multiples method was proved. Experiments on two identical pumps were carried out. The presented model gives optimal input data for the pumps' rotational speed and valve positions. The results show that control valves are especially helpful for improvement of a single pump's efficiency and reliability. However, in the system of parallel pumps, throttling losses in the valves caused a significant

Mukherjee et al. (2015a) found out if measuring steps can be taken in the water distribution systems then the flow received at many outlets can be very high. From comparison between measuring steps and initial running condition at various outlets highest incremental percentage was recorded to be around 600 %. By comparing the above with initial flow condition it can be said that this hike was recorded that those places where the flow was near to zero during the peak time.

Mukherjee et al. (2015b) worked on transient analysis of pipeline network for drinking purpose in Assam, India is to study the transient behaviour of the proposed raw water pipeline for drinking purpose which is linked between intake well at Brahmaputra river to Jalukbari water treatment plant (WTP).

Mandal (2015) worked on pipe network design and analysis for ash disposal system of Thermal Power plant is studied in this work. As a case study, the total schematic drawing of the Ash disposal system from main plant to ash disposal area or ash pond has been considered. The network comprises of Ash Slurry Sump from which two pumps are in series supplying ash slurry to the ash pond situated at approximately 3.5 km away from main plant boundary.

Das (2015) studied the basic techniques of landscape irrigation system design. Intended as a very basic text for irrigation design, this proceeds with the application of softwares like GPS Garmin MapSource, AutoCAD, WaterGEMS and HAMMER these softwares are equally important in water treatment pipeline designs.

Pathan and Kahalekar (2015) carried out a study related to design of Water supply network with an objective of minimizing the overall cost while meeting the water demand requirements in the sufficient quantity, quality and at satisfactory pressure i.e. finding out such an optimal geometrical layout which delivers known demands from source to all individual consumers for a long period. In this paper design of water supply network duly considering optimization in addition to the cost minimization, minimum head requirement and minimum chlorine requirement is presented. Gradient method is one in which the pipe discharges and nodal heads are taken as the basic

unknowns in equationing the Q-H equations. The non linear Q-H equations for the pipe head loss are linearised and solved by Gradient method. WaterGEMS software algorithm is based on Gradient method gives optimal solution for the design of new as well as expansion of existing water supply network. The software also gives how the chlorine concentrations changes throughout the network. Water quality results are represented either using colour coding, tables or graphs and helps to discover what better initial values for chlorine concentration might be set in the network. Decision variables involves are pipe diameter, reservoir elevations and reservoir capacity etc. with flow as primary variable.

Saha (2016) worked on the transient analysis of pipe networks using HAMMER software at the Mukutmanipur area of the Purulia piped water supply scheme. Sudden power failure, pump failure, valve failure were the main reasons behind the hydraulic transient in a water supply line. This work described the generation, propagation and reflection of pressure waves in liquid-filled pipe systems causing surge and waterhammer. The hydraulic modelling of the clear water transmission main of the study area was first done and followed by the steady-state analysis of the same by WaterGEMS software. Finally, the maximum transient pressured developed in the network and the factor of safety of the pipe experiencing the maximum transient pressure was checked as per Indian standards and American Water Work Association standards, respectively.

Mukherjee et al. (2016) worked on hydraulics of pipeline systems and checked the behaviour of such steam pipeline which are mainly affected by thermal stresses where realized on the real life operation of a captive power plant at Chhattisgarh, India.

Ganguly (2016) deals with a study that is basically a test through software simulation of the usage of flow control valves (FCVs) to control the flow in order to meet the demand in a drinking water pipeline network system. A case study in this research has been undertaken to affirm the usage of the valves. By seeing the results of the pressures and hydraulic grades of the total pipe network system along with few geographical undulations as depicted in the table of elevations, it can be said that the usage of air valves are very much necessary to the proper demand in this case.

Halder (2016) studied a closed pipe network of one of the command area zone under the water supply scheme from River Rupnarayan to calculate various parameters such as hydraulic grade, pressure, flow, velocity and unit headloss in the whole piped network. Before that study, the River Rupnarayan was chosen by PHED to supply potable water to the residents of a rural area near Panskura block of Purba Medinipur District in West Bengal. During the analysis in this study, EPANET software has been used. As per the data received the inputs were given to the software and accordingly the outcomes were interpreted in graphical format. The whole network of service area under one of the zone of the said water supply scheme, here Brindabanchak Gram Panchayat consists about 364 pipes and 337 junctions. There were junctions where the flow has becomes very less inspite of the fact that the pressure is there is due to the non-utilisation of valves. The results were also compared with a popular pipeline designing software LOOP. The obtained flow outcomes of the pipe network system using EPANET and LOOP softwares had a similarity of 96%. It suggests that by using any one of the software, these results could be adjusted.

Saha (2016) worked on Mukutmanipur area of Purulia piped water supply scheme has been taken for case study. Generally hydraulic transient in a Water Supply line is usually caused by sudden power failure, pump failure, valve failure etc. This thesis analyses surge and water hammer concerns the generation, propagation and reflection of pressure waves in liquid-filled pipe systems. The abrupt changes in pressures due to transients generate water hammer, thus invoking water

structure interaction. The numerical simulation of water hammer events is usually based on one-dimensional mathematical models.

Sarkar (2016) dealt on the study that describes estimation of energy required in different processes in Garden Reach Water Works (GRWW), a conventional water works which is engaged to supply-transmit of potable water to Southern part of Kolkata Municipal Corporation (KMC) area and many other municipalities in West Bengal, India after treatment. The study also deals with estimation of energy required in transmitting water to the four booster pumping station (BPS)s fed from GRWW through Calcutta City (CC) Grid.

Mukherjee et al. (2017) worked on designing of smart piping systems are governed by Industrial and International Codes and Standards. Design of piping system includes the pipe and fitting sizing, thickness calculation, equipment layout, pipe routing, support type, support location finalization and stress analysis. Pipeline network smart support design and stress analysis for a thermal power plant were studied in this work. As a case study, the schematic diagram of a steam pipeline from super heater outlet header to the inlet of high pressure turbine of Sagardighi Thermal Power station located at Murshidabad district, West Bengal, India was considered.

Mehta et al. (2017) studied on design of water distribution systems with an objective of minimizing the overall cost while meeting the water demand requirements at adequate pressures. However during operations of water supply systems, cases of pressure drops, Leakages and contamination occur and the main challenge is the lack of a simple tool to accurately predict zones of low pressures and areas where quality is compromised. This study will investigate the operations of Punagam area Water Distribution system in Surat city in terms of pressure Variations from the Treatment Works to the consumer points using WATERGEMS V8i software. The WATERGEMS V8i programme analyses the pressure at each node, track the flow of water in each pipe and height of the water in each tank during simulation. After simulation of existing water distribution network, results were presented in various forms and compared with the field actual data. This paper covers the water scarcity problems to consumer and the problem of leakage in the distribution system in particular with an explanation of its causes and its impact on various aspects of life and a clarification of the possibility of effectively using of geographic information systems to contribute in the management of this problem. The results obtained verified that the pressures at all junctions at all pipes are feasible enough to provide adequate water to the network of the study area. Simulated water pressure did not vary significantly with the actual values indicating that the pipes still had their hydraulic capacities even though some sections of the network need augmentation.

Bhojar and Mane (2017) carried out a Modelling and Optimization of water distribution system is addressed in this paper by WaterGEMS and EPANET. A water distribution network is used to show the algorithm performance and the obtained results are compared with those given by using dynamic programming to solve the same problem under the same conditions. The work presented in this thesis has been driven by the need for reduced, while at the same time suitably accurate, models to imitate the complex and nonlinear nature of water distribution systems to optimize their operation. WaterGEMS and EPANET are software that models the water transmission and distribution piping system. It is used to build a hypothetical model which is simulated and run to observe the performance of the network. Nagpur transmission network was designed and modelled for this study. The model is built from source- Pench Dam to the MBR in seminary hills.

Mehta and Prajapati (2018) studied on design of water distribution networks to deliver water from a source in the adequate quantity and at satisfactory pressure to individual consumers. To

solve any problem, design of new or upgradation of existing water distribution network is to be necessary. So, such type of problem can be solved using LOOP 4.0, STANET, EPANET 2.0, and WATERGEMS software. Surat City facing problems like water scarcity and pressure fluctuation so for study purpose Punagam area is selected for analyzing the existing water distribution network using WATERGEMS V8i. The objective of our study is to analyze the existing water distribution network of Punagam area using WATERGEMS V8i and to recommend some measures if present network does not fulfil the present and future demand. The results obtained verified that the pressures at all junctions and the flows with their velocities at all pipes are feasible enough to provide adequate water to the network of the study area.

Salunke *et al.* (2018) studied efficient water distribution networks based on advance computing systems include modern hydraulic modeling. In present study water distribution network of Bakori region of Wagholi is designed which is located at district Pune, State Maharashtra, India. For the design of BakoriPhata water distribution network, study of present population, population of the three decades, daily water demand, flow characteristics and also survey of the village is done with help of digital GPS .Water distribution network for the villages is analyzed and designed with help of Bentleys WATERGEMS software. Water distribution network systems are designed to deliver water from a source in the adequate quantity, quality and at satisfactory pressure to all individual consumers. Water distribution network are designed with an objective of minimizing the overall cost while meeting the water demand requirements at adequate pressures. The system is a pipeline network consisting of one source node and several demand nodes is considered to find its optimal geometrical layout which delivers known demands from source to consumers over a long period of time.

Dumane *et al.* (2018) studied to fulfil the increasing demand day by day by designing efficient water distribution networks based on advance computing systems include modern hydraulic modeling and designing software. In present study water distribution network of Bakori region of Wagholi is designed which is located at district Pune, State Maharashtra, India. For the design of BakoriPhata water distribution network, study of present population, population of the three decades, daily water demand, flow characteristics and also survey of the village is done with help of digital GPS .Water distribution network for the villages is analyzed and designed with help of Bentleys WATERGEMS software. Water distribution network systems are designed to deliver water from a source in the adequate quantity, quality and at satisfactory pressure to all individual consumers. Water distribution network are designed with an objective of minimizing the overall cost while meeting the water demand requirements at adequate pressures. The system is a pipeline network consisting of one source node and several demand nodes is considered to find its optimal geometrical layout which delivers known demands from source to consumers over a long period of time.

Mehta and Joshi (2019) studied on hydraulic design and analysis of Rural Water Distribution System (WDS) for Nava shihora region of zone 1 of the state of Gujarat, India. Water supply distribution system is designed for this study for population estimated for future 30 years. LOOP 4.0 and Water Gems v8i software have been used and the results are compared to determine the economical size of pipes for water distribution system. The economical size of pipes of water supply distribution system is designed by considering the constraints; residual pressure at each node, velocity of flow in pipe, head loss in pipes, material of pipes, elevated service reservoir level, peak factor and available commercial pipe diameters. Further water distribution system has been analyzed for extended period simulation (EPS) for the present population scenario for intermittent

water supply using Water Gems v8i. Further water supply system is analyzed the residual chlorine concentration at nodes and in the pipe links and also the total cost of water supply system of rural region is estimated.

Debnath (2019) studied the water distribution network of Bhogpur gram panchayat at Panskura-II block in West Bengal by using WaterCAD software. The design and analyses of the water distribution network for Surface Water Based Water Supply Scheme at Panskura- II (also referred to as Kolaghat Block), Zone-III (Bhogpur Gram Panchayet) of PurbaMedinipur district using WaterCAD software was discussed in this study. At the end of the analysis, it was found that the resulting pressures at all the nodes and the links velocities were satisfied enough to provide water to the study area.

Gouri Sankar Bhunia et al. (2020) With the increasing demands for water due to growing population, urban expansion, agricultural development and groundwater resources are gaining much attention, particularly in Gopiballavpur block, Paschim Medinipur district (West Bengal, India). Present study used cohesive approach of remote sensing and geographic information system to deliver an appropriate platform for convergent study of multi-disciplinary data and decision building for artificial groundwater recharge. Thematic maps were generated from Landsat8-Operational land Imager (OLI) and Shuttle Radar Topographic Mission (SRTM), and aquifer parameter thematic layers were organized from conventional field data. The weighted linear combination method was used to determine the weights of various themes and their classes, namely 'very good', 'good', 'poor' and 'very poor' for identifying recharge potential zone. It has been concluded that 14.58% area has very good groundwater recharge potentiality of the study area. The area having 'good', 'moderate' and 'low' recharge potential is about 32.77%, 39.67% and 12.98%, respectively.

Jwan Sabah Mustafa et al.(2021)The study presented a method for estimating aquifer storage coefficient from recovery test data meanwhile, it is hard to determine especially for single well test cases. The method involves an equation based on the principle of Jacob's modified Theis equation by measuring residual drawdown data versus recovery time in the production well. The main objectives of this study is to determine the reliability of this equation in the selected area and to evaluate and compare the results with the pumping test results as well. The method is starting by estimating the Aquifer parameters (Transmissivity and Storativity) which involves plotting residual drawdown as a function of time, later substituting the obtained test values in an appropriate transient groundwater flow equations based on the aquifer characteristics and types to find the parameter values. Finally, the study concluded that the proposed equation is reliable for determine the Storativity of the aquifer for the single well test, and also can be used as a check for the parameters that obtained from pumping test results and thus the method is verified the objective of the study.

Lawal Abdullateef et al. (2021) The increasing demand for water occasioned by harsh climatic conditions, population explosion, and increasing urbanization has necessitated more attention and reliance on groundwater resources, particularly in water-limited regions. Thus, judicious management of available groundwater resources becomes crucial to meet the freshwater requirements in such zones. In this study, remote sensing and geographic information system were deployed to delineate groundwater recharge zones in semi-arid geological transition zones of

Bauchi, northeastern Nigeria. Seven thematic layers comprising elevation, slope, land use/land cover, drainage density, lithology, magnetic lineament density, and hydraulic head were integrated based on their degree of influence in groundwater recharge. Normalization of the weights was achieved through the analytical hierarchical process (AHP), while the overall integration of the thematic maps was actualized by overlay analysis in ArcGIS 10.3.1 environment to generate a final groundwater recharge zone map of the area. The resulting map was delineated into three different zones: low, moderate, and high, occupying 20% (627 km²), 77% (2352 km²), and 3% (80 km²) respectively. The overall assessment of recharge zones revealed that a high percentage of the southwestern part of the study are characterized dominantly by poor groundwater recharge potential, attributable to high elevations and impervious rock outcrops with associated steep slopes, thus limited infiltration owing to the high velocity of runoff. The northwestern and parts of the southwestern zones, underlain by migmatite/gneiss, and partly granites, however, exhibited medium-low recharge potential, owing to the occurrence of considerably lower altitudes and occupied by thicker regoliths and underlying rocks of medium high lineament densities. The sandstones revealed predominantly medium-high recharge potential, attributable to high permeability, lower hydraulic heads, and relatively flat geomorphology which enhances meteoric recharge and base flow processes.

Patil et al. (2023) carried out a study of a growing population country like India needs a sufficient amount of resources. Nowadays, most of our rural areas are not having a sufficient quantity of potable drinking water facilities, so the main objective of this study is to provide an efficient and optimal water distribution network design using LOOP and WaterGEMS software by satisfying CPHEEO norms and Jal Jeevan Mission guidelines. The project is carried on Awaradi village in Gokak taluk, Belagavi district. This project is carried out the designing rural drinking water with 55 LPCD. The population is forecasted for a design period of 30 years (2051) from 2021. The survey is carried out in the proposed village to collect ground data and area topographical profile. Then further hydraulic

calculations are made with the use of LOOP 5.0 software and WaterGEMS Software. The velocity and head losses are high in the LOOP software design as compared with the WaterGEMS software. The pressure values are slightly more in the WaterGEMS software, but both the software results are meeting the CPHEEO norms as well as Jal Jeevan Mission guidelines with a pressure head of 7 m.

Labhadeet al. (2021) carried out a study of Nimgaon (Madh) village have done and Water Distribution Network (WDN) was designed, which was located at district Nashik, State Maharashtra, India. For the design of Nimgaon (Madh) water distribution network study of present population, forecast Population for the three-decade, daily water demand, flow and also survey of village Nimgaon (Madh) was done with the help of Auto Level. From the Level survey, map was created and also elevation and length of Pipeline required for the village was calculated. The node no. and pipe no. were denoted on map of villages. Water Distribution Network of village was designed with the WaterGems/WaterCad software and compared with manually result. It was found that software result was more accurate, save time and manpower than manual result. Water is essential element required for the sustenance of life. Demand for drinking is increasing on continual basis with corresponding increasing population. This ever-increasing demand can be fulfilled by designing efficient water distribution networks based on advance computing systems include modern hydraulic modeling and designing software.

Chapter 3-Details of Study Area

3.1 Study Area:

The Udaynarayanpur Zone I&II Piped Water Supply Scheme covers 12 (Twelve) nos. of habitations in 04 (Four) nos. of mouzas of Block Udaynarayanpur, P.S. Udaynarayanpur under Howrah District in the state of West Bengal. The total area covered under the scheme is about 2120.6 hectare with a total population of 35066 as per 2011 census and average population density of 16.54 persons per hectare. The area is predominantly habited by SC, total percentage being of 20.382 % of total population.

Presently no piped water supply facility / sustainable drinking water supply system exists within the scheme jurisdiction & people of the area are using hand pump tube well as source of potable water most of which became dry during summer seasons. Water borne diseases like diarrhoea/ Amibiosis / typhoid etc. are common within the command area. Considering the sufferings of the people Udaynarayanpur Zone I&II Piped Water Supply System was initiated.

NRDWP guideline recommends for supply of water up to household level through pipe line. Therefore, water demand for every household including connections to schools/Anganwadis/Health Centres etc. through Community Tank are also considered in this project.

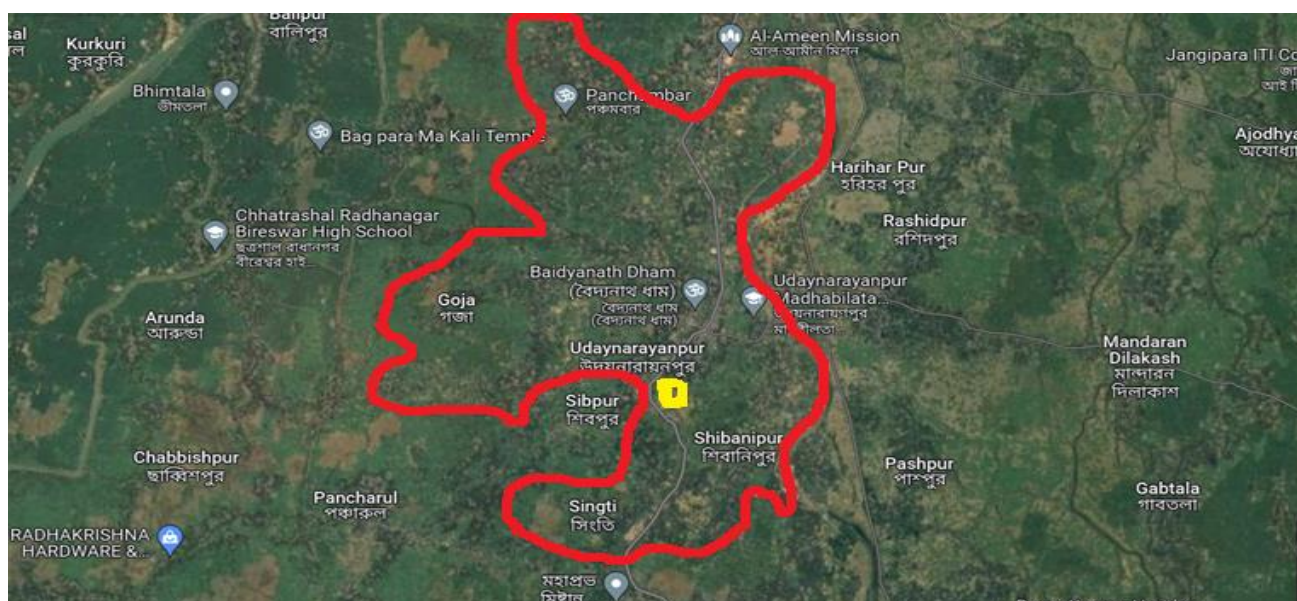


Figure 2: Map of Udaynarayanpur Zone I & Zone II with mouja boundary

3.2 Salient Features:

Table 1: Salient Features of Udaynarayanpur Zone I & II PWSS

1	Name of the scheme	Udaynarayanpur Zone I&II piped water supply scheme Block: Udaynarayanpur , District: Howrah
2	Name of the District	Howrah
3	Location	The proposed command area falls under Block Udaynarayanpur , Sub-Division Uluberia, District Howrah and within 6 km radius from Bloc Head Quarter, 50.3 km away from Sub-Division Head Quarter, 43.5 km away from District Head Quarter and is connected with Road networks. Nearest Railway Station is Amta 23.2 km and nearest Airport is Dum Dum 58.6 km away from the Headworks site of the proposed command area. The area falls within dry and arid region of the state.
4	Name of the Block	Udaynarayanpur
5	Number of Mouzas (As per Census 2001)	14
6	Number of habitation	16
7	Number of Population (2011)	35066
8	Command area	2120.6 hectares
10	Per Capita Service Level	55lpcd
11	Source of Water	Ground Water
12	Number of tubewells	2(Working), 4(proposed)

Table 2: Details of Mouza within the study Area

Sl. No.	Name of the Village/ Mouza	J.L. No.	2011 Census		
			Total	SC	ST
1.	Udaynarayanpur	17	1575	375	3
2.	Singti	33	6324	630	4
3.	Jangalpara belgram(50%)	36	2487	669	28
4.	Senpur Dwitiya	37	258	0	0
5.	Kurchi Binodbati	15	6522	1190	30
6.	Pratap Chak	16	1090	28	0
8.	Etarai	19	1689	462	4
9.	Goja	7	4203	1170	0
10.	Sitapur	9	2451	696	28
11.	Baira Kurchi	11	1185	135	0
12.	Harihar Dwitiya	14	1580	481	3
13.	Rajapur	34	1810	373	0
14.	Sibanipur	35	1404	168	0
	Total =		35066	7046	101
Total SC / ST Population					7147
Percentage of SC / ST Population					20.382
Population Density (persons/Ha)					16.54

Table 3: Details of Tubewells (Proposed)

Sl. No.	Ultimate Demand	Pumping Hours	Expected yield of the proposed tubewell	Nos. of tubewell proposed	Details of the tubewell with length of the strainer
1.Zone-I	895 KLD	16	36.875 m3/hr	2	300 mm x 200 mm Diameter x Depth 230 m Housing: Dia 300 mm length 48 m
2.Zone-II	1656 KLD	16	34.156 m3/hr	2	300 mm x 200 mm Diameter x Depth 230 m Housing: Dia 300 mm length 48 m

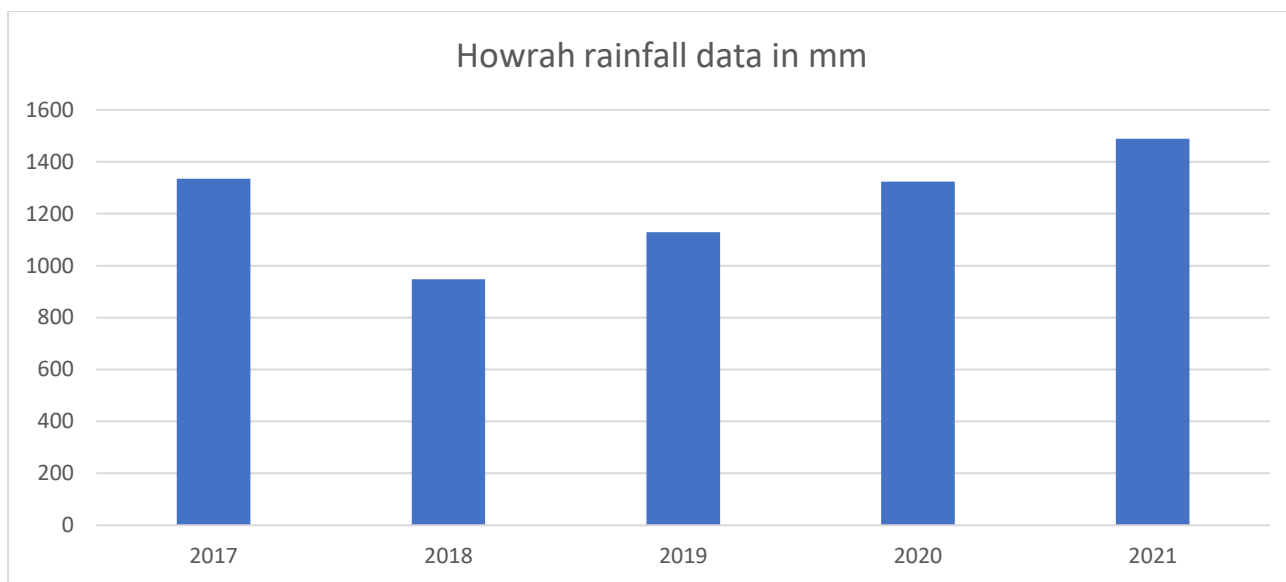


Figure 3: Rainfall Data of Howrah District

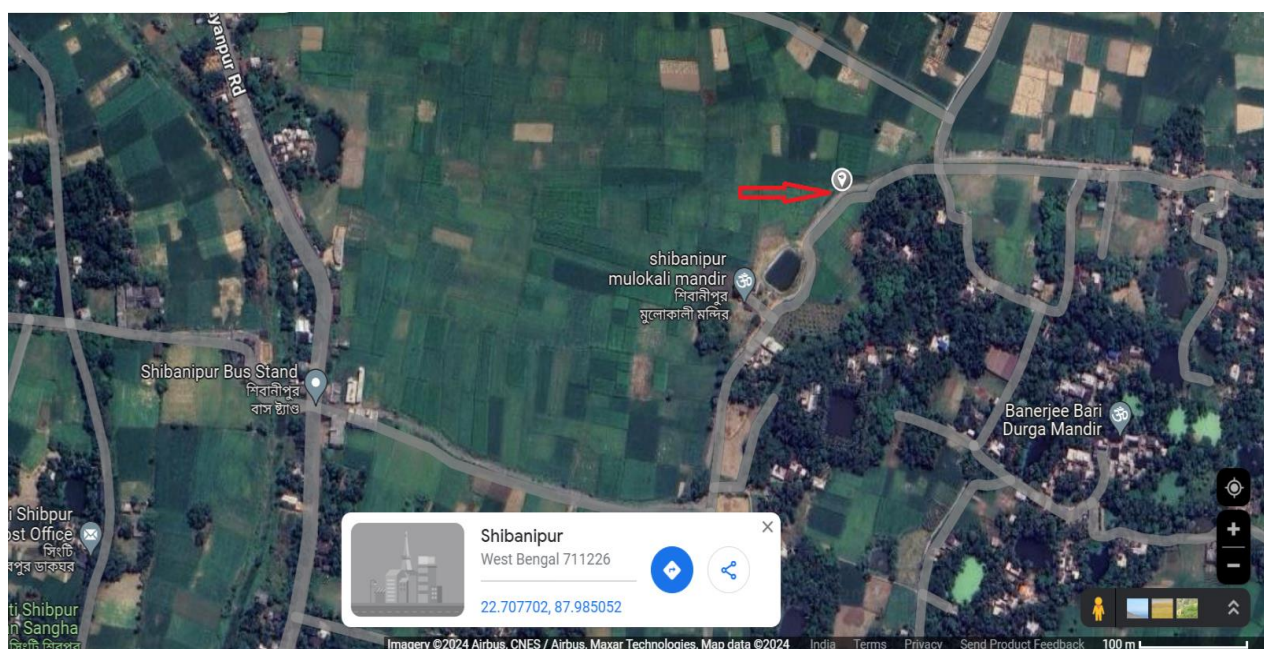


Figure 4 Tubewell location (22.707702, 87.985052)

Chapter 4-Methodology

4.1 Methodology flow chart:

The steps involved to address the specific objective of this study are as follows.

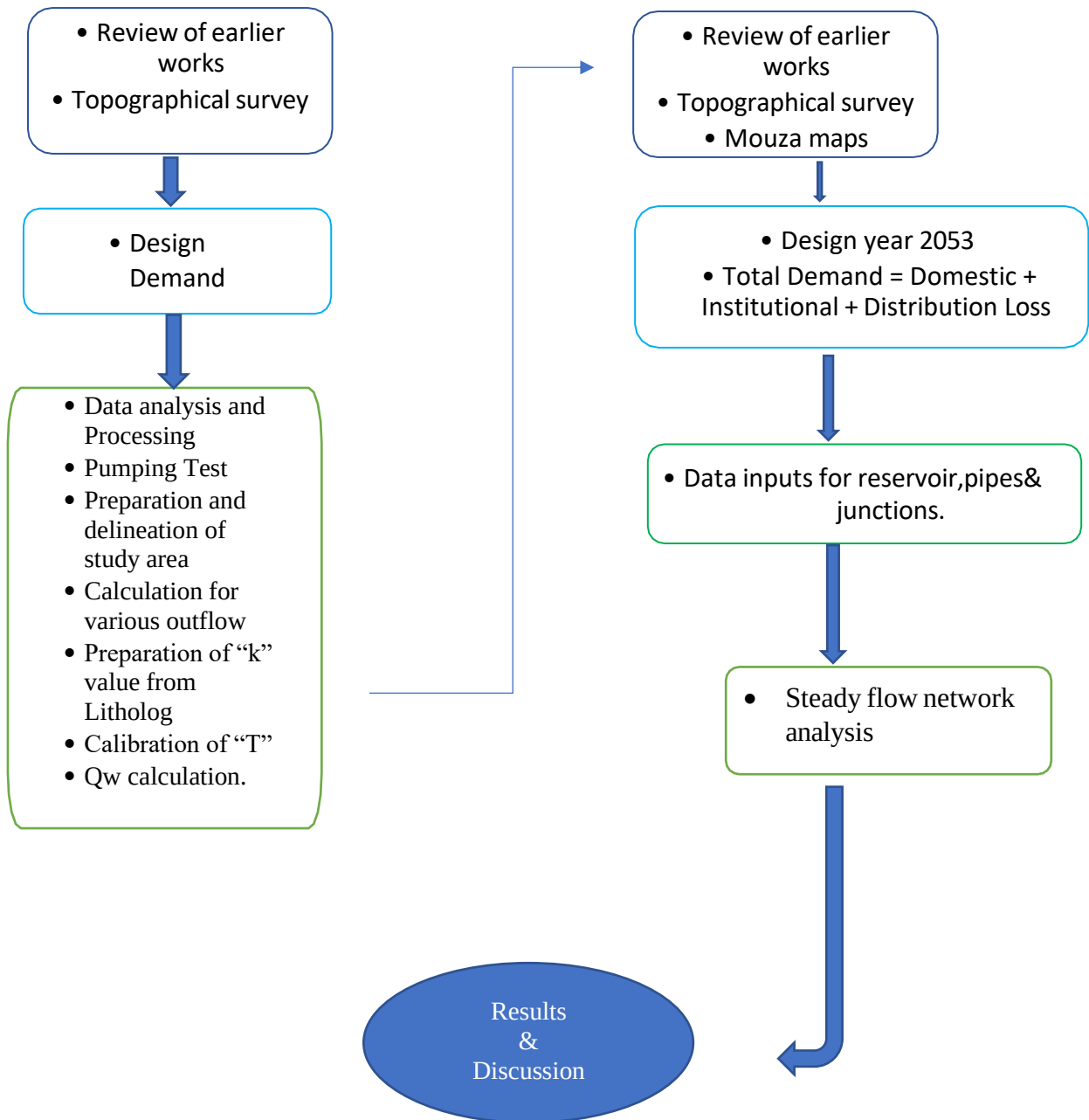


Figure 5: Methodology flow chart

Step 1 Data collection:

Earlier paper works were reviewed which helped to collect data for this study. In this context to study and for the implementation of the water distribution network data related to topographic survey along with roadways, paths, and the planned pipe alignments are required. Topographical survey data in form of AutoCAD drawing was collected from WBPHEd office. Along with this the details of mouzas of Udaynarayanpur Zone I&II PWSS was also collected

from their website. The availability of groundwater from an aquifer at a place depends upon the rates of withdrawal and replenishment (recharge). An unconfined aquifer (also known as water table aquifer) is one in which a free water surface, i.e. a water table exists. Only the saturated zone of this aquifer is of importance in groundwater studies. Recharge of this aquifer takes place through infiltration of precipitation from the ground surface. A well driven into an unconfined aquifer will indicate a static water level corresponding to the water table level at that location.

Step 2 Estimation of total demand:

The ultimate design population of the study area has been calculated using the Geometrical Increase Method which was described in section 4.1.4. This method is used as this method gives a higher value than other population forecasting methods, which is more acceptable in design for the safety point of view. At first, the geometric mean of the decadal growth rate of the past five decades of this district is calculated. Then using the equation mentioned in equation no 4.3 and considering 30 years design year the projected population on 2053 is determined from the population of 2011 census which was collected and the projected population of each Mouza are given in Column 1 of Table 7.1(b). The Domestic demand of the study area is determined by multiplying the values of column 1 by

70 as mentioned in Table 4.1. Column 3 consists of institutional demand which is determined by considering 5% of domestic demand (5% of Column 1). In column 4 the distribution loss is determined considering 10% of domestic demand and institutional demand. In column 6 the total demand is determined considering 3 as the peak factor as per the CPHEEO manual. The design demand is determined considering total demand.

All the calculations have been made as per CPHEEO Manual 1999 and WBPHEED Schedule (2013).

The Details are mentioned in tables (Source: District Census Handbook Howrah 2011)

Table 4: Decadal Growth Rate of Howrah

Year	Pop.	±% p.a.
1901	850,514	—
1911	943,502	+1.04%
1921	997,403	+0.56%
1931	1,098,867	+0.97%
1941	1,490,304	+3.09%
1951	1,611,373	+0.78%
1961	2,038,477	+2.38%
1971	2,417,286	+1.72%
1981	2,966,861	+2.07%
1991	3,729,644	+2.31%
2001	4,273,099	+1.37%
2011	4,850,029	+1.27%
Avarage		+1.596%

ZONE-I**Table 5: Demand calculation of the study area**

Stages of demand	Domestic demand	Institutional demand	Distribution loss	Treatment loss	Total	Fire Fighting demand
	kLD	kLD	kLD	kLD	kLD	kLD
	1	2	3	4	5	6
		1*5/100	[1+2]/9	[1+2]/19	1+2+3+4	100√P
Present(2021)	766.00	39.00	90.00	0.00	895.00	374.00
Intermediate(2036)	904.00	46.00	106.00	0.00	1056.00	406.00
Ultimate(2051)	1011.00	51.00	118.00	0.00	1180.00	429.00

ZONE-II

Table 6: Demand calculation of the study Area

Stages of demand	Domestic demand	Institutional demand	Distribution loss	Treatment loss	Total	Fire Fighting demand
	kLD	kLD	kLD	kLD	kLD	kLD
	1	2	3	4	5	6
		$1*5/100$	$[1+2]/9$	$[1+2]/19$	$1+2+3+4$	$100\sqrt{P}$
Present(2021)	1420.00	71.00	166.00	0.00	1657.00	509.00
Intermediate(2036)	1675.00	84.00	195.00	0.00	1955.00	552.00
Ultimate(2051)	1874.00	94.00	219.00	0.00	2186.00	584.00

Step 3 WaterGEMS model creation:

The Mouza Map of the Study area was collected from the WBPHEd website and keeping its AutoCAD drawing in the background, the pipeline distribution system was drawn using a network simulation software WaterGEMS. The pipelines were drawn along the road embankment.

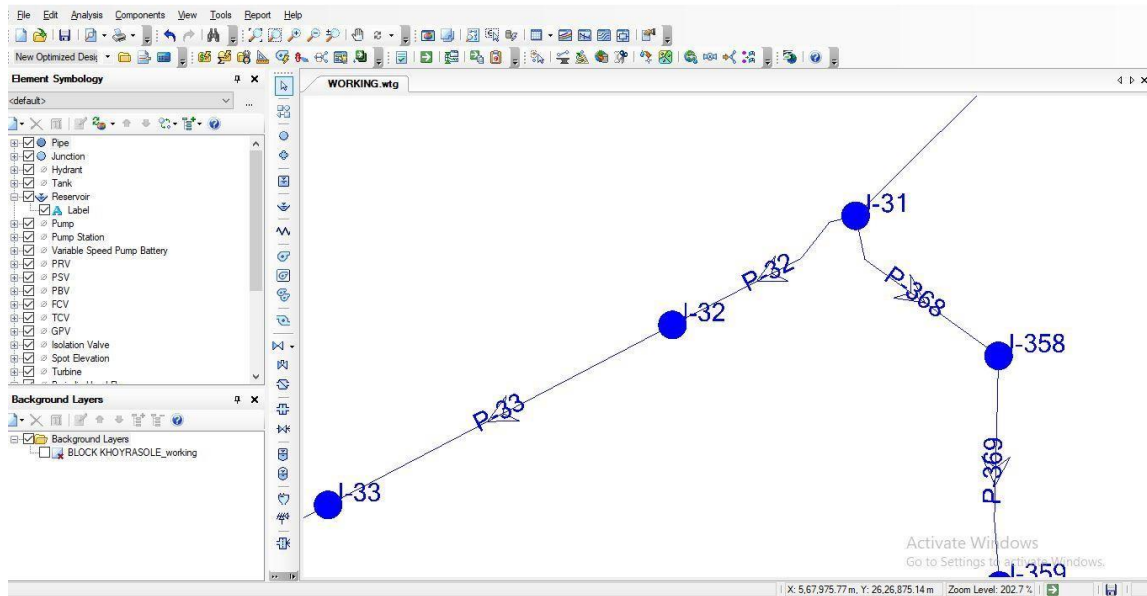


Figure 6: Drawing network in WaterGEMS V8i

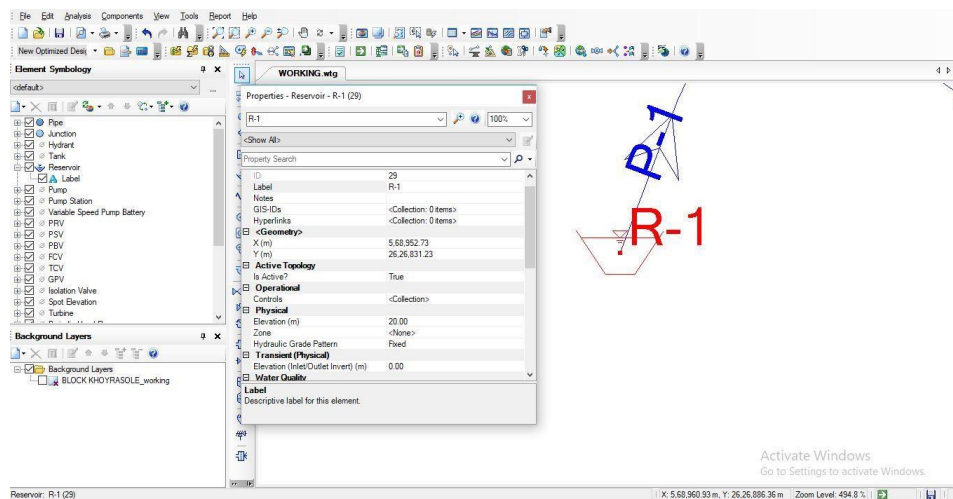


Figure 7: Property editor for Reservoir in WaterGEMS V8i

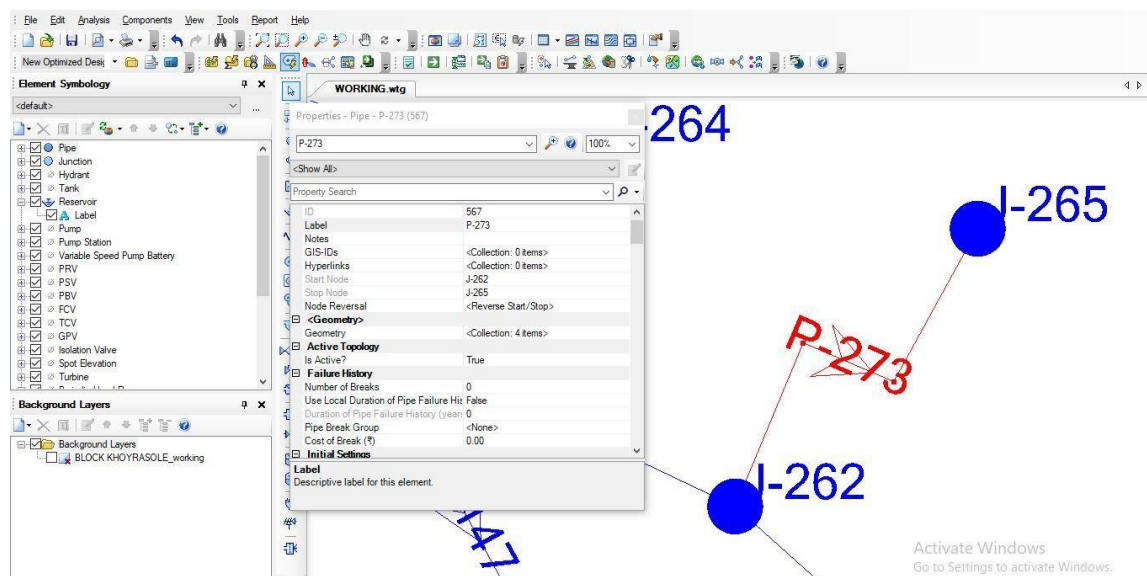


Figure 8: Property editor for pipeline in WaterGEMS

Most of the hydraulic analysis software has common input data requirements. These data are grouped into pipe data and node data. Pipe data are the assigned pipe number, pipe diameter (mm), Hazen-Williams C-value, length (m) and diameter (mm). Node data are assigned node number, elevation (m) and water demand (lps). Pump curve data are the assigned head (m) and flow (lps).

In this network, there are 426 junctions and 426 pipes. The input parameters for Junctions and pipes which are used during the hydraulic analysis are mentioned below in table where J, P, T indicates Junction, Pipe, Tank respectively and the suffix of J, P, T represents its number. The topography is almost plain and the elevation is 75m. Here we have used one type of pipe is UPVC pipe. The Hazen William constant is considered 145 for UPVC pipes

Table 7: Input data of Junction and Pipe

Label	Demand (L/s)	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C
P-1	0.059	22	R-1	J-1	250	DI	140
P-2	0.158	21	J-1	J-2	116.4	UPVC	145
P-3	0.124	151	J-2	J-3	102.6	UPVC	145
P-4	0.083	68	J-3	J-4	102.6	UPVC	145
Detailed Input data of junctions and pipes is attached to Annexure -1							

Step 4 Hydraulic Model Simulations:

In the case of the steady-state mechanism by clicking validates option the network can be validated. If there is some problem it will show to the bottom dialogue box otherwise “No Problem” message is shown in the dialogue box. After that to compute and get the result we have to click compute button under the analysis tab. The software computes pressure (kPa), pressure head (m) at each junction and the flow (l/s), velocity (m/s), head losses, the rate of head loss (m/m) in each pipe

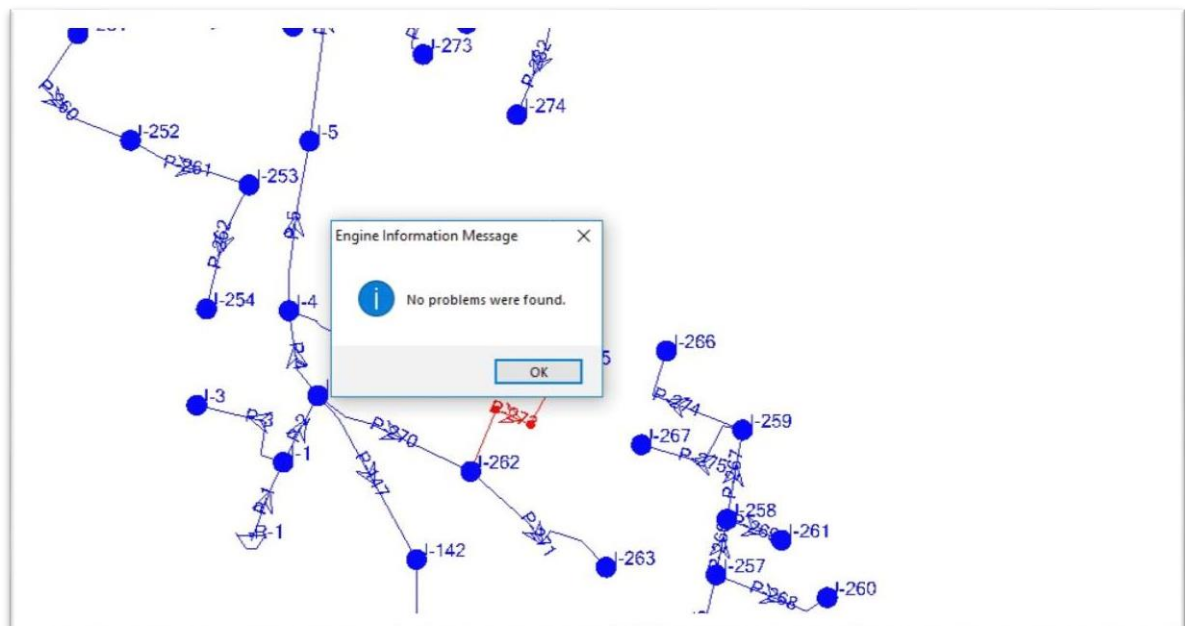


Figure 9: Network validated

Step 5 Results and Analysis:

The result generated by the software can be seen in the flex table. The pipe diameter has to be optimized repeatedly to get the calculated output value as per the CPHEEO guidelines.

Both the results generated by the two network simulation software respectively can be copied to excel files and to analyze the network parameters the different graphs generated by the software itself were used. The software-generated graphs are shown in Chapter 7.

4.2 Findings for tubewell:

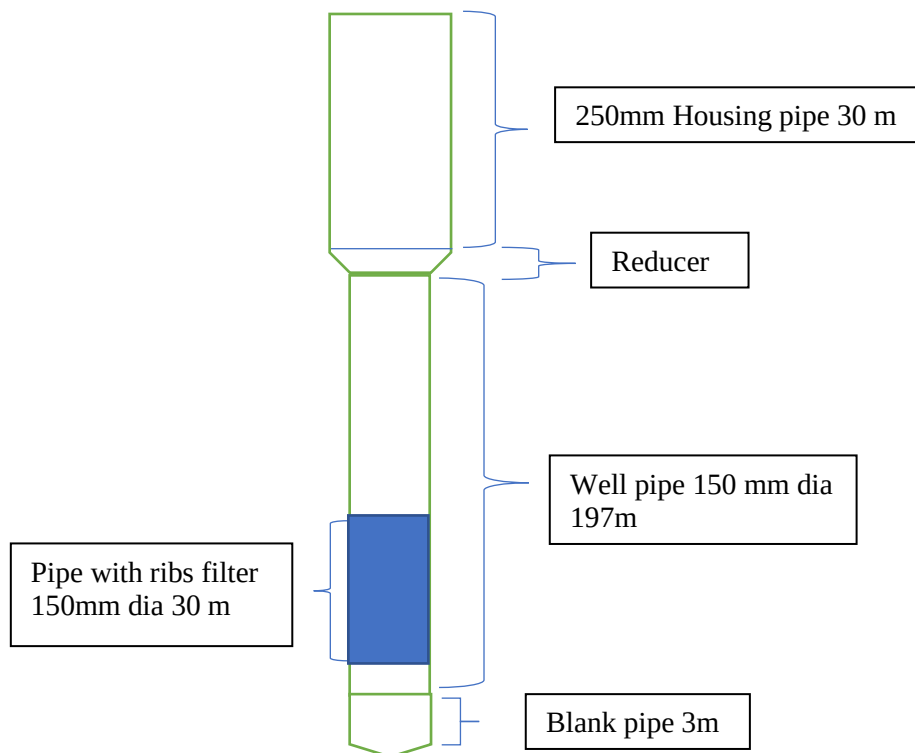
The borehole has been Drilled by Direct Mud Circulation Method by Mechanized Rotary Rig. The tubewell size is 250mmX150mm dia with the use of uPVC pipes and uPVC ribbed strainers. The bore was found to be clear upto a depth 225 mtrs against the drilling depth of 230 mts. The SP(Self Potential) and resistivity readings are taken at an interval of 3mtrs.

After studying the geological and geophysical properties of the borehole and intercepting the logging datas through SP and resistivity graphs, the findings and recommendation are:

1. Depth of Drilled : 230 m
2. Depth electrologged : 225m
3. Aquifer Zone : 133m-167m
4. Recommended strainer zone : 135m-165m
5. Litholog;

0-15m	: Top soil and Clay (yellow)
15-43m	: Clay (yellow)
43-52m	: Clay (grey black)
52-235m	: Clay and Sandy clay (yellow)
135-165m	: Fine to Medium sand (grey yellow)
165-184m	: Fine to medium sand (grey yellow)
184-230m	: Clay (yellow)

Tubewell diagram



Chapter 5- Tubewell analysis & Water Distribution Network

5.1 Specific Yield and Specific Retention:

Specific yield and specific retention are two important parameters used in hydrogeology to describe how water is stored and moves within an aquifer.

Specific Yield (S_y):

Specific yield refers to the ratio of the volume of water that an aquifer will yield by gravity drainage to the total volume of the aquifer. It represents the portion of water that an aquifer releases under the influence of gravity and is typically expressed as a percentage or decimal fraction.

The equation to calculate specific yield is:

$$S_y = V_w / V_t$$

Where:

S_y is the specific yield (dimensionless)

V_w is the volume of water that drains out of the aquifer due to gravity (cubic meters or cubic feet)

V_t is the total volume of the aquifer (cubic meters or cubic feet)

Specific Retention (S_r):

Specific retention refers to the volume of water retained in an aquifer per unit volume of aquifer material. It represents the portion of water that is retained within the pore spaces of the aquifer material against the pull of gravity and is typically expressed as a percentage or decimal fraction.

The equation to calculate specific retention is:

$$S_r = V_r / V_t$$

Where:

S_r is the specific retention (dimensionless)

V_r is the volume of water retained within the aquifer material (cubic meters or cubic feet)

V_t is the total volume of the aquifer (cubic meters or cubic feet)

It's important to note that specific yield and specific retention are often determined through laboratory tests or estimated using empirical relationships based on the characteristics of the aquifer material, such as porosity, grain size distribution, and hydraulic conductivity. These parameters play a crucial role in understanding groundwater storage, flow, and availability within aquifer systems.

While porosity gives a measure of the water-storage capability of a formation, not all the water held in the pores is available for extraction by pumping or draining by gravity. The pores hold back some water by molecular attraction and surface tension. The actual volume of water that can be extracted by the force of gravity from a unit volume of aquifer material is known as the specific yield.

5.2 Storage Coefficient or Storativity:

Storage coefficient, also known as storativity, is a dimensionless parameter used in hydrogeology to describe the ability of an aquifer to store water per unit decline or rise in hydraulic head. It represents the volume of water that a unit volume of aquifer material releases or takes in under a unit change in hydraulic head. Storativity takes into account both specific yield (which accounts for gravity drainage) and specific storage (which accounts for compression and expansion of the aquifer material).

The equation to calculate storativity (S) is:

$$S = S_y + S_s$$

Where:

S is the storage coefficient or storativity (dimensionless)

S_y is the specific yield (dimensionless)

S_s is the specific storage (dimensionless)

Specific storage (S_s) represents the compressibility of the aquifer material and is typically expressed in units of inverse length (e.g., 1/m or 1/ft).

The relationship between storativity, specific yield, and specific storage can be complex and depends on factors such as the porosity, compressibility, and hydraulic properties of the aquifer material.

Storativity is an important parameter in groundwater flow modeling and aquifer analysis, as it influences the response of aquifers to changes in groundwater levels, such as those caused by pumping or recharge events. It helps hydrogeologists understand how much water can be extracted from or stored in an aquifer under various conditions.

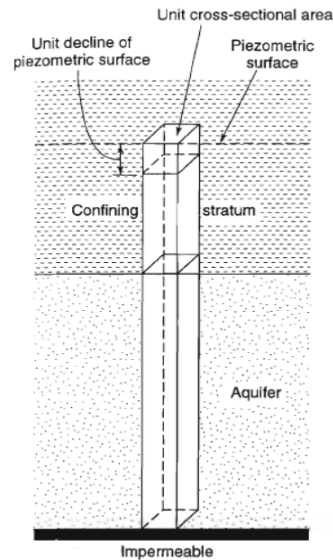


**Figure 10: Illustrative sketches for defining storage coefficient of a confined aquifer
(Todd & Mays, 2005)**

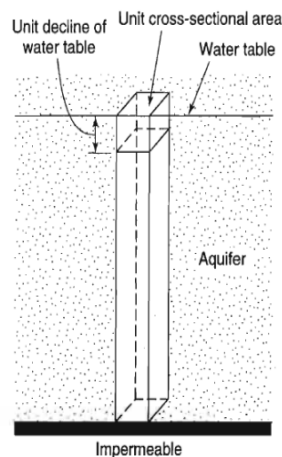


**Figure 11: Illustrative sketches for defining storage coefficient of an unconfined aquifer
(Todd & Mays, 2005)**

Specific Storage:

Specific storage (S_s) is a parameter used in hydrogeology to describe the ability of an aquifer material to release or take in water per unit volume per unit change in hydraulic head. It represents the compressibility of the aquifer material. Specific storage is particularly important in unconfined

aquifers or where changes in hydraulic head lead to significant changes in the volume of water stored in the aquifer.

The equation to calculate specific storage is:

$$S_s = (1/n) \cdot (\Delta V / \Delta h)$$

Where:

S_s is the specific storage (units of 1/length, often expressed in m^{-1} or ft^{-1})

n is the porosity of the aquifer material (dimensionless, ranging from 0 to 1)

Δ is the change in volume of water in the aquifer (cubic meters or cubic feet)

Δh is the change in hydraulic head (meters or feet)

Specific storage quantifies how much the volume of water stored in the aquifer changes with a change in hydraulic head. It is a measure of the compressibility of the aquifer material, with higher values indicating greater compressibility.

Specific Storage:

Specific storage is a crucial parameter in groundwater flow modeling, especially when analyzing transient or time-varying conditions. It influences the rate at which water flows into or out of the aquifer in response to changes in pumping rates, recharge rates, or other hydrological events.

Darcy's Law:

Darcy's Law is a fundamental principle in hydrogeology and fluid dynamics that describes the flow of fluids (usually water) through porous media, such as soil or rock. It's named after the French engineer Henry Darcy who first formulated it in the 19th century.

The law states that the rate of flow of water through a porous medium is directly proportional to the hydraulic gradient and the cross-sectional area through which the water flows, and inversely proportional to the length of the flow path and the fluid's viscosity. Mathematically, it can be expressed as:

$$Q = -k \cdot (A/L) \cdot (h_2 - h_1)$$

Where:

Q is the volumetric flow rate (volume of fluid passing through a given cross-sectional area per unit time),

k is the hydraulic conductivity of the porous medium (a measure of its ability to transmit water), typically measured in units of velocity (e.g., meters per second or feet per day),

A is the cross-sectional area through which the fluid flows (orthogonal to the flow direction),

L is the length of the flow path,

h_1 and h_2 are the hydraulic heads (elevation of the water surface relative to a reference point) at points 1 and 2 along the flow path, respectively.

In this equation, the hydraulic gradient $(h_2 - h_1)/L$ represents the change in hydraulic head per unit length of flow path, and $-k$ accounts for the resistance to flow posed by the porous medium.

Darcy's Law is applicable under certain conditions, such as when the flow is steady, the fluid is incompressible, and the porous medium is homogeneous and isotropic. Despite its simplifications, it serves as a foundational concept in groundwater hydrology and is widely used in various engineering applications, including groundwater modeling, contaminant transport, and petroleum reservoir engineering.

Coefficient of Permeability:

The coefficient of permeability, often denoted as k or K , is a fundamental property of porous media that quantifies its ability to transmit fluids. It's a key parameter in Darcy's Law, as mentioned earlier.

The coefficient of permeability is defined as the rate of flow of fluid through a unit cross-sectional area of the porous medium under a unit hydraulic gradient. Mathematically, it can be expressed as:

$$k = Q \cdot L \cdot A \cdot \Delta h$$

Where:

k is the coefficient of permeability (often in units of velocity, such as m/s or cm/s),

Q is the volumetric flow rate of fluid passing through the medium (m³/s or cm³/s),

L is the length of the flow path (m or cm),

A is the cross-sectional area perpendicular to the flow direction (m² or cm²),

Δh is the difference in hydraulic head (m or cm) between two points along the flow path.

This equation essentially states that the coefficient of permeability is the proportionality constant relating the flow rate of fluid to the hydraulic gradient, cross-sectional area, and length of the flow path. A higher coefficient of permeability indicates greater ease of fluid flow through the porous medium.

The coefficient of permeability is influenced by various factors including the properties of the fluid (such as viscosity), the properties of the porous medium (such as porosity and grain size distribution), and the geometry of the medium. It's typically determined experimentally through laboratory tests such as constant head or falling head permeability tests, where the flow rate through a sample of the porous medium is measured under controlled conditions.

The coefficient of permeability is a crucial parameter in fields like hydrogeology, civil engineering, and soil mechanics, as it governs the movement of fluids through soils, rocks, and other porous materials. Understanding this property is essential for various applications, including groundwater flow modeling, design of drainage systems, and assessment of contaminant transport in aquifers.

Transmissibility:

In hydrogeology, the transmissibility of water, often denoted as T , refers to the ability of an aquifer to transmit water through it under a unit hydraulic gradient. It's a measure of the aquifer's hydraulic conductivity in combination with its thickness. Transmissibility is particularly relevant when analyzing the flow of groundwater through porous media.

The equation for transmissibility is:

$$T = k \cdot b$$

Where:

T is the transmissibility (often in units of velocity times thickness, such as m²/s or ft²/day),

k is the hydraulic conductivity of the aquifer (m/s or ft/day),

b is the thickness of the aquifer through which water is flowing (m or ft).

This equation indicates that transmissibility is the product of hydraulic conductivity and aquifer thickness. It essentially represents the capacity of the aquifer to transmit groundwater flow per unit width of the aquifer. A higher transmissibility value indicates a greater ability of the aquifer to transmit water.

Transmissibility is a critical parameter in groundwater hydrology, as it influences the rate and direction of groundwater flow within an aquifer. It's used extensively in groundwater modeling to simulate and predict groundwater flow patterns, drawdown effects from pumping wells, and contaminant transport.

Understanding transmissibility is essential for water resource management, environmental protection, and various engineering applications related to groundwater, such as well field design, aquifer storage and recovery projects, and groundwater remediation strategies.

Sands and Gravels:

Coefficient of Permeability: 10⁻² to 10⁻⁴ m/s

Intrinsic Permeability: 10⁻¹⁰ to 10⁻⁸ m²

Clayey Soils:

Coefficient of Permeability: 10⁻⁶ to 10⁻¹⁰ m/s

Intrinsic Permeability: 10^{-14} to 10^{-10} m²

Silty Soils:

Coefficient of Permeability: 10^{-5} to 10^{-8} m/s

Intrinsic Permeability: 10^{-13} to 10^{-10} m²

Limestones:

Coefficient of Permeability: 10^{-5} to 10^{-2} m/s

Intrinsic Permeability: 10^{-12} to 10^{-8} m²

Sandstones:

Coefficient of Permeability: 10^{-4} to 10^{-11} m/s

Intrinsic Permeability: 10^{-11} to 10^{-7} m²

Fractured Rocks (such as granite):

Coefficient of Permeability: 10^{-5} to 10^{-2} m/s

Intrinsic Permeability: 10^{-11} to 10^{-7} m²

These values are approximate and can vary depending on factors such as porosity, grain size distribution, degree of consolidation, and the presence of fractures or other structural features. They are typically determined through laboratory tests or estimated based on empirical relationships and geological characteristics of the porous media.

5.3 Steady-State Well Hydraulics:

Steady-State Well Hydraulics: Steady-state well hydraulics refers to the condition where the rate of water withdrawal from a well remains constant over time, and the groundwater system reaches a stable equilibrium. This condition is often assumed in groundwater modeling and analysis to simplify calculations.

Pre-pumping Water Level: The pre-pumping water level, also known as the initial groundwater level or static water level, is the natural level of groundwater in an aquifer before any pumping activity occurs. It represents the equilibrium condition where the rate of recharge equals the rate of discharge.

Pumping Water Level: The pumping water level is the groundwater level observed in a well or pumping borehole during pumping. It is typically lower than the pre-pumping water level due to the extraction of water from the aquifer.

Drawdown: Drawdown is the decrease in groundwater level observed in a well or observation point as a result of pumping. It represents the difference between the pre-pumping water level and the pumping water level.

Cone of Depression: The cone of depression is the conical-shaped depression formed in the water table or potentiometric surface around a pumping well due to drawdown. It represents the extent of influence of the pumping well on the surrounding groundwater flow regime.

Radius of Influence: The radius of influence, also known as the capture radius or radius of influence, is the distance from a pumping well within which the drawdown caused by pumping is significant. It defines the area from which the pumping well extracts groundwater.

Unsteady Flow: Unsteady flow refers to groundwater flow conditions where hydraulic head or groundwater levels change with time. This typically occurs during pumping or recharge events, when the groundwater system is not in equilibrium.

Steady Flow: Steady flow refers to groundwater flow conditions where hydraulic head or groundwater levels remain constant over time. This occurs when the rate of water extraction or recharge remains constant, and the groundwater system reaches a stable equilibrium.

Recuperation or Recovery: Recuperation or recovery is the process by which groundwater levels return to their pre-pumping levels after pumping ceases. It represents the natural recharge of the aquifer and the restoration of groundwater levels following pumping activity.

Understanding these terms is essential for assessing groundwater resources, designing well systems, and managing groundwater extraction sustainably. They provide insights into the behavior of aquifers and the effects of pumping on groundwater levels and flow patterns.

5.4 Cooper-Jacob Method of Solution:

The Cooper-Jacob method provides a systematic approach to solving the nonlinear flow equations governing groundwater movement. By discretizing the domain and iteratively solving the linearized equations, it allows for the approximation of complex groundwater flow scenarios. This method is particularly valuable in practical groundwater management and engineering applications where accurate predictions of groundwater behavior are essential.

Top of Form

The groundwater flow equation, typically expressed as Darcy's law combined with the continuity equation, represents the fundamental equation in groundwater hydrodynamics:

$$\nabla \cdot (K \nabla h) = S$$

Where:

h is the hydraulic head,

K is the hydraulic conductivity tensor,

S is the source/sink term.

Method Steps:

Discretization: The domain is divided into discrete elements (e.g., finite difference cells or finite elements) to approximate the continuous flow equations.

Linearization: Nonlinear terms in the equations are linearized using an iterative approach.

Iteration: The linearized equations are solved iteratively until convergence is achieved.

Update: Hydraulic head values are updated based on the iterative solution.

Convergence Criterion: The iteration continues until the difference between successive iterations falls below a predefined tolerance level.

The utility of the series expression for $W(u)$ given by Eq. is that for small values of (u) is,

$$W(u) = -0.5772157 - \ln u$$

$$\text{Therefore, } s(u) = \frac{Q_w}{4\pi T} [-0.5772157 - \ln u]$$

$$\text{or, } s(u) = \frac{Q_w}{4\pi T} \left[-0.5772157 - \ln \left(\frac{r^2 S}{4Tt} \right) \right]$$

$$\text{or, } s(u) = \frac{2.303 Q_w}{4\pi T} \log \left(\frac{2.25 T t}{r^2 S} \right)$$

This approximation was first applied to the analysis of groundwater flow by **Cooper and Jacob (1946)** and is commonly referred to as the **Cooper-Jacob approximation**.

For $u < 0.03$ and the error is less than 1%, and for $u = 0.1$ the error is about to 5%. Typical applications of the **Cooper-Jacob approximation** are limited to $u < 0.05$.

Application of the **Cooper-Jacob approximation** in cases where there is a constant pumping rate, usually consists of the following steps:

- Step1: Plot S vs (r^2/t) from the measurement taken from the well, different r value can be used.
- Step 2: Fit a straight line to the data corresponding to the $u < 0.5$
- Step 3: Determine the a and b from the equation best fit line
- Step 4: Solve T and S from corresponding equation.

Application:

The Cooper-Jacob method in groundwater hydrodynamics finds application in various

groundwater modeling scenarios, including:

Aquifer Simulation: Modeling flow and transport in aquifers with heterogeneous properties.

Well Hydraulics: Analyzing the behavior of pumping wells and their impact on groundwater levels.

Contaminant Transport: Simulating the movement of contaminants through groundwater systems.

Managed Aquifer Recharge: Optimizing strategies for injecting water into aquifers for storage and later recovery.

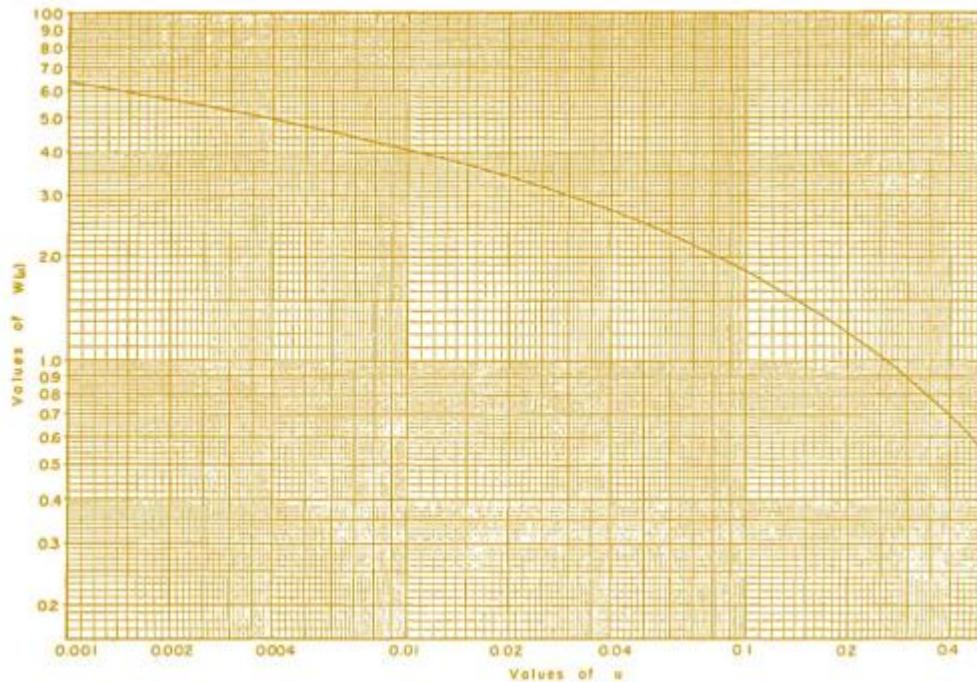


Figure 12: Plot of $W(u)$ vs u known as a type curve (Bruin & Hudson Jr., 1961)

u	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
$\times 1$	0.2194	0.1489	0.0130	0.0038	0.0011	0.0004	0.0001	0.0000	0.0000
$\times 10^{-1}$	1.8229	1.2227	0.9057	0.7024	0.5598	0.4544	0.3738	0.3106	0.2602
$\times 10^{-2}$	4.0379	3.3547	2.9591	2.6813	2.4679	2.2953	2.1508	2.0269	1.9187
$\times 10^{-3}$	6.3315	5.6394	5.2349	4.9482	4.7261	4.5448	4.3916	4.2591	4.1423
$\times 10^{-4}$	8.6332	7.9401	7.5348	7.2472	7.0242	6.8420	6.6879	6.5545	6.4368
$\times 10^{-5}$	10.9357	10.2428	9.8372	9.5494	9.3264	9.1440	8.9899	8.8564	8.7386

Figure 13: Values of $W(u)$ & u

Tubewell sustainability analysis:

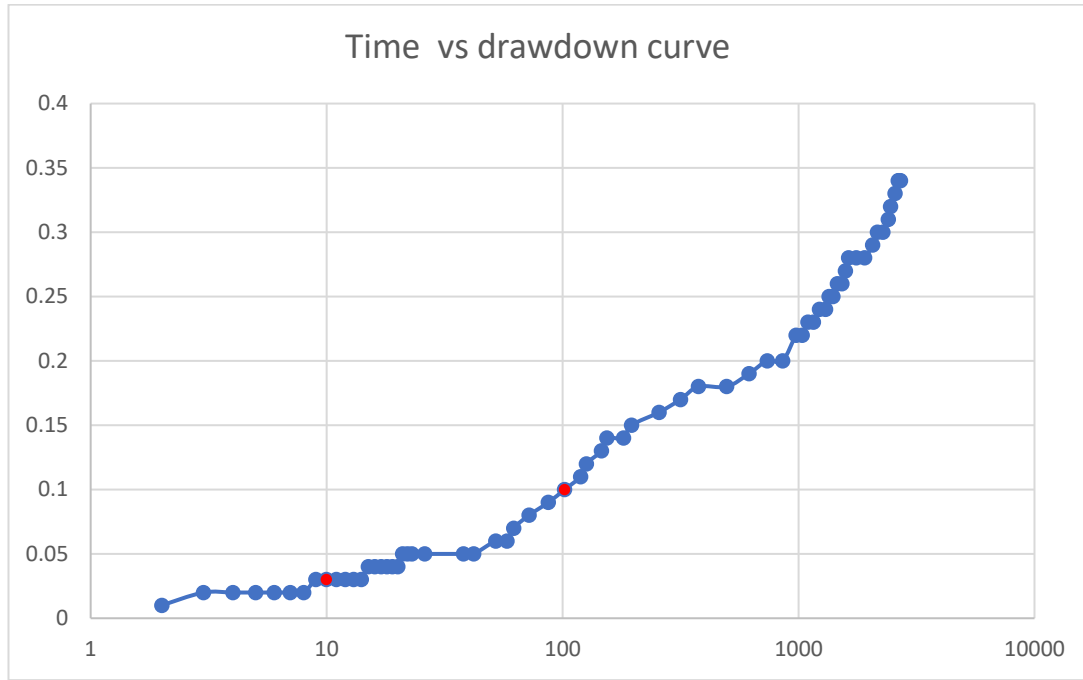


Figure 14: Time vs Drawdown curve of Tubewell

Recuperation data attached as annexure 3

Drawdown from the graph comes out to be $\Delta s = 0.525$.

Now we can calculate T using following equation

$$T = \frac{2.3 \times Q}{4\pi \Delta s}$$

Where putting $Q = 1253.52$ cum/day we get $T = 1188$,

$$u_w = \frac{r_w^2 \times s_y}{4\pi t}$$

Putting all the values $u_w = 6.485 \times 10^{-10}$, which is less than equal to 0.004 with error less than 0.1%

Now using

$$W_{(u_w)} = -0.5772 - \ln(u_w)$$

$$W_{(u_w)} = 20.579$$

Now according to the Theis equation

$$Q_w = \frac{4\pi T s_w}{W_{(u_w)}}$$

$$Q_w = 7254.35 \text{ cum/day}$$

$$Q_w = 302.26 \text{ cum/hr}$$

$$Q_w = 4836 \text{ cum/day (as pumping hour is 16 hrs)}$$

And the obtained yield is much higher than required for the said schemes where demand is 2186 cum/day.

5.5 Population Forecasting:

The design population will have to be calculated considering some factors governing the future growth and development of the project area in the industrial, commercial, educational social and administrative spheres. Special factors causing certain emigration or influx of population should also be foreseen to the extent possible.

A judgment based on this factor would help in selecting the most suitable method of deriving the probable trend of population growth in the area or areas in the project from out of the following methods, graphically interpreted where necessary.

5.5.1 Demographic method of population projection:

Population change can occur only in three ways (i) By Birth (ii) By Death (iii) Migration. Population forecasts are frequently obtained by preparing and summing up separate but related projections of natural increases and net migration and are expressed below.

The net effect of births and deaths on population is termed as a natural increase (natural decrease if death exceeds birth).

Migration also affects the number of birth and death in an area and so, projections of the net migration are prepared before the projection of natural increase.

This method thus takes into account the prevailing and anticipated birth rate and death rate of the region and city for the period under consideration. An estimate is also made of the emigration from and immigration to the city, growth of the city area wise and the net increase of population calculated accordingly considering all these factors, by arithmetical balancing.

5.5.2 Arithmetic Increase Method:

This method is generally applicable to large and old cities. In this method, the average increase in population per decade is calculated from the past records and added to the present population to find out the population in the next decade. This method gives low value and is suitable for well-settled and established communities. This method is given in equation.

$$P_n = [P_0 + n\bar{x}]$$

where,

P_n = Prospective or forecasted population after n decades.

P_0 = Population at present.

n = Number of decades between now and the future.

$\bar{x}$ = Average (arithmetic mean) of population increases in the known decades.

5.5.3 Incremental Increase Method:

In this method, the increment in arithmetical increase is determined from the past decade and the average of that increment is added to the average increase. This method increases the figures obtained by the arithmetic increase method. This method is given in equation number (5.2).

$$P_n = P_0 + n\bar{x} + \left[\frac{n(n+1)}{2} \right] \bar{y}$$

where,

$\bar{x}$ = Average increase of population of known decades.

$\bar{y}$ = Average incremental increases of the known decades.

5.5.4 Geometrical Increase method:

In this method percentage increase is assumed to be the rate of growth and the average of the percentage increases is used to find out future increments in population. This method gives much higher value and is mostly applicable for growing towns and cities having vast scope for expansion. This method is given in equation no (5.3).

$$P_n = P_0 \left(1 + \frac{r}{100} \right)^n$$

where,

r = Assumed growth rate (%).

5.5.5 Graphical Method:

In this approach, there are two methods. In one, only the city in question is considered and in the second, other similar cities are also taken into account.

a) Graphical Method based on Single City:

In this method, the population curve of the city is smoothly extended for getting future value. This extension has to be done carefully and it requires vast experience and good judgment. The line of best fit may be obtained by the method of least squares.

b) Graphical Method based on cities with similar growth pattern:

In this method, the city in question is compared with other cities which have already undergone the same phases of development that the city in question is likely to undergo and based on this comparison a graph between populations and decades is plotted.

5.5.6 Logistic Method:

The S-shaped logistic curve for any city gives a complete trend of growth of the city right from beginning to saturation limit of the population of the city.

5.5.7 Method of density:

In this approach, the trend in the rate of density increase of population for each sector of a city is found out and population forecast is done for each sector based on the above approach. The addition of sector-wise population gives the population of the city.

5.5.8 Per capita supply:

Per capita supply depends upon following factors-

Basic needs:

Pipe water supplies for communities should provide adequately for the following as applicable:

- a. Domestic needs such as drinking, cooking, bathing, washing, flushing of toilets, gardening and individual air conditioning.
- b. Industrial Needs.
- c. Public purpose such as street washing or watering, flushing of sewers, watering of public parks.
- d. Industrial and commercial uses including central air conditioning.
- e. Fire fighting.
- f. Requirements of livestock; and
- g. Minimum permissible “unaccounted for water (UFW)”

5.1.9 Factors affecting consumption:

a. Size of the city

The per capita demand for big cities is generally large as compared to the smaller towns as the larger cities, required huge quantities of water for maintaining clean and healthy environments.

b. Characteristics of population and standard of living:

Rich and upper-class communities generally consume more water to their affluent living standards than poor or middle-class communities. The habit of the persons also affects consumption.

c. Industrial and Commerce:

The type and number of different industries also affect consumption. Commercial consumption is that of retail and wholesale mercantile houses and office buildings.

d. Climatic Condition:

In hot weather, the consumption of water is more compared to that during cold weather.

e. Metering:

The consumption of water when supply is metered is less compared to that when the water charges are on a flat rate basis.

5.5.10 Recommendations:

The Environmental Hygiene Committee suggested certain optimum service levels for communities based on population groups. In the code of Basin Requirements of Water Supply, Drainage and Sanitation (IS 1172-1983) as well as the National Building Code, a minimum of 135 lpcd has been recommended for all residents provided with a full flushing system for excreta disposal. Through the manual on sewerage and sewage treatment recommends a supply of 150 lpcd wherever sewage exists/ is contemplated, intending to conserve water, a minimum of 135 lpcd is now recommended.

It is well recognised that minimum water requirements for domestic and other essential beneficial uses should be met through the public water supply. Other needs of water including industries etc may have to be supplemented from other systems depending upon the constraints imposed by the availability of capital finances and the proximity of water sources having adequate quantities of acceptable quality which can be economically utilized for public water supplies.

Based on the objectives of full coverage of urban communities with easy access to portable drinking water in quantities recommended to meet the domestic and other essential non-domestic needs, the following recommendations are made.

a) Domestic and non-domestic needs:

The recommended values for domestic and non-domestic purposes are given in Table (CPHEEO Manual, 1999).

Table 8: Recommendation per capita water supply level for designing schemes

Serial number	Classifications of Towns / Cities	Recommended maximum water supply level (lpcd)
1	Towns provided with piped water supply but without a sewerage system	70
2.	Cities provided with piped water supply where sewerage system is existing/contemplated	135
3	Metropolitan and megacities provided with piped water supply where sewerage system is existing/contemplated.	150

i. In urban areas, where water is provided through public stand posts, 40 lpcd should be considered.

ii. Figures exclude “unaccounted for water (UFW)” which should be limited to 15%. as per the CPHEEO manual (1999).

iii. Figures include requirements of water for commercial, institutional and minor industries.

However, the bulk supply to each establishment should be assessed separately with proper justification.

b) Institutional needs:

The water requirements for the institution should be provided in addition to the provisions indicated above, where required, if they are of considerable magnitude and not covered in the provisions already made. The individual requirements are mentioned in the following Table 3 (CPHEEO manual, 1999).

Table 9 Institutional demand

Serial Number	Institutions	Litres Per head per day
1	Hospital (including Laundry)	
	a. Number of beds exceeding 100 b. Number of beds not exceeding 100	450 (per bed) 340 (per bed)
2	Hotels	180 (per bed)
3	Hostel	135
4	Nurses homes and medical quarters	135

5	Boarding School / Colleges	135
6	Restaurants	70 per seat
7	Airports and Seaports	70
8	Junction Station and intermediate stations where mail or express stoppage (Both Railway and Bus stations) is provided.	70
9	Terminal Stations	45
10	Intermediate Stations (excluding mail and express stops)	45
11	Day school / Colleges	45
12	Office	45
13	Factories	45
14	Cinema, Concert hall and theatre	15

5.5.11 Fire fighting demand:

It is usually to provide for firefighting demand as a coincident draft on the distribution system along with the normal supply to the consumers as assumed. A provision in kilo litres/day based on the equation of

$$100\sqrt{P}$$

where P = Populations in thousands may be adopted for communities larger than 50,000.

It is desirable that 1/3rd of the fire fighting requirements from part of the service storage the balance requirement may be distributed in several static tanks at strategic points. These static tanks may be filled from the nearby ponds stream or canals by water tankers wherever feasible. The high-rise building should be provided with adequate fire storage from the protected water supply distribution.

5.5.12 Industrial needs:

While the per capita rates of supply recommended will ordinarily include the requirement of small industries (other than factories) distributed within a town, separate provisions will have to be included for meeting the demands likely to be made by specific industries within the urban areas. The forecast of this demand will be based on the nature and magnitude of each such industry and the quantity of water required per unit of production. The potential for industrial expansion should be carefully investigated so that the availability of adequate water supply may attract such industries and add to the economic prosperity of the community as can be seen from the tabulation the quantities of water used by industry vary widely. They are also affected by many factors such as cost and availability of water, waste

disposal problems, management and the types of processes involved. Individual studies of the water requirement of a specific industry should therefore be made for each location, the values given below serve only as guidelines. In the context of the reuse of water in several industries, the requirement for freshwater is getting reduced considerably. All the water requirement in Kiloliters per unit is defined in Table(CPHEEO manual, 1999).

Table 10: Industrial Demand

Industry	Unit of Production	Water requirement in Kiloliters per unit
Automobile	Vehicle	40
Distillery	Kilolitre alcohol	122-170
Fertiliser	Ton	80-200
Leather	100 kg (Tanned)	4
Paper	Tonne	200-400
Special Quality paper	Tonne	400-1000
Straw Board	Tonne	75-100
Petroleum Refinery	Tonne (Crude)	1-2
Steel	Tonne	200-250
Sugar	Tonne (Cane Crushed)	1-5
Textile	100 kg (Goods)	8-14

5.5.13 Pressure Requirements:

Piped water supplies should be designed on a continuous 24 hrs basis to distribute water to the consumer at adequate pressure at all points. Intermittent Supplies are neither desirable from the public health point of view nor economical for towns where one-storied buildings are common and for supply to the ground level storage tanks in multi-storied buildings, the minimum residual pressure at ferrule point should be 7 m for direct supply. Where two-storied buildings are common, it may be 12 m and where 3 storied buildings are prevalent 17 m or as stipulated by local bye-laws. The pressure required for firefighting would have to

be boosted by the fire engines.

5.6 Design Period:

Water Supply projects may be designed normally to meet the requirements over thirty years after their completion. The time lag between design and completion of the project should be taken into account which should not exceed two years to five years depending on the size of the project. The thirty years may however be modified in regard to certain components of the project depending on useful life or the facility for carrying out extension when required and rate of interest so that expenditure far ahead of utility is avoided. Necessary land for future expansion/duplication of components should be acquired at the beginning itself. Where expensive tunnels and large aqueducts are involved entailing large capital outlay for duplication, they may be designed for ultimate project requirements. Where failure such as the collapse of steel pipes under vacuum put the pipeline out of commission for a long time or the pipe location presents special hazards such as floods, ice, and mining, etc., duplicate lines may necessary.

Project components may be designed to meet the requirements of the following design period.

The design period of different structures is mentioned in the following Table 4.4(CPHEEO manual, 1999). In this study we have considered 30 years design period of the distribution system as mentioned in the below Table.

Table 11:Design Period of different components

Serial number	Item	Design period (in years)
1	Storage by Dam	50
2	Infiltration works	30
3	Pumping	
	i) Pump House	30
	ii) Electric Motor and pump	15
4	Water Treatment unit	15
5	Pipe Connection to several treatment unit	30
6	Raw water and clear water conveying main	30
7	Clearwater reservoir at the headwork, balancing tank and	15
8	Distribution System	30

5.7 Methods of Distribution:

The prime objective of a water distribution system design is to provide an adequate amount of pressure (as per CPHEEO guidelines) at the consumer end. Depending upon the elevation of the reservoir (water source) and that of the city or village, the topography of the area and other local conditions and considerations, the water may be supplied through the distribution system in the following three ways

- Gravitational System.
- Pumping System.
- By combined gravity and pumping system. These systems are described

below:

- a) **Gravitational System:** In this system, the water is supplied from the water source which is situated at a higher elevation than the distribution area (consumers) with comparatively lower elevation, by the actions of gravity without any use of pump. For proper functioning of this system, sufficient difference of head between source and the distribution area (consumers), is required to maintain adequate pressure at the consumer end after considering frictional and other loss.

Advantages of Gravity system:

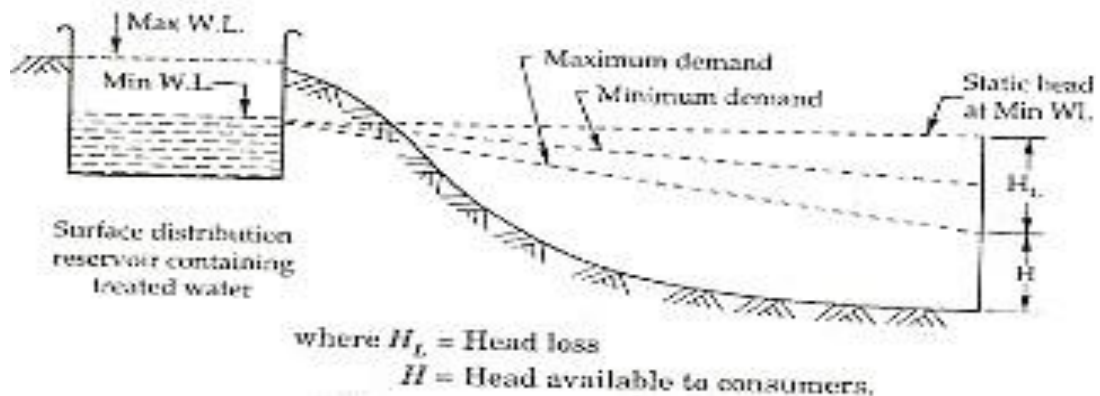


Figure 15: Gravitational System (source: Book of garg, 2015)

- This method is the most economical and reliable method as no pumping is required at any stage
- Pressure does not change suddenly.
- The maintenance cost is very low.
- This will keep the leakages and the wastages to be minimum.

- b) **Pumping System:** In the pumping system, treated water is directly pumped into the distribution mains without storing it anywhere. High lift pumps are required in these systems which have to operate at variable speeds to meet the variable demand of water. This type of system is generally used where the elevation of the source is lower than the elevation of the distribution area (consumers). The pumps are used to improve the required pressure head to distribute the water to the consumers and storage reservoir. This type of system is very useful during fires as it can force a large volume of water under high pressure in the required direction.

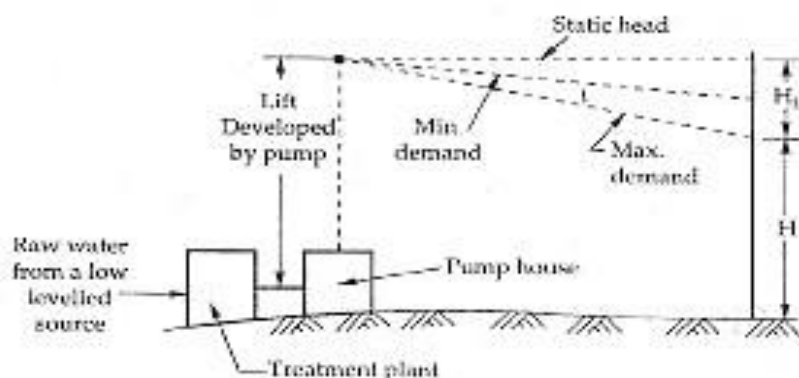


Figure 16: Pumping System (source: Book of Garg, 2015)

Disadvantages of pumping system:

- Continuous power supply and monitoring are needed at the pumping station, to provide the desired flow in the distribution system.
- This pumping system depends on the power supply if the power supply fails, there will be a complete stoppage of the water supply.

c) **Combined gravity and pumping system:** In this system, the treated water is pumped out at a constant rate and stored into an overhead reservoir, from where it is distributed to the consumer by the actions of gravity. Sometimes the entire water is first of all pumped into the distribution reservoir, and many a time, it is pumped into the distribution main and distribution reservoir simultaneously. During low demand periods the reservoir stores the excess water and during high demand periods it supplies to the consumers. This system is very productive, economical and dependable.

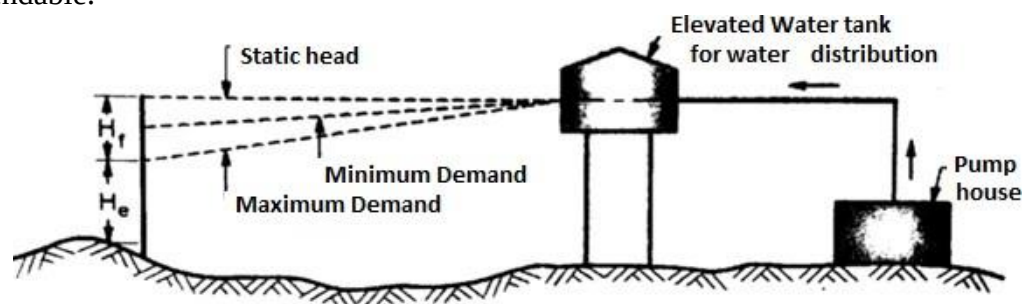


Figure 17: Combined Gravity and Pumping system
(international journal of Mechanical Engg. Vol 7 No. 5 May, 2022)

5.8 Distribution Systems (Network Configurations)

The distribution pipes are generally laid below the road pavements so both of their layouts are the same. Depending upon the local conditions and orientation of roads the network systems are divided into four different types. They are:

- i) Dead End System (Tree)
- ii) Radial System
- iii) Grid Iron System (Loop)
- iv) Ring System

Dead End System

In the dead-end system, which is also sometimes called the Tree system, there is one pipe, from which a number of sub-main pipes (generally right angle) originate.

Each sub-main then divides into several branch pipes, called laterals. From the laterals service connections are given to the consumers.

Dead End or Tree System

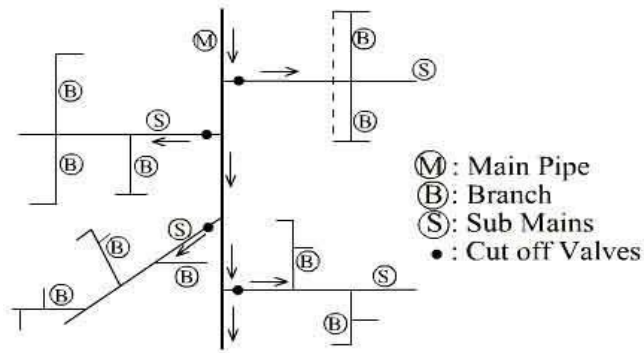


Figure 18: Dead End System (source: Book of Garg,2015)

This type of layout may have to be adopted for older towns that have developed haphazardly without properly planned roads.

Advantages of this system are:

- a) The design and building of this system are very simple. The distribution network can be solved very easily.
- b) Very few cut-off valves (i.e. sluice valves) are required in this system.
- c) Laying the pipe is very easy, shorter pipe lengths are needed.

Disadvantages of this system are:

- a) Any repair or damage in any pipeline will completely stop the water supply in the area being fed by the pipe as in this method water can reach a particular point only through one route.
- b) There are many numbers of dead ends in this system that prevents the free circulation of water and the quality of water gets decreased due to stagnation of water.

Grid-iron System

In this system, the main pipes, sub-main pipes, branch pipes are connected to each other. This type of system is mainly designed for a well-planned city or town where the roads are generally developed in a grid-iron pattern.

Advantages of this system are:

- a) The friction loss and the diameter of the pipe are reduced as the water reaches different places through more than one route.
- b) In the time of repair and maintenance, a small area will be devoid of complete supply as some suppliers will be reaching at the point from some another route.

Water remains in continuous circulation as all the pipes are interconnected and there is no dead-end hence the quality does not get reduced.

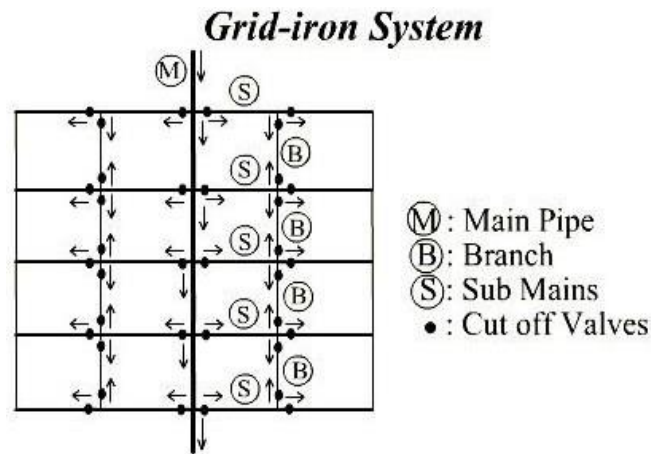


Figure 19: Grid Iron System(source: Book of Garg, 2015)

Disadvantages of this system are:

- a) Its construction is costlier.
- b) The design is difficult and costlier.
- c) The system requires more length of pipelines and a larger number of sluice valves.

Ring System:

In this system, a closed ring, either circular or rectangular, of the main pipe is formed around the area to be served. The distribution area is divided into rectangular or circular blocks, and main water pipes are laid on the periphery of these blocks. These types of systems are ideal for cities having well-planned roads.

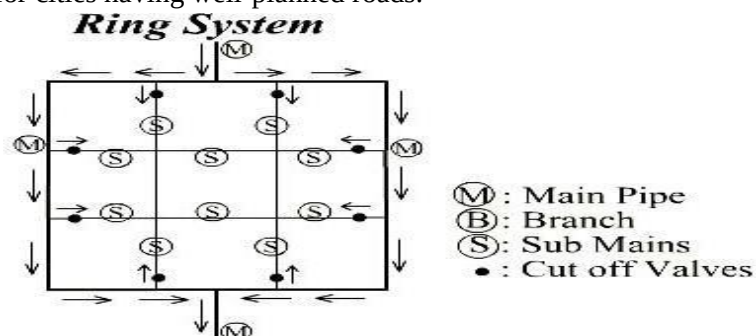


Figure 20: Ring System (source: Book of Garg, 2015)

Advantages of this system are:

- a) As the water is continuously circulating so water does not get stagnant.
- b) Repair works can be done without affecting the other part of the network.
- c) A large quantity of water is available for fire fighting.

Disadvantages of this system are:

- a) A longer length and large diameter pipes are required.
- b) More cut-off valves are necessary.
- c) Skilled manpower is necessary while laying pipes.

Radial System:

In this system, water is supplied from the water main pipe to the distribution reservoir through pumping and then the water is supplied through the radially laid distribution pipes to the consumers. This type of system is designed for those towns having a system of radial roads from different centres, where the pipelines can be laid in a radial method by placing

the distribution reservoir at the centres.

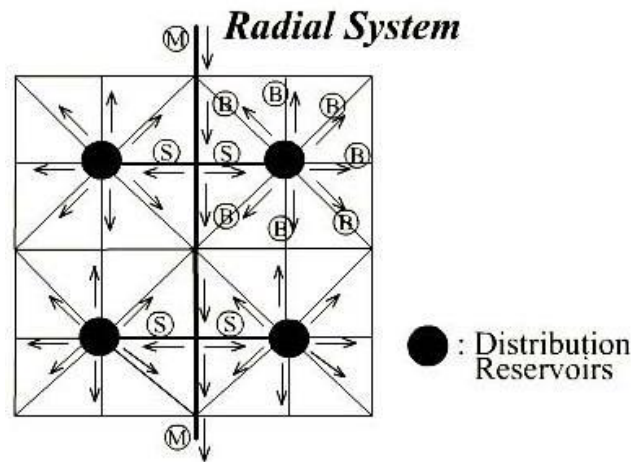


Figure 21: Radial System (source: Book of Garg, 2015)

Advantages of this system are:

- a) This system ensures adequate pressure and efficient water distribution
- b) It is very easy to calculate pipe sizes.
- c) Head loss is very small because of quick discharge.

Disadvantages of this system are:

- a) The cost of the project is more because of the number of individual distribution reservoirs.
- b) A fault on the single feeder or distributor causes an interruption in the supply to all the users connected to that distributor.

5.9 Hydraulics of network systems:

Pipeline networks include series pipes, parallel pipes, and branching pipes. These simple networks can be converted to an equivalent pipe, which helps simplify and analyse these networks. The equivalent pipes are those pipes when more than one pipe delivers the same rate of flow.

Series Pipes:

For a system with two or more pipes in series, the total head loss is,

$$h_{Le} = \sum h_{Li}$$

Or

$$K_e Q^n = \sum K_i Q^{ni} = K_1 Q^{n1} + K_2 Q^{n2} + K_3 Q^{n3} + \dots$$

where K_e is the pipe coefficient for the equivalent pipe. When using Hazen-Williams equation, all $n=1.85$ and when using Darcy-Weisbach equation, $n=2$ for rough pipes and $n=1.75$ for smooth pipes for fully turbulent flow:

therefore K_e simplifies to

$$K_e = K_1 + K_2 + \dots = \sum K_i$$

For Darcy-Weisbach equation

$$K = \frac{8fL}{\pi^2 g D^5} \quad h_L \text{ is the head loss in m, } L \text{ is the pipe length in m, } Q \text{ is}$$

the flow rate in m^3/s , D is the pipe diameter in m, and g is the acceleration due to gravity, 9.81 m/s^2 .

For Hazen-Williams equation

$$K = \frac{\phi L}{C^{1.85} D^{4.87}}$$

where $\phi = 4.73$ for U.S customary units and $\phi = 10.66$ for SI units. The head loss h_L is in m: L is the pipe length in Q is the flow rate in m^3/s , D is the pipe diameter in m.

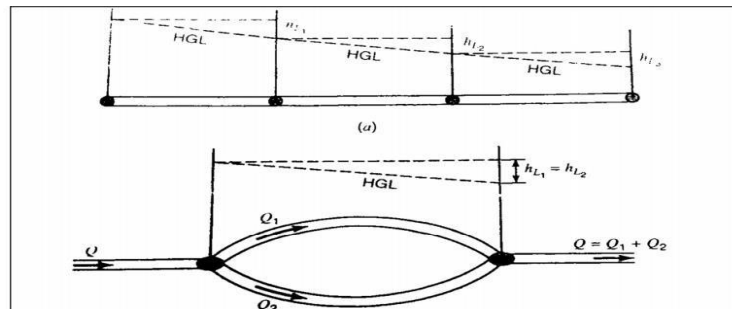


Figure 22: (a) Series Pipe system (b) Parallel pipe system (source: Book of Garg , 2015)

Parallel Pipes:

The Concept of an equivalent pipe can be applied to two or more pipes that are parallel then the head loss of each pipe between junctions must be equal:

$$h_L = h_{L1} = h_{L2} = h_{L3} = h_{L4} \dots$$

The total flow rate is the sum of individual flows in each pipe and is given as

$$Q = Q_1 + Q_2 + Q_3 + Q_4 + \dots$$

Substituting

$$Q = \left(\frac{h_L}{K_e} \right)^{\frac{1}{n}}, \text{ from } h_L = KQ^n, \text{ into equation yields.}$$

$$\left(\frac{h_L}{K_e} \right)^{\frac{1}{n_e}} = \left(\frac{h_L}{K_1} \right)^{\frac{1}{n_1}} + \left(\frac{h_L}{K_2} \right)^{\frac{1}{n_2}} + \left(\frac{h_L}{K_3} \right)^{\frac{1}{n_3}} + \dots = \sum_{i=1}^n \left(\frac{h_L}{K_i} \right)^{\frac{1}{n_i}}$$

When using the Hazen-Williams Equation-

All n_i are equal

$$\left(\frac{1}{K_e} \right)^{\frac{1}{n}} = \left(\frac{1}{K_1} \right)^{\frac{1}{n}} + \left(\frac{1}{K_2} \right)^{\frac{1}{n}} + \left(\frac{1}{K_3} \right)^{\frac{1}{n}} + \dots = \sum_{i=1}^n \left(\frac{1}{K_i} \right)^{\frac{1}{n}}$$

Branching Pipe Flow:

The flow distribution in branching systems can be determined by applying the continuity and energy equations.

Flow Continuity Equation:

The sum of inflows entering the junction equals the sum of flows leaving the junction.

$$\sum \text{Inflow} = \sum \text{Outflow}$$

When the junction J is considered as shown in Fig.4.10 where five pipes are interconnected and there is an outflow demand. The directions of flows Q_1 , Q_2 and Q_4 are entering the junction, while the directions of flows Q_3 , Q_5 and Q_6 are leaving the junction. By common sense, the total flow entering the junction should be equal to the total flow leaving the junction because it neither creates nor stores any flow inside, and thus, the Figure represents it.

$$Q_1 + Q_2 + Q_4 = Q_3 + Q_5 + Q_6$$

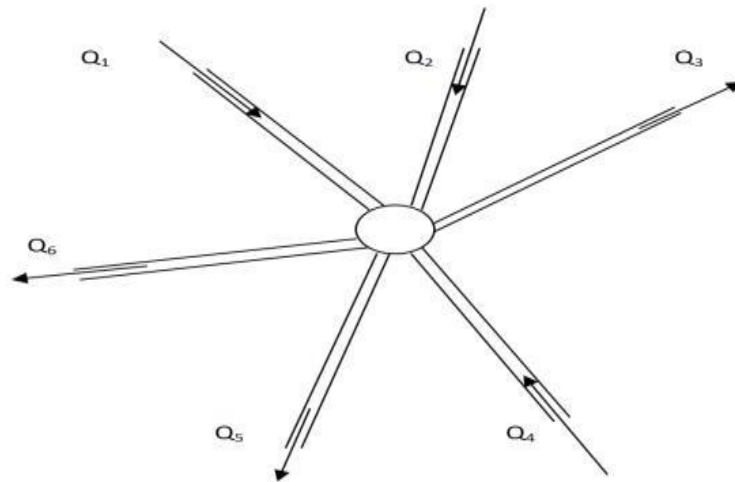


Figure 23: Flow across a Junction

Energy Equation:

The difference in hydraulic head between any two junctions within any pipe system equals the net head losses between junctions are represented in equation number (5.8)

$$[P_a + Z_a] - [P_b + Z_b] = h_l - h_p$$

And

$$P_a + Z_a + \frac{V_a^2}{2g} + h_p = P_b + Z_b + \frac{V_b^2}{2g} + h_l$$

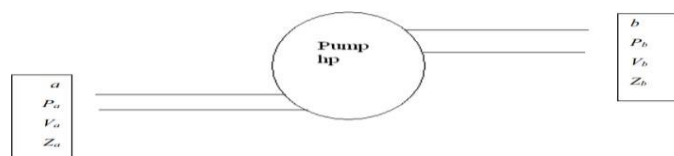


Figure 19: Flow through the pump.

Chapter 6-Application of WaterGEMS Software

6.1 Overview of WaterGEMS software:

WaterGEMS from Bentley Systems helps engineers to model, design and analyze complex pressurized piping systems. This software has a powerful graphical interface (both in Stand-Alone and AutoCAD mode) makes it easy to quickly layout a complex network of pipes, tanks, pumps, and more.

In industries, this network simulation software is used to

- a) Perform steady-state analyses of water distribution systems with pumps, tanks, and control valves.
- b) Perform extended period simulations to determine the piping system's response in varying supply and demand schedules.
- c) Perform water quality simulations to determine the water source and age, or track the growth or decay of a chemical constituent throughout the network.
- d) Perform Fire Flow Analysis on the system to determine how your system will behave under extreme conditions.
- e) Create multiple sets of hydraulic, physical property, operational, initial setting, fire flow, cost, and water quality alternatives.
- f) Calibrate our design manually or with the assistance of the Darwin Calibrator, which utilizes the power of Genetic Algorithms.

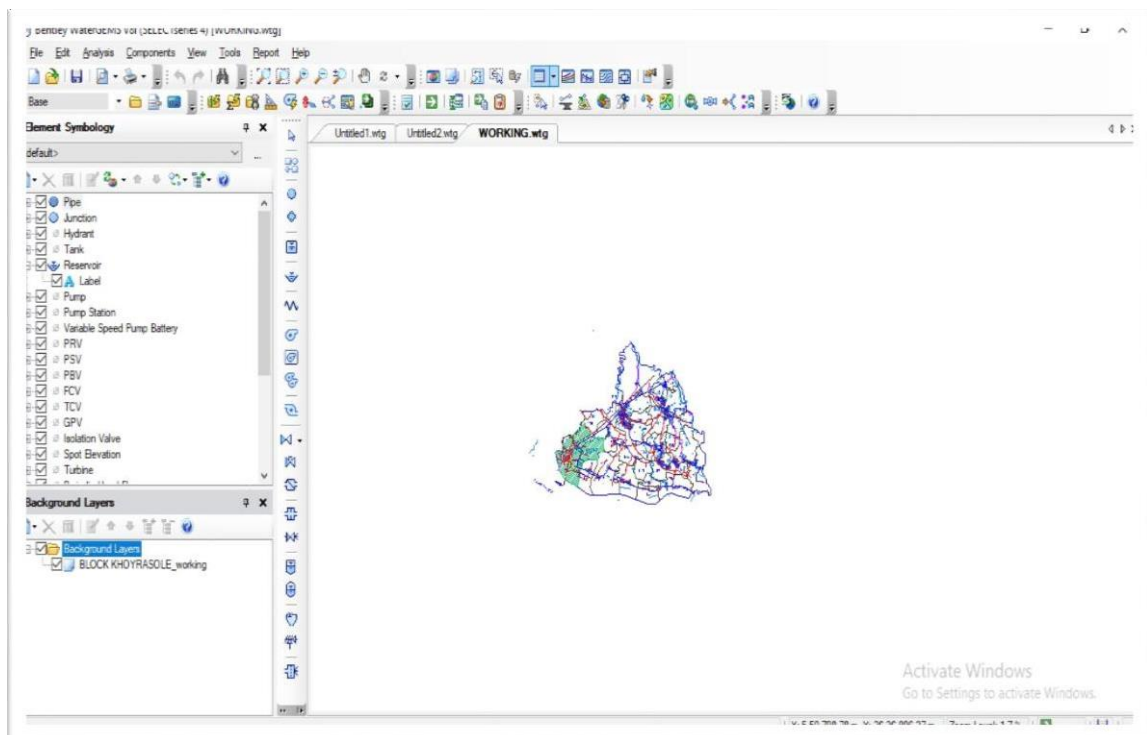


Figure 24: WaterGEMS V8i Home screen

Hydraulic Model Capabilities:

- a) This network simulation software perform steady-state, extended period and water quality simulations

- b) This network simulation software reduces time wasted on preparing the bill of quantities, thus it helps the civil engineer in estimating construction costs.
- c) It helps the civil engineer to determine water sources and age at any element in the system. Model cylindrical and non-cylindrical tanks and constant hydraulic grade source nodes.
- d) This network simulation software will help us to design multiple time-variable demands at any junction node. This software provides solutions to model flow valves, pressure-reducing valves, pressure sustaining valves, pressure breaking valves and throttle control valves.
- e) This network simulation software can track conservative and non-conservative chemical constituents present in water.

Physical Components of the software :

The basic physical components of the software is junction , pipe, reservoir , tank, pump. A brief description of all the components is narrated below.

Junctions:

Junctions are points in the network where links join together and where water enters or leaves the network. The basic input data required for junctions are:

- Elevation above some reference level.
- Water demand i.e. the rate of withdrawal from the network.
- Initial water quality.

The output results computed for junctions are

- Hydraulic head (internal energy per unit weight of water)
- Pressure
 - Water quality. Junctions can also:
- Have their demand vary with time.
- Have multiple categories of demands assign to them.

Reservoir:

Reservoirs are nodes that represent an infinite external source or sink of water to the network. They are used to model such things as lakes, rivers, groundwater aquifers, and tie-ins to other systems. The primary input properties for a reservoir are its hydraulic head (equal to the water surface elevation if the reservoir is not under pressure) and its initial quality for water quality analysis. Because a reservoir is a boundary point to a network, its head and water quality cannot be affected by what happens within the network. Therefore it has no computed output properties.

Tanks:

Tanks are nodes with storage capacity, where the volume of stored water can vary with time during a simulation. The primary input properties for tanks are:

- Elevation (Base).
- Elevation / Level (Minimum)
- Elevation / Level (Initial)
- Elevation / Level (Maximum)
- Elevation (in the Physical section of tank properties).

• Diameter (or shape if non-cylindrical) The principal computed outputs are:

- Total head (water surface elevation)
- Flow output

Tanks can also be used as water quality source points.

Pipes:

Pipes are link elements that connect junction nodes, pumps, valves, tanks, and reservoirs. The principal hydraulic input parameters for pipes are,

- Start and end nodes
- Diameter
- Length
- Roughness coefficient (for determining head loss)
 - Status (open, closed, or contains a check valve).
- Computed outputs for pipes include
 - flow rate
 - velocity
 - headloss

The hydraulic head lost by water flowing in a pipe due to friction with the pipe walls can be computed using one of three different equations:

- i. Hazen-Williamsequation
- ii. Darcy-Weisbach equation
- iii. Chezy-Manning equation

The Hazen-Williams equation is the most commonly used headlossequation in the US. It cannot be used for liquids other than water and was originally developed for turbulent flow only. The Darcy-Weisbach equation is the most theoretically correct. It applies to all flow regimes and to all liquids. The Chezy-Manning equation is more commonly used for open channel flow. Each equation uses the following equation to compute headloss between the start and end node of the pipe. In this study Hazen Williams equation is considered during hydraulic analysis using WaterGEMS, EPANET software.

Table 12: Pipe Headloss equations for full flow

Pipe Head Loss Equation Name	Pipe Head Loss Equation
Hazen-Williamequation	$K = \frac{\phi L}{C^{1.85} D^{4.87}}$
Darcy-Weisbach Equation	$h_L = \frac{8 f L Q^2}{\pi^2 g d^5}$
Chezy-Manning Equation	$h_L = \frac{n^2 L Q^2}{0.0972 d^5}$

Where C=Hazen-Williams roughness co-efficient, f=Darcy-Weisbach Friction factor, L=pipe length
Q= flow rate (cum/s)

Table 13: roughness coefficients for new pipes

Material	Hazen-Williams, C (unit less)	Darcy-Weisbach, ε (m $\times 10^{-3}$)	Chezy-Manning, N (unit less)
Cast Iron	130-140	0.259	0.012-0.015
Concrete lined	120-140	0.3-3.0	0.012-0.017
Galvanized Iron	120	0.152	0.015-0.017
Plastic	145	0.002	0.011-0.015
Steel	140-150	0.046	0.015-0.017
Vitrified clay	110		0.013-0.015

Choosing a pipe material, pipes can be assigned a material type chosen from an engineering library. Each material type is associated with various pipe properties, such as roughness coefficient and roughness height. When a material is selected, these properties are automatically assigned to the pipe.

Minor Loss Type:

Minor head losses (also called local losses) are caused by the added turbulence that occurs at bends and fittings. The importance of including such losses depends on the layout of the network and the degree of accuracy required. They can be accounted for

by assigning the pipe a minor loss coefficient. The minor head loss becomes the product of this coefficient and the velocity head of the pipe, i.e

$$h_L = K \frac{V^2}{2g}$$

Where, K is minor loss coefficient, V is flow velocity (length/time) and g is the acceleration of gravity (length/time²).

Valves:

A valve is a node element that opens, throttles, or closes to satisfy a condition you specify. The following valve types are available in the softwares:

Their principal input parameters include:-

- start and end nodes
- diameters settings
- status

The computed outputs for a valve are flow rate and head loss.

Valve Type Description

Pressure Reducing Valve (PRV): PRVs throttle to prevent the downstream hydraulic grade from exceeding a set value. If the downstream grade rises above the set value, the PRV will close. If the head upstream is lower than the valve setting, the valve will open fully.

Pressure Sustaining Valve (PSV): A Pressure Sustaining Valve (PSV) is used to maintain a set pressure at a specific point in the pipe network. The valve can be in one of three states:

Partially opened (i.e., active) to maintain its pressure setting on its upstream side when the downstream pressure is below this value

Fully open if the downstream pressure is above the setting

Closed if the pressure on the downstream side exceeds that on the upstream side (i.e., reverse flow is not allowed).

Pressure Breaker Valve (PBV) PBVs are used to force a specified pressure (head) drop across the valve. These valves do not automatically check the flow and will actually boost the pressure in the direction of reverse flow to achieve a downstream grade that is lower than the upstream grade by a set amount.

Pumps:

Pumps are links that impart energy to a fluid thereby raising its hydraulic head. The principal input parameters for a pump are its start and end nodes and its pump curve (the combination of heads and flows that the pump can produce). In lieu of a pump curve, the pump could be represented as a constant energy device, one that supplies a constant amount of energy (horsepower or kilowatts) to the fluid for all combinations of flow and head. The principal output parameters are flow and head gain.

6.2 The WaterGEMS workspace consist of the following elements:

- Standard Toolbar
- Edit Toolbar
- Analysis Toolbar
- Scenarios Toolbar
- Compute Toolbar
- View Toolbar
- Help Toolbar
- Layout Toolbar
- Tools Toolbar
- Zoom Toolbar
- Customizing WaterGEMS Toolbars and Buttons
- WaterGEMS Dynamic Manager

The Standard toolbar contains controls for opening, closing, saving, and printing of projects which are simulated by the above software. Commands and usages of this toolbar.

- **New:** To Create dialog box opens, allowing us to define a name and directory location for the new project.
- **Open:** To allow us to browse the project to be opened.
- **Close:** To close the currently open project.
- **Close all:** To close all the projects that are opened.
- **Save:** To Save the current project.
- **Save as:** To save all the projects that are opened.
- **Print Preview:** To Open the Print Preview window, displaying the current view of the network as it will be printed.
- **Print:** To print the current view of the network.

Edit Toolbar:

- The Edit toolbar contains controls for deleting, finding, undoing, and redoing actions in the above mentioned software. Commands and usages of this toolbar.
- **Undo:** To Cancel our most recent action.
- **Redo:** To Re-do the last cancelled action.
- **Delete:** To Delete the currently selected element(s) from the network.
- **Clear Highlight:** To Remove the highlighting that can be applied using the Network Navigator.
- **Find Element:** To Find a specific element by choosing it from a menu containing all elements in the current model.
- **Analysis Toolbar:** The Analysis toolbar contains controls for analyzing WaterGEMS

- **Totalizing Flow Meters:** To allow us to view, edit, and create flow meter definitions.
- **Hydrant Flow Curves:** To allow us to view, edit, and create hydrant flow definitions.
- **System Head Curves:** To allow us to view, edit, and create system head definitions
- **Post Calculation Processor:** Here we can perform statistical analysis for an element or elements on various results obtained during an extended period simulation calculation.
- **Energy Costs:** Here we can view, edit, and create energy cost scenarios.
- **Darwin Calibrator:** Here we can view, edit, and create calibration studies.
- **Darwin Designer:** Here we can view, edit, and create designer studies.
- **Darwin Scheduler:** Here we can view, edit, and create Scheduler studies.
- **Criticality:** Here we can view, edit, and create Criticality studies.
- **Pressure Zone:** Here we can view, edit, and create Pressure Zone studies.

Scenarios Toolbar

- The Scenarios toolbar contains controls for creating scenarios in WaterGEMS V8i projects. Commands and usages of this toolbar.
- **Scenario List Box:** It helps us to change the current scenario.
- **Scenarios:** We can create, view, and manage project scenarios.
- **Alternatives:** Here we can create, view, and manage project alternatives.
- **Calculation Options:** Here we can create different profiles for different calculation settings.
- **Compute Toolbar:** The Compute toolbar contains controls for computing WaterGEMS projects.
- Commands and usages of this toolbar
- **Validate:** Run a diagnostic check on the network data to alert us to possible problems that may be encountered during calculation.
- **Compute:** It is used to calculate the water distribution network as per the input inserted and determine the output values.
- **EPS Results Browser:** To manipulate the currently displayed time step and to animate the drawing pane
 - Fire Flow Results Browser:
 - Flushing Results Browser:
 - Calculation Summary:
 - User Notifications:

} To open the respective dialogue boxes.

View Toolbar:

- The View toolbar contains controls for viewing WaterGEMS projects. Commands and usages of this toolbar.
- **Element Symbology:** To create, view, and manage the element symbol settings for the project.
- **Background Layers:** To create, view, and manage the background layers associated with the project
- **Network Navigator:** To Open the Network Navigator dialog box
- **Selection Sets:** To Open the Selection Sets Manager, allowing you to create, view, and modify the selection sets associated with the project.
- **Queries:** To Opens the Query Manager.
- **Prototypes:** To Opens the Prototypes Manager.
- **Flex Tables:** To create, view, and manage the tabular reports for the project.
- **Graphs:** To create, view, and manage the graphs for the project.
- **Profiles:** To create, view, and manage the profiles for the project.
- **Contours:** We can create, view, and manage named views
- **Named Views:** Here we can create, view, and manage named views.
- **Aerial View:** Here we can zoom to can zoom to different elements in the project.
- **Properties:** To open the property editor.
- **Customizations:** To open the customization manager

Layout Toolbar :

- The Layout toolbar is used to layout a model in the WaterGEMS V8i drawing pane. Commands and usages of this toolbar.

- **Select:** To Change our mouse cursor into a select. When this tool is active, click on the drawing pane to place the element.
- **Pipe:** To Change our mouse cursor into a pipe. When this tool is active, click on the drawing pane to place the element.
- **Junction:** To Change our mouse cursor into a junction. When this tool is active, click on the drawing pane to place the element.
- **Hydrant:** To Change our mouse cursor into a hydrant. When this tool is active, click on the drawing pane to place the element.
- **Tank:** To Change our mouse cursor into a tank. When this tool is active, click on the drawing pane to place the element.
- **Reservoir:** To Change our mouse cursor into a Reservoir. When this tool is active, click on the drawing pane to place the element.
- **Pump** To Change our mouse cursor into a pump. When this tool is active, click on the drawing pane to place the element.
- **Variable Speed Pump Battery:** To Change our mouse cursor into a variable speed pump battery. When this tool is active, click on the drawing pane to place the element.
- **Isolation Valve:** To Change our mouse cursor into an Isolation Valve. When this tool is active, click on the drawing pane to place the element.
- **Spot Elevation:** To Change our mouse cursor into a Spot Elevation. When this tool is active, click on the drawing pane to place the element.
- **Turbine:** To Change our mouse cursor into a turbine. When this tool is active, click on the drawing pane to place the element.
- **Periodic Head flow:** To Change our mouse cursor into a periodic head flow. When this tool is active, click on the drawing pane to place the element.
- **Air Valve:** To Change our mouse cursor into an air valve. When this tool is active, click on the drawing pane to place the element.
- **Hydro pneumatic Tank:** To Change our mouse cursor into a hydro pneumatic tank. When this tool is active, click on the drawing pane to place the element.
- **Surge Valve:** To Change our mouse cursor into a Surge Valve. When this tool is active, click on the drawing pane to place the element.
- **Check Valve:** To Change our mouse cursor into a check valve. When this tool is active, click on the drawing pane to place the element.
- **Rupture Disk:** To Change our mouse cursor into a rupture disk. When this tool is active, click on the drawing pane to place the element.
- **Discharge to Atmosphere:** To Change our mouse cursor into a discharge to the atmosphere. When this tool is active, click on the drawing pane to place the element.
- **Orifice between Pipes:** To Change our mouse cursor into an orifice between pipes. When this tool is active, click on the drawing pane to place the element.
- **Valve with Linear Area Change:** To Change our mouse cursor into a valve with linear area change. When this tool is active, click on the drawing pane to place the element.
- **Surge Tank:** To Change our mouse cursor into a surge tank. When this tool is active, click on the drawing pane to place the element.
- **Border:** To Change our mouse cursor into a border. When this tool is active, click on the drawing pane to place the element.
- **Text:** To Change our mouse cursor into a text. When this tool is active, click on the drawing pane to place the element.
- **Line:** To Change our mouse cursor into a line. When this tool is active, click on the drawing pane to place the element.

Tools Toolbar

- The Tools toolbar provides quick access to the same commands that are available in the Tools menu. Commands and usages of this toolbar
- **Active Topology Selection:** To open a Select dialog to select areas in the drawing.
- **Model Builder:** We can create, edit, and manage Model Builder connections to be used in the model-building/model synchronising process.
- **Trex:** We can select the data source type, set the elevation dataset, choose the model and features.
- **SCADA Connect:** Using this tool we can add or edit signals.
- **SkelebratorSkeletonizer:** It is used to define how to skeletonise our network.
- **Load Builder:** After opening this tool we can create a manage load builder template.
- **Thiessen Polygon:** It is used to create thissen polygon
- **Demand Control Center:** Here we can add new demands, delete existing demands, or modify existing demands
- **Unit Demand Control Center:** Here we can add new unit demands, delete existing unit demands, or modify existing unit demands
- **Hyperlinks:** Associate external files, such as pictures or movie files, with elements
- **User Data Extensions:** To add and define custom data fields. For example, you can add new fields such as the pipe installation date.
- **Compact Database:** To eliminate the empty data records, thereby defragmenting the data store and improving the performance of the file.
- **Synchronize Drawing:** To Synchronize the current model drawing with the project database.
- **Update Database Cache:** It Ensures consistency between the database and the model by recalculating and updating certain cached information.
- **Update Results from Project Directory:** This command copies the model result files (if any) from the project directory (the directory where the project .mdb file is saved) to the custom result file directory
- **Copy Results to Project Directory:** This command copies the result files that are currently being used by the model to the project directory.
- **Assign Isolation Valves to Pipes:** Here we can find the nearest pipe for each selected isolation and assign the valve to that pipe.
- **Batch Pipe Split:** To open the Batch Pipe Split dialog
- **Customize:** To open the external tool dialog box
- **Options:** To open the Options dialog box, which allows us to change Global settings, Drawing, Units, Labelling, and project-wise.

Zoom Toolbar:

- The Zoom toolbar provides access to the zooming and panning tools. Command and usage of this toolbar
- **Zoom Extents:** To set the view so that the entire model is visible in the drawing pane.
- **Zoom Window:** To activate the manual zoom tool, where you can specify a portion of the drawing to enlarge.
- **Zoom In:** To magnify the current view in the drawing pane
- **Zoom Out:** To reduce the current view in the drawing pane.
- **Zoom Real-time:** It allows us to zoom in and out by moving the mouse while the left mouse button is depressed.
- **Zoom Next:** To reset the zoom level to the setting that was active before a Zoom Previous command was executed.
- **Pan:** It allows us to move the model within the drawing pane.
- **Refresh Drawing:** To update the main window view according to the latest information contained in the Bentley WaterGEMS V8i data store.

Chapter 7-Results and Discussion

7.1Output:

The output parameters obtained from the above mentioned software are elevation, hydraulic grade, pressure, pressure head for each junctions and flow, velocity, headloss gradient and headloss for each pipe.

Table 14: Output obtained from WatwrGEMS software

Label	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)	Headloss Gradient (m/m)	Headloss (m)
P-1	R-1	J-1	350	DI	140	27.81	0.567	0.001	0.35
P-2	J-1	J-2	300	UPVC	145	5.479	0.515	0.002	0.3
P-3	J-2	J-3	300	UPVC	145	3.062	0.370	0.002	0.09
P-4	J-3	J-4	250	UPVC	145	2.907	0.352	0.001	0.15
		Minimum (m/s)		0.001	P-33, P-845, P-765,P-273, P-676,P-283		83.4	UPVC	
Headloss	Maximum (m)		0.78		P-824		83.8	UPVC	
	Minimum (m)		0		P-214, P-216, P-367		83.8	UPVC	

Parameter	Maximum/Minimum	Value	Pipe Number	Diameter	Material
Flow	Maximum (l/s)	27.81	P-1	350	DI
	Minimum (l/s)	0.003	P-181, P-203	83.4	UPVC
Velocity	Maximum (m/s)	0.816	P-49	186.4	UPVC

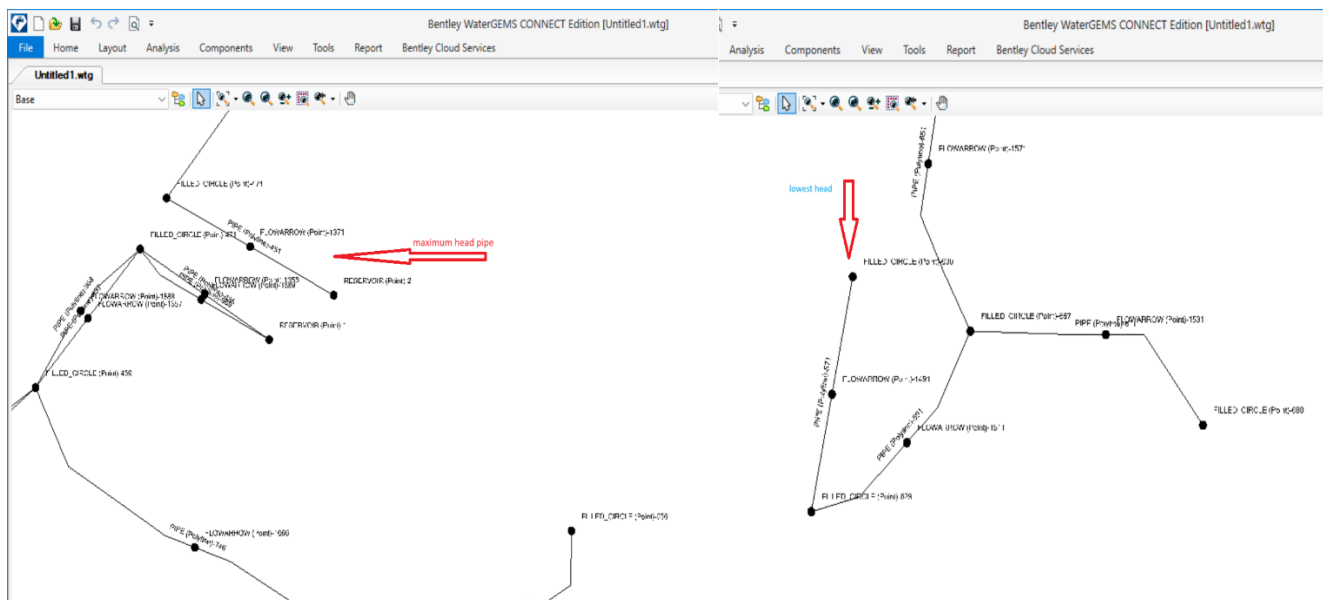


Figure 25: Shows the maximum and minimum values of each output parameter

Parameter	Maximum/Minimum	Value	Junction Number
Pressure (kPa)	Maximum	156.362	J-1
	Minimum	113.924	J-365
Pressure Head (m)	Maximum	15.96	J-1
	Minimum	9.65	J-189

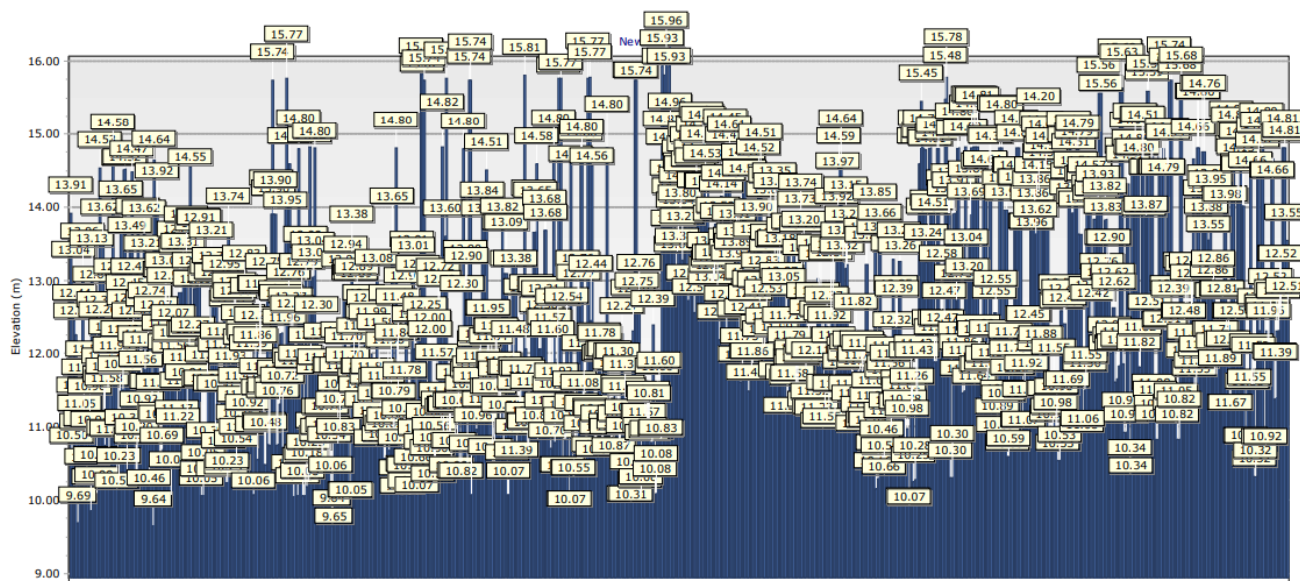


Figure 26: Profile of pressure at different junction

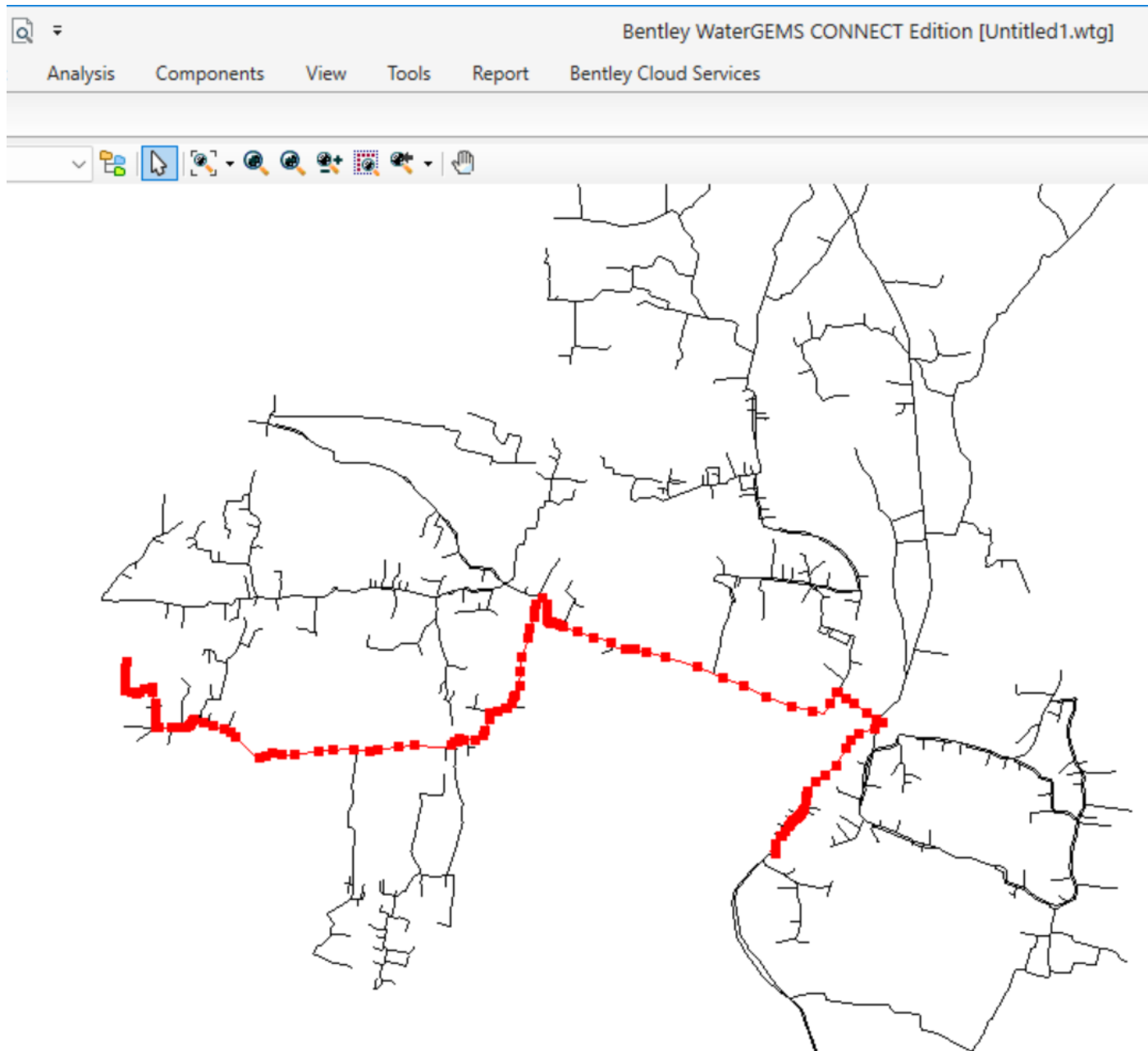


Figure 27: longest path of the water supply network highlighted in red

Chapter 8-Conclusion and Future scope of study

8.1 Conclusions:

WaterGEMS, computer-based modelling software for water distribution networks, was used in this study to conduct an empirical analysis of the water distribution system in Udaynarayanpur Zone I&II PWSS region of Udaynarayanpur block in the district of Howrah.

The main view of this work is to analyse the water distribution network and lookout the deficiencies (if any) in it is analysis, establishment and its usage. Based on the above study, it was found that the resulting pressures at all the junctions and the flows with their velocities at all pipes are adequate enough to provide water to the study area as per the consumer needs. There may be leakages in the pipes which results in the pressure difference which consequently results into the scarcity of water. Comparison of these results indicates that the simulated model seems to be reasonably close to actual network. With the use of this software one can indeed analyze the network at the desk and can foresee the error, if any, in the design and consequently the changes required to be done in such designs for its successful execution at site. The result reveals that the software used for the design has the capability to handle various pipe network problems without changing in model of or mathematical formulation. The software used was viable alternative to other methods particularly in view of accuracy and its results in a simpler algorithm, without any iterative process. At the end of the analysis it was found that the resulting minimum pressures at all the nodes and the links velocities are satisfy enough to provide water to the study area. The model results shows value of minimum pressure is

9.65 m of H₂O which is within the limit as per CEEPHO manual.

So our model has a good efficacy.

8.2 Future Scopes of Study:

This study consists of a huge number of node and pipe elements and whose length is obtained from GIS map which is less accurate and needs ground verification and in design considered ground is fairly level which not true in reality there are more or less undulation in actual in future considering actual ground elevation more accurate result may be obtained. Along with there are various software which deal with the pipeline analysis. More detailed data are required to have an accurate study of stress analysis at the bends and the supports to the joints of the pipeline. CAESAR software is perfect match to that study. CAESAR is an advanced personal computer based tool for the engineer who designs or analysis piping system. QGIS data base model are available then complicated network analysis can also be processed.

The hydraulic analysis of this gravity type network may be done again considering the loss which will occur if we use of pressure reducing valve to reduce the pressure at different points of lower elevation level and air relief valve to release the air entrapped in pipes at the highest elevation points in this gravity flow network.

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ANNEXURE-1

Input Parameters for hydraulic analysis.

ANNEXURE-2

Input Parameters for hydraulic analysis.

ANNEXURE -3

Recuperation test data.

Annexure –I
Input parameters

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen- Williams C
P-1	405	276	277	350	DI	140
P-2	20	259	277	350	DI	140
P-3	21	106	142	350	DI	140
P-4	22	471	258	350	DI	140
P-5	23	258	89	350	DI	140
P-6	28	126	106	350	DI	140
P-7	29	81	126	350	DI	140
P-8	42	89	81	350	DI	140
P-9	45	R-2	472	350	DI	140
P-10	50	142	259	350	DI	140
P-11	74	472	471	350	DI	140
P-12	120	229	230	300	DI	140
P-13	143	244	238	300	DI	145
P-14	107	447	454	300	DI	140
P-15	30	468	230	300	DI	140
P-16	33	276	468	300	DI	140
P-17	106	238	276	300	DI	145
P-18	115	229	422	300	DI	140
P-19	205	230	447	300	DI	140
P-20	36	R-1	469	300	DI	140
P-21	38	469	467	300	DI	140
P-22	10	385	437	233	uPVC	140
P-23	49	73	74	233	uPVC	145
P-24	146	238	239	233	uPVC	145
P-25	440	274	275	233	uPVC	145
P-26	781	278	274	233	uPVC	145
P-27	14	264	103	233	uPVC	145
P-28	14	275	264	233	uPVC	145
P-29	16	194	49	233	uPVC	145
P-30	15	438	189	233	uPVC	140
P-31	17	190	38	233	uPVC	145
P-32	17	265	95	233	uPVC	145
P-33	26	39	439	233	uPVC	145
P-34	26	42	165	233	uPVC	145
P-35	27	48	194	233	uPVC	145
P-36	33	165	271	233	uPVC	145
P-37	34	36	441	233	uPVC	145
P-38	34	182	36	233	uPVC	145
P-39	35	38	39	233	uPVC	145
P-40	35	250	97	233	uPVC	145

P-41	37	95	250	233	uPVC	145
P-42	38	114	249	233	uPVC	145
P-43	39	441	117	233	uPVC	145
P-44	40	443	182	233	uPVC	145
P-45	42	444	391	233	uPVC	145
P-46	44	34	48	233	uPVC	145
P-47	45	20	42	233	uPVC	145
P-48	60	270	443	233	uPVC	145
P-49	56	447	225	233	uPVC	140
P-50	58	448	260	233	uPVC	140
P-51	71	249	239	233	uPVC	145
P-52	72	103	159	233	uPVC	145
P-53	78	117	20	233	uPVC	145
P-54	79	189	190	233	uPVC	145
P-55	88	225	121	233	uPVC	140
P-56	87	97	114	233	uPVC	145
P-57	93	439	34	233	uPVC	145
P-58	106	121	438	233	uPVC	140
P-59	111	159	265	233	uPVC	145
P-60	119	455	456	233	uPVC	140
P-61	127	457	385	233	uPVC	145
P-62	177	458	444	233	uPVC	145
P-63	178	459	460	233	uPVC	140
P-64	193	461	462	233	uPVC	140
P-65	228	463	459	233	uPVC	140
P-66	222	460	464	233	uPVC	145
P-67	234	462	453	233	uPVC	140
P-68	239	464	457	233	uPVC	145
P-69	261	456	465	233	uPVC	140
P-70	243	432	461	233	uPVC	140
P-71	251	271	278	233	uPVC	145
P-72	326	465	458	233	uPVC	145
P-73	282	466	455	233	uPVC	140
P-74	293	455	463	233	uPVC	140
P-75	413	467	466	233	uPVC	140
P-76	497	454	432	233	uPVC	140
P-77	31	270	235	233	uPVC	145
P-78	65	235	244	233	uPVC	145
P-79	55	74	448	233	uPVC	140
P-80	32	453	73	233	uPVC	140
P-81	245	270	238	186.4	uPVC	145
P-82	16	433	434	186.4	uPVC	145
P-83	18	434	435	186.4	uPVC	145
P-84	52	436	433	186.4	uPVC	145
P-85	128	437	436	186.4	uPVC	145
P-86	153	435	396	186.4	uPVC	145
P-87	163	437	381	186.4	uPVC	145

P-88	15	62	108	167.8	uPVC	145
P-89	17	251	399	167.8	uPVC	145
P-90	21	401	256	167.8	uPVC	145
P-91	23	15	16	167.8	uPVC	145
P-92	23	318	402	167.8	uPVC	145
P-93	26	403	140	167.8	uPVC	145
P-94	26	273	242	167.8	uPVC	145
P-95	33	406	136	167.8	uPVC	145
P-96	34	49	240	167.8	uPVC	145
P-97	36	240	146	167.8	uPVC	145
P-98	37	140	251	167.8	uPVC	145
P-99	37	53	52	167.8	uPVC	145
P-100	39	154	407	167.8	uPVC	145
P-101	38	241	272	167.8	uPVC	145
P-102	44	263	408	167.8	uPVC	145
P-103	41	408	409	167.8	uPVC	145
P-104	43	16	346	167.8	uPVC	145
P-105	45	234	15	167.8	uPVC	145
P-106	56	358	233	167.8	uPVC	145
P-107	56	108	192	167.8	uPVC	145
P-108	60	272	2	167.8	uPVC	145
P-109	62	138	139	167.8	uPVC	145
P-110	63	153	154	167.8	uPVC	145
P-111	132	192	138	167.8	uPVC	145
P-112	67	243	406	167.8	uPVC	145
P-113	69	415	416	167.8	uPVC	145
P-114	74	417	418	167.8	uPVC	145
P-115	75	416	419	167.8	uPVC	145
P-116	75	420	417	167.8	uPVC	145
P-117	91	419	340	167.8	uPVC	145
P-118	93	256	62	167.8	uPVC	145
P-119	97	421	415	167.8	uPVC	145
P-120	106	146	241	167.8	uPVC	145
P-121	109	422	423	167.8	uPVC	145
P-122	111	418	318	167.8	uPVC	145
P-123	112	409	360	167.8	uPVC	145
P-124	129	233	234	167.8	uPVC	145
P-125	149	360	424	167.8	uPVC	145
P-126	147	424	335	167.8	uPVC	145
P-127	137	425	422	167.8	uPVC	145
P-128	141	242	243	167.8	uPVC	145
P-129	159	399	262	167.8	uPVC	145
P-130	148	340	426	167.8	uPVC	145
P-131	191	421	427	167.8	uPVC	145
P-132	199	428	341	167.8	uPVC	145
P-133	249	2	273	167.8	uPVC	145
P-134	275	423	428	167.8	uPVC	145

P-135	278	426	425	167.8	uPVC	145
P-136	312	345	431	167.8	uPVC	145
P-137	311	139	432	167.8	uPVC	145
P-138	329	431	402	167.8	uPVC	145
P-139	379	415	420	167.8	uPVC	145
P-140	382	407	357	167.8	uPVC	145
P-141	24	341	421	167.8	uPVC	145
P-142	17	252	401	167.8	uPVC	145
P-143	48	163	252	167.8	uPVC	145
P-144	82	49	144	167.8	uPVC	145
P-145	39	144	163	167.8	uPVC	145
P-146	91	262	54	167.8	uPVC	145
P-147	21	54	1	167.8	uPVC	145
P-148	20	79	263	167.8	uPVC	145
P-149	16	1	40	167.8	uPVC	145
P-150	43	40	79	167.8	uPVC	145
P-151	41	136	57	167.8	uPVC	145
P-152	47	57	50	167.8	uPVC	145
P-153	19	50	403	167.8	uPVC	145
P-154	27	52	404	167.8	uPVC	145
P-155	34	404	405	167.8	uPVC	145
P-156	56	412	168	167.8	uPVC	145
P-157	55	413	153	167.8	uPVC	145
P-158	56	405	412	167.8	uPVC	145
P-159	61	260	414	167.8	uPVC	145
P-160	73	168	413	167.8	uPVC	145
P-161	92	414	358	167.8	uPVC	145
P-162	202	429	53	167.8	uPVC	145
P-163	215	260	429	167.8	uPVC	145
P-164	265	427	430	167.8	uPVC	145
P-165	298	430	337	167.8	uPVC	145
P-166	48	73	74	167.8	uPVC	145
P-167	16	364	302	149.2	uPVC	145
P-168	17	365	293	149.2	uPVC	145
P-169	20	366	367	149.2	uPVC	145
P-170	21	368	369	149.2	uPVC	145
P-171	24	370	371	149.2	uPVC	145
P-172	40	301	372	149.2	uPVC	145
P-173	42	373	312	149.2	uPVC	145
P-174	57	293	298	149.2	uPVC	145
P-175	59	295	297	149.2	uPVC	145
P-176	61	301	374	149.2	uPVC	145
P-177	71	372	370	149.2	uPVC	145
P-178	71	375	376	149.2	uPVC	145
P-179	76	308	377	149.2	uPVC	145
P-180	77	378	379	149.2	uPVC	145
P-181	92	376	303	149.2	uPVC	145

P-182	95	302	380	149.2	uPVC	145
P-183	112	381	382	149.2	uPVC	145
P-184	115	374	383	149.2	uPVC	145
P-185	129	384	366	149.2	uPVC	145
P-186	124	385	384	149.2	uPVC	145
P-187	123	386	364	149.2	uPVC	145
P-188	129	380	383	149.2	uPVC	145
P-189	133	387	373	149.2	uPVC	145
P-190	134	371	378	149.2	uPVC	145
P-191	143	388	298	149.2	uPVC	145
P-192	159	377	389	149.2	uPVC	145
P-193	144	367	390	149.2	uPVC	145
P-194	180	391	387	149.2	uPVC	145
P-195	162	392	368	149.2	uPVC	145
P-196	159	393	386	149.2	uPVC	145
P-197	161	390	365	149.2	uPVC	145
P-198	168	394	393	149.2	uPVC	145
P-199	171	297	395	149.2	uPVC	145
P-200	173	396	394	149.2	uPVC	145
P-201	198	335	397	149.2	uPVC	145
P-202	186	395	375	149.2	uPVC	145
P-203	192	369	308	149.2	uPVC	145
P-204	232	391	392	149.2	uPVC	145
P-205	230	379	299	149.2	uPVC	145
P-206	255	389	388	149.2	uPVC	145
P-207	291	397	326	149.2	uPVC	145
P-208	307	382	295	149.2	uPVC	145
P-209	4	313	314	130.4	uPVC	145
P-210	126	340	341	130.4	uPVC	145
P-211	715	467	455	130.4	uPVC	145
P-212	1,268	455	385	130.4	uPVC	145
P-213	12	385	437	130.4	uPVC	145
P-214	12	130	227	130.4	uPVC	145
P-215	16	44	130	130.4	uPVC	145
P-216	17	318	319	130.4	uPVC	145
P-217	18	224	320	130.4	uPVC	145
P-218	19	246	321	130.4	uPVC	145
P-219	21	10	11	130.4	uPVC	145
P-220	22	75	322	130.4	uPVC	145
P-221	22	320	323	130.4	uPVC	145
P-222	22	27	70	130.4	uPVC	145
P-223	25	131	27	130.4	uPVC	145
P-224	28	200	155	130.4	uPVC	145
P-225	30	55	44	130.4	uPVC	145
P-226	36	156	200	130.4	uPVC	145
P-227	41	85	325	130.4	uPVC	145
P-228	44	187	223	130.4	uPVC	145

P-229	45	227	131	130.4	uPVC	145
P-230	59	326	327	130.4	uPVC	145
P-231	54	70	328	130.4	uPVC	145
P-232	57	155	85	130.4	uPVC	145
P-233	77	11	329	130.4	uPVC	145
P-234	80	101	330	130.4	uPVC	145
P-235	84	331	332	130.4	uPVC	145
P-236	93	333	334	130.4	uPVC	145
P-237	90	328	10	130.4	uPVC	145
P-238	88	335	331	130.4	uPVC	145
P-239	101	314	315	130.4	uPVC	145
P-240	103	336	337	130.4	uPVC	145
P-241	114	223	224	130.4	uPVC	145
P-242	137	337	333	130.4	uPVC	145
P-243	134	342	156	130.4	uPVC	145
P-244	137	327	343	130.4	uPVC	145
P-245	139	344	345	130.4	uPVC	145
P-246	141	346	55	130.4	uPVC	145
P-247	143	347	313	130.4	uPVC	145
P-248	157	319	336	130.4	uPVC	145
P-249	152	245	246	130.4	uPVC	145
P-250	180	348	349	130.4	uPVC	145
P-251	168	350	245	130.4	uPVC	145
P-252	157	329	317	130.4	uPVC	145
P-253	173	324	351	130.4	uPVC	145
P-254	207	332	352	130.4	uPVC	145
P-255	198	353	354	130.4	uPVC	145
P-256	195	334	355	130.4	uPVC	145
P-257	200	323	75	130.4	uPVC	145
P-258	207	356	342	130.4	uPVC	145
P-259	214	357	356	130.4	uPVC	145
P-260	223	349	344	130.4	uPVC	145
P-261	230	351	347	130.4	uPVC	145
P-262	240	343	359	130.4	uPVC	145
P-263	250	360	348	130.4	uPVC	145
P-264	267	355	353	130.4	uPVC	145
P-265	281	322	350	130.4	uPVC	145
P-266	428	359	361	130.4	uPVC	145
P-267	453	362	363	130.4	uPVC	145
P-268	305	345	362	130.4	uPVC	145
P-269	16	267	187	130.4	uPVC	145
P-270	112	358	134	130.4	uPVC	145
P-271	129	134	267	130.4	uPVC	145
P-272	241	283	906	116.4	uPVC	145
P-273	244	310	739	116.4	uPVC	145
P-274	345	396	393	116.4	uPVC	145
P-275	12	280	281	116.4	uPVC	145

P-276	17	282	283	116.4	uPVC	145
P-277	38	284	285	116.4	uPVC	145
P-278	50	286	287	116.4	uPVC	145
P-279	56	288	289	116.4	uPVC	145
P-280	59	290	291	116.4	uPVC	145
P-281	73	292	288	116.4	uPVC	145
P-282	115	299	300	116.4	uPVC	145
P-283	128	290	301	116.4	uPVC	145
P-284	127	302	290	116.4	uPVC	145
P-285	126	281	285	116.4	uPVC	145
P-286	130	303	304	116.4	uPVC	145
P-287	159	304	284	116.4	uPVC	145
P-288	144	300	305	116.4	uPVC	145
P-289	152	291	280	116.4	uPVC	145
P-290	158	306	282	116.4	uPVC	145
P-291	167	305	307	116.4	uPVC	145
P-292	183	303	291	116.4	uPVC	145
P-293	178	308	309	116.4	uPVC	145
P-294	182	307	310	116.4	uPVC	145
P-295	177	289	306	116.4	uPVC	145
P-296	187	283	311	116.4	uPVC	145
P-297	257	309	312	116.4	uPVC	145
P-298	244	311	286	116.4	uPVC	145
P-299	7	284	292	116.4	uPVC	145
P-300	66	289	717	116.4	uPVC	145
P-301	367	437	396	116.4	uPVC	145
P-302	284	393	364	116.4	uPVC	145
P-303	17	364	302	116.4	uPVC	145
P-304	103	302	380	116.4	uPVC	145
P-305	130	380	383	116.4	uPVC	145
P-306	115	383	374	116.4	uPVC	145
P-307	61	374	301	116.4	uPVC	145
P-308	43	301	372	116.4	uPVC	145
P-309	74	372	370	116.4	uPVC	145
P-310	25	370	371	116.4	uPVC	145
P-311	135	371	378	116.4	uPVC	145
P-312	304	378	299	116.4	uPVC	145
P-313	39	469	467	100	uPVC	140
P-314	37	R-1	469	100	uPVC	140
P-315	8	3	4	83.8	uPVC	145
P-316	8	3	5	83.8	uPVC	145
P-317	13	6	7	83.8	uPVC	145
P-318	19	8	9	83.8	uPVC	145
P-319	19	12	13	83.8	uPVC	145
P-320	21	6	14	83.8	uPVC	145
P-321	26	9	17	83.8	uPVC	145
P-322	26	18	19	83.8	uPVC	145

P-323	27	20	21	83.8	uPVC	145
P-324	29	9	22	83.8	uPVC	145
P-325	29	23	24	83.8	uPVC	145
P-326	30	25	26	83.8	uPVC	145
P-327	30	27	28	83.8	uPVC	145
P-328	30	12	29	83.8	uPVC	145
P-329	30	30	31	83.8	uPVC	145
P-330	30	32	33	83.8	uPVC	145
P-331	30	34	35	83.8	uPVC	145
P-332	30	36	37	83.8	uPVC	145
P-333	35	40	41	83.8	uPVC	145
P-334	35	42	43	83.8	uPVC	145
P-335	35	44	45	83.8	uPVC	145
P-336	36	46	47	83.8	uPVC	145
P-337	37	50	51	83.8	uPVC	145
P-338	39	54	6	83.8	uPVC	145
P-339	40	55	56	83.8	uPVC	145
P-340	40	57	58	83.8	uPVC	145
P-341	40	59	60	83.8	uPVC	145
P-342	40	2	61	83.8	uPVC	145
P-343	40	62	63	83.8	uPVC	145
P-344	40	64	65	83.8	uPVC	145
P-345	40	66	67	83.8	uPVC	145
P-346	40	68	69	83.8	uPVC	145
P-347	40	70	71	83.8	uPVC	145
P-348	41	72	12	83.8	uPVC	145
P-349	51	75	76	83.8	uPVC	145
P-350	42	77	78	83.8	uPVC	145
P-351	42	79	80	83.8	uPVC	145
P-352	42	81	82	83.8	uPVC	145
P-353	44	83	84	83.8	uPVC	145
P-354	45	85	86	83.8	uPVC	145
P-355	45	87	88	83.8	uPVC	145
P-356	46	89	90	83.8	uPVC	145
P-357	47	91	92	83.8	uPVC	145
P-358	49	93	94	83.8	uPVC	145
P-359	48	95	96	83.8	uPVC	145
P-360	49	97	98	83.8	uPVC	145
P-361	49	99	100	83.8	uPVC	145
P-362	50	101	102	83.8	uPVC	145
P-363	50	103	104	83.8	uPVC	145
P-364	50	1	105	83.8	uPVC	145
P-365	50	106	107	83.8	uPVC	145
P-366	50	108	109	83.8	uPVC	145
P-367	50	110	111	83.8	uPVC	145
P-368	50	112	113	83.8	uPVC	145
P-369	53	114	115	83.8	uPVC	145

P-370	55	23	116	83.8	uPVC	145
P-371	55	117	118	83.8	uPVC	145
P-372	55	119	120	83.8	uPVC	145
P-373	55	121	122	83.8	uPVC	145
P-374	55	123	124	83.8	uPVC	145
P-375	58	125	66	83.8	uPVC	145
P-376	56	126	127	83.8	uPVC	145
P-377	58	128	129	83.8	uPVC	145
P-378	57	132	133	83.8	uPVC	145
P-379	59	134	135	83.8	uPVC	145
P-380	59	136	137	83.8	uPVC	145
P-381	60	140	141	83.8	uPVC	145
P-382	60	142	143	83.8	uPVC	145
P-383	60	144	145	83.8	uPVC	145
P-384	60	146	147	83.8	uPVC	145
P-385	60	148	149	83.8	uPVC	145
P-386	61	150	23	83.8	uPVC	145
P-387	61	151	152	83.8	uPVC	145
P-388	83	155	156	83.8	uPVC	145
P-389	65	157	158	83.8	uPVC	145
P-390	65	159	160	83.8	uPVC	145
P-391	65	161	162	83.8	uPVC	145
P-392	66	163	164	83.8	uPVC	145
P-393	66	165	166	83.8	uPVC	145
P-394	88	167	168	83.8	uPVC	145
P-395	69	169	170	83.8	uPVC	145
P-396	70	171	172	83.8	uPVC	145
P-397	70	173	174	83.8	uPVC	145
P-398	70	175	176	83.8	uPVC	145
P-399	78	178	179	83.8	uPVC	145
P-400	72	180	181	83.8	uPVC	145
P-401	82	182	3	83.8	uPVC	145
P-402	80	183	184	83.8	uPVC	145
P-403	79	185	186	83.8	uPVC	145
P-404	80	187	188	83.8	uPVC	145
P-405	80	157	191	83.8	uPVC	145
P-406	86	192	193	83.8	uPVC	145
P-407	80	194	195	83.8	uPVC	145
P-408	90	198	199	83.8	uPVC	145
P-409	85	200	201	83.8	uPVC	145
P-410	90	202	203	83.8	uPVC	145
P-411	90	204	205	83.8	uPVC	145
P-412	90	206	207	83.8	uPVC	145
P-413	109	66	208	83.8	uPVC	145
P-414	98	209	210	83.8	uPVC	145
P-415	95	211	212	83.8	uPVC	145
P-416	100	213	214	83.8	uPVC	145

P-417	100	215	216	83.8	uPVC	145
P-418	100	217	218	83.8	uPVC	145
P-419	120	219	220	83.8	uPVC	145
P-420	110	221	222	83.8	uPVC	145
P-421	112	225	226	83.8	uPVC	145
P-422	125	227	228	83.8	uPVC	145
P-423	159	231	232	83.8	uPVC	145
P-424	133	235	236	83.8	uPVC	145
P-425	130	130	237	83.8	uPVC	145
P-426	157	245	246	83.8	uPVC	145
P-427	159	247	248	83.8	uPVC	145
P-428	169	252	253	83.8	uPVC	145
P-429	176	254	255	83.8	uPVC	145
P-430	192	256	257	83.8	uPVC	145
P-431	186	260	261	83.8	uPVC	145
P-432	200	262	263	83.8	uPVC	145
P-433	226	266	267	83.8	uPVC	145
P-434	211	268	269	83.8	uPVC	145
P-435	296	182	271	83.8	uPVC	145
P-436	611	279	274	83.8	uPVC	145
P-437	114	338	339	83.8	uPVC	145
P-438	191	275	338	83.8	uPVC	145
P-439	12	161	398	83.8	uPVC	145
P-440	20	400	183	83.8	uPVC	145
P-441	22	279	150	83.8	uPVC	145
P-442	28	339	279	83.8	uPVC	145
P-443	48	183	268	83.8	uPVC	145
P-444	49	150	410	83.8	uPVC	145
P-445	49	411	161	83.8	uPVC	145
P-446	85	268	411	83.8	uPVC	145
P-447	256	206	410	83.8	uPVC	145
P-448	31	440	202	83.8	uPVC	145
P-449	31	64	275	83.8	uPVC	145
P-450	34	72	185	83.8	uPVC	145
P-451	36	278	442	83.8	uPVC	145
P-452	50	446	91	83.8	uPVC	145
P-453	74	449	151	83.8	uPVC	145
P-454	95	151	450	83.8	uPVC	145
P-455	94	91	440	83.8	uPVC	145
P-456	119	442	72	83.8	uPVC	145
P-457	107	451	452	83.8	uPVC	145
P-458	121	450	64	83.8	uPVC	145
P-459	130	202	451	83.8	uPVC	145
P-460	151	185	446	83.8	uPVC	145
P-461	13	452	400	83.8	uPVC	145
P-462	59	470	238	83.8	uPVC	145
P-463	85	244	470	83.8	uPVC	145

P-464	5	473	474	83.8	uPVC	145
P-465	9	475	476	83.8	uPVC	145
P-466	9	477	478	83.8	uPVC	145
P-467	11	87	479	83.8	uPVC	145
P-468	11	480	481	83.8	uPVC	145
P-469	11	482	483	83.8	uPVC	145
P-470	12	484	485	83.8	uPVC	145
P-471	12	486	487	83.8	uPVC	145
P-472	12	148	169	83.8	uPVC	145
P-473	12	488	489	83.8	uPVC	145
P-474	12	490	491	83.8	uPVC	145
P-475	13	93	494	83.8	uPVC	145
P-476	13	495	25	83.8	uPVC	145
P-477	13	496	497	83.8	uPVC	145
P-478	14	498	499	83.8	uPVC	145
P-479	15	324	500	83.8	uPVC	145
P-480	17	501	502	83.8	uPVC	145
P-481	17	504	505	83.8	uPVC	145
P-482	18	506	507	83.8	uPVC	145
P-483	18	502	508	83.8	uPVC	145
P-484	18	509	510	83.8	uPVC	145
P-485	18	511	180	83.8	uPVC	145
P-486	18	512	513	83.8	uPVC	145
P-487	19	68	514	83.8	uPVC	145
P-488	19	515	516	83.8	uPVC	145
P-489	19	517	518	83.8	uPVC	145
P-490	20	519	520	83.8	uPVC	145
P-491	21	521	504	83.8	uPVC	145
P-492	20	285	506	83.8	uPVC	145
P-493	21	522	523	83.8	uPVC	145
P-494	23	169	87	83.8	uPVC	145
P-495	27	32	524	83.8	uPVC	145
P-496	24	410	525	83.8	uPVC	145
P-497	27	408	526	83.8	uPVC	145
P-498	26	529	480	83.8	uPVC	145
P-499	27	99	530	83.8	uPVC	145
P-500	26	280	531	83.8	uPVC	145
P-501	27	313	532	83.8	uPVC	145
P-502	27	533	534	83.8	uPVC	145
P-503	28	535	536	83.8	uPVC	145
P-504	28	474	537	83.8	uPVC	145
P-505	28	483	538	83.8	uPVC	145
P-506	28	539	540	83.8	uPVC	145
P-507	29	339	541	83.8	uPVC	145
P-508	29	542	543	83.8	uPVC	145
P-509	30	545	546	83.8	uPVC	145
P-510	31	547	548	83.8	uPVC	145

P-511	31	370	551	83.8	uPVC	145
P-512	38	198	552	83.8	uPVC	145
P-513	31	480	553	83.8	uPVC	145
P-514	31	8	93	83.8	uPVC	145
P-515	31	534	554	83.8	uPVC	145
P-516	31	383	555	83.8	uPVC	145
P-517	33	556	517	83.8	uPVC	145
P-518	32	557	558	83.8	uPVC	145
P-519	32	506	559	83.8	uPVC	145
P-520	32	560	561	83.8	uPVC	145
P-521	32	562	563	83.8	uPVC	145
P-522	33	497	254	83.8	uPVC	145
P-523	34	564	565	83.8	uPVC	145
P-524	33	483	566	83.8	uPVC	145
P-525	33	541	567	83.8	uPVC	145
P-526	34	568	569	83.8	uPVC	145
P-527	34	414	571	83.8	uPVC	145
P-528	35	196	148	83.8	uPVC	145
P-529	47	123	572	83.8	uPVC	145
P-530	37	562	8	83.8	uPVC	145
P-531	36	573	556	83.8	uPVC	145
P-532	36	556	574	83.8	uPVC	145
P-533	36	575	564	83.8	uPVC	145
P-534	36	471	576	83.8	uPVC	145
P-535	37	577	578	83.8	uPVC	145
P-536	39	579	580	83.8	uPVC	145
P-537	40	524	581	83.8	uPVC	145
P-538	37	417	583	83.8	uPVC	145
P-539	38	304	584	83.8	uPVC	145
P-540	38	583	585	83.8	uPVC	145
P-541	38	586	587	83.8	uPVC	145
P-542	38	588	589	83.8	uPVC	145
P-543	38	590	591	83.8	uPVC	145
P-544	43	481	592	83.8	uPVC	145
P-545	40	392	593	83.8	uPVC	145
P-546	40	330	594	83.8	uPVC	145
P-547	40	595	596	83.8	uPVC	145
P-548	41	597	598	83.8	uPVC	145
P-549	41	443	217	83.8	uPVC	145
P-550	41	599	600	83.8	uPVC	145
P-551	45	601	586	83.8	uPVC	145
P-552	42	483	602	83.8	uPVC	145
P-553	43	603	604	83.8	uPVC	145
P-554	42	411	605	83.8	uPVC	145
P-555	46	361	606	83.8	uPVC	145
P-556	45	607	608	83.8	uPVC	145
P-557	43	380	609	83.8	uPVC	145

P-558	44	610	611	83.8	uPVC	145
P-559	44	612	178	83.8	uPVC	145
P-560	45	613	614	83.8	uPVC	145
P-561	46	615	597	83.8	uPVC	145
P-562	46	543	616	83.8	uPVC	145
P-563	47	173	619	83.8	uPVC	145
P-564	63	620	621	83.8	uPVC	145
P-565	47	534	622	83.8	uPVC	145
P-566	47	494	623	83.8	uPVC	145
P-567	50	624	625	83.8	uPVC	145
P-568	47	518	522	83.8	uPVC	145
P-569	48	292	626	83.8	uPVC	145
P-570	47	627	628	83.8	uPVC	145
P-571	47	629	630	83.8	uPVC	145
P-572	48	474	631	83.8	uPVC	145
P-573	48	632	633	83.8	uPVC	145
P-574	62	517	634	83.8	uPVC	145
P-575	57	377	636	83.8	uPVC	145
P-576	48	523	637	83.8	uPVC	145
P-577	49	470	638	83.8	uPVC	145
P-578	49	314	639	83.8	uPVC	145
P-579	51	640	641	83.8	uPVC	145
P-580	50	642	487	83.8	uPVC	145
P-581	49	643	644	83.8	uPVC	145
P-582	50	645	646	83.8	uPVC	145
P-583	58	647	648	83.8	uPVC	145
P-584	53	649	650	83.8	uPVC	145
P-585	51	393	651	83.8	uPVC	145
P-586	59	219	511	83.8	uPVC	145
P-587	54	655	627	83.8	uPVC	145
P-588	52	656	490	83.8	uPVC	145
P-589	53	489	657	83.8	uPVC	145
P-590	54	650	658	83.8	uPVC	145
P-591	54	575	659	83.8	uPVC	145
P-592	53	660	661	83.8	uPVC	145
P-593	53	662	663	83.8	uPVC	145
P-594	54	496	664	83.8	uPVC	145
P-595	55	665	620	83.8	uPVC	145
P-596	56	520	666	83.8	uPVC	145
P-597	54	539	667	83.8	uPVC	145
P-598	55	668	669	83.8	uPVC	145
P-599	55	288	670	83.8	uPVC	145
P-600	55	407	671	83.8	uPVC	145
P-601	55	586	672	83.8	uPVC	145
P-602	60	499	573	83.8	uPVC	145
P-603	65	673	533	83.8	uPVC	145
P-604	55	674	675	83.8	uPVC	145

P-605	57	568	676	83.8	uPVC	145
P-606	58	321	677	83.8	uPVC	145
P-607	63	655	678	83.8	uPVC	145
P-608	57	374	679	83.8	uPVC	145
P-609	75	530	680	83.8	uPVC	145
P-610	59	681	682	83.8	uPVC	145
P-611	59	601	683	83.8	uPVC	145
P-612	60	684	685	83.8	uPVC	145
P-613	60	119	495	83.8	uPVC	145
P-614	59	679	686	83.8	uPVC	145
P-615	63	462	687	83.8	uPVC	145
P-616	64	631	688	83.8	uPVC	145
P-617	60	629	689	83.8	uPVC	145
P-618	65	690	691	83.8	uPVC	145
P-619	60	482	529	83.8	uPVC	145
P-620	62	521	545	83.8	uPVC	145
P-621	62	234	692	83.8	uPVC	145
P-622	62	693	694	83.8	uPVC	145
P-623	81	499	695	83.8	uPVC	145
P-624	62	344	696	83.8	uPVC	145
P-625	66	697	698	83.8	uPVC	145
P-626	64	699	700	83.8	uPVC	145
P-627	77	615	701	83.8	uPVC	145
P-628	63	702	703	83.8	uPVC	145
P-629	68	704	656	83.8	uPVC	145
P-630	64	603	705	83.8	uPVC	145
P-631	72	583	706	83.8	uPVC	145
P-632	63	707	708	83.8	uPVC	145
P-633	68	709	710	83.8	uPVC	145
P-634	75	711	712	83.8	uPVC	145
P-635	65	710	713	83.8	uPVC	145
P-636	69	544	196	83.8	uPVC	145
P-637	66	346	198	83.8	uPVC	145
P-638	71	217	204	83.8	uPVC	145
P-639	65	404	714	83.8	uPVC	145
P-640	73	715	473	83.8	uPVC	145
P-641	66	631	716	83.8	uPVC	145
P-642	68	718	719	83.8	uPVC	145
P-643	77	720	721	83.8	uPVC	145
P-644	66	681	643	83.8	uPVC	145
P-645	72	523	655	83.8	uPVC	145
P-646	69	668	722	83.8	uPVC	145
P-647	67	209	697	83.8	uPVC	145
P-648	68	723	724	83.8	uPVC	145
P-649	68	657	588	83.8	uPVC	145
P-650	69	211	173	83.8	uPVC	145
P-651	69	481	725	83.8	uPVC	145

P-652	69	204	68	83.8	uPVC	145
P-653	69	577	726	83.8	uPVC	145
P-654	69	178	727	83.8	uPVC	145
P-655	77	728	729	83.8	uPVC	145
P-656	71	730	731	83.8	uPVC	145
P-657	71	180	732	83.8	uPVC	145
P-658	73	494	733	83.8	uPVC	145
P-659	73	673	734	83.8	uPVC	145
P-660	72	735	736	83.8	uPVC	145
P-661	72	412	577	83.8	uPVC	145
P-662	73	352	737	83.8	uPVC	145
P-663	74	244	738	83.8	uPVC	145
P-664	79	316	715	83.8	uPVC	145
P-665	74	739	740	83.8	uPVC	145
P-666	75	478	662	83.8	uPVC	145
P-667	75	433	741	83.8	uPVC	145
P-668	75	742	743	83.8	uPVC	145
P-669	75	510	624	83.8	uPVC	145
P-670	86	445	673	83.8	uPVC	145
P-671	76	403	744	83.8	uPVC	145
P-672	78	570	745	83.8	uPVC	145
P-673	79	533	746	83.8	uPVC	145
P-674	77	742	747	83.8	uPVC	145
P-675	76	748	749	83.8	uPVC	145
P-676	77	707	750	83.8	uPVC	145
P-677	97	751	752	83.8	uPVC	145
P-678	81	567	753	83.8	uPVC	145
P-679	86	325	612	83.8	uPVC	145
P-680	78	727	18	83.8	uPVC	145
P-681	80	609	709	83.8	uPVC	145
P-682	88	312	607	83.8	uPVC	145
P-683	81	697	519	83.8	uPVC	145
P-684	80	656	754	83.8	uPVC	145
P-685	94	59	756	83.8	uPVC	145
P-686	84	757	603	83.8	uPVC	145
P-687	83	727	32	83.8	uPVC	145
P-688	87	573	758	83.8	uPVC	145
P-689	86	759	760	83.8	uPVC	145
P-690	85	231	570	83.8	uPVC	145
P-691	89	512	761	83.8	uPVC	145
P-692	100	762	763	83.8	uPVC	145
P-693	118	764	765	83.8	uPVC	145
P-694	109	767	764	83.8	uPVC	145
P-695	88	763	768	83.8	uPVC	145
P-696	131	498	769	83.8	uPVC	145
P-697	88	536	770	83.8	uPVC	145
P-698	88	771	772	83.8	uPVC	145

P-699	95	624	674	83.8	uPVC	145
P-700	89	473	498	83.8	uPVC	145
P-701	89	321	774	83.8	uPVC	145
P-702	102	775	776	83.8	uPVC	145
P-703	90	777	723	83.8	uPVC	145
P-704	110	694	778	83.8	uPVC	145
P-705	90	779	515	83.8	uPVC	145
P-706	90	522	632	83.8	uPVC	145
P-707	95	543	780	83.8	uPVC	145
P-708	90	233	575	83.8	uPVC	145
P-709	117	640	781	83.8	uPVC	145
P-710	101	674	629	83.8	uPVC	145
P-711	99	582	782	83.8	uPVC	145
P-712	92	749	783	83.8	uPVC	145
P-713	95	613	784	83.8	uPVC	145
P-714	100	346	699	83.8	uPVC	145
P-715	109	785	123	83.8	uPVC	145
P-716	102	683	786	83.8	uPVC	145
P-717	95	787	704	83.8	uPVC	145
P-718	113	788	647	83.8	uPVC	145
P-719	97	315	789	83.8	uPVC	145
P-720	112	371	790	83.8	uPVC	145
P-721	117	557	791	83.8	uPVC	145
P-722	110	689	792	83.8	uPVC	145
P-723	97	435	711	83.8	uPVC	145
P-724	98	723	793	83.8	uPVC	145
P-725	99	794	795	83.8	uPVC	145
P-726	123	325	175	83.8	uPVC	145
P-727	101	783	475	83.8	uPVC	145
P-728	107	732	211	83.8	uPVC	145
P-729	103	796	797	83.8	uPVC	145
P-730	104	776	798	83.8	uPVC	145
P-731	112	368	799	83.8	uPVC	145
P-732	105	547	771	83.8	uPVC	145
P-733	108	800	801	83.8	uPVC	145
P-734	129	802	665	83.8	uPVC	145
P-735	103	689	803	83.8	uPVC	145
P-736	129	378	804	83.8	uPVC	145
P-737	106	520	805	83.8	uPVC	145
P-738	110	785	806	83.8	uPVC	145
P-739	109	476	615	83.8	uPVC	145
P-740	121	646	807	83.8	uPVC	145
P-741	107	402	590	83.8	uPVC	145
P-742	106	491	808	83.8	uPVC	145
P-743	107	787	535	83.8	uPVC	145
P-744	112	806	809	83.8	uPVC	145
P-745	107	810	811	83.8	uPVC	145

P-746	122	319	812	83.8	uPVC	145
P-747	110	564	813	83.8	uPVC	145
P-748	124	760	751	83.8	uPVC	145
P-749	108	254	814	83.8	uPVC	145
P-750	108	475	815	83.8	uPVC	145
P-751	120	491	810	83.8	uPVC	145
P-752	109	381	735	83.8	uPVC	145
P-753	149	816	817	83.8	uPVC	145
P-754	112	818	707	83.8	uPVC	145
P-755	118	763	819	83.8	uPVC	145
P-756	110	287	820	83.8	uPVC	145
P-757	112	665	821	83.8	uPVC	145
P-758	116	620	702	83.8	uPVC	145
P-759	127	487	730	83.8	uPVC	145
P-760	116	824	825	83.8	uPVC	145
P-761	116	760	826	83.8	uPVC	145
P-762	114	453	640	83.8	uPVC	145
P-763	137	827	693	83.8	uPVC	145
P-764	146	449	828	83.8	uPVC	145
P-765	114	484	610	83.8	uPVC	145
P-766	119	737	829	83.8	uPVC	145
P-767	150	806	830	83.8	uPVC	145
P-768	116	812	831	83.8	uPVC	145
P-769	117	131	832	83.8	uPVC	145
P-770	117	418	833	83.8	uPVC	145
P-771	117	359	834	83.8	uPVC	145
P-772	145	835	836	83.8	uPVC	145
P-773	118	580	837	83.8	uPVC	145
P-774	144	317	838	83.8	uPVC	145
P-775	145	737	839	83.8	uPVC	145
P-776	119	642	840	83.8	uPVC	145
P-777	119	331	841	83.8	uPVC	145
P-778	230	560	568	83.8	uPVC	145
P-779	122	747	842	83.8	uPVC	145
P-780	122	840	843	83.8	uPVC	145
P-781	121	844	796	83.8	uPVC	145
P-782	122	299	579	83.8	uPVC	145
P-783	121	736	845	83.8	uPVC	145
P-784	123	846	847	83.8	uPVC	145
P-785	122	662	668	83.8	uPVC	145
P-786	129	848	779	83.8	uPVC	145
P-787	125	25	496	83.8	uPVC	145
P-788	122	529	762	83.8	uPVC	145
P-789	139	518	849	83.8	uPVC	145
P-790	123	850	851	83.8	uPVC	145
P-791	138	852	613	83.8	uPVC	145
P-792	125	853	767	83.8	uPVC	145

P-793	141	841	854	83.8	uPVC	145
P-794	127	660	802	83.8	uPVC	145
P-795	135	352	848	83.8	uPVC	145
P-796	133	338	855	83.8	uPVC	145
P-797	127	510	99	83.8	uPVC	145
P-798	136	837	595	83.8	uPVC	145
P-799	137	590	660	83.8	uPVC	145
P-800	137	305	777	83.8	uPVC	145
P-801	129	330	509	83.8	uPVC	145
P-802	128	720	856	83.8	uPVC	145
P-803	165	857	816	83.8	uPVC	145
P-804	137	811	858	83.8	uPVC	145
P-805	143	489	818	83.8	uPVC	145
P-806	131	600	859	83.8	uPVC	145
P-807	144	427	560	83.8	uPVC	145
P-808	137	699	128	83.8	uPVC	145
P-809	146	332	860	83.8	uPVC	145
P-810	138	812	861	83.8	uPVC	145
P-811	137	700	209	83.8	uPVC	145
P-812	135	391	853	83.8	uPVC	145
P-813	148	323	862	83.8	uPVC	145
P-814	136	807	800	83.8	uPVC	145
P-815	137	479	562	83.8	uPVC	145
P-816	147	563	759	83.8	uPVC	145
P-817	143	846	794	83.8	uPVC	145
P-818	137	460	863	83.8	uPVC	145
P-819	137	727	864	83.8	uPVC	145
P-820	144	702	824	83.8	uPVC	145
P-821	200	730	865	83.8	uPVC	145
P-822	172	320	866	83.8	uPVC	145
P-823	166	607	867	83.8	uPVC	145
P-824	178	646	868	83.8	uPVC	145
P-825	142	869	119	83.8	uPVC	145
P-826	142	604	775	83.8	uPVC	145
P-827	144	354	870	83.8	uPVC	145
P-828	155	409	871	83.8	uPVC	145
P-829	144	643	539	83.8	uPVC	145
P-830	148	431	835	83.8	uPVC	145
P-831	146	423	872	83.8	uPVC	145
P-832	147	389	873	83.8	uPVC	145
P-833	152	477	742	83.8	uPVC	145
P-834	148	794	874	83.8	uPVC	145
P-835	148	329	512	83.8	uPVC	145
P-836	150	797	875	83.8	uPVC	145
P-837	152	645	876	83.8	uPVC	145
P-838	151	452	877	83.8	uPVC	145
P-839	153	398	878	83.8	uPVC	145

P-840	154	490	536	83.8	uPVC	145
P-841	200	515	718	83.8	uPVC	145
P-842	278	771	599	83.8	uPVC	145
P-843	161	879	501	83.8	uPVC	145
P-844	159	676	880	83.8	uPVC	145
P-845	173	647	757	83.8	uPVC	145
P-846	177	792	881	83.8	uPVC	145
P-847	207	770	811	83.8	uPVC	145
P-848	208	800	882	83.8	uPVC	145
P-849	167	883	681	83.8	uPVC	145
P-850	213	712	884	83.8	uPVC	145
P-851	200	885	231	83.8	uPVC	145
P-852	165	555	879	83.8	uPVC	145
P-853	191	175	785	83.8	uPVC	145
P-854	202	541	886	83.8	uPVC	145
P-855	173	357	887	83.8	uPVC	145
P-856	170	327	888	83.8	uPVC	145
P-857	182	502	852	83.8	uPVC	145
P-858	172	777	889	83.8	uPVC	145
P-859	177	372	890	83.8	uPVC	145
P-860	235	729	547	83.8	uPVC	145
P-861	188	839	397	83.8	uPVC	145
P-862	191	363	748	83.8	uPVC	145
P-863	177	610	486	83.8	uPVC	145
P-864	188	891	557	83.8	uPVC	145
P-865	184	819	892	83.8	uPVC	145
P-866	223	606	893	83.8	uPVC	145
P-867	182	740	488	83.8	uPVC	145
P-868	184	749	642	83.8	uPVC	145
P-869	210	863	894	83.8	uPVC	145
P-870	200	694	895	83.8	uPVC	145
P-871	187	440	896	83.8	uPVC	145
P-872	192	897	827	83.8	uPVC	145
P-873	213	898	542	83.8	uPVC	145
P-874	227	850	899	83.8	uPVC	145
P-875	191	354	900	83.8	uPVC	145
P-876	197	345	846	83.8	uPVC	145
P-877	192	779	601	83.8	uPVC	145
P-878	218	887	901	83.8	uPVC	145
P-879	199	365	902	83.8	uPVC	145
P-880	203	901	482	83.8	uPVC	145
P-881	204	287	903	83.8	uPVC	145
P-882	206	310	477	83.8	uPVC	145
P-883	218	128	112	83.8	uPVC	145
P-884	232	612	904	83.8	uPVC	145
P-885	232	840	905	83.8	uPVC	145
P-886	215	532	684	83.8	uPVC	145

P-887	227	316	857	83.8	uPVC	145
P-888	312	524	907	83.8	uPVC	145
P-889	238	893	908	83.8	uPVC	145
P-890	224	650	850	83.8	uPVC	145
P-891	236	619	869	83.8	uPVC	145
P-892	258	358	885	83.8	uPVC	145
P-893	303	717	645	83.8	uPVC	145
P-894	254	902	909	83.8	uPVC	145
P-895	251	348	897	83.8	uPVC	145
P-896	242	910	728	83.8	uPVC	145
P-897	294	773	649	83.8	uPVC	145
P-898	247	911	910	83.8	uPVC	145
P-899	247	485	891	83.8	uPVC	145
P-900	249	582	911	83.8	uPVC	145
P-901	293	649	883	83.8	uPVC	145
P-902	257	900	844	83.8	uPVC	145
P-903	332	908	912	83.8	uPVC	145
P-904	270	913	720	83.8	uPVC	145
P-905	326	906	898	83.8	uPVC	145
P-906	322	870	914	83.8	uPVC	145
P-907	338	326	690	83.8	uPVC	145
P-908	372	875	915	83.8	uPVC	145
P-909	328	903	913	83.8	uPVC	145
P-910	319	914	788	83.8	uPVC	145
P-911	343	909	916	83.8	uPVC	145
P-912	320	889	917	83.8	uPVC	145
P-913	332	363	484	83.8	uPVC	145
P-914	358	419	918	83.8	uPVC	145
P-915	11	570	247	83.8	uPVC	145
P-916	23	247	125	83.8	uPVC	145
P-917	49	272	157	83.8	uPVC	145
P-918	19	171	221	83.8	uPVC	145
P-919	11	221	544	83.8	uPVC	145
P-920	37	49	213	83.8	uPVC	145
P-921	18	213	59	83.8	uPVC	145
P-922	32	398	110	83.8	uPVC	145
P-923	21	110	206	83.8	uPVC	145
P-924	57	680	83	83.8	uPVC	145
P-925	21	83	521	83.8	uPVC	145
P-926	37	196	46	83.8	uPVC	145
P-927	80	46	197	83.8	uPVC	145
P-928	29	153	30	83.8	uPVC	145
P-929	41	30	177	83.8	uPVC	145
P-930	41	10	11	83.8	uPVC	145
P-931	32	15	16	83.8	uPVC	145
P-932	94	38	39	83.8	uPVC	145
P-933	39	48	49	83.8	uPVC	145

P-934	47	52	53	83.8	uPVC	145
P-935	64	130	131	83.8	uPVC	145
P-936	71	138	139	83.8	uPVC	145
P-937	75	153	154	83.8	uPVC	145
P-938	160	189	190	83.8	uPVC	145
P-939	120	223	224	83.8	uPVC	145
P-940	135	233	234	83.8	uPVC	145
P-941	150	240	241	83.8	uPVC	145
P-942	150	242	243	83.8	uPVC	145
P-943	166	249	250	83.8	uPVC	145
P-944	186	136	251	83.8	uPVC	145
P-945	205	258	259	83.8	uPVC	140
P-946	204	264	265	83.8	uPVC	145
P-947	208	49	256	83.8	uPVC	145
P-948	303	272	273	83.8	uPVC	145
P-949	85	293	294	83.8	uPVC	145
P-950	93	295	296	83.8	uPVC	145
P-951	111	297	296	83.8	uPVC	145
P-952	145	298	294	83.8	uPVC	145
P-953	9	315	316	83.8	uPVC	145
P-954	15	317	101	83.8	uPVC	145
P-955	24	154	324	83.8	uPVC	145
P-956	44	445	239	83.8	uPVC	145
P-957	100	400	449	83.8	uPVC	145
P-958	113	238	445	83.8	uPVC	145
P-959	13	492	493	83.8	uPVC	145
P-960	17	399	77	83.8	uPVC	145
P-961	17	503	362	83.8	uPVC	145
P-962	23	132	171	83.8	uPVC	145
P-963	25	527	528	83.8	uPVC	145
P-964	30	330	215	83.8	uPVC	145
P-965	31	77	132	83.8	uPVC	145
P-966	30	549	550	83.8	uPVC	145
P-967	37	321	582	83.8	uPVC	145
P-968	43	215	219	83.8	uPVC	145
P-969	46	617	618	83.8	uPVC	145
P-970	48	549	635	83.8	uPVC	145
P-971	51	493	652	83.8	uPVC	145
P-972	58	653	654	83.8	uPVC	145
P-973	64	653	527	83.8	uPVC	145
P-974	76	617	492	83.8	uPVC	145
P-975	81	528	755	83.8	uPVC	145
P-976	87	492	766	83.8	uPVC	145
P-977	96	361	773	83.8	uPVC	145
P-978	106	467	653	83.8	uPVC	145
P-979	113	822	823	83.8	uPVC	145
P-980	120	693	503	83.8	uPVC	145

P-981	169	823	787	83.8	uPVC	145
P-982	144	528	617	83.8	uPVC	145
P-983	145	527	549	83.8	uPVC	145
P-984	153	444	822	83.8	uPVC	145

**Annexure-II
Output Parameters**

Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
1	0.05	12.51	12.49	42	0.06	14.8	14.77
2	0.18	13.55	13.52	43	0.02	14.8	14.77
3	0.05	14.81	14.78	44	0.04	11.67	11.64
4	0	14.81	14.78	45	0.02	11.67	11.64
5	0	14.81	14.78	46	0.08	12.45	12.43
6	0.04	12.52	12.5	47	0.02	12.45	12.43
7	0.01	12.52	12.5	48	0.06	13.98	13.95
8	0.05	12.31	12.28	49	0.22	13.95	13.92
9	0.04	12.31	12.28	50	0.05	12.81	12.78
10	0.08	11.39	11.37	51	0.02	12.81	12.78
11	0.07	11.38	11.36	52	0.06	11.89	11.87
12	0.05	14.66	14.63	53	0.15	11.93	11.91
13	0.01	14.66	14.63	54	0.08	12.52	12.5
14	0.01	12.52	12.5	55	0.11	11.71	11.69
15	0.05	11.96	11.94	56	0.02	11.71	11.69
16	0.05	11.95	11.92	57	0.07	12.86	12.83
17	0.01	12.31	12.28	58	0.02	12.86	12.83
18	0.05	10.92	10.9	59	0.08	13.95	13.92
19	0.01	10.92	10.9	60	0.02	13.95	13.92
20	0.08	14.8	14.77	61	0.02	13.55	13.52
21	0.01	14.8	14.77	62	0.08	13.88	13.85
22	0.02	12.31	12.28	63	0.02	13.88	13.85
23	0.08	14.57	14.54	64	0.1	14.76	14.73
24	0.02	14.57	14.54	65	0.02	14.76	14.73
25	0.09	10.32	10.3	66	0.11	11.85	11.83
26	0.02	10.32	10.3	67	0.02	11.85	11.83
27	0.04	11.57	11.55	68	0.07	14.8	14.77
28	0.02	11.57	11.55	69	0.02	14.8	14.77
29	0.02	14.66	14.63	70	0.06	11.55	11.52
30	0.05	11.55	11.52	71	0.02	11.55	11.52
31	0.02	11.55	11.52	72	0.1	14.66	14.63
32	0.07	10.91	10.89	73	0.07	12.67	12.65
33	0.02	10.91	10.89	74	0.08	12.64	12.61
34	0.09	14.01	13.99	75	0.14	11.67	11.65
35	0.02	14.01	13.99	76	0.03	11.67	11.65
36	0.05	14.81	14.78	77	0.05	12.67	12.65
37	0.02	14.81	14.78	78	0.02	12.67	12.65
38	0.08	14.13	14.1	79	0.06	12.48	12.45
39	0.08	14.11	14.08	80	0.02	12.48	12.45
40	0.05	12.5	12.48	81	0.06	15.68	15.65

41	0.02	12.5	12.48	82	0.02	15.68	15.65
83	0.06	10.82	10.8	130	0.12	11.64	11.62
84	0.02	10.82	10.8	131	0.13	11.6	11.58
85	0.08	11.05	11.02	132	0.06	12.62	12.59
86	0.02	11.05	11.02	133	0.03	12.62	12.59
87	0.04	12.39	12.37	134	0.16	12	11.98
88	0.02	12.39	12.37	135	0.03	12	11.98
89	0.06	15.74	15.71	136	0.17	12.9	12.87
90	0.02	15.74	15.71	137	0.03	12.9	12.87
91	0.1	14.55	14.52	138	0.14	13.83	13.8
92	0.02	14.55	14.52	139	0.24	13.82	13.79
93	0.05	12.31	12.28	140	0.06	12.76	12.74
94	0.03	12.31	12.28	141	0.03	12.76	12.74
95	0.05	14.79	14.76	142	0.07	15.56	15.53
96	0.03	14.79	14.76	143	0.03	15.56	15.53
97	0.09	14.8	14.77	144	0.1	13.93	13.9
98	0.03	14.8	14.77	145	0.03	13.93	13.9
99	0.11	10.83	10.81	146	0.11	13.84	13.81
100	0.03	10.83	10.81	147	0.03	13.84	13.81
101	0.08	11.08	11.06	148	0.06	12.42	12.4
102	0.03	11.08	11.06	149	0.03	12.42	12.4
103	0.07	14.79	14.76	150	0.07	14.57	14.54
104	0.03	14.79	14.76	151	0.12	14.59	14.56
105	0.03	12.51	12.49	152	0.03	14.59	14.56
106	0.05	15.59	15.56	153	0.12	11.55	11.52
107	0.03	15.59	15.56	154	0.11	11.5	11.47
108	0.06	13.87	13.84	155	0.09	11.06	11.04
109	0.03	13.87	13.84	156	0.13	11.08	11.06
110	0.05	14.51	14.48	157	0.1	13.62	13.59
111	0.03	14.51	14.48	158	0.03	13.62	13.59
112	0.14	11.82	11.79	159	0.13	14.79	14.76
113	0.03	11.82	11.79	160	0.03	14.79	14.76
114	0.09	14.8	14.77	161	0.07	14.51	14.48
115	0.03	14.8	14.77	162	0.03	14.51	14.48
116	0.03	14.57	14.54	163	0.08	13.92	13.89
117	0.09	14.8	14.77	164	0.03	13.92	13.89
118	0.03	14.8	14.77	165	0.07	14.8	14.77
119	0.14	10.34	10.32	166	0.03	14.8	14.77
120	0.03	10.34	10.32	167	0.05	11.69	11.67
121	0.13	14.31	14.28	168	0.11	11.69	11.67
122	0.03	14.31	14.28	169	0.06	12.41	12.39
123	0.11	10.92	10.9	170	0.04	12.41	12.39
124	0.03	10.92	10.9	171	0.06	12.58	12.55
125	0.04	11.85	11.83	172	0.04	12.58	12.55
126	0.06	15.63	15.6	173	0.1	10.53	10.51
127	0.03	15.63	15.6	174	0.04	10.53	10.51
128	0.22	11.82	11.8	175	0.2	10.98	10.95

129	0.03	11.82	11.8	176	0.04	10.98	10.95
177	0.02	11.55	11.52	224	0.13	11.79	11.77
178	0.1	10.94	10.92	225	0.14	14.39	14.36
179	0.04	10.94	10.92	226	0.06	14.39	14.36
180	0.09	10.78	10.76	227	0.1	11.64	11.61
181	0.04	10.78	10.76	228	0.07	11.63	11.61
182	0.24	14.81	14.78	229	0.12	14.64	14.61
183	0.08	14.52	14.49	230	0.19	14.68	14.65
184	0.04	14.52	14.49	231	0.24	11.87	11.85
185	0.14	14.64	14.61	232	0.08	11.87	11.85
186	0.04	14.64	14.61	233	0.22	12.07	12.04
187	0.07	11.88	11.85	234	0.2	11.99	11.97
188	0.04	11.87	11.85	235	0.12	14.81	14.78
189	0.13	14.2	14.18	236	0.07	14.81	14.78
190	0.14	14.15	14.12	237	0.07	11.64	11.62
191	0.04	13.62	13.59	238	0.43	14.82	14.79
192	0.15	13.86	13.83	239	0.14	14.81	14.78
193	0.05	13.86	13.83	240	0.12	13.89	13.86
194	0.06	13.96	13.93	241	0.16	13.69	13.66
195	0.04	13.96	13.93	242	0.17	13.2	13.18
196	0.07	12.45	12.43	243	0.19	13.04	13.02
197	0.04	12.45	12.43	244	0.19	14.82	14.79
198	0.1	11.92	11.89	245	0.25	11.49	11.47
199	0.05	11.92	11.89	246	0.17	11.46	11.44
200	0.08	11.07	11.05	247	0.1	11.86	11.83
201	0.05	11.07	11.05	248	0.08	11.85	11.83
202	0.13	14.53	14.5	249	0.15	14.8	14.77
203	0.05	14.53	14.5	250	0.13	14.8	14.77
204	0.12	14.8	14.77	251	0.13	12.73	12.7
205	0.05	14.8	14.77	252	0.12	13.91	13.88
206	0.19	14.51	14.48	253	0.09	13.91	13.88
207	0.05	14.51	14.48	254	0.17	10.3	10.28
208	0.06	11.85	11.83	255	0.09	10.3	10.28
209	0.16	11.79	11.77	256	0.27	13.9	13.87
210	0.05	11.79	11.77	257	0.1	13.9	13.87
211	0.14	10.59	10.57	258	0.13	15.78	15.74
212	0.05	10.59	10.57	259	0.15	15.48	15.45
213	0.08	13.95	13.92	260	0.28	12.47	12.45
214	0.05	13.95	13.92	261	0.1	12.47	12.45
215	0.09	10.96	10.94	262	0.24	12.58	12.55
216	0.05	10.96	10.94	263	0.14	12.47	12.44
217	0.11	14.8	14.77	264	0.12	14.79	14.76
218	0.05	14.8	14.77	265	0.18	14.79	14.76
219	0.12	10.89	10.87	266	0.12	11.89	11.86
220	0.06	10.89	10.87	267	0.2	11.89	11.86
221	0.07	12.55	12.53	268	0.18	14.51	14.48
222	0.06	12.55	12.53	269	0.11	14.51	14.48

223	0.15	11.84	11.82	270	0.18	14.81	14.78
271	0.31	14.8	14.77	318	0.08	13.21	13.19
272	0.24	13.62	13.59	319	0.16	13.22	13.19
273	0.31	13.24	13.22	320	0.11	11.78	11.76
274	0.97	14.79	14.76	321	0.11	11.46	11.43
275	0.36	14.79	14.76	322	0.16	11.66	11.64
276	0.29	14.83	14.8	323	0.2	11.77	11.75
277	0.23	15.45	15.42	324	0.11	11.37	11.35
278	0.57	14.79	14.76	325	0.13	11.03	11.01
279	0.35	14.58	14.55	326	0.36	11.82	11.8
280	0.15	11.43	11.41	327	0.19	11.78	11.75
281	0.11	11.42	11.39	328	0.08	11.49	11.47
282	0.14	10.28	10.25	329	0.2	11.3	11.28
283	0.34	10.25	10.23	330	0.15	11.02	11
284	0.16	11.26	11.24	331	0.15	12.07	12.05
285	0.14	11.3	11.27	332	0.23	12.05	12.03
286	0.23	10.07	10.05	333	0.12	13.22	13.19
287	0.28	10.05	10.03	334	0.15	13.15	13.13
288	0.14	10.98	10.95	335	0.23	12.11	12.08
289	0.23	10.78	10.76	336	0.14	13.28	13.25
290	0.24	11.61	11.59	337	0.28	13.32	13.3
291	0.31	11.6	11.57	338	0.23	14.64	14.61
292	0.1	11.24	11.22	339	0.09	14.59	14.56
293	0.12	13.26	13.23	340	0.19	13.97	13.94
294	0.18	13.26	13.23	341	0.18	13.92	13.89
295	0.36	12.39	12.36	342	0.18	11.13	11.11
296	0.16	12.35	12.32	343	0.2	11.68	11.65
297	0.26	12.32	12.29	344	0.23	12.5	12.47
298	0.27	13.28	13.25	345	0.5	12.56	12.53
299	0.36	11.26	11.24	346	0.18	11.92	11.89
300	0.2	10.98	10.96	347	0.2	11.15	11.13
301	0.18	11.56	11.53	348	0.36	12.37	12.34
302	0.18	11.78	11.76	349	0.21	12.42	12.4
303	0.31	11.68	11.66	350	0.24	11.55	11.52
304	0.25	11.48	11.46	351	0.21	11.27	11.25
305	0.35	10.66	10.63	352	0.22	12.01	11.99
306	0.26	10.5	10.48	353	0.25	12.87	12.85
307	0.27	10.46	10.44	354	0.28	12.77	12.75
308	0.35	13.66	13.63	355	0.24	13.03	13
309	0.34	13.72	13.7	356	0.22	11.23	11.21
310	0.49	10.28	10.26	357	0.41	11.34	11.32
311	0.33	10.16	10.14	358	0.27	12.11	12.09
312	0.3	13.85	13.83	359	0.42	11.52	11.5
313	0.09	11.09	11.06	360	0.27	12.34	12.32
314	0.08	11.08	11.06	361	0.3	11.3	11.28
315	0.11	11.05	11.03	362	0.41	12.27	12.25
316	0.17	11.03	11.01	363	0.52	11.97	11.95

317	0.17	11.17	11.15	364	0.11	11.8	11.78
365	0.29	13.25	13.22	412	0.1	11.75	11.73
366	0.12	13.2	13.17	413	0.07	11.61	11.58
367	0.13	13.2	13.17	414	0.1	12.33	12.3
368	0.23	13.74	13.71	415	0.29	13.86	13.83
369	0.17	13.73	13.71	416	0.08	13.89	13.86
370	0.1	11.49	11.46	417	0.1	13.38	13.36
371	0.21	11.47	11.45	418	0.16	13.31	13.29
372	0.22	11.53	11.51	419	0.28	13.92	13.89
373	0.14	13.86	13.84	420	0.24	13.46	13.43
374	0.18	11.58	11.56	421	0.17	13.88	13.85
375	0.2	11.87	11.84	422	0.19	14.61	14.58
376	0.13	11.79	11.76	423	0.28	14.47	14.44
377	0.23	13.6	13.57	424	0.16	12.22	12.2
378	0.26	11.4	11.38	425	0.22	14.45	14.42
379	0.24	11.36	11.34	426	0.23	14.13	14.1
380	0.21	11.71	11.69	427	0.32	13.71	13.68
381	0.3	13.05	13.03	428	0.25	14.14	14.12
382	0.32	12.87	12.84	429	0.22	12.19	12.16
383	0.21	11.63	11.6	430	0.3	13.52	13.49
384	0.2	13.18	13.16	431	0.42	12.84	12.81
385	0.2	13.17	13.14	432	0.56	13.77	13.74
386	0.22	11.99	11.97	433	0.11	12.99	12.96
387	0.24	13.9	13.87	434	0.03	12.97	12.95
388	0.31	13.35	13.32	435	0.21	12.96	12.93
389	0.43	13.49	13.46	436	0.14	13.04	13.01
390	0.24	13.22	13.19	437	0.23	13.16	13.13
391	0.46	13.95	13.92	438	0.06	14.22	14.19
392	0.34	13.82	13.79	439	0.06	14.09	14.06
393	0.29	12.25	12.22	440	0.17	14.53	14.5
394	0.26	12.53	12.5	441	0.04	14.8	14.77
395	0.28	12.09	12.07	442	0.08	14.76	14.73
396	0.25	12.83	12.81	443	0.07	14.81	14.78
397	0.36	11.99	11.96	444	0.29	13.96	13.93
398	0.1	14.51	14.48	445	0.13	14.81	14.78
399	0.1	12.7	12.68	446	0.11	14.57	14.54
400	0.07	14.52	14.49	447	0.19	14.44	14.41
401	0.02	13.9	13.88	448	0.06	12.56	12.53
402	0.24	13.18	13.15	449	0.17	14.55	14.52
403	0.06	12.79	12.76	450	0.11	14.66	14.63
404	0.07	11.86	11.84	451	0.13	14.52	14.49
405	0.05	11.82	11.8	452	0.14	14.52	14.49
406	0.05	12.95	12.92	453	0.2	12.72	12.7
407	0.25	11.48	11.46	454	0.32	14.4	14.37
408	0.06	12.44	12.41	455	0.54	14.32	14.29
409	0.16	12.41	12.39	456	0.29	14.27	14.24
410	0.17	14.56	14.53	457	0.28	13.27	13.24

411	0.09	14.51	14.48	458	0.39	14.03	14
459	0.32	13.8	13.78	506	0.05	11.3	11.27
460	0.42	13.64	13.61	507	0.01	11.3	11.27
461	0.23	13.38	13.35	508	0.01	11.42	11.4
462	0.26	13.08	13.05	509	0.08	10.87	10.85
463	0.4	14.03	14	510	0.12	10.85	10.83
464	0.36	13.46	13.43	511	0.04	10.81	10.79
465	0.45	14.15	14.12	512	0.14	11.3	11.28
466	0.54	14.96	14.93	513	0.01	11.3	11.28
467	0.4	15.93	15.9	514	0.01	14.8	14.77
468	0.03	14.75	14.72	515	0.16	11.85	11.83
469	0	15.96	15.93	516	0.01	11.85	11.83
470	0.1	14.82	14.79	517	0.06	10.69	10.67
471	0.07	15.81	15.78	518	0.11	10.69	10.66
472	0.09	15.93	15.9	519	0.05	11.78	11.76
473	0.09	10.83	10.81	520	0.1	11.78	11.76
474	0.04	10.83	10.81	521	0.05	10.82	10.8
475	0.12	11.6	11.58	522	0.08	10.68	10.66
476	0.06	11.6	11.58	523	0.08	10.68	10.66
477	0.29	10.08	10.06	524	0.2	10.91	10.88
478	0.07	10.08	10.06	525	0.01	14.56	14.53
479	0.08	12.39	12.36	526	0.01	12.44	12.41
480	0.04	10.78	10.76	527	0.18	15.77	15.74
481	0.06	10.78	10.76	528	0.19	15.77	15.73
482	0.15	10.81	10.78	529	0.11	10.78	10.76
483	0.06	10.81	10.78	530	0.05	10.83	10.81
484	0.24	11.62	11.59	531	0.02	11.43	11.41
485	0.14	11.61	11.59	532	0.13	11.08	11.06
486	0.1	11.57	11.55	533	0.09	14.8	14.77
487	0.1	11.57	11.55	534	0.06	14.8	14.77
488	0.15	10.08	10.06	535	0.08	12.77	12.75
489	0.16	10.07	10.05	536	0.19	12.76	12.74
490	0.16	12.76	12.73	537	0.01	10.83	10.81
491	0.18	12.75	12.73	538	0.01	10.81	10.78
492	0.14	15.74	15.71	539	0.12	10.55	10.53
493	0.05	15.74	15.71	540	0.01	10.55	10.53
494	0.07	12.3	12.28	541	0.14	14.58	14.55
495	0.04	10.33	10.3	542	0.19	10.07	10.05
496	0.1	10.31	10.29	543	0.13	10.06	10.04
497	0.02	10.31	10.28	544	0.04	12.54	12.51
498	0.12	10.75	10.73	545	0.05	10.82	10.8
499	0.08	10.75	10.72	546	0.02	10.82	10.8
500	0.01	11.37	11.35	547	0.2	10.51	10.49
501	0.14	11.42	11.4	548	0.02	10.51	10.48
502	0.17	11.42	11.4	549	0.17	15.77	15.74
503	0.07	12.27	12.25	550	0.02	15.77	15.74
504	0.02	10.82	10.8	551	0.02	11.49	11.46

505	0.01	10.82	10.8	552	0.02	11.92	11.89
553	0.02	10.78	10.76	600	0.09	10.46	10.44
554	0.02	14.8	14.77	601	0.16	11.84	11.82
555	0.15	11.6	11.58	602	0.02	10.81	10.78
556	0.05	10.7	10.68	603	0.1	11.95	11.92
557	0.18	11.57	11.55	604	0.1	11.94	11.92
558	0.02	11.57	11.55	605	0.02	14.51	14.48
559	0.02	11.3	11.27	606	0.14	11.28	11.26
560	0.22	13.68	13.65	607	0.23	13.84	13.82
561	0.02	13.68	13.65	608	0.03	13.84	13.82
562	0.11	12.31	12.28	609	0.1	11.71	11.68
563	0.09	12.3	12.28	610	0.18	11.59	11.57
564	0.1	12.06	12.04	611	0.02	11.59	11.57
565	0.02	12.06	12.04	612	0.19	10.96	10.94
566	0.02	10.81	10.78	613	0.22	11.38	11.35
567	0.06	14.58	14.55	614	0.03	11.38	11.35
568	0.17	13.65	13.63	615	0.12	11.6	11.58
569	0.02	13.65	13.63	616	0.04	10.06	10.04
570	0.09	11.86	11.83	617	0.21	15.74	15.71
571	0.02	12.33	12.3	618	0.04	15.74	15.71
572	0.02	10.92	10.9	619	0.15	10.5	10.48
573	0.1	10.72	10.69	620	0.12	12.9	12.88
574	0.02	10.7	10.68	621	0.03	12.9	12.88
575	0.1	12.06	12.04	622	0.03	14.8	14.77
576	0.02	15.81	15.78	623	0.03	12.3	12.28
577	0.09	11.75	11.73	624	0.12	10.82	10.79
578	0.02	11.75	11.73	625	0.03	10.82	10.79
579	0.13	11.24	11.21	626	0.04	11.24	11.22
580	0.12	11.23	11.21	627	0.05	10.68	10.65
581	0.02	10.91	10.88	628	0.03	10.68	10.65
582	0.2	11.39	11.37	629	0.11	10.77	10.75
583	0.08	13.38	13.36	630	0.03	10.77	10.75
584	0.03	11.48	11.46	631	0.09	10.83	10.81
585	0.02	13.38	13.36	632	0.07	10.68	10.66
586	0.07	11.84	11.82	633	0.03	10.68	10.66
587	0.02	11.84	11.82	634	0.03	10.69	10.67
588	0.08	10.07	10.05	635	0.04	15.77	15.74
589	0.03	10.07	10.05	636	0.04	13.6	13.57
590	0.15	13.09	13.07	637	0.03	10.68	10.66
591	0.02	13.09	13.07	638	0.03	14.82	14.79
592	0.02	10.78	10.76	639	0.03	11.08	11.06
593	0.03	13.82	13.79	640	0.15	12.72	12.69
594	0.02	11.02	11	641	0.03	12.72	12.69
595	0.14	11.22	11.2	642	0.19	11.57	11.55
596	0.03	11.22	11.2	643	0.14	10.56	10.54
597	0.05	11.6	11.58	644	0.03	10.56	10.54
598	0.02	11.6	11.58	645	0.39	10.33	10.31

599	0.17	10.47	10.44	646	0.27	10.3	10.28
647	0.18	12	11.98	694	0.2	12.26	12.24
648	0.03	12	11.98	695	0.04	10.75	10.72
649	0.34	10.68	10.66	696	0.03	12.5	12.47
650	0.17	10.66	10.64	697	0.11	11.79	11.76
651	0.04	12.25	12.22	698	0.04	11.79	11.76
652	0.04	15.74	15.71	699	0.16	11.84	11.81
653	0.18	15.82	15.79	700	0.11	11.82	11.8
654	0.05	15.82	15.79	701	0.04	11.6	11.58
655	0.1	10.68	10.65	702	0.17	12.89	12.86
656	0.15	12.77	12.74	703	0.03	12.89	12.86
657	0.09	10.07	10.05	704	0.13	12.79	12.76
658	0.03	10.66	10.64	705	0.03	11.95	11.92
659	0.03	12.06	12.04	706	0.04	13.38	13.36
660	0.17	13.01	12.98	707	0.2	10.05	10.03
661	0.03	13.01	12.98	708	0.05	10.05	10.03
662	0.19	10.07	10.05	709	0.11	11.7	11.68
663	0.04	10.07	10.05	710	0.1	11.7	11.68
664	0.03	10.31	10.29	711	0.13	12.94	12.92
665	0.16	12.91	12.89	712	0.22	12.94	12.91
666	0.03	11.78	11.76	713	0.05	11.7	11.68
667	0.03	10.55	10.53	714	0.03	11.86	11.84
668	0.19	10.06	10.04	715	0.08	10.92	10.9
669	0.04	10.06	10.04	716	0.03	10.83	10.81
670	0.04	10.98	10.95	717	0.29	10.76	10.74
671	0.03	11.48	11.46	718	0.14	11.85	11.82
672	0.03	11.84	11.82	719	0.04	11.85	11.82
673	0.12	14.8	14.77	720	0.37	9.65	9.63
674	0.13	10.79	10.77	721	0.06	9.64	9.63
675	0.03	10.79	10.77	722	0.05	10.06	10.04
676	0.11	13.65	13.63	723	0.2	10.54	10.52
677	0.03	11.46	11.43	724	0.05	10.54	10.52
678	0.03	10.68	10.65	725	0.04	10.78	10.76
679	0.09	11.58	11.56	726	0.04	11.75	11.73
680	0.07	10.82	10.8	727	0.19	10.92	10.9
681	0.15	10.56	10.54	728	0.17	10.63	10.61
682	0.03	10.56	10.54	729	0.16	10.59	10.57
683	0.09	11.84	11.81	730	0.21	11.56	11.54
684	0.15	11.08	11.06	731	0.04	11.56	11.54
685	0.03	11.08	11.06	732	0.09	10.7	10.68
686	0.05	11.58	11.56	733	0.04	12.3	12.28
687	0.03	13.08	13.05	734	0.04	14.8	14.77
688	0.03	10.83	10.81	735	0.14	13.04	13.02
689	0.14	10.76	10.74	736	0.15	13.04	13.01
690	0.21	11.81	11.79	737	0.18	12	11.97
691	0.03	11.81	11.79	738	0.04	14.82	14.79
692	0.03	11.99	11.97	739	0.25	10.23	10.21

693	0.17	12.27	12.24	740	0.2	10.18	10.16
741	0.06	12.99	12.96	788	0.23	12.05	12.02
742	0.24	10.06	10.03	789	0.05	11.05	11.03
743	0.06	10.05	10.03	790	0.09	11.47	11.45
744	0.04	12.79	12.76	791	0.06	11.57	11.55
745	0.04	11.86	11.83	792	0.15	10.76	10.74
746	0.04	14.8	14.77	793	0.08	10.54	10.52
747	0.15	10.05	10.03	794	0.21	12.5	12.48
748	0.14	11.72	11.7	795	0.05	12.5	12.48
749	0.19	11.63	11.61	796	0.12	12.49	12.47
750	0.06	10.05	10.03	797	0.13	12.47	12.45
751	0.12	12.27	12.24	798	0.05	11.93	11.91
752	0.05	12.27	12.24	799	0.09	13.74	13.71
753	0.04	14.58	14.55	800	0.35	10.23	10.21
754	0.06	12.76	12.74	801	0.08	10.23	10.21
755	0.06	15.77	15.73	802	0.14	12.95	12.93
756	0.05	13.95	13.92	803	0.05	10.76	10.74
757	0.14	11.96	11.94	804	0.1	11.4	11.38
758	0.05	10.72	10.69	805	0.06	11.78	11.76
759	0.12	12.28	12.25	806	0.2	10.91	10.89
760	0.17	12.27	12.25	807	0.2	10.26	10.24
761	0.05	11.3	11.28	808	0.08	12.75	12.73
762	0.12	10.76	10.74	809	0.06	10.91	10.89
763	0.16	10.75	10.72	810	0.18	12.74	12.72
764	0.18	13.9	13.87	811	0.35	12.74	12.71
765	0.09	13.9	13.87	812	0.2	13.21	13.18
766	0.07	15.74	15.71	813	0.06	12.06	12.04
767	0.18	13.91	13.88	814	0.06	10.3	10.28
768	0.05	10.75	10.72	815	0.06	11.6	11.58
769	0.07	10.75	10.73	816	0.17	11	10.97
770	0.23	12.75	12.72	817	0.08	11	10.97
771	0.25	10.48	10.46	818	0.2	10.05	10.03
772	0.05	10.48	10.46	819	0.16	10.74	10.72
773	0.21	11.12	11.1	820	0.09	10.05	10.03
774	0.05	11.46	11.43	821	0.06	12.91	12.89
775	0.13	11.94	11.91	822	0.21	13.49	13.47
776	0.11	11.93	11.91	823	0.22	13.2	13.17
777	0.31	10.55	10.52	824	0.14	12.89	12.86
778	0.06	12.26	12.24	825	0.06	12.89	12.86
779	0.22	11.86	11.84	826	0.06	12.27	12.24
780	0.07	10.06	10.04	827	0.17	12.28	12.25
781	0.06	12.72	12.69	828	0.08	14.55	14.52
782	0.05	11.39	11.37	829	0.06	12	11.97
783	0.1	11.62	11.59	830	0.08	10.91	10.89
784	0.07	11.38	11.35	831	0.06	13.21	13.18
785	0.22	10.92	10.9	832	0.06	11.6	11.58
786	0.05	11.84	11.81	833	0.06	13.31	13.29

787	0.29	12.83	12.8	834	0.06	11.52	11.5
835	0.16	12.83	12.81	882	0.16	10.23	10.21
836	0.08	12.83	12.81	883	0.24	10.59	10.57
837	0.2	11.22	11.2	884	0.17	12.93	12.91
838	0.08	11.17	11.15	885	0.24	11.95	11.93
839	0.18	11.99	11.97	886	0.11	14.58	14.55
840	0.25	11.56	11.54	887	0.21	11.14	11.11
841	0.14	12.07	12.05	888	0.09	11.78	11.75
842	0.09	10.05	10.03	889	0.38	10.51	10.49
843	0.06	11.56	11.54	890	0.14	11.53	11.5
844	0.2	12.53	12.5	891	0.23	11.58	11.56
845	0.09	13.04	13.01	892	0.1	10.74	10.72
846	0.25	12.51	12.49	893	0.24	11.22	11.2
847	0.06	12.51	12.49	894	0.16	13.62	13.59
848	0.14	11.92	11.9	895	0.11	12.26	12.24
849	0.07	10.69	10.66	896	0.1	14.53	14.5
850	0.3	10.63	10.61	897	0.23	12.3	12.27
851	0.07	10.63	10.61	898	0.42	10.09	10.07
852	0.25	11.39	11.36	899	0.12	10.63	10.61
853	0.2	13.92	13.89	900	0.24	12.64	12.62
854	0.07	12.07	12.05	901	0.22	10.94	10.92
855	0.07	14.64	14.61	902	0.35	13.13	13.1
856	0.1	9.64	9.62	903	0.41	9.85	9.83
857	0.21	11	10.98	904	0.12	10.96	10.94
858	0.11	12.74	12.71	905	0.12	11.56	11.54
859	0.07	10.46	10.44	906	0.44	10.21	10.19
860	0.08	12.05	12.03	907	0.17	10.9	10.88
861	0.07	13.21	13.18	908	0.3	11.19	11.17
862	0.08	11.77	11.74	909	0.46	13.06	13.03
863	0.27	13.62	13.59	910	0.26	10.8	10.78
864	0.07	10.92	10.9	911	0.26	11.05	11.03
865	0.11	11.56	11.54	912	0.18	11.18	11.16
866	0.09	11.78	11.76	913	0.46	9.69	9.67
867	0.13	13.84	13.82	914	0.34	12.25	12.22
868	0.14	10.3	10.28	915	0.2	12.44	12.42
869	0.2	10.38	10.36	916	0.27	13.04	13.02
870	0.25	12.58	12.55	917	0.25	10.5	10.47
871	0.08	12.41	12.39	918	0.19	13.91	13.89
872	0.08	14.47	14.44				
873	0.11	13.49	13.46				
874	0.08	12.5	12.48				
875	0.28	12.45	12.43				
876	0.12	10.33	10.31				
877	0.08	14.52	14.49				
878	0.08	14.51	14.48				
879	0.25	11.49	11.47				
880	0.08	13.65	13.63				

881	0.09	10.76	10.73				
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Annexure 3

Recuperation test						
Place: Sbibanipur Mouza, Udaynarayanpur Block, Howrah						
SL NO	TIME	INTERVAL (MIN)	TIME SCIENCE PUMPING BEGAN (min)	WATER LEVEL (m)	STATIC WATER LEVEL (m)	DRAWDOWN (m)
1	16:15	1	1	20	20	
2	16:16	1	2	20.01	20	0.01
3	16:17	1	3	20.02	20	0.02
4	16:18	1	4	20.02	20	0.02
5	16:19	1	5	20.02	20	0.02
6	16:20	1	6	20.02	20	0.02
7	16:21	1	7	20.02	20	0.02
8	16:22	1	8	20.02	20	0.02
9	16:23	1	9	20.03	20	0.03
10	16:24	1	10	20.03	20	0.03
11	16:25	1	11	20.03	20	0.03
12	16:26	1	12	20.03	20	0.03
13	16:27	1	13	20.03	20	0.03
14	16:28	1	14	20.03	20	0.03
15	16:29	1	15	20.04	20	0.04
16	16:30	1	16	20.04	20	0.04
17	16:31	1	17	20.04	20	0.04
18	16:32	1	18	20.04	20	0.04
19	16:33	1	19	20.04	20	0.04
20	16:34	1	20	20.04	20	0.04
21	16:35	1	21	20.05	20	0.05
22	16:36	1	22	20.05	20	0.05
23	16:37	1	23	20.05	20	0.05
24	16:40	3	26	20.05	20	0.05
25	16:52	12	38	20.05	20	0.05
26	16:56	4	42	20.05	20	0.05
27	17:06	10	52	20.06	20	0.06
28	17:12	6	58	20.06	20	0.06
29	17:16	4	62	20.07	20	0.07
30	17:26	10	72	20.08	20	0.08
31	17:41	15	87	20.09	20	0.09
32	17:56	15	102	20.1	20	0.1
33	18:13	17	119	20.11	20	0.11
34	18:20	7	126	20.12	20	0.12
35	18:40	20	146	20.13	20	0.13
36	18:48	8	154	20.14	20	0.14

37	19:15	27	181	20.14	20	0.14
38	19:30	15	196	20.15	20	0.15
39	20:30	60	256	20.16	20	0.16
32	21:30	60	316	20.17	20	0.17
33	22:30	60	376	20.18	20	0.18
34	0:30	120	496	20.18	20	0.18
35	2:30	120	616	20.19	20	0.19
36	4:30	120	736	20.2	20	0.2
37	6:30	120	856	20.2	20	0.2
38	8:30	120	976	20.22	20	0.22
39	9:30	60	1036	20.22	20	0.22
32	10:30	60	1096	20.23	20	0.23
33	11:30	60	1156	20.23	20	0.23
34	12:40	70	1226	20.24	20	0.24
35	13:55	75	1301	20.24	20	0.24
36	14:40	45	1346	20.25	20	0.25
37	15:30	50	1396	20.25	20	0.25
38	16:35	65	1461	20.26	20	0.26
39	17:40	65	1526	20.26	20	0.26
32	18:34	54	1580	20.27	20	0.27
33	19:23	49	1629	20.28	20	0.28
34	21:30	127	1756	20.28	20	0.28
35	0:00	150	1906	20.28	20	0.28
36	2:30	150	2056	20.29	20	0.29
37	4:10	100	2156	20.3	20	0.3
38	6:10	120	2276	20.3	20	0.3
39	8:10	120	2396	20.31	20	0.31
32	9:10	60	2456	20.32	20	0.32
33	11:00	110	2566	20.33	20	0.33
34	12:17	77	2643	20.34	20	0.34
35	12:40	23	2666	20.34	20	0.34
36	13:20	40	2706	20.34	20	0.34

