CE 432

Course Title: Design of Water Supply, Sanitation and Sewerage Systems

Design of Water Supply, Sanitation and Sewerage Systems of a Tannery Village

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ACKNOWLEDGMENTS

The author of this report would like to express their deepest gratitude to Snigdha Afsana, and Mashiat Hossain, Assistant Professor, Department of Civil Engineering, BUET for their guidance on this project showing the path of conducting successful research and above all for always being there as our mentor. They shared their wisdom with us in analyzing subject matters and at the same time valued my thinking approach to synthesize those topics. Their suggestions drove us towards better ways of thinking, their reviews helped in solving problems. The authors are also grateful to Dr. Rowshan Mamtaz, Professor, Department of Civil Engineering, BUET and Dr. Provat Kumar Saha, Assistant Professor Department of Civil Engineering, BUET for providing adequate support.

The authors are also grateful to their fellow group mates of Group-4 for their co-operation and moral support.

ABSTRACT

As an integral part of the Environmental Engineering design sessional course, this report covers the water supply, sanitation and sewerage system design of a proposed industrial village. This report also covers the basic overview of Effluent Treatment Plant design, which is an indispensable part of any industry. A layout of an industrial village consisting of a Textile Industry has been proposed and various components of it were selected and located from practical sense. An estimation of the population of the area has been done based on the organogram prepared for the industry and the estimation was done for both current and future scenario considering a design period of 10 and 20 years. The water demand as well as firefighting demand for the estimated population has been calculated. Taking the geological information of the area into consideration, water wells have been designed as a source of water supply for meeting the demand of the whole area. Pump capacity has been calculated and pumping schedule has been designed for the pumps after gaining practical knowledge about pumps and pumping station from a tour to the pumping stations of BUET. For the distribution of the water, pipe network has been designed for selected area and the pipe sizes have been calculated as well. Moreover, the wastewater generated in the whole area has also been estimated and a sanitary sewerage system was designed. The water distribution in a typical building of the area has been designed as a model for the other buildings and the drainage system of the building has also been designed. In addition to this, basic operational concept of effluent treatment plant has also been covered in this report.

Introduction

The main objectives of the course **CE-432** titled 'DESIGN OF WATER SUPPLY SYSTEM & SEWERAGE SYSTEM FOR A TANNERY INDUSTRIAL VILLAGE' are as follows:

1. Design of infrastructure for the collection, transmission, storage, and distribution of water for residential, commercial establishments, industry as well as for such public needs as firefighting.
2. Design of network of pipes for the collection of wastewaters, or sewage of this wastewater
3. Design of system of pipes and fixtures installed in a building for the distribution and use of potable (drinkable) water and the removal of waterborne wastes.

Tannery transforms raw hides and skins into leather for manufacturing articles like shoes, bags, suitcases, belt, wallet, jacket and many other products. In the past, leather processing was done manually using certain indigenous methods. The first tannery in Bangladesh territory was set up at Narayanganj sometime in the 1940s. It was later shifted to Hazaribag area of Dhaka, which eventually turned into a place packed with various tanneries.

Leather industry is a major industry in Bangladesh and the Government of Bangladesh has declared it as a priority sector. The industry was the second largest export sector of Bangladesh in 2014–15. The industry also plays a good role in creating employment. However, Human Right Watch reported that it is responsible for pollution of air, water, and soil, that lead to serious health problems in the population.

Bangladesh produces approximately 200-220 million sq feet of raw hides and skins, about 85% of which is exported in crust and finished form. The rest is used for producing leather goods to cater to the domestic market. Leather is a traditional export item of Bangladesh.

Some reputed tanneries of Bangladesh are Dhaka Leather, Apex Tannery, Lexco, Karim Lather, Samata Tannery, Bay Tannery, Lexco, Reliance. Tannery industrial estate has been developed in Savar with a view to providing all sorts of infrastructural facilities and to make it environment friendly. As a result, tanneries located at populated area of Hazaribag has been transferred to Savar industrial site.

The aim of this sessional is to design water supply and sewerage system of an industrial village. The first phase is the design of water supply system and the procedures for design of water supply system are as follows.

The structure and relationship of the different groups of people is illustrated in an Organogram. It also reflects the demographic structure of the industrial village. So, an organogram is prepared for the industry. The layout allocates space for different components in the area, provided for the village. Proper placement of different facilities can ensure a healthy environment to the employees and their families. So a layout is drawn to provide the best possible environment to its dwellers by utilizing the sources available to us. Parks, Playground, canteens, mosques, banks, shops and hospitals were provided in the industrial village. Fire station is also established to ensure fire safety. The layout also meets the demand of future extension. Effluent Treatment Plant (ETP) and power stations are also installed in the industrial village.

After estimation of the water demand, the next task is the collection of water to meet the demand. The water demand of the industrial village is completely met by groundwater sources. Water wells were designed to provide maximum performance with minimum cost for longest service life. The numbers of wells required to meet the demand is also determined. Rapid depletion of ground water level in Bangladesh is considered seriously so that it can meet the demand up to 20 years. Well log of wells and bore log of the soil strata is attached with this report.

The transmission of the collected water will be carried out by submersible pump. The capacities of the pumps are calculated as it has to lift the water from source to the overhead water tank. A pumping schedule was prepared to ensure continuous supply of water and also to meet the demand for firefighting. To gather practical experience about pumping schedule, pumping stations of BUET were visited. The water demand fluctuates at different hours of the day but the supply system must be capable to supply the maximum demand of the day. So water demands for different hours of the day were assumed to design supply system.

The distribution system must ensure delivery of water at appropriate quantity, quality and pressure to the consumer. Branched and looped network system is provided in the industrial village. AutoCAD drawing showing the location of water wells, pumps, overhead water tank, and distribution line is added along the report.

The second phase is to design sanitation and sewerage system of the industrial village. The first task is to estimate the quantity of the wastewater generation. The quantity of the wastewater is estimated from amount of water supplied and amount of infiltration. The storm water is not included in calculation of waste water. For the design of the sewer system the gravity flow is considered to reduce the cost. Only the design of the trunk sewer is added to this report as a sample of the design of sewer. Appurtenances of sanitary sewer system like manholes also considered in the design of the sewer system. A longitudinal profile of the trunk sewer is also illustrated in the report.

The third phase of the project is to design household plumbing system. The plumbing system of a residential building has been included in this report. At first plumbing system is designed for distribution and use of potable (drinkable) water. Major elements under this category includes riser, up feed or down feed distribution pipes, overhead and underground water tanks, plumbing fixtures and traps. Then plumbing system for the removal of waterborne wastes is designed. The design includes soil, waste and vent pipes, building drains – sewers with their respective connections, devices and appurtenances.

Learning environmental engineering hydraulics design is the main focus of the sessional. To provide quality water and proper management of the wastewater are vital issues especially in the context of Bangladesh. No doubt this sessional has high lightened both of these topics. This project has undoubtedly made us confident to face the challenges in the field of water supply and sanitation

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ABBREVIATION

MD: Managing Director

GM: General Manager

DGM: Deputy General Manager

HR: Human Resource

FM: Fineness Modulus

HP: Horse Power

BHP: Break Horse Power

WHP: Working Horse Power

I/I: Infiltration/Inflow

UGWR: Underground Water Reservoir

OH: Overhead

WW: Wastewater

FU: Fixture Unit

WSFU: Water Supply Fixture Unit

DFU: Drainage Fixture Unit

ETP: Effluent Treatment Plant

CETP: Common Effluent Treatment Plant

EPS: Effluent Pumping Station

SPGS: Sludge Power Generation Syste

CHAPTER 1

PREPARATION OF ORGANOGRAM

Introduction

Tannery transforms raw hides and skins into leather for manufacturing articles like shoes, bags, suitcases, belt, wallet, jacket and many other products. In the past, leather processing was done manually using certain indigenous methods. The first tannery in Bangladesh territory was set up at Narayanganj sometime in the 1940s. It was later shifted to Hazaribag area of Dhaka, which eventually turned into a place packed with various tanneries.

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Methodology

This lab report contains the detailed layout, organogram and water demand calculations of a Tannery Industrial Estate.

• The Tannery Industrial Estate has been built on land measuring 100 acres.

• As shown in the layout the Tannery Industrial Estate has a highway on one side and a river flowing on the other side.

• Reasonable estimates were taken for several calculations from credible sources. The Bangladesh National Building Code (BNBC) 2006 was used for several estimation and calculation.

• Appropriate assumptions were also made based on similar industries and other reputed tanneries in Bangladesh.

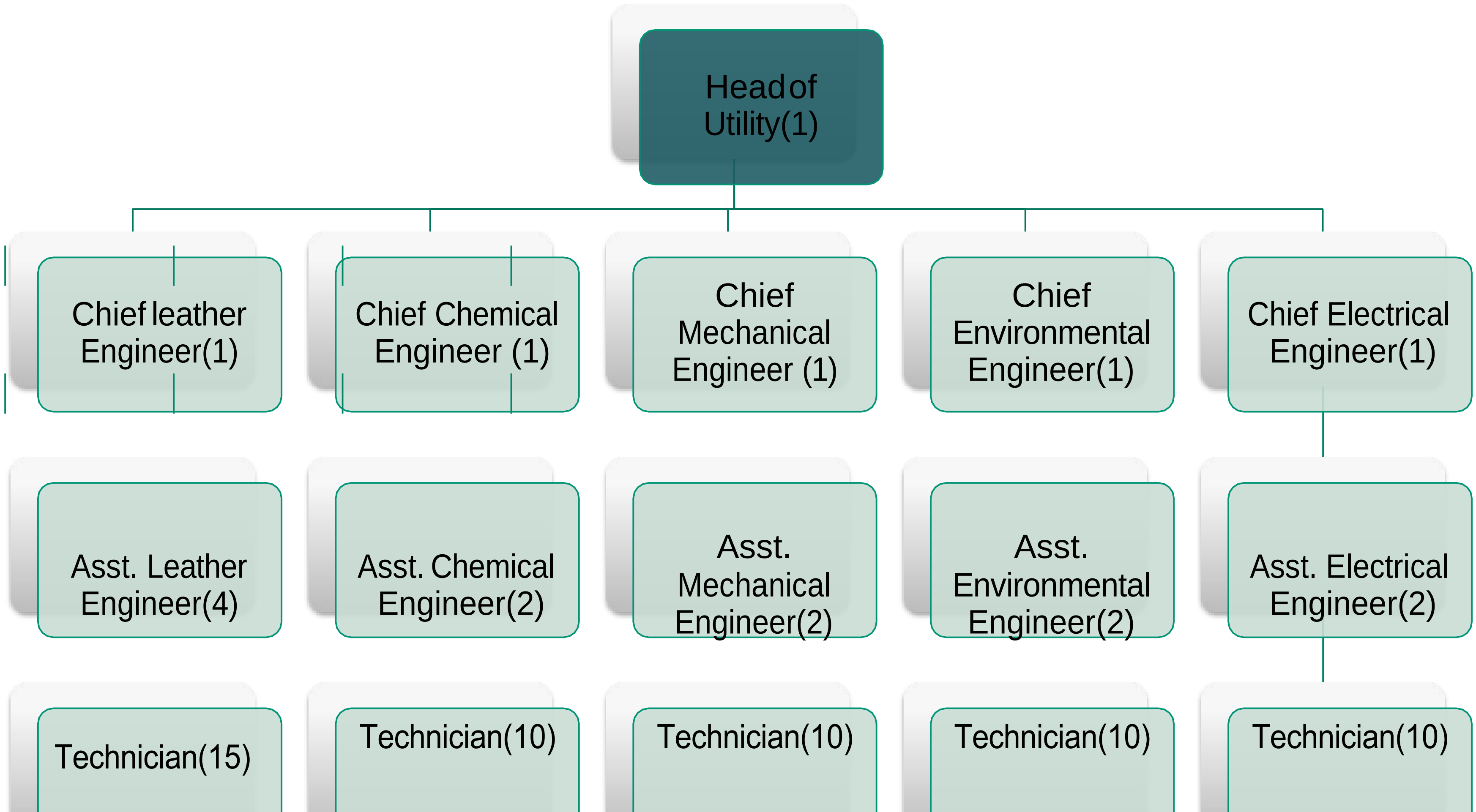
• The layout of the Tannery Industrial Estate was designed in detail keeping in mind several other facilities required for an industrial estate.

• The Organogram of the Tannery Estate was constructed from the Hierarchy structure of similar sized Tannery industries. The organogram consists of the detailed chain of commands of several zones in the Tannery Estate park.

• The water demand calculation include the present water demand, water demand after 10 years, and the water demand after 20 years.

Organogram

An organogram is a diagram that explains the relationship between different people in an organization. An organogram describes the jobs of each establishment at different levels and describes their relationships. It is generally known as Organizational Chart.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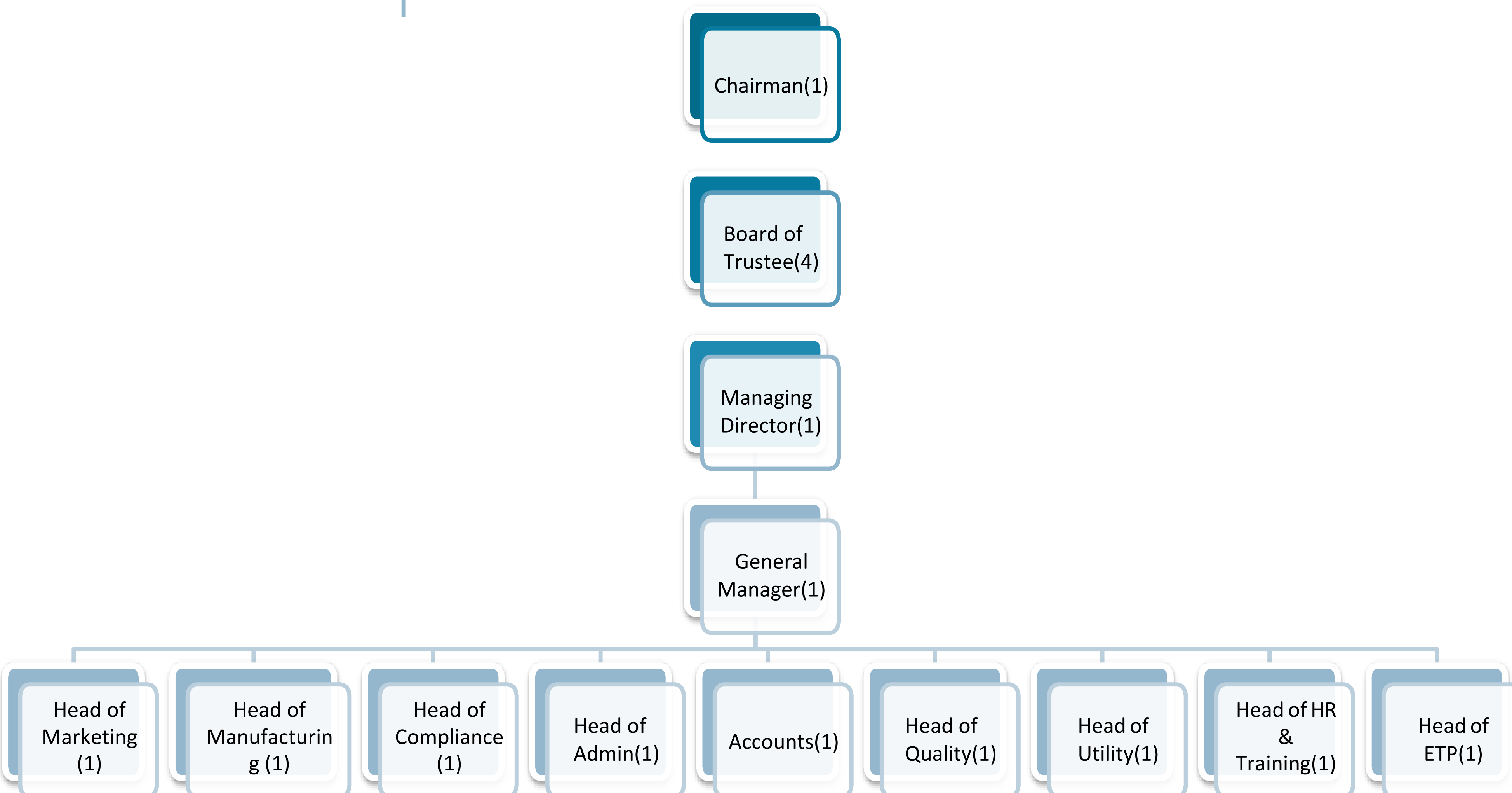
Chief Chemical Engineer (1)
Chief Mechanical Engineer (1)
Chief Environmental Engineer(1)
Chief Electrical Engineer(1)
Asst. Leather Engineer(4)
Asst. Chemical Engineer(2)
Asst. Mechanical Engineer(2)
Asst. Environmental Engineer(2)
Asst. Electrical Engineer(2)
Technician(15)
Technician(10)
Technician(10)
Technician(10)
Technician(10)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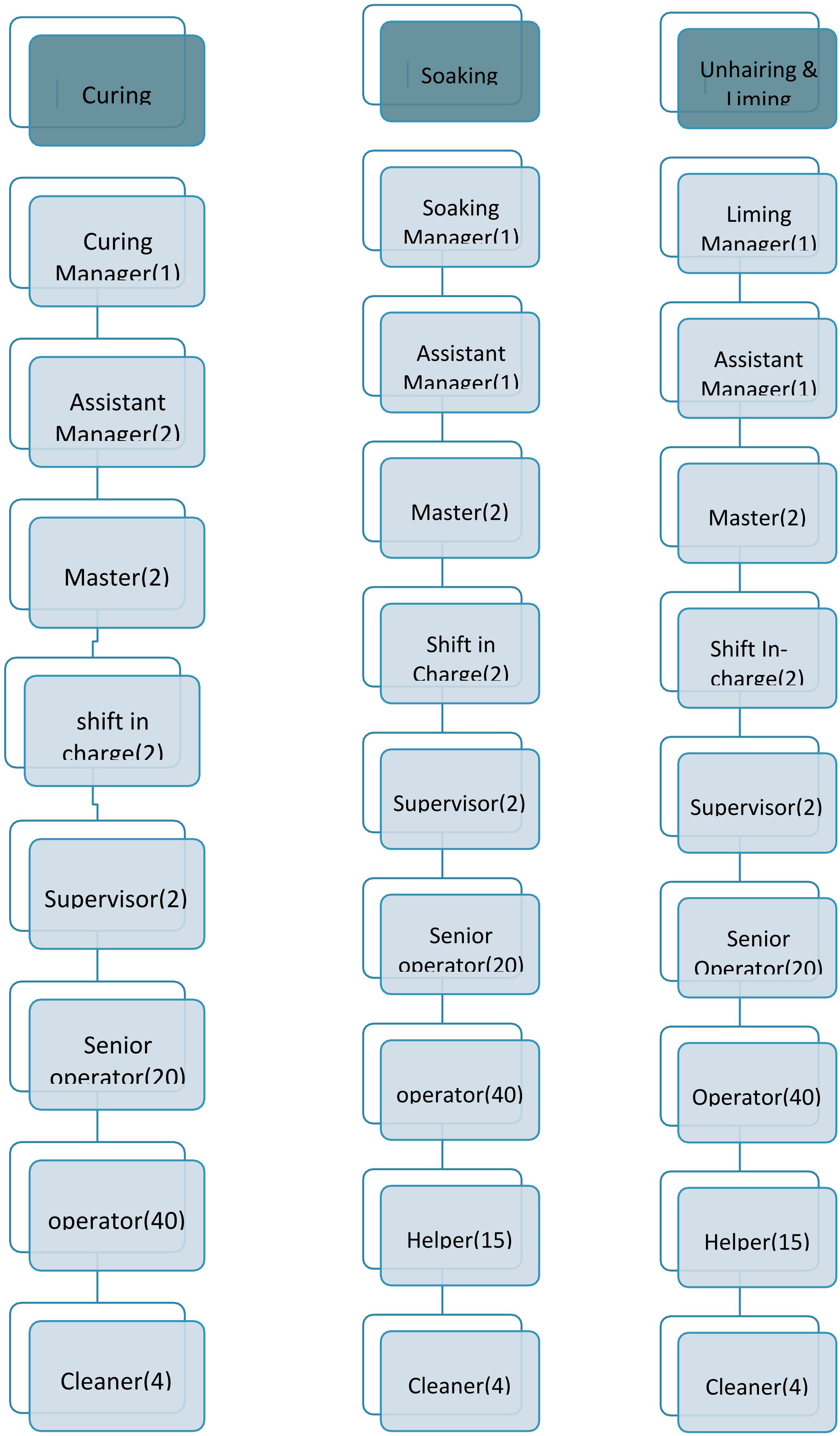
Board of Trustee(4)
Managing Director(1)
General Manager(1)
Head of Marketing (1)
Head of Manufacturing (1)
Head of Compliance (1)
Head of Admin(1)
Accounts(1)
Head of Quality(1)
Head of Utility(1)
Head of HR & Training(1)
Head of ETP(1)


Curing
Curing Manager(1)
Assistant Manager(2)
Master(2)
shift in charge(2)
Supervisor(2)
Senior operator(20)
operator(40)
Cleaner(4)
Soaking
Soaking Manager(1)
Assistant Manager(1)
Master(2)
Shift in Charge(2)
Supervisor(2)
Senior operator(20)
operator(40)
Helper(15)
Cleaner(4)
Unhairing & Liming
Liming Manager(1)
Assistant Manager(1)
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Shift In-charge(2)
Supervisor(2)
Senior Operator(20)
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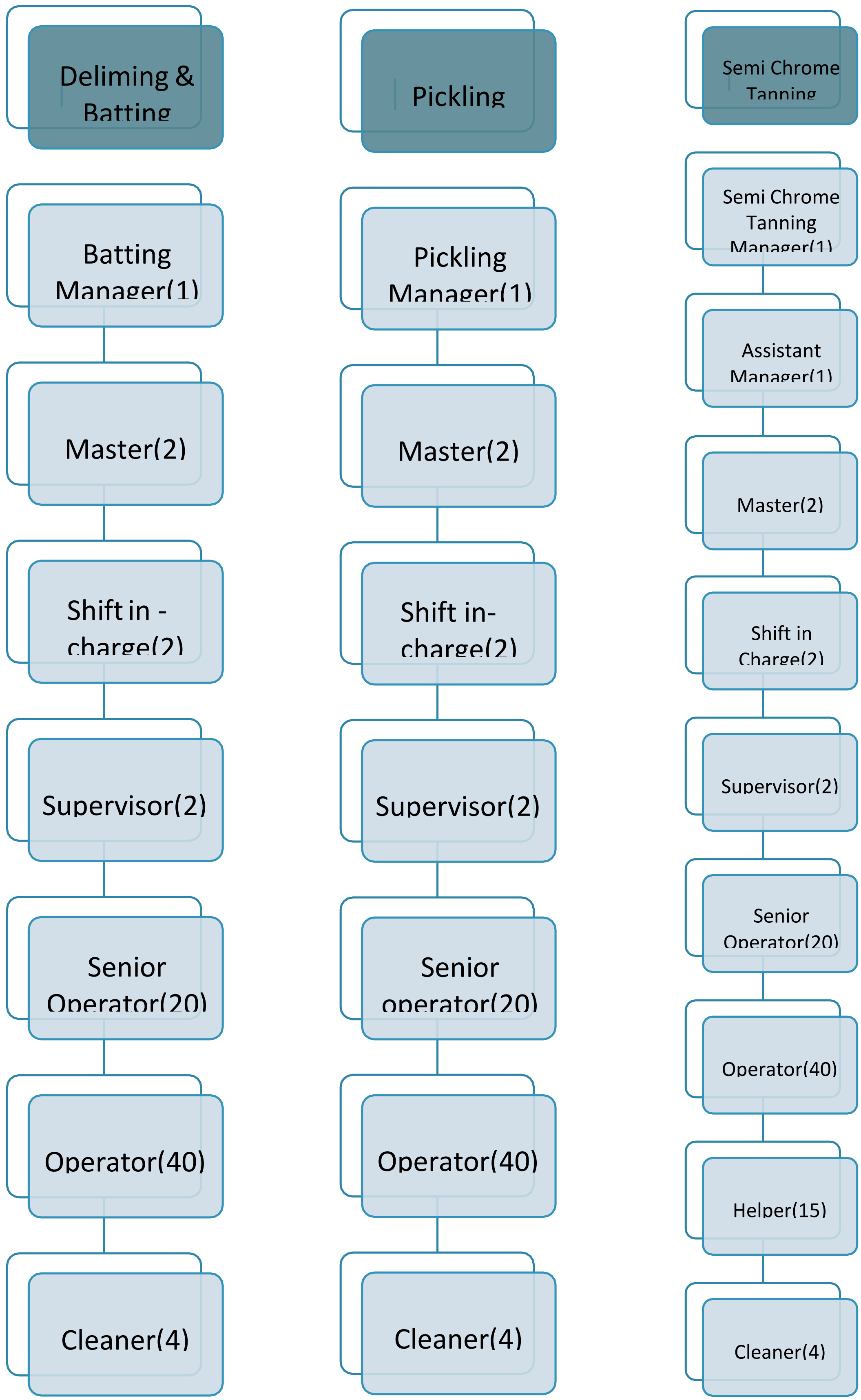

Deliming & Batting
Batting Manager(1)
Master(2)
Shift in - charge(2)
Supervisor(2)
Senior Operator(20)
Operator(40)
Cleaner(4)
Pickling
Pickling Manager(1)
Master(2)
Shift in-charge(2)
Supervisor(2)
Senior operator(20)
Operator(40)
Cleaner(4)
Semi Chrome Tanning
Semi Chrome Tanning Manager(1)
Assistant Manager(1)
Master(2)
Shift in Charge(2)
Supervisor(2)
Senior Operator(20)
Operator(40)
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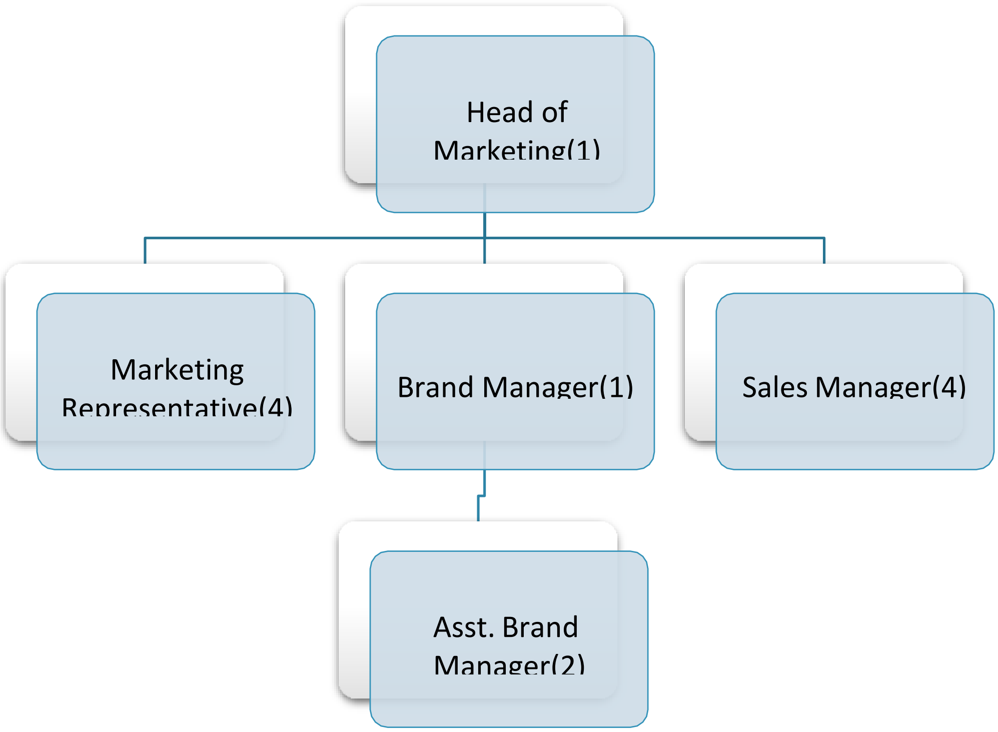
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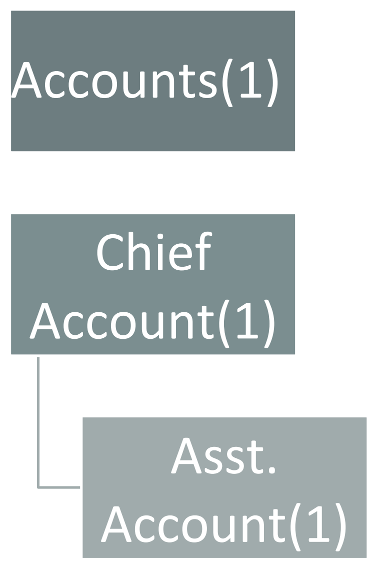
Marketing Representative(4)
Brand Manager(1)
Sales Manager(4)
Asst. Brand Manager(2)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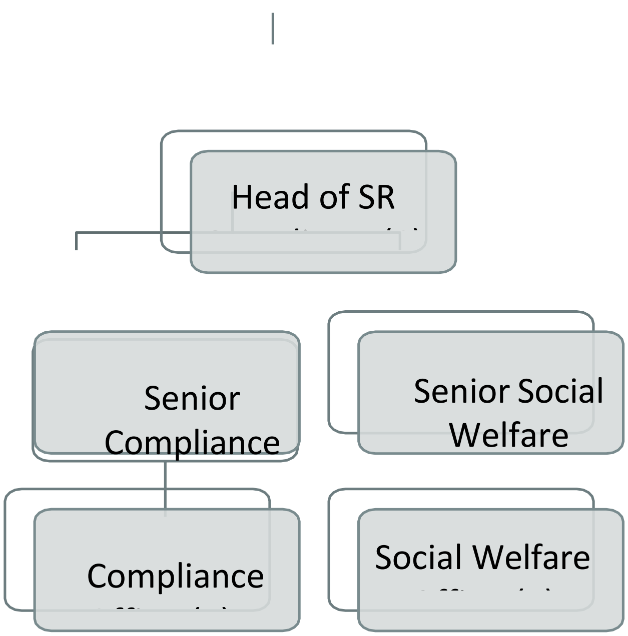
Chief Account(1)
Asst. Account(1)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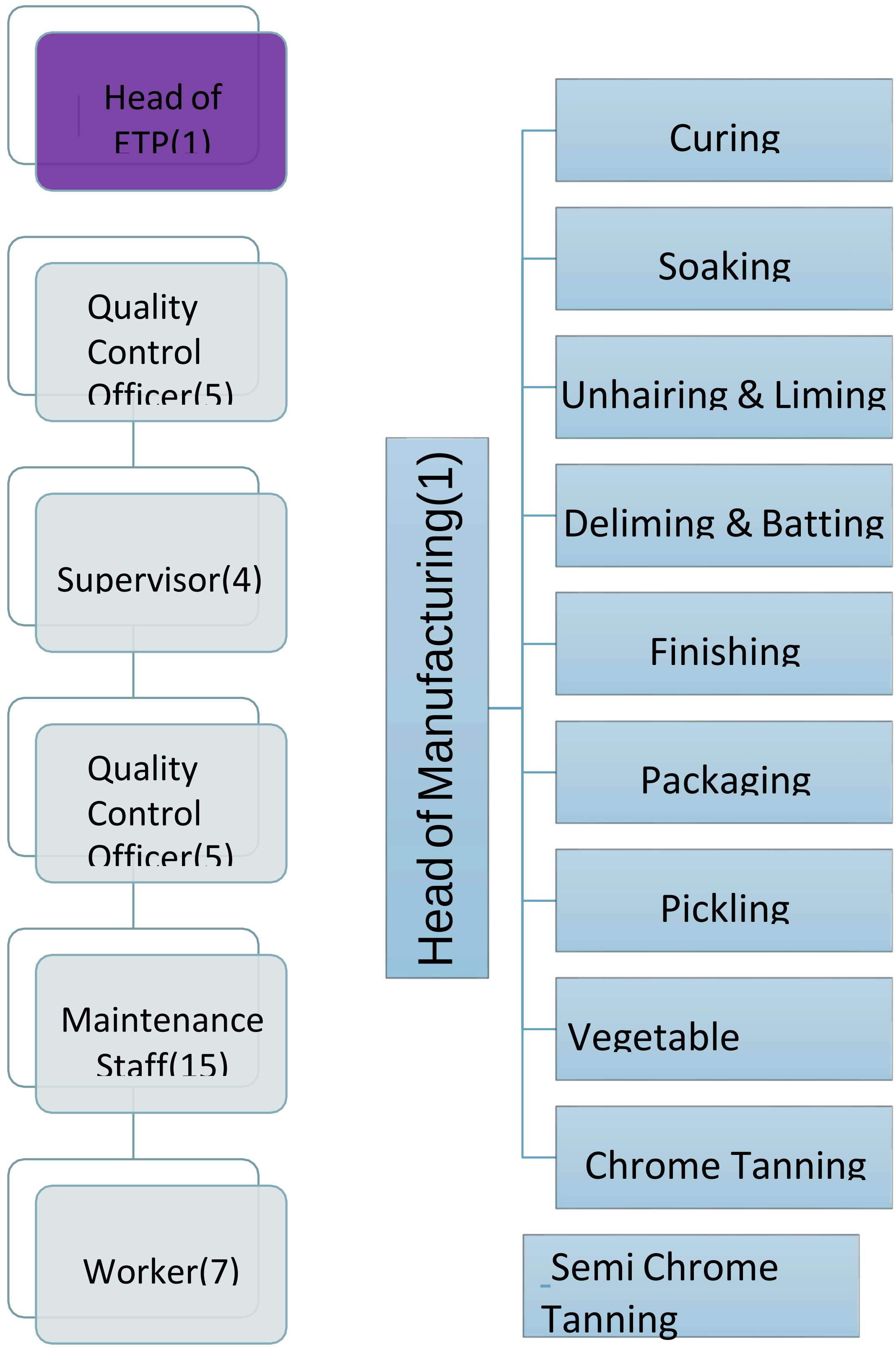
Senior Compliance
Senior Social Welfare
Compliance
Social Welfare


Head of ETP(1)
Quality Control Officer(5)
Supervisor(4)
Quality Control Officer(5)
Maintenance Staff(15)
Worker(7)
Head of Manufacturing(1)
Curing
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Unhairing & Liming
Deliming & Batting
Finishing
Packaging
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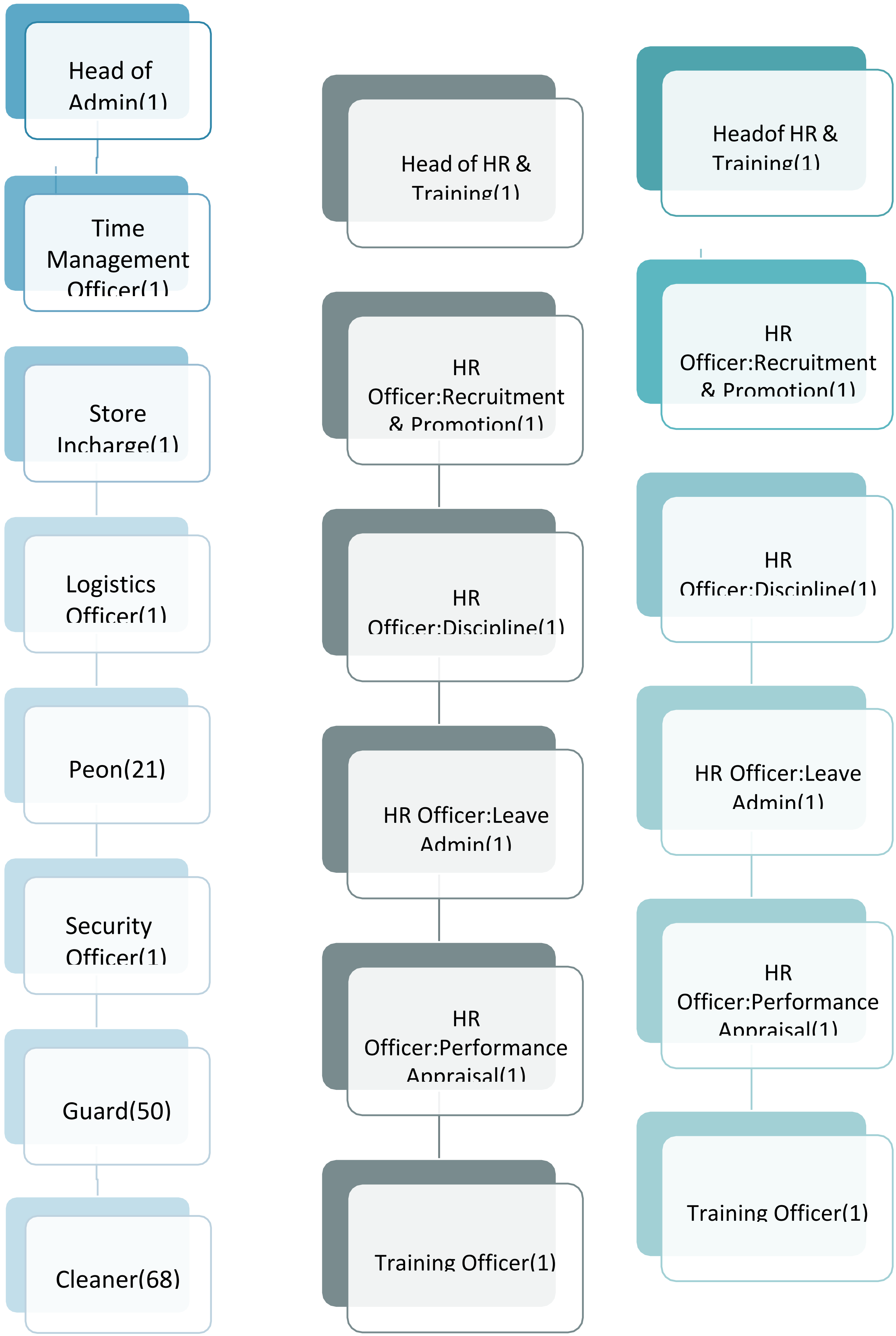
Vegetable
Chrome Tanning
Semi Chrome Tanning


Head of Admin(1)
Time Management Officer(1)
Store Incharge(1)
Logistics Officer(1)
Peon(21)
Security Officer(1)
Guard(50)
Cleaner(68)
Head of HR & Training(1)
HR Officer:Recruitment & Promotion(1)
HR Officer:Discipline(1)
HR Officer:Leave Admin(1)
HR Officer:Performance Appraisal(1)
Training Officer(1)
Headof HR & Training(1)
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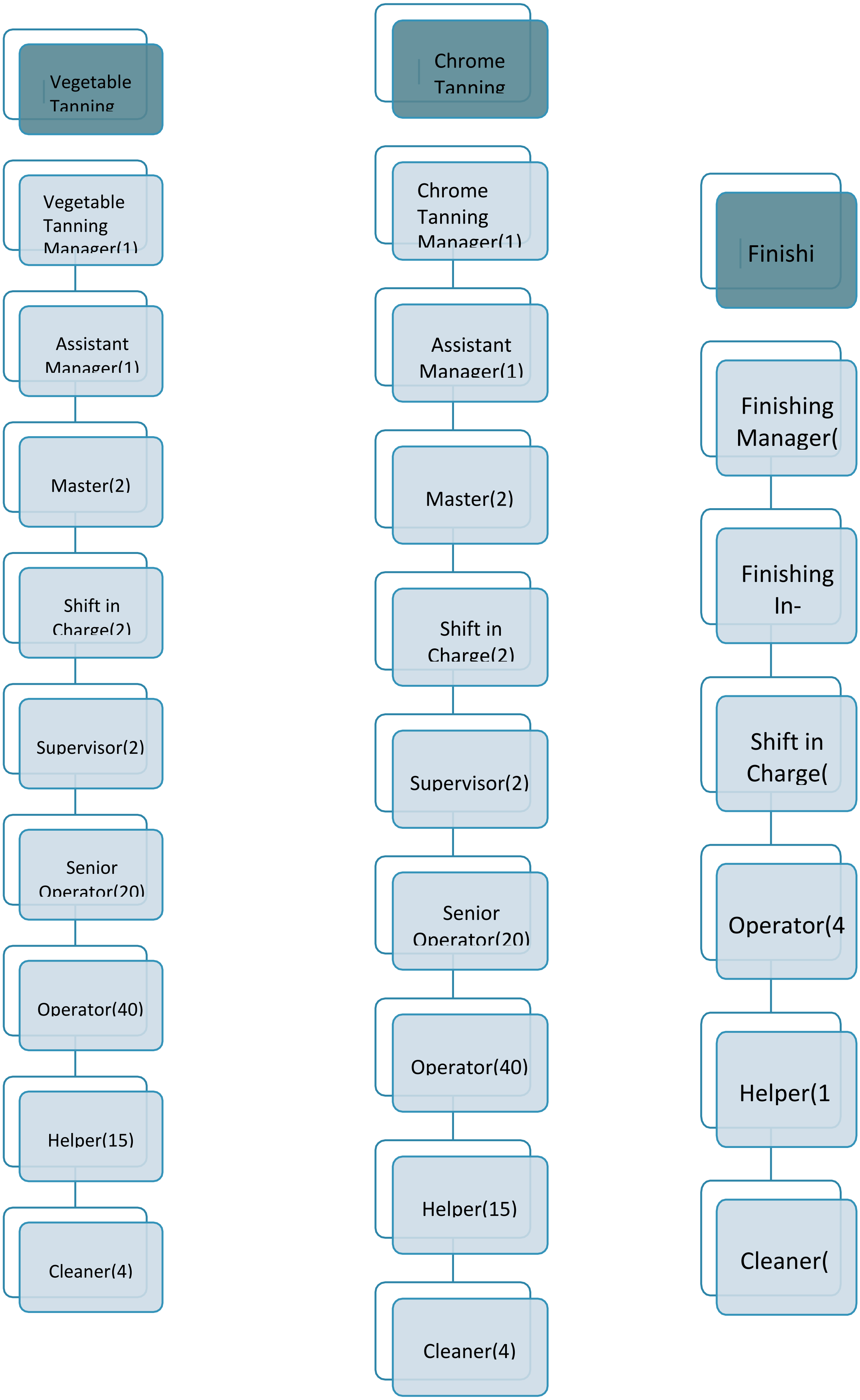
Vegetable Tanning
Vegetable Tanning Manager(1)
Assistant Manager(1)
Master(2)
Shift in Charge(2)
Supervisor(2)
Senior Operator(20)
Operator(40)
Helper(15)
Cleaner(4)
Chrome Tanning
Chrome Tanning Manager(1)
Assistant Manager(1)
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Operator(4
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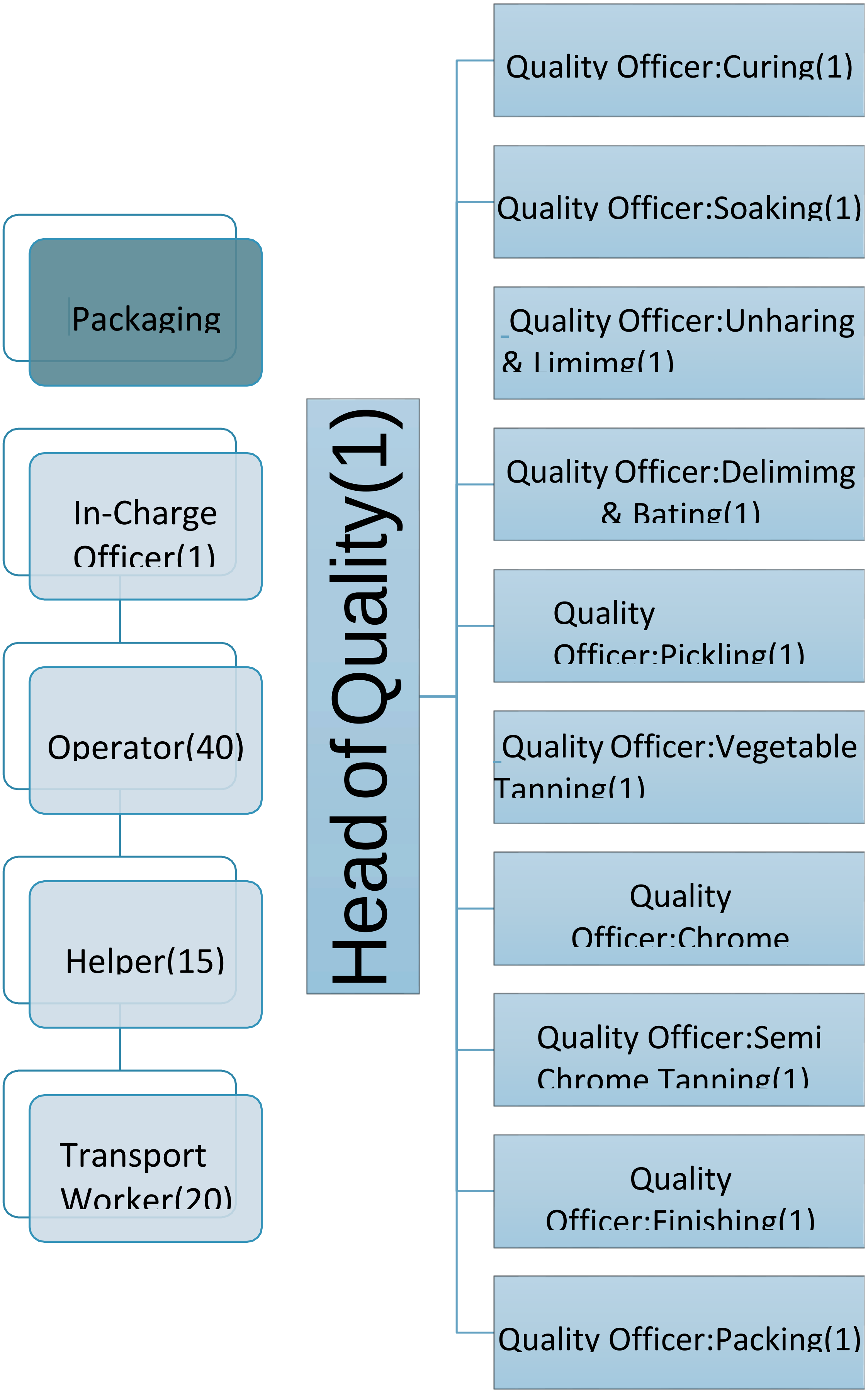
Cleaner(



Packaging
In-Charge Officer(1)
Operator(40)
Helper(15)
Transport Worker(20)
Head of Quality(1)
Quality Officer:Curing(1)
Quality Officer:Soaking(1)
Quality Officer:Unharing & Limimg(1)
Quality Officer:Delimimg & Bating(1)
Quality Officer:Pickling(1)
Quality Officer:Vegetable Tanning(1)
Quality Officer:Chrome
Quality Officer:Semi Chrome Tanning(1)
Quality Officer:Finishing(1)
Quality Officer:Packing(1)

CHAPTER 2

DRAWING LAYOUT

Layout

There are some characteristics of our drawn layout. These are- Administrative Zone, Industrial Zone (Including individual units), Residential Zone, Common Service Area, etc. are shown in layout. A highway is on one side of the village and a river flowing along another side. Internal road network is clearly visible in the layout. The ETP location is such that the final treated effluent can be discharged in the adjacent river.

The road network is designed considering route for incoming raw material and outgoing finished products. In the residential zone separate types of quarters is allocated for employees of different administrative status. Common facilities like School, Mosque,Hospital, Community center, Bank, ATM, Super store, Parking, Canteen etc. is included. Provisions of parks, playing fields, green spaces, gardens is kept in the village. Provisions for future land area expansion for different types of zones (e.g. residential, industrial) is kept while preparing the layout. The layout follows grid pattern, which is advantageous while designing pipe network for water distribution and wastewater collection.

The layout is drawn using AutoCAD. Proper layering is incorporated in the drawing so that different parts like: overall layout, water distribution network, sewer network can be separately visible if needed. The primary step was to determine the necessary zones in our industrial village. Industrial zone is the main part of the village. The other parts of the village get mobilized centering this part. The industrial zone consists of various departments like-

- Soaking
- Liming
- Deliming/Batting
- Pickling
- Tanning
- Rechrome tanning
- Neutralization
- Retanning
- Dyeing
- Fat Liquoring

- Pre tanning
- Chrome tanning
- Lime fleshing

For the residential purpose of the workers and the officers, the residential zone is provided. Due to ranking difference between them we have provided 4 different classes of quarters for employees with family and dorm for the bachelors except 1st class officers. There is a playground kept between the industrial and residential zone to keep the environment of residential zone cool, calm and healthy. The 1st class and 2nd class employees were given quarters beside river for better environment. The hospital is also near from the residential place of 1st class officers. A separate parkis provided between the 1st and 2nd class residential zone. For good security system we have provided guard room on each of the entrances. Adequate common services should be provided to the dwellers for improved living condition. Mosque, School, Canteen, Super shop, Parking space, Bank and ATM, Fire services, Power station etc. in our village. These facilities are also placed by considering the convenience of the residents and workers. We have provided space future extension of different facilities. The ETP is just by the side of river so that the final treated effluent can be discharged in the adjacent river. Firefighting station is provided at a location which is advantageous to deal accidents in any place of the village within the minimum it.

Assumption:

Firefighting-

1. Only one fire incidence occurs per day
2. Each station/ facility should be served by two fire hydrants at a time
3. Nozzle diameter of the hydrant is 3 inches
4. Velocity of water in the pipe is 3 fps
5. Each hydrant will supply water for 30 minutes

Water Demand

Industrial Processes-

1. Soaking-3000 L/tonnes
2. Liming- 2500 L/tonnes
3. Deliming/Batting- 1500 L/tonnes
4. Pickling- 800 L/tonnes
5. Tanning- 1000 L/tonnes
6. Rechrome tanning- 600 L/tonnes
7. Neutralization- 800 L/tonnes
8. Dyeing- 1000 L/tonnes
9. Fat Liquoring- 1500 L/tonnes
10. Pretanning- 34000 L/tonnes
11. Chrome Tanning- 6000 L/tonnes
12. Lime fleshing- 1000 L/tonnes

- Growth Factors-

1. 10 years- 20% increase from present
2. 20 years- 40% increase from present

- Technology used in Tannery IndustryImproved process technology (Optimization and recycling)

Tannery hide raw material consumption (UNDO report) 9 tonnes- 12,000 sq ft per day

Tannery hide production

300 pieces per day
25 kg/ piece
7.5 tonnes per day

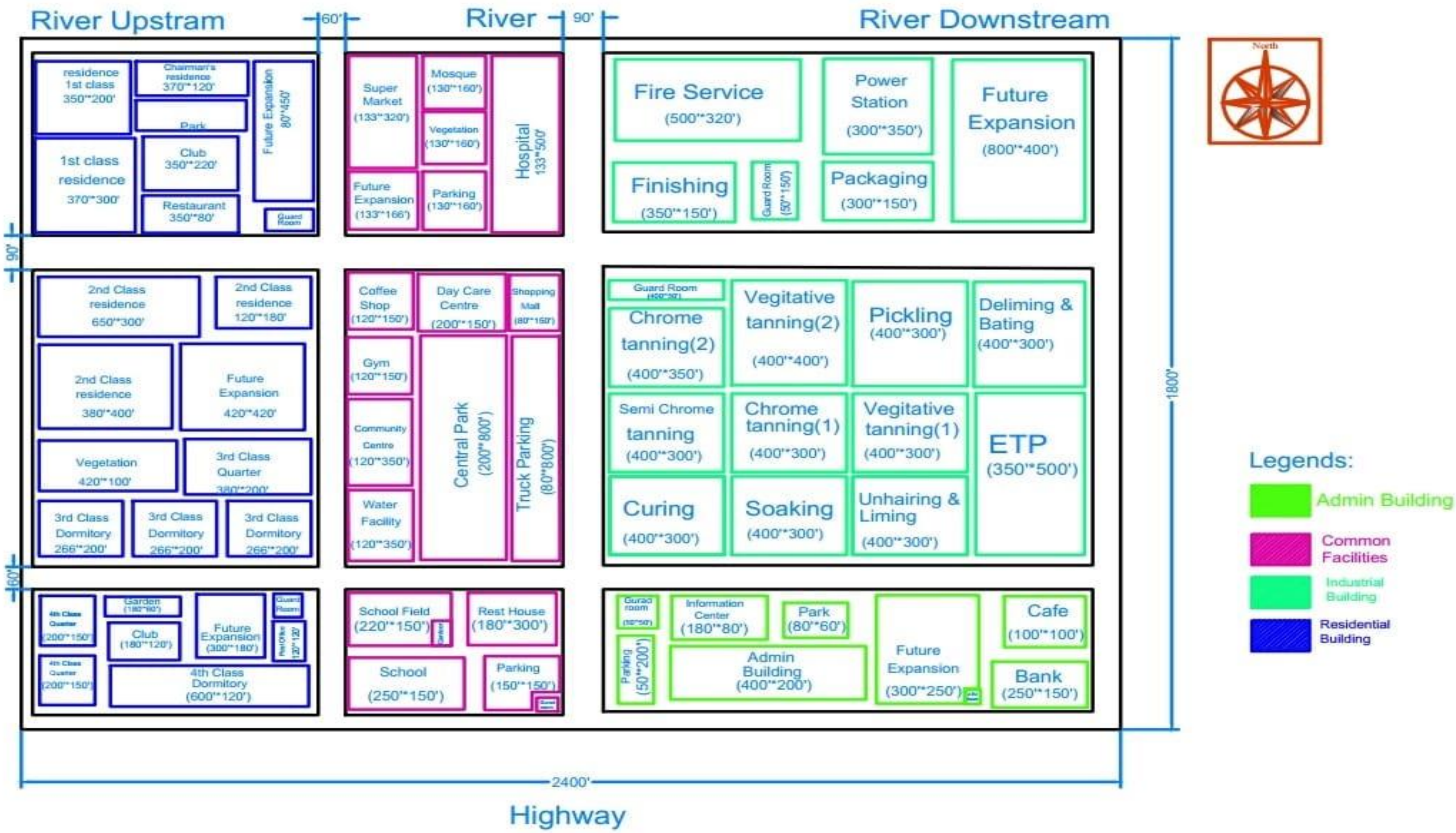


Figure 2. 1 Layout of Tannery village

CHAPTER 3

POPULATION ESTIMATION

Population Estimation

Assumptions:

Residential zone:

There are mainly four classes of residents.

1st class:

a) Designation of allotted employee: Chairman, Board of trustee, MD,GM, Heads, chiefs .
b) 100% have residential facilities
c) No dorm
d) Family member = 6
e) Growth rate = 0.7%

f) Board of trustee does not have residential facilities.

2nd class:

a) Designation of allotted employee: Market Representative, Brand Manager, Sales Manager, Senior Officer, Compliance & Social Welfare Officer, HR Officer, Asst. Engineer, Manager, In Charge Officer, Head & Asst. Headmaster, Power Station Engineer, Fire Service Chief.
b) 100% have residential facilities
c) 80% have family quarter, 20% have dorm
d) Family member = 5
e) Growth rate for family quarter = 1.2%
f) The dorm capacity has increased by 30% after10 years & 50% after 20 years.

3rd class:

a) Designation of allotted employee: Store in Charge, Logistics Officer, Technician, Quality Officer, Supervisor, Maintenance Officer, Asst. Manager, Master, Senior Operator, Teacher , Imam, Cook, Nurse, Gym Trainer, Fire

Service & Super shop Staff, Bank Officer .
b) 75% have residential facilities

c) Among them 60% have family quarter, 40% have dorm
d) Family member = 5
e) Growth rate for family quarter = 1.5%
f) The dorm capacity has increased by 30% after10 years & 50% after 20 years

4th class:
a) Designation of allotted employee: Guards, Security Officer, Operator, Helper, Cleaner, Transport Worker, Staff, Driver , Worker, Rest House & Resort cook.
b) 60% have residential facilities
c) Among them 40% have family quarter, 60% have dorm
d) Family member = 5
e) Growth rate for family quarter = 1.7%
f)The dorm capacity has increased by 30% after10 years & 50% after 20 years

Administrative zone

1) Growth predicted after 10 years = 10%
2) Growth predicted after 20 years = 20%

Industrial zone

1) Growth predicted after 10 years = 20%
2) Growth predicted after 20 years = 40%

Common Services

1) Growth predicted after 10 years = 10%
2) Growth predicted after 20 years = 20%

Used Formula

For a certain design period, Future population

$= P * (1 + r)^{\wedge n}$

Where, P = Present population, r = Growth rate (%), n = Design period (years)

Sample Calculation:

For 1st class quarter of residential zone,
1st class officers:

- ✓ Chairman (1)
- ✓ Board of trustee (4)
- ✓ Managing director (1)
- ✓ General Manager(1)
- ✓ Heads (8)
- ✓ Chief(6)

Total employee number = 21
Accommodation given 100%
Assumed family member = 6
Total present population = 21*6 = 126
Annual growth rate = 0.70%
Population after 10 years = 126*(1+0.007)^10 = 135
Population after 20 years = 126*(1+0.007)^20 = 145

Table 3.1 Population Estimation for Residential Zone

1st Class		2nd Class	
Residential Type	**Population number**	**Residential Type**	**Population number**
Total Number of employee	21	Total Number of employee	67
% having Residential Facilities	100	% having Residential Facilities	100
% having Quarter Facilities	100	% having Quarter Facilities	80
% having Dorm	0	% having Dorm	20
Residential Employee (Quarter)	21	Residential Employee (Quarter)	53
Assumed Family Member	6	Assumed Family Member	5
Total Quarter Population	126	Total Quarter Population	265
Annual Growth Rate (assumed)	0.70%	Annual Growth Rate (assumed)	1.20%
Population after 10 Years	135	Population after 10 Years	299
Population after 20 Years	145	Population after 20 Years	337
Dorm Population	0	Dorm Population	14
Population after 10 Years	0	Population after 10 Years	19
Population after 20 Years	0	Population after 20 Years	21

Table 3.1 Population Estimation for Residential Zone

3rd Class		4th Class	
Residential Type	**Population number**	**Residential Type**	**Population number**
Total Number of employee	429	Total Number of employee	827
% having Residential Facilities	75	% having Residential Facilities	60
% having Quarter Facilities	60	% having Quarter Facilities	40
% having Dorm	40	% having Dorm	60
Residential Employee (Quarter)	193	Residential Employee (Quarter)	198
Assumed Family Member	5	Assumed Family Member	5
Total Quarter Population	965	Total Quarter Population	990
Annual Growth Rate (assumed)	1.50%	Annual Growth Rate (assumed)	1.70%
Population after 10 Years	1120	Population after 10 Years	1172
Population after 20 Years	1300	Population after 20 Years	1387
Dorm Population	129	Dorm Population	298
Population after 10 Years	168	Population after 10 Years	387
Population after 20 Years	194	Population after 20 Years	447

Table 3.2 Population Estimation for Common Services Zone

Designation	Population Number	Designation	Population Number
School		**Club**	
Head and Asst. Head	2	Manager	2
Teacher	40	Staff	10
Student	600	Security Officer	2
Staff & Cleaner	28	Guard	8
Mosque		**Bank**	
Imam	3	Manager	1
Staff & Cleaner	5	Asst. Manager	2
Canteen & Restaurant		Staff	8
Manager	4	Officer	10
Cook	6	Guard	8
Staff	20	**Post Office**	
Hospital		Manager	1
Doctor	6	Asst. Manager	2
Nurse	18	Staff	8
Staff	30	Guard	2
Driver	3	**Rest House & Resort**	
Power Station		Cook	6
Engineer	1	Staff	12
Worker	6	Cleaner	4
Guard	2	Guard	6
Fire Service		**Gym**	
Fire Fighter	20	Manager	1
Chief	1	Trainer	4
Staff	6	Guard	2

Parks			
Gardener	6		
Staff	10	**Central Security Officer**	4
Guard	2		
Super Shop & Market			
Manager	2		
Staff	20		
Guard	8		
Security Officer	2		

Total Current Population	**955**
Growth Rate After 10 Years (Assumed)	10%
Population After 10 Years	1051
Growth Rate after 20 Years (assumed)	20%
Population After 20 Years	1146

Table 3.3 Population Estimation for Administrative Zone

Designation	Population Number	Designation	Population Number
Chairman	1	Senior Officer	3
Board of Trustee	4	Compliance and Social Welfare Officer	2
Managing Director	1	HR Officer	5
General Manager	1	Assistant Accountant	1
Heads	8	Store in Charge	1
Chiefs	6	Logistics Officer	1
Market Representative	4	Security Officer	1
Brand Manager	1	Guards	50
Assistant Brand Manager	4	Peons	20
Sales Manager	4	Cleaners	60

Summary of Estimation for Administrative Zone

Total Current Population	178
Growth Rate After 10 Years (Assumed)	10%
Population After 10 Years	196
Growth Rate after 20 Years (assumed)	20%
Population After 20 Years	214

Table 3.4 Population Estimation for Industrial Zone

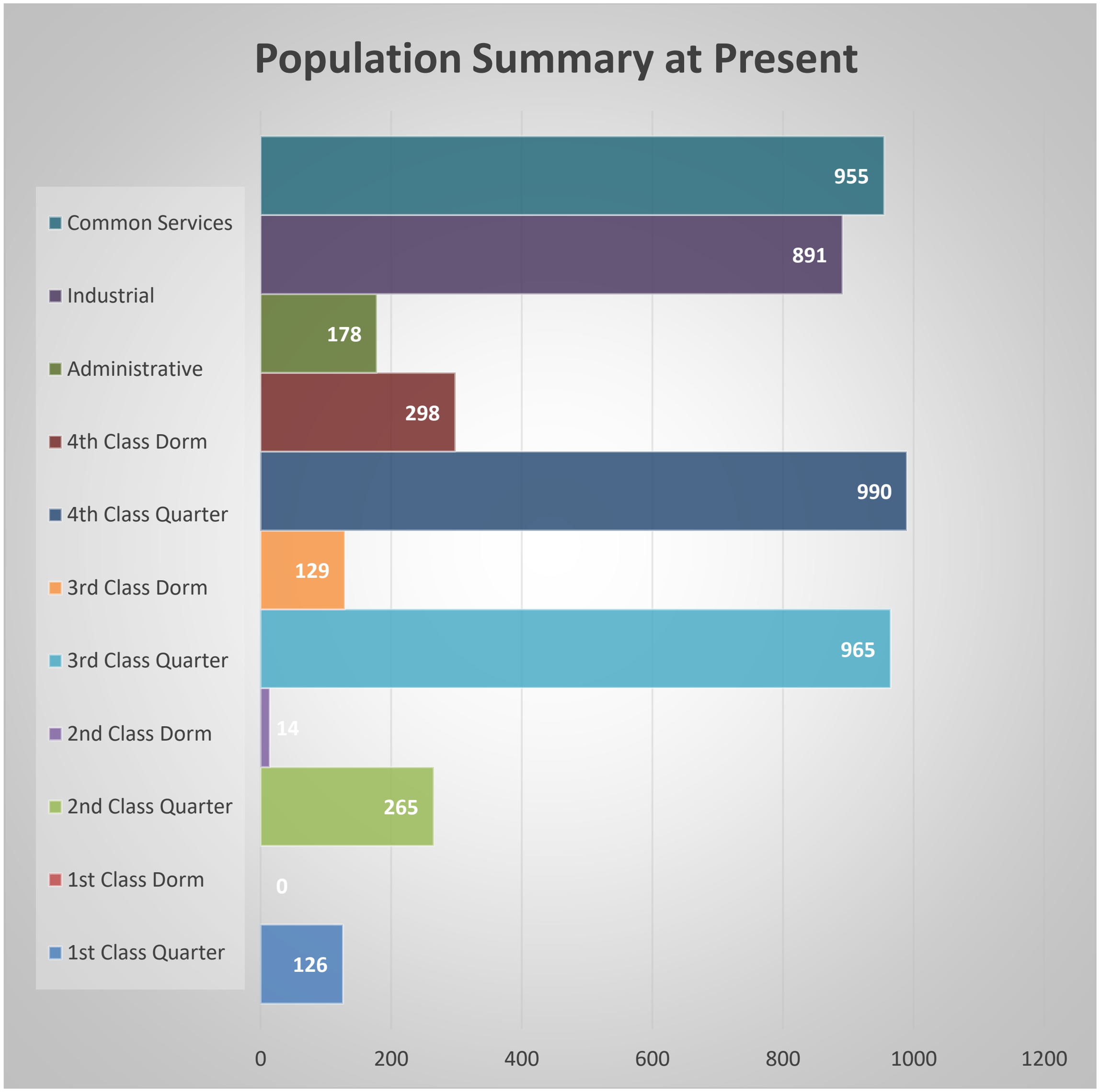
Designation	Population Number	Designation	Population Number
Assistant Engineer	12	Master	16
Manager	9	Shift In Charge	18
In-Charge Officer	2	Senior Operator	160
Supervisor	14	Worker	7
Quality Officer	15	Operator	400
Maintenance Staff	15	Helper	105
Assistant Manager	7	Cleaners	36
Technician	55	Transport Workers	20

Summary of Estimation for Industrial Zone

Total Current Population	891
Growth Rate After 10 Years (Assumed)	20%
Population After 10 Years	1070
Growth Rate after 20 Years (assumed)	40%
Population After 20 Years	1248

Table 3.5 Summary of Population Calculation

Time/ Zones	Residential								Administrative	Industrial	Common Services
	1st Class		2nd Class		3rd Class		4th Class				
	Family	Dorm	Family	Dorm	Family	Dorm	Family	Dorm			
Present	126	0	265	14	965	129	990	298	178	891	955
10 years later	135	0	299	19	1120	168	1172	387	196	1070	1051
20 years later	145	0	337	21	1300	194	1387	447	214	1248	1146



Population Summary at Present
Common Services
Industrial
Administrative
4th Class Dorm
4th Class Quarter
3rd Class Dorm
3rd Class Quarter
2nd Class Dorm
2nd Class Quarter
1st Class Dorm
1st Class Quarter
955
891
178
298
990
129
965
14
265
0
126
0
200
400
600
800
1000
1200

CHAPTER 4

WATER DEMAND CALCULATION

Water Demand Calculation

Sample Calculation:

For 1st class quarter (From **Table**),

Present population = 126
Population after 10 years = 135
Population after 20 years = 145
Per capita consumption = 260 lpcd
Duration = 24 hours
Average present water demand = 126*260 = 32760lpd
Average Demand after 10 years = 135 *260 = 35100 lpd
Average Demand after 20 years = 145 *260 =37700 lpd
Peak factor = 2.5
Peak present water demand = 32760*2.5 = 81900 lpd
Peak demand after 20 years = 35100*2.5 = 87750 lpd
Peak Demand after 20 years = 37700*2.5 = 94250 lpd

Industrial Water Demand

Water requirement for industrial purpose should include two aspects:

- Water for industrial production
- Water for personal consumption

Water for Industrial Production

Assumptions:

a) 3600 Kg of finished product per day.
b) 55 liter water is required per kg hides.

c) Industry grow will increase by 20% after10 years & 40% after 20 years.
d) Peak factor is assumed to be 1.4 **.**

Sample Calculation

Present production rate = 3600 kg/day
Water requirement = 55 liter/ kg
Present water consumption = 3600*55= 198000 liter/day
Peak present water demand = 198000*1.4 = 352044 liter/day
Production rate after 10 years = 3600 *1.2= 4320 kg/day
Water consumption after 10 years = 4320* 55 = 237600kg/day
Peak water demand after 10 years = 237600*1.4 = 422520

Water for Personal Consumption

Assumptions

a) 2 shifts; each 8 hours.
b) It is in occupancy G1: Low hazard industries in BNBC and per capita consumption is 40 lpcd **.**
c) Peak factor is assumed to be 1.4

Sample calculation

From **Table**, Present total workers = 891
Per capita consumption = 40 lpcd
No. of shift = 2
Duration of each shift = 8 hours
Time factor =24/ (8*2) =1.5
Peak factor = 1.4
Present water demand = 891*40*1.5 = 53460lpd
Peak water demand = 53460*1.4 = 74844 lpd

Administrative water demand calculation:
Assumptions

a) From BNBC, Occupancy Category is F1: Office and per capita consumption is 45 lpcd **[4-13]**
b) Peak factor is assumed to be 1.4
Sample Calculation
From **Table,** Present population = 178
Per capita consumption = 45 lpcd
Time factor = 24/(8*2)= 1.5
Average present demand = 2*178*45 = 16020 lpd
Peak Factor = 1.4
Peak present demand = 16020 *1.4 =22428 lpd

Total demand =1.4*1.5*16020 = 33642 lpd
Population after 10 years = 196
Average present demand = 2*196*45 = 17640lpd
present demand = 17640*1.5 *1.4 = 37044 lpd
Population after 10 years = 214
Average present demand = 2*214*45 = 19260 lpd
Peak present demand = 19260 *1.5*1.4 = 40446 lpd

Sample calculation for Common Facilities:
For school, Present population = 670 (**table**)
Per capita consumption = 45 lpd
Duration = 6 hours
Average present demand = 670*45*24/6 =120600 lpd
Peak factor = 4
Peak present demand =120600 *4 = 482400 lpd

Water demand for fire fighting

Assumption

a) Only one fire incidence occurs per day.
b) Each station/ facility should be served by two fire hydrants at a time.
c) Nozzle diameter of the hydrant is 3 inches.
d) Velocity of water in the pipe is 3 fps.
e) Each hydrant will supply water for 30 minutes.

Sample Calculation

Diameter 3" and flow velocity 3 fps Flow
occurs for 30 min
Volume of water flowing in one hydrant = Q*t = π x (3/12) ^2/4x 3 x 30 x 60
= 265 cft
Number of fire hydrants = 2
Total volume of water required for firefighting = 2*265.07 = 530.14 cft * 28.317
= 15012 liter

Positioning of Fire Hydrants

The distance between two fire hydrants should be max 300' (80-120m) and distance from any point of the road should not exceed 150' (50 m). We also need to ensure that from an arbitrary point at least two fire hydrants are reachable at any time. Considering this facts we have placed fire hydrants in our village and the positions of fire hydrants are shown in the layout in **figure**

Table 4.1 Residential Water Demand													
Apartment/Dorm	Building Type	Present Population	Per Capita Consumption lpcd	Duration (hrs)	Average Present Demand, Lpd	Peak Present Demand, Lpd	Population after 10 years	Average Demand after 10 years, Lpd	Peak Demand after 10 years, Lpd	Population after 20 years	Average Demand after 20 years, Lpd	Peak Demand after 20 years, Lpd
Apartment	1st class	126	260	24	32760	81900	135	35100	87750	145	37700	94250
	2nd class	265	180	24	47700	119250	299	53820	134550	337	60660	151650
	3rd class	965	120	24	115800	289500	1120	134400	336000	1300	156000	390000
	4th class	990	80	24	79200	198000	1172	93760	234400	1387	110960	277400
Dorm	2nd and 3rd	143	70	24	10010	25025	187	13090	32725	215	15050	37625
	4th class	298	50	24	14900	37250	387	19350	48375	447	22350	55875
Total						750925			873800			1006800

Table 4.2 Common Zone Water Demand

Facility	Present Population	Per Capita Consumption lpcd	Duration (hrs)	Average Present Demand, Lpd	Peak Present Demand, Lpd	Population after 10 years	Average Demand after 10 years, Lpd	Peak Demand after 10 years, Lpd	Population after 20 years	Average Demand after 20 years, Lpd	Peak Demand after 20 years, Lpd
School	670	45	8	90450	361800	737	99495	397980	804	108540	434160
Mosque	350	5	5	8400	33600	385	9240	36960	420	10080	40320
Bank	50	30	8	4500	18000	55	4950	19800	60	5400	21600
Hospital	100	340	24	34000	136000	110	37400	149600	120	40800	163200
Canteen	100	50	8	15000	60000	110	16500	66000	120	18000	72000
Fire Station	27	70	24	1890	7560	30	2079	8316	32	2268	9072
Power station	9	8	24	72	288	10	79	317	11	86	346
ETP	32	8	24	256	1024	35	282	1126	38	307	1229
Supershop	40	45	8	5400	21600	44	5940	23760	48	6480	25920
Park	30	12	5	1728	6912	33	1901	7603	36	2074	8294
Club	100	45	8	13500	54000	110	14850	59400	120	16200	64800
Post office	13	45	16	878	3510	14.3	965.25	3861	16	1053	4212
Resort	50	180	24	9000	36000	55	9900	39600	60	10800	43200
Gym	67	5	16	503	2010	73.7	552.75	2211	80	603	2412
Total Demand	-	-	-	-	742304	-	-	816534	-	-	890765

Table 4.3 Industrial Water Demand

Water Use for Industrial Production

Present Production Rate (kg/d)	Future Production Rate (kg/d)		Water Requirement for production (litre per kg)	Time Factor	Present Water Demand (lpd)	Future Water Demand (lpd)	
	After 10 years	After 20 years				After 10 years	After 20 years
4,000	4800	5600	220	1	880000	1056000	1232000

Water Use for Personal Consumption

Total Workers at Present	Total Workers		No. of Shifts	Time Factor	Per Capita Consumption (lpcd)	Present Water Demand (lpd)	Future Water Demand	
	After 10 years	After 20 years					After 10 years	After 20 years
891	1070	1248	2	1.5	40	53460	64200	74880

Industrial Water Demand Summary

	At Present	After 10 years	After 20 years	Peak Factor (Assumed)	Peak Water Demand at Present	Peak Water Demand after 10 yrs	Peak Water Demand after 20 yrs
Total Industrial Water Demand (lpd)	933460	1120200	1306880	1.4	1306844	1568280	1829632

1. Assuming 220 litre water for production of per kg hides (From BNBC 2006 Report)

2. Assuming 2 shifts of 8 hours

3. Assuming personal Consumption 40 lpcd

4. Assuming industry growth rate 20% for 10 years and 40% for 20 years

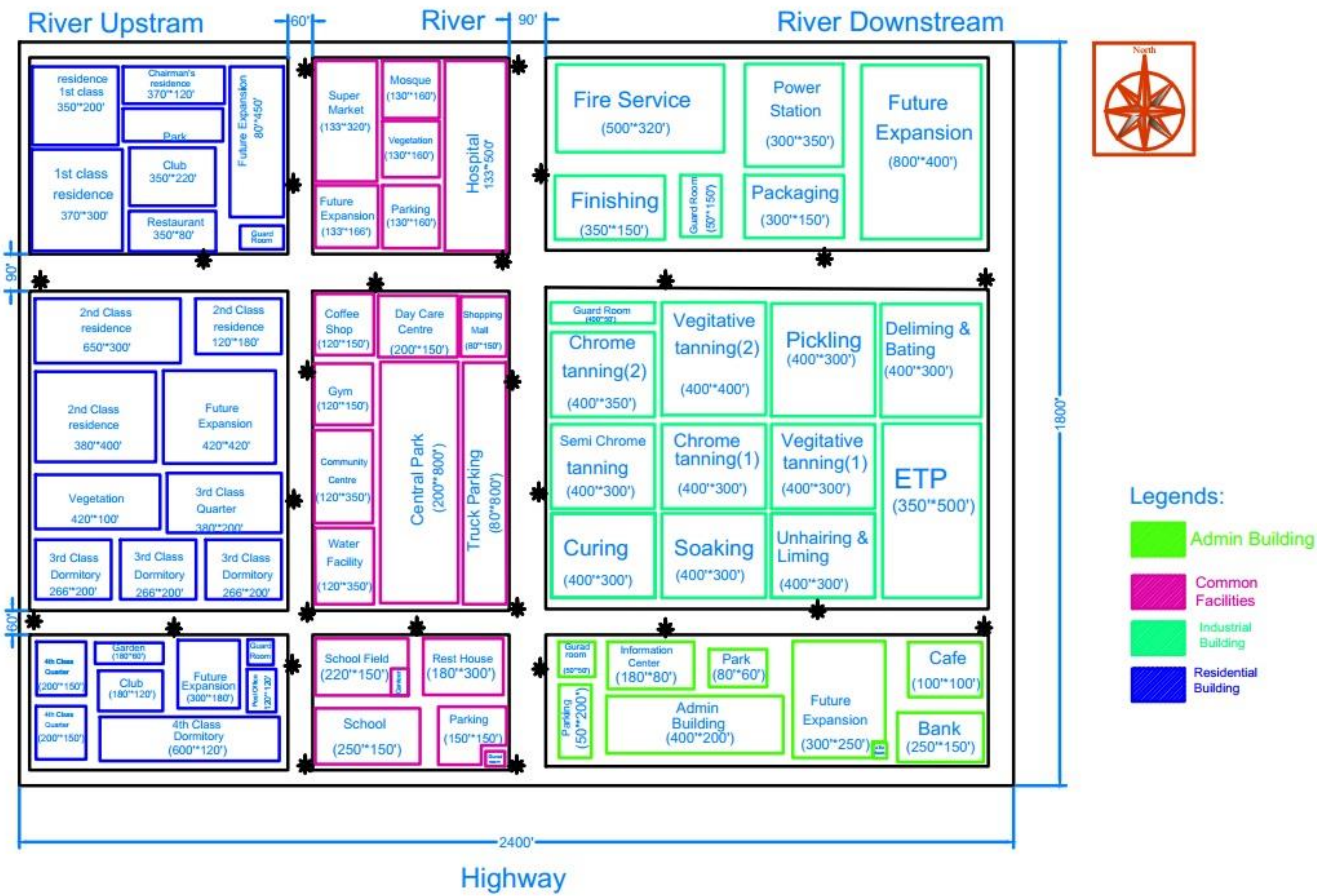
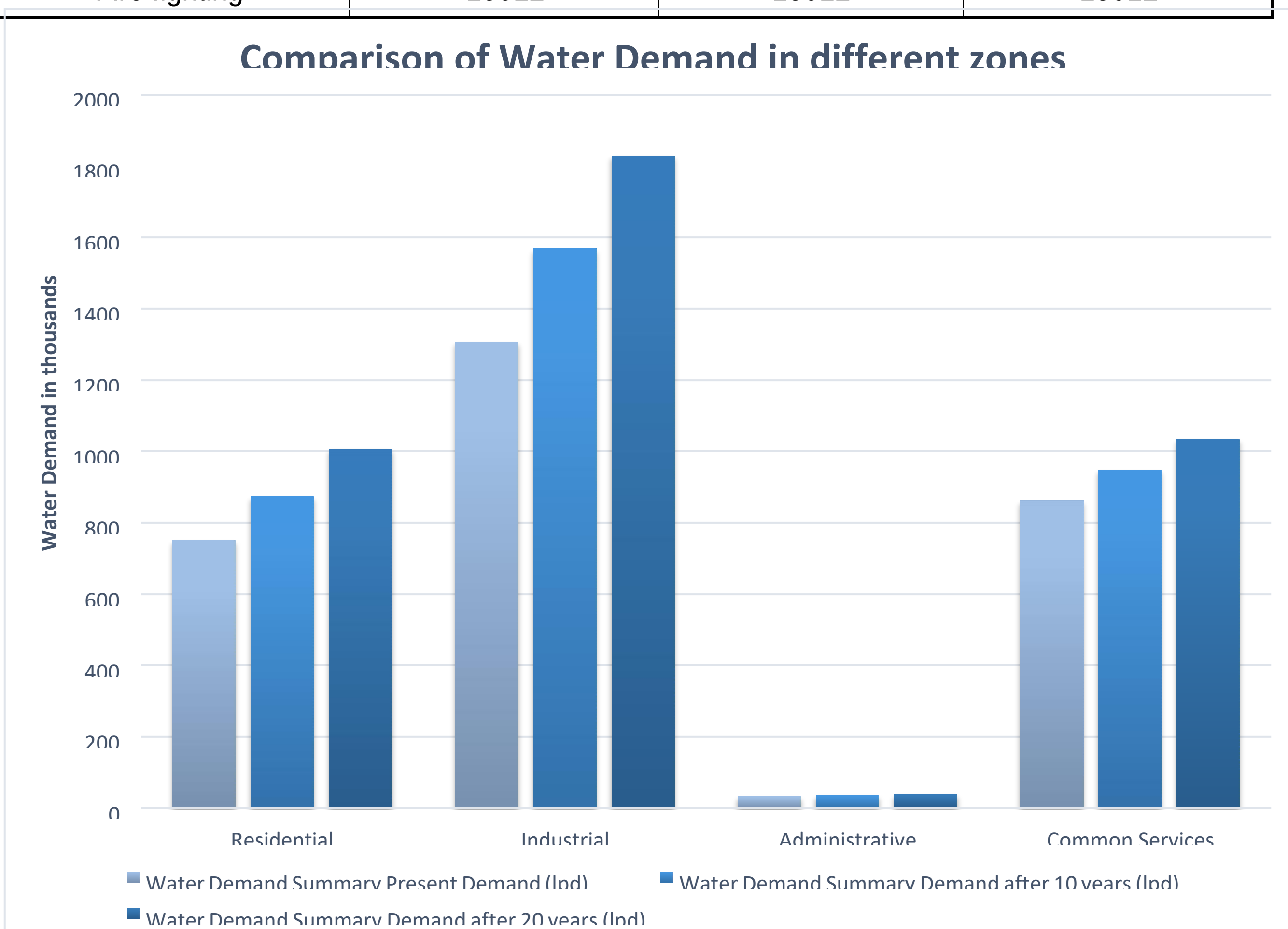


Figure 4. 1 Layout of Fire Hydrant

Table 4.4 Water Demand Summary			
Zones	**Present Demand (lpd)**	**Demand after 10 years (lpd)**	**Demand after 20 years (lpd)**
Residential	750925	873800	1006800
Industrial	1306844	1568280	1829632
Administrative	33642	37044	40446
Common Services	862904	949194	1035485
Fire fighting	15012	15012	15012



CHAPTER 5

WATER WELL DESIGN

Introduction:

- Well design means selecting the proper dimensional factors for well structure and choosing the materials to be used in its construction
- Prime considerations of well design are:

a) Service life

b) Cost and

c)Performance

- A properly designed well serves the following:

a) Allows the water to enter at low velocity

b) Prevents the entry of sand

c) Serve as the structural retainer to support the loose formation material

Water well is a hole, shaft, or excavation used for the purpose of extracting ground water from the subsurface. Water may flow to the surface naturally after excavation of the hole or shaft. Such a well is known as a Flowing artesian well. More commonly, water must be pumped out of the well. Most wells are vertical shafts, but they may also be horizontal or at an inclined angle. Horizontal wells are commonly used in bank filtration, where surface water is extracted via recharge through river bed sediments into horizontal wells located underneath or next to a stream. The main objective of this design is to determine the position of strainer through which water can flow at an attainable velocity. To determine strainer position, soil classification is done according to the data provided. Afterwards, we have determined yield of well and number of well for different zone at different time span of project. Number of well largely depends on the pumping hours of a well and minimum distance of a well from a remote point.

Water well design has been done considering an industrial area of 100 hectare having four distinguishing zones named as Industrial Zone, Common Service Zone, Residential zone and Administrative Zone. We considered here that Industrial, Administrative and Common Service (Hospital, Canteen, Fire Station, Power station, ETP, Shop),Fire Service for this zone will be one side of the respected area and Residential, Common Services(School, Mosque, Bank, Park, Canteen, Shop), Fire service for this zone will be on the other side.

So the Scope of the study can be presented below as:

- ❖ Grain size distribution for different soil layers
- ❖ Locating the aquifer and water bearing strata
- ❖ Determination of strainer length and position
- ❖ Design of gravel pack material
- ❖ Selection of strainer size
- ❖ Yield of well

Types of Aquifer:

Ground water aquifers may be classified as either water table or artesian aquifers.

- ❖ Water-table Aquifer/Unconfined Aquifer
- ❖ Water Table
- ❖ Artesian Aquifer/Confined or Pressure Aquifers
- ❖ Piezometric Surface
- ❖ Flowing Artesian Well
- ❖ Non-Flowing Artesian Well

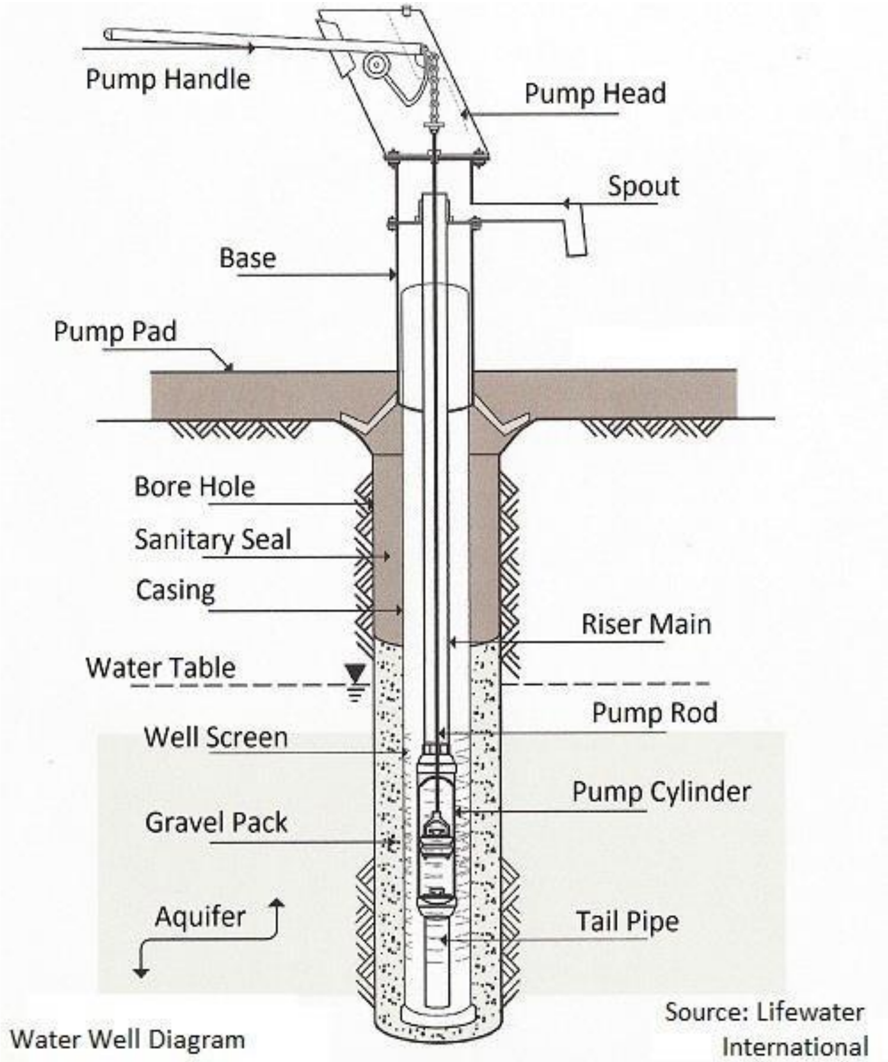


Figure 5. 1 Components of water well

Fig: Components of water well

Methodology:

Grain Size Distribution for Different Soil Layer Grain size distribution curves are drawn for different soil layers using soil data. Effective grain size (D10, D30, D60) and uniformity coefficient are found for each layer. From Grain Size Distribution data, we can choose the water bearing soil layer. For Determining Water Bearing Soil Layer, we have to know relative percentage of different particles using MIT classification of soil.

MIT Classification of soil is presented below:

Table 5.1 MIT Classification	
Silt/Clay	< 0.06 mm
Fine Sand	0.06 – 0.20 mm
Medium Sand	0.20 – 0.60 mm
Course Sand	0.60 – 2.00 mm
Fine Gravel	> 2.00 mm

Locating the Aquifer and Water Bearing Strata:

During the determination of the location of aquifer is that chosen layer must have good water carrying capacity, good permeability. On the other hand, it should be economic enough that means if we found suitable layer nearer to the water table, we need not to go deep down to extract water. The more we go downwards, water quality may get deteriorated. Factors to be considered for locating water bearing strata are given below:

- Greater uniformity coefficient increases permeability.
- Higher fineness modulus means bigger soil particles.
- Higher percentage of course and medium sand indicates higher water carrying capacity.

Table 5.2 Soil Classification according to Fineness Modulus Values :	
F.M.<1	Clay & Silt
F.M.=1	Fine Sand with Silt
F.M.>1	Medium to course sand which has potential to good permeability and presence of water

Determination of Strainer Length and Position:

Primary factors:

- Length of casing pipe must be selected first.
- Casing pipe must be sufficient enough so that submersible pump always remains below water.

Length of the casing pipe is the summation of four lengths:

- Static water level at present.
- Assumed drawdown of 10’ to 15’ [5-1] while pumping each time.
- Average rate of water level declination (per year) *Design life
- Safety distance of 10’to 15’

After the length of the casing pipe and depth of the submersible pump being ensured, we can think about Strainer Position.

Limitation of strainer length:

Table 5.3 Recommended Screening according to Aquifer Thickness

Aquifer Thickness	Recommended Screening
<25’	70% Screening
25’-50’	75% Screening
>50’	80% Screening

- As it is very difficult to maintain the vertical alignment of a long strainer, it will not be practical to go beyond 100’screening

- Strainer should not be extended up to the bottom of the aquifer to allow the upward converging flow of water during pumping.

Between two strainers of a discontinuous aquifer a Blank Pipe is provided. Blank pipe is placed at the bottom of the strainer to trap particles that may enter into the pipe through upward converging flow.

Well Screen Diameter:

Usually 4" and 6" diameter are common. Screen diameter is selected to satisfy an essential basic principle, i.e. enough total area of screen openings so that the entrance velocity is equal or less than 0.1 ft/sec.

Design of Gravel Pack Material:

To design the gravel pack material, the grain size distribution curve of the comparatively finest layer within the aquifer is drawn on a semi log paper. Some assumptions were made before this calculation:

1. 70% (D30) size of the finest sand is multiplied by a factor 4-6 depending on the sand type. For Cu ≤ 1.5, multiplying factor = 4 is used& for Cu ≥ 2.5, multiplying factor = 6 is used. This is the first point on the curve that represents the grading of the artificial gravel pack material.
2. Through this initial point on the gravel pack curve, a smooth curve nearly parallel with the aquifer material curve is drawn by trial and error method, representing a material with a uniformity coefficient 2.5 or less.
3. 3-8 inch diameter envelop of gravel will surround the entire screen.

Yield of Well:

Well yield is calculated using strainer opening area. Yield of a well can be calculated as follows:

Yield = (area of strainer x flow velocity) / factor of safety.

The factor of safety is considered assuming blockage while operation. Different slot size have different opening area. Consideration of slot opening area is given below:

Table 5.4 Screen Opening according to Slot Size

Slot Size	Assumed Opening(Steel Screening)
40 slot	20%
30 slot	15%
20 slot	10%

Data Analysis and Calculation:

a) Sample Calculation of Grain Size Distribution

At 150-200 ft depth,

Grain size distribution at different depth is done based on the soil property data provided. The main focus of this analysis is to select the suitable water bearing layer.

Total Material Retained at #4, #8, #16, #30, #40, #50, #100, #200 and Pan = 0+2.5+3.7+2.6+20.4+35.3+32.2+1.2+2.1=100 gm.

Percent of Material Retained = (2.5/100)*100 % =2.5% [for #8 Sieve]

Cumulative Percent Retained at #8 Sieve = 0.00+2.5%= 2.5%

Percent Finer at #8 Sieve= 100-2.5 = 97.5.

Fineness Modulus (Only Standard Sieve) (#4, #8, #16, #30, #50, #100) =(0.00+2.5+6.2+8.8+64.5+96.7) /100= 1.787

From Graph, Using Table, we have found the Percentage of Fine Sand, Medium Sand and Course Sand.

From Graph, D10 = 0.173 mm, D30 = 0.28 mm, D60 = 0.382 mm
Uniformity Co-efficient, Cu =D60/D10 = 2.205.

Table 5.5 Gradation Chart of Sieve Analysis At Depth 150-250'

Sieve No	Sieve Size, mm	Material Retained	% Retained	Cumulative % Retained	% Finer	FM	Values from Graph
4	4.75	0	0	0	100	**1.787**	**D10=.18** **D30=.28** **D60= .39** **CU=2.17** **Coarse Sand = 10%** **Medium Sand = 84%** **Fine Sand = 6%**
8	2.36	2.5	2.5	2.5	97.5		
16	1.18	3.7	3.7	6.2	93.8		
30	0.6	2.6	2.6	8.8	91.2		
40	0.425	20.4	20.4	29.2	70.8		
50	0.3	35.3	35.3	64.5	35.5		
100	0.15	32.2	32.2	96.7	3.3		
200	0.075	1.2	1.2	97.9	2.1		
PAN		2.1	2.1	100	0		
Total		100					

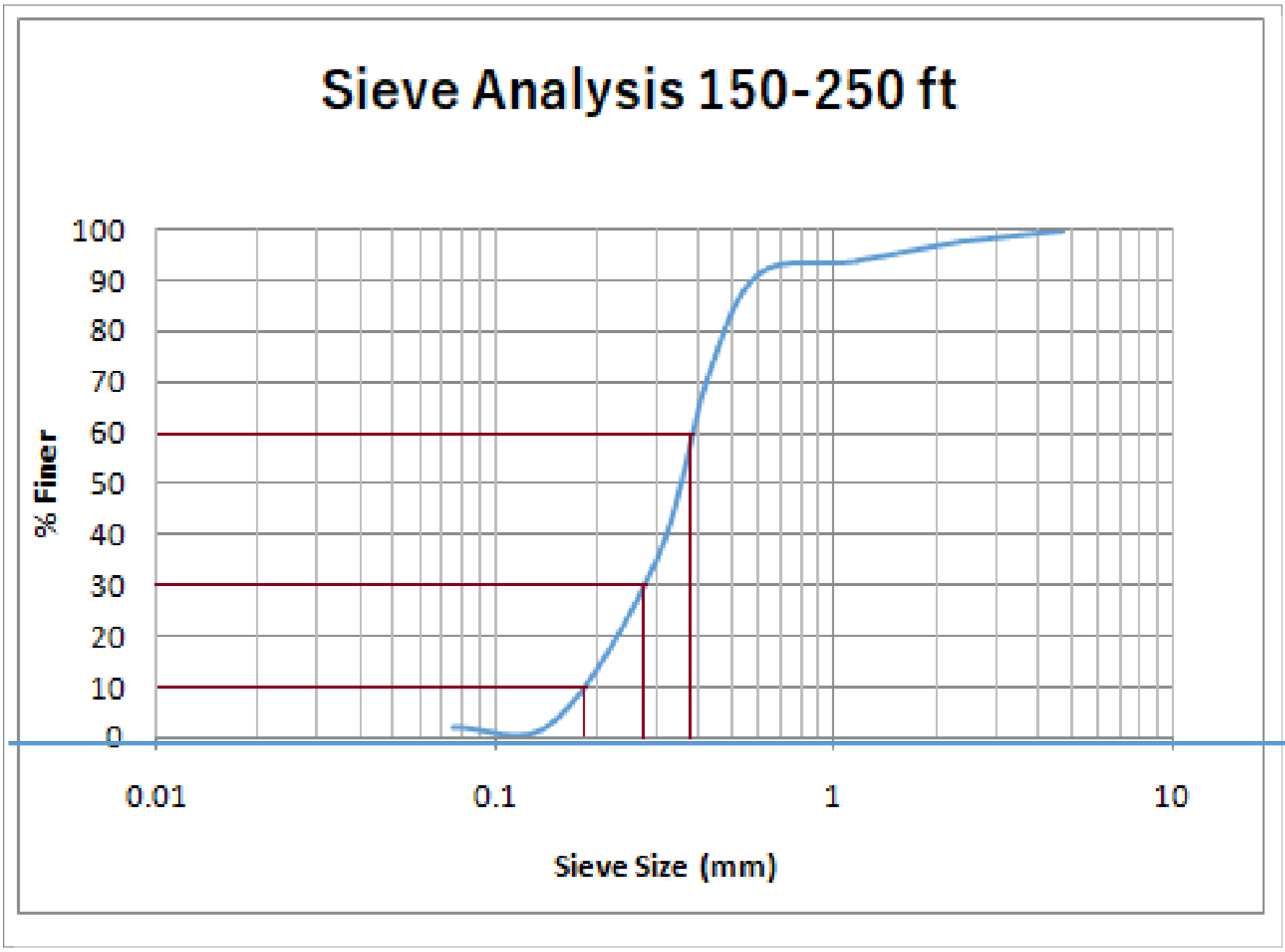


Figure 5. 2 Seive Analysis 150-250 ft

Table 5.6 Gradation Chart of Sieve Analysis At Depth 250-280'

Sieve No	Sieve Size, mm	Material Retained	% Retained	Cumulative % Retained	% Finer	FM	Values from Graph
4	4.75	0	0	0	100	1.341	**D10=.14** **D30=.22** **D60= .33** **CU=2.35** **Coarse Sand = 0%** **Medium Sand = 68%** **Fine Sand = 32%**
8	2.36	0	0	0	100		
16	1.18	0	0	0	100		
30	0.6	0.8	0.8	0.8	99.2		
40	0.425	16.2	16.2	17	83		
50	0.3	28.5	28.5	45.5	54.5		
100	0.15	42.3	42.3	87.8	12.2		
200	0.075	9.5	9.5	97.3	2.7		
PAN		2.7	2.7	100	0		
Total		100					

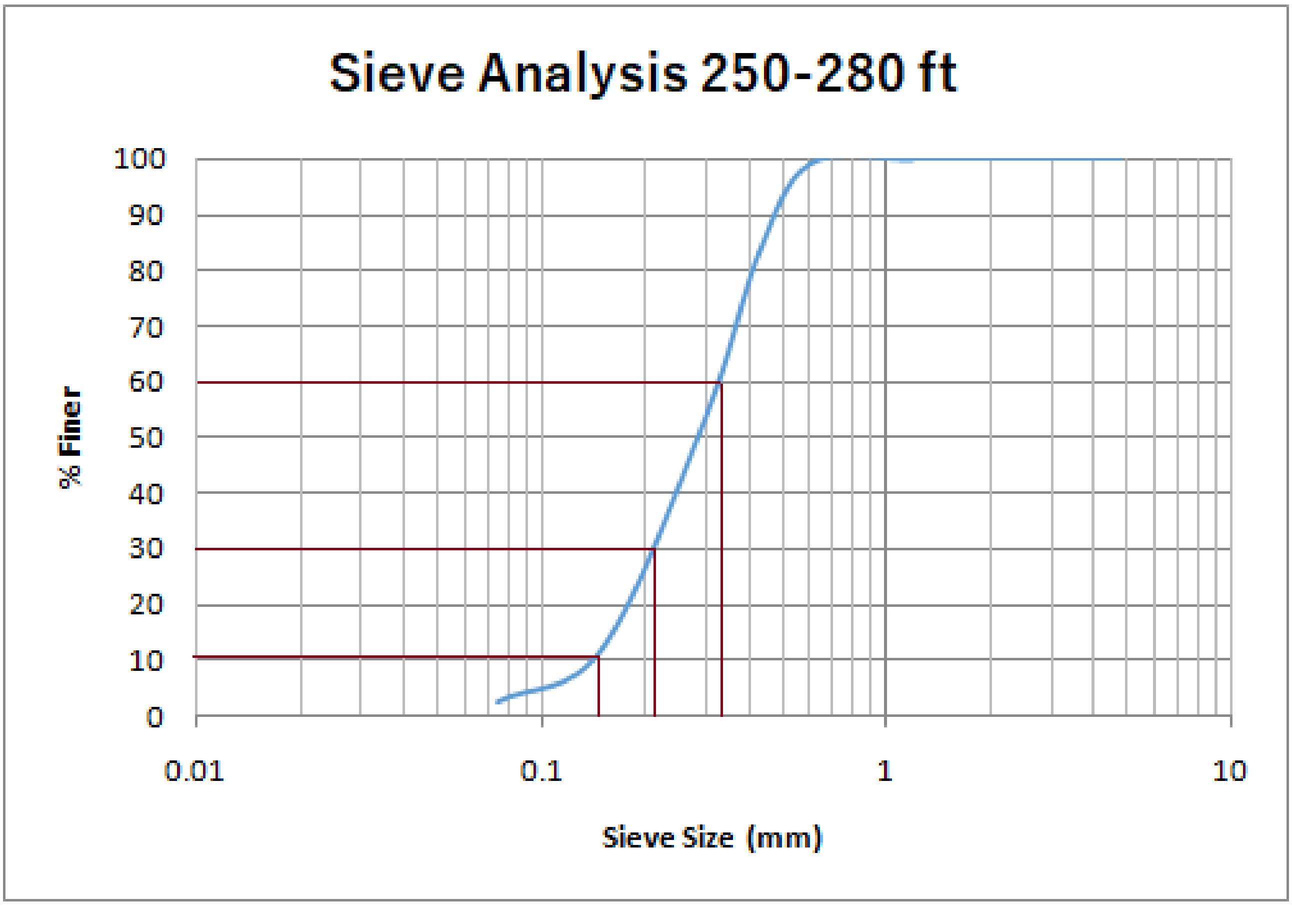


Figure 5. 3 Seive Analysis 250-280 ft

Table 5.7 Gradation Chart of Sieve Analysis At Depth 280-310'

Sieve No	Sieve Size, mm	Material Retained	% Retained	Cumulative % Retained	% Finer	FM	Values from Graph
4	4.75	0	0	0	100	1.381	**D10=.13** **D30=.22** **D60= .35** **CU=2.69** **Coarse Sand = 0%** **Medium Sand = 74%** **Fine Sand = 26%**
8	2.36	0	0	0	100		
16	1.18	0	0	0	100		
30	0.6	0.8	0.8	0.8	99.2		
40	0.425	16.2	16.2	17	83		
50	0.3	32.5	32.5	49.5	50.5		
100	0.15	38.3	38.3	87.8	12.2		
200	0.075	9.5	9.5	97.3	2.7		
PAN		2.7	2.7	100	0		
Total		100					

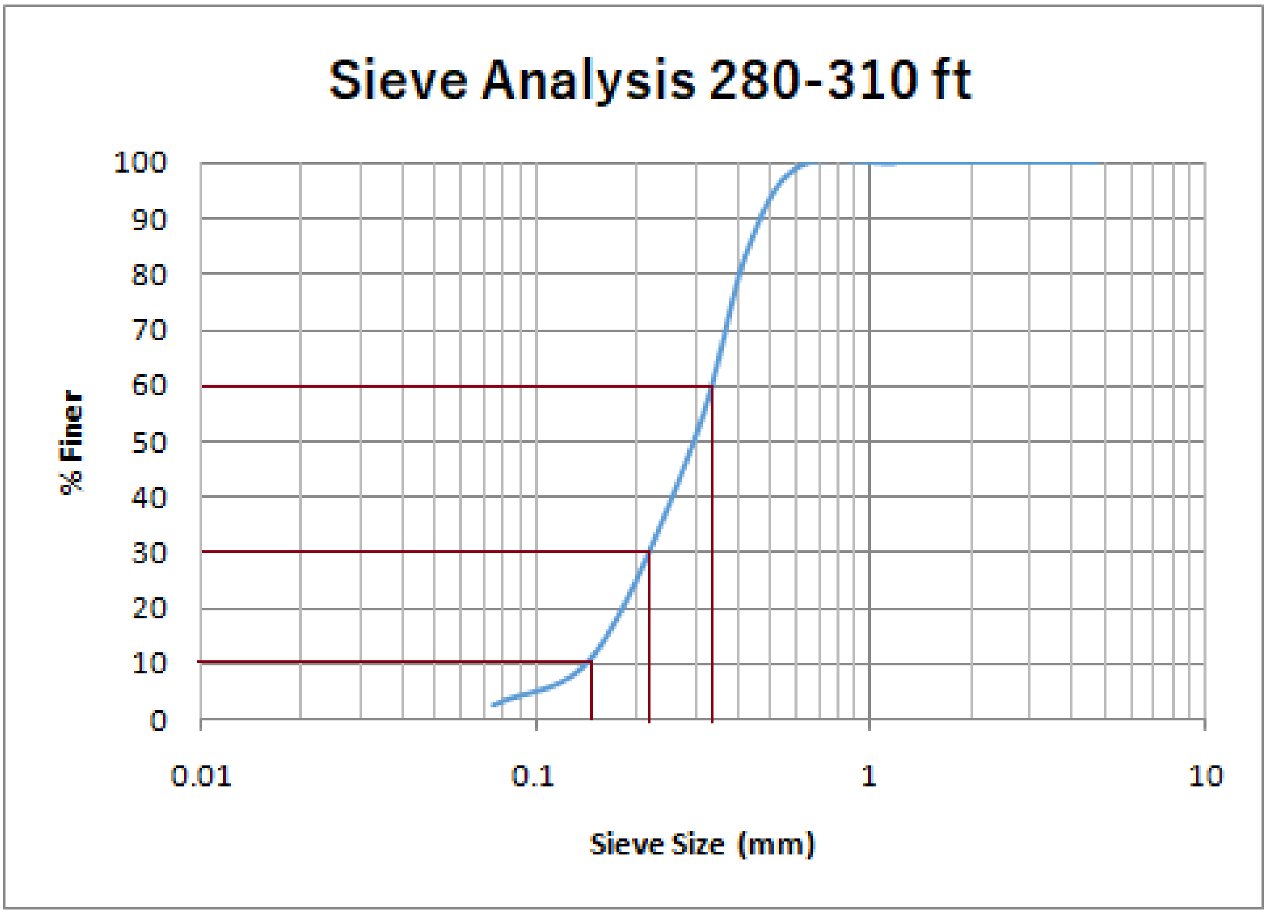


Figure 5. 4 Seive Anlaysis 280-310 ft

Table 5.8 Gradation Chart of Sieve Analysis At Depth 310-370'

Sieve No	Sieve Size, mm	Material Retained	% Retained	Cumulative % Retained	% Finer	FM	Values from Graph
4	4.75	0	0	0	100	1.691	**D10=.17**
8	2.36	0	0	0	100		**D30=.27**
16	1.18	4.3	4.3	4.3	95.7		**D60= .41**
30	0.6	3.6	3.6	7.9	92.1		**CU=2.41**
40	0.425	19.5	19.5	27.4	72.6		**Coarse Sand = 8%**
50	0.3	36.9	36.9	64.3	35.7		**Medium Sand = 76%**
100	0.15	28.3	28.3	92.6	7.4		**Fine Sand = 16%**
200	0.075	6.1	6.1	98.7	1.3		
PAN		1.3	1.3	100	0		
Total		100					

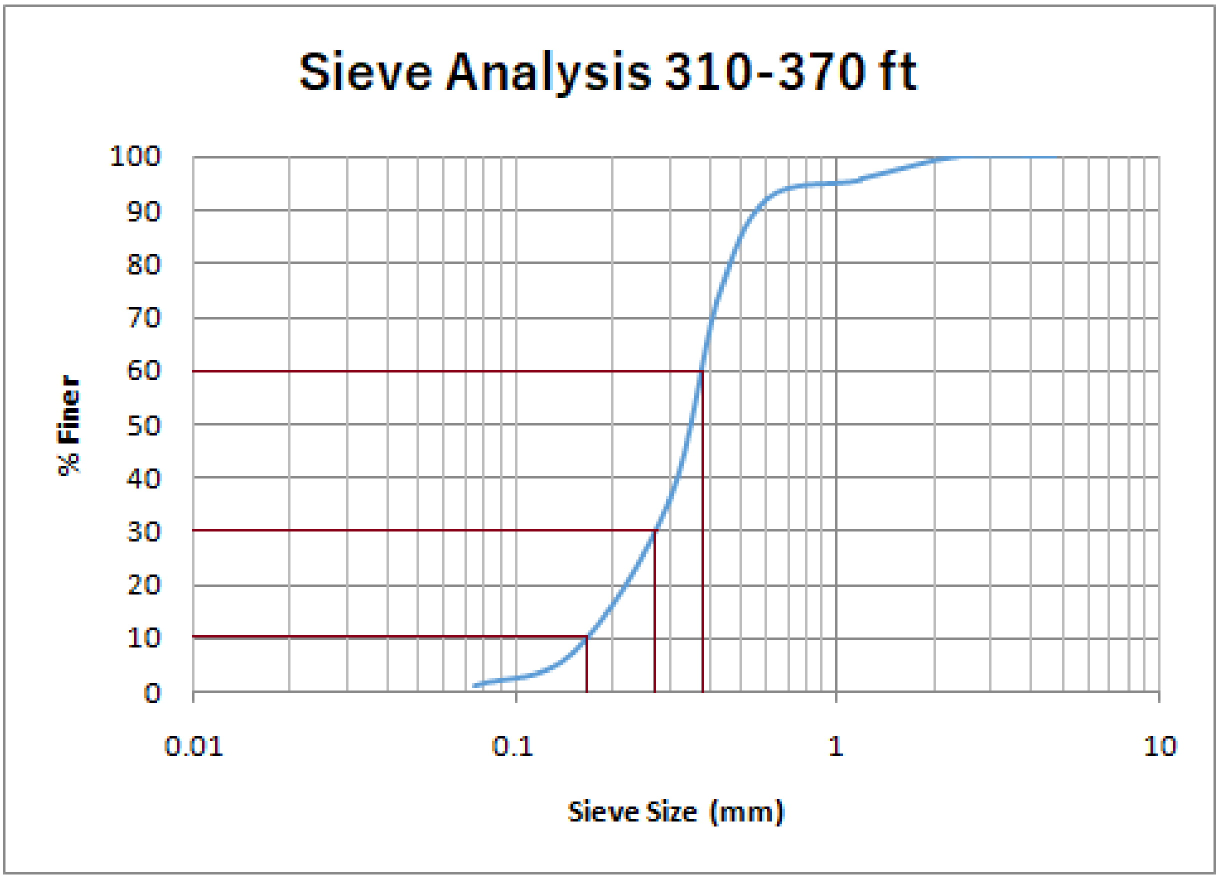


Figure 5. 5 Seive Analysis 310-370 ft

Table 5.9 Gradation Chart of Sieve Analysis At Depth 370-400'

Sieve No	Sieve Size, mm	Material Retained	% Retained	Cumulative % Retained	% Finer	FM	Values from Graph
4	4.75	0	0	0	100	**1.523**	**D10=.16** **D30=.24** **D60= .35** **CU=2.19** **Coarse Sand = 42%** **Medium Sand =48%** **Fine Sand = 10%**
8	2.36	0	0	0	100		
16	1.18	0	0	0	100		
30	0.6	2	2	2	98		
40	0.425	16.1	16.1	18.1	81.9		
50	0.3	40.5	40.5	58.6	41.4		
100	0.15	33.1	33.1	91.7	8.3		
200	0.075	6.5	6.5	98.2	1.8		
PAN		1.8	1.8	100	0		
Total		100					

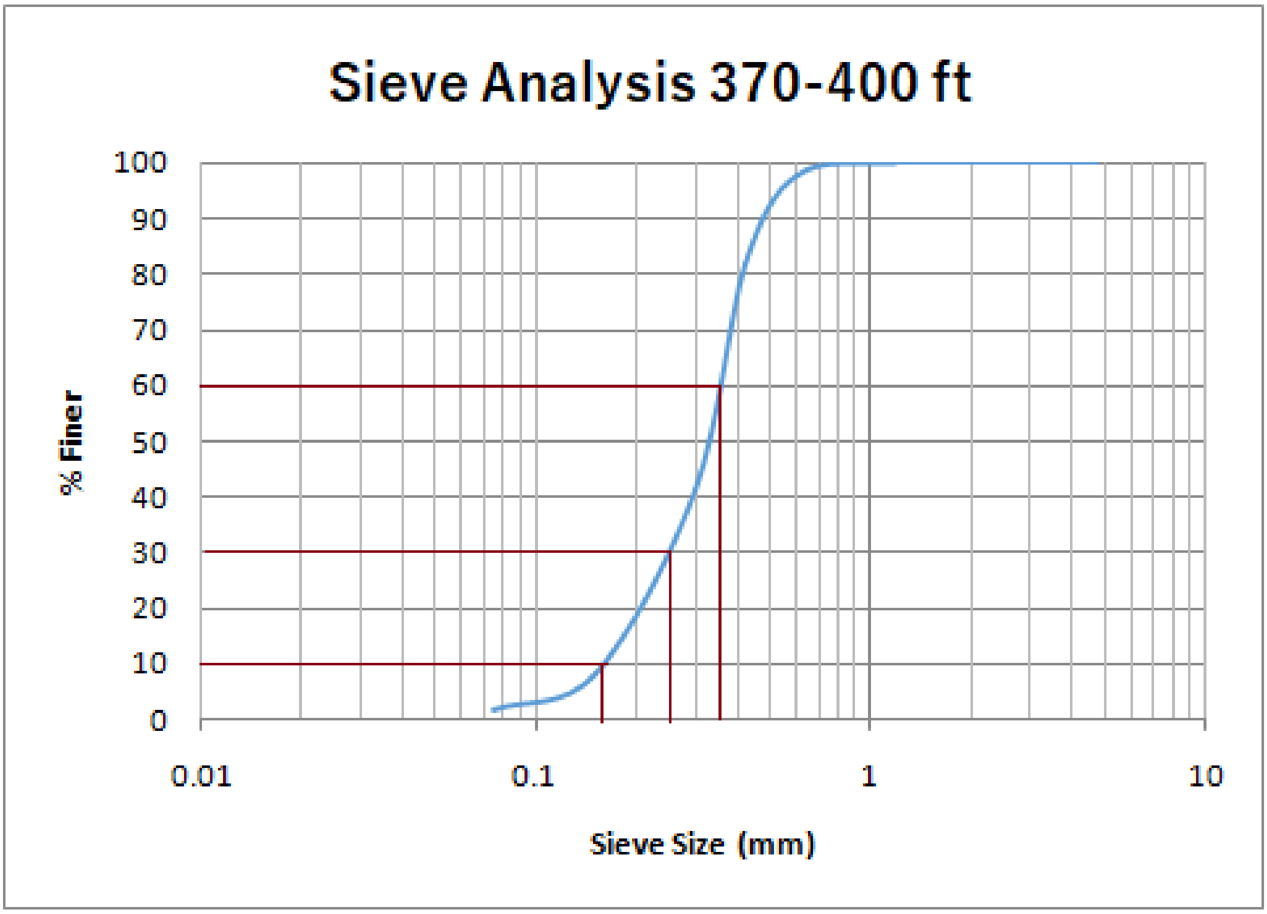


Figure 5. 6 Seive Analysis 370-400 ft

Table 5.10 Gradation Chart of Sieve Analysis At Depth 400-410'

Sieve No	Sieve Size, mm	Material Retained	% Retained	Cumulative % Retained	% Finer	FM	Values from Graph
4	4.75	0	0	0	100	1.708	**D10=.18**
8	2.36	0	0	0	100		**D30=.29**
16	1.18	0	0	0.00	100.00		**D60= .38**
30	0.6	5.8	5.8	5.80	94.20		**CU=2.11**
40	0.425	16.2	16.2	22.00	78.00		**Coarse Sand = 6%**
50	0.3	44.9	44.9	66.90	33.10		**Medium Sand = 79%**
100	0.15	31.2	31.2	98.10	1.90		**Fine Sand = 15%**
200	0.075	1.4	1.4	99.50	0.50		
PAN		0.5	0.5	100	0		
Total		100					

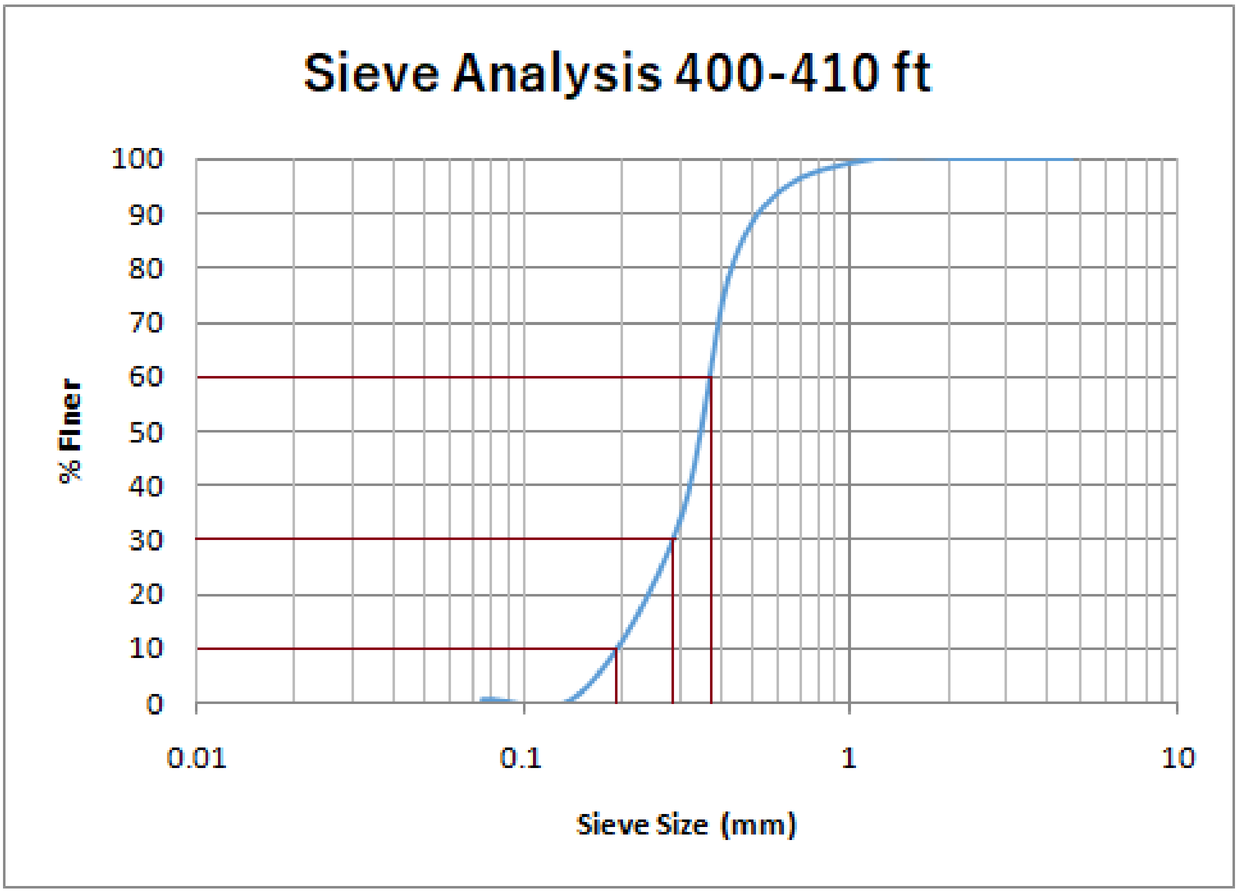


Figure 5. 7 Seive Analysis 400-410 ft

a) Locating the Aquifer and Water Bearing Strata:

All soil sample data are summarized in a table to find available water bearing soil strata, presented below. From 200 to 410 feet depth, percent of medium sand is in suitable percentage, F.M.>1,(using table) that means bigger soil particle, Uniformity Co-efficient is greater that means good permeability. As suitable layer is found at upper side, there is no need to go deep down to find location of Aquifer.

Table 5.11 SUMMARY OF THE GRAIN SIZE DISTRIBUTION

Sample Depth (ft)	D10 (mm)	D30 (mm)	D60 (mm)	CU = D60 /D10	FM	% Coarse Sand	% Medium Sand	% Fine Sand
150-250	0.18	0.28	0.39	2.16667	1.79	10	84	6
250-280	0.14	0.22	0.33	2.35714	1.34	0	68	32
280-310	0.13	0.24	0.35	2.69231	1.38	0	74	26
310-370	0.17	0.27	0.41	2.41176	1.69	8	76	16
370-400	0.16	0.24	0.35	2.1875	1.52	42	48	10
400-410	0.18	0.29	0.38	2.11111	1.71	6	79	15

Location of water bearing soil layer 200-410 ft

a) Determination of Strainer Length and Position:

Given, the static water level at 200 ft.

Average rate of water level declination (per year) = 2 ft

Design period= 20 years.

Drawdown of 15’, while pumping each

time Safety distance of 15’.

So length of the Housing pipe= (200+2*20+15+15) = 270

Aquifer depth= (410-270) = 140’, which is more than 50’. So,80% of the aquifer screening can be made which gives the strainer length of = (140 * 0.80) = 112'. But as we know that maximum safe length of the strainer is 100’.

The value of F.M. and C_U at 270 feet depth was not good enough. To get a better value of F.M.& C_U we provided strainer from 280 ft. Because greater value of F.M. & C_U means bigger particle size and better permeability. Hence, water can be withdrawn from this depth with greater ease.

So, from 270’-280’ we provided a blank pipe of 10 ft.

6 inch diameter envelop of gravel pack material will surround the entire screen.

Length of Housing Pipe: 270 ft. Length of the Strainer: 100 ft.

Strainer will cover at a Depth of 280 ft to 380 ft

b) Design of Gravel Pack Material:

The Layer having Lower Fineness Modulus of 1.381 and Greatest Uniformity Co-efficient of 2.60 within the Aquifer Depth is selected for installation of the Strainer at Sample depth 280 ft.

At a depth 280 ft, D30 was found 0.22 and this value is multiplied by 6 and the value is found by 1.3.

Table 5.12 Gradation Chart of Sieve Analysis At Depth 280-310'

Sieve No	Sieve Size, mm	Material Retained	% Retained	Cumulative % Retained	% Finer	FM
4	4.75	0	0	0	100	**1.381**
8	2.36	0	0	0	100	
16	1.18	0	0	0	100	
30	0.6	0.8	0.8	0.8	99.2	
40	0.425	16.2	16.2	17	83	
50	0.3	32.5	32.5	49.5	50.5	
100	0.15	38.3	38.3	87.8	12.2	
200	0.075	9.5	9.5	97.3	2.7	
PAN		2.7	2.7	100	0	
Total		100				

Then by drawing a parallel line from previous one, we found the first Gravel Pack Material Curve.

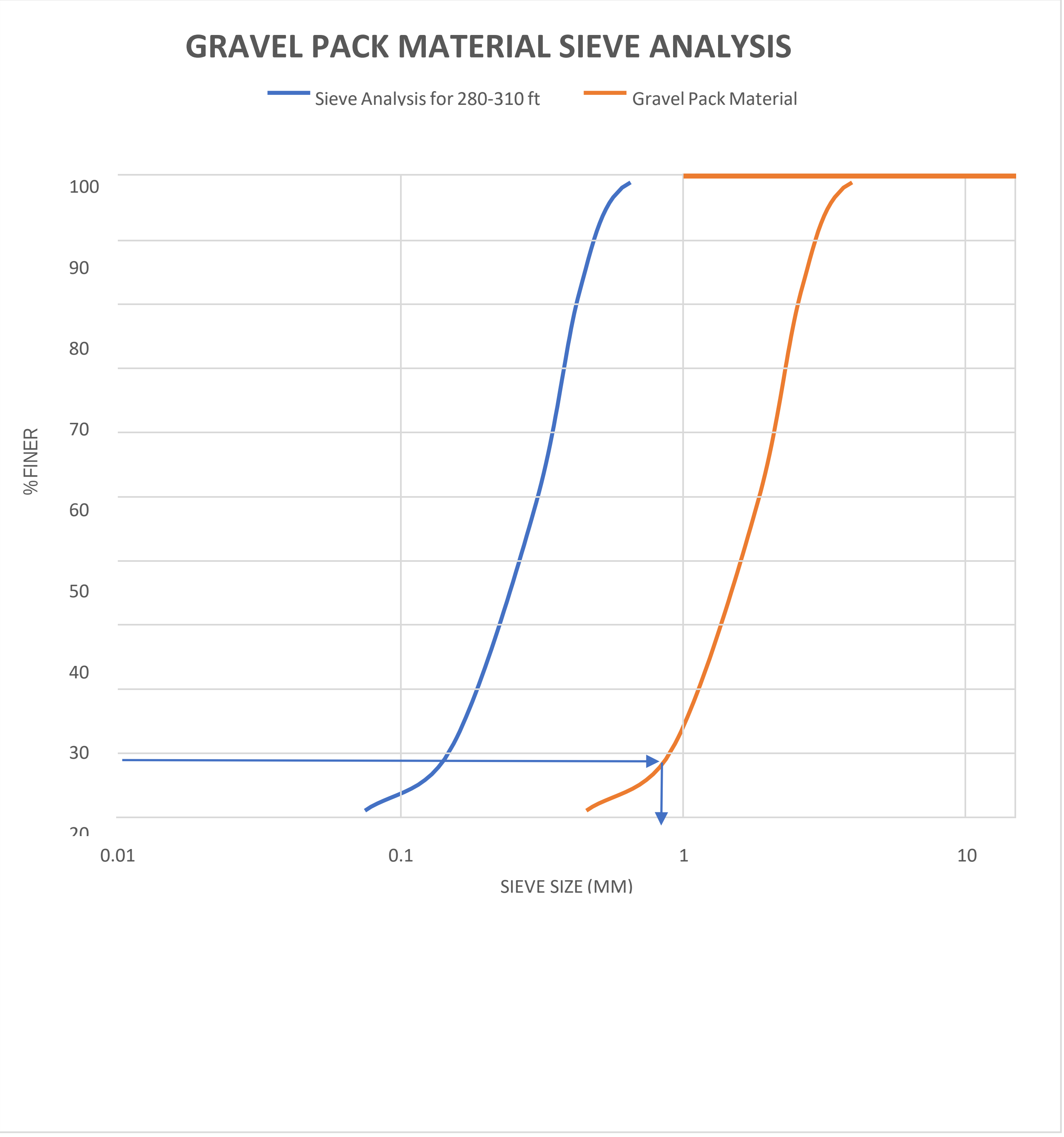


Figure 5. 8 Gravel pack material sieve analysis

From Gravel Pack Curve, we have determined Percent Finer from Gravel Pack Material for sieve sizes (#4, #8, #16, #30, #40, #50, #100, and #200).

Percent Finer for Sieve No. 8 is 74% (From Graph)

Cumulative Percent Retained= 100-74=26%

Percent Retain for #8 = 26-0=26%

Range of Percent Retained= 26% +/- 8%= 18~34 %

From Graph, D60=2mm, D10=.85mm; Uniformity Co-efficient= 2/.85=2.35<2.5; So Ok.

Table 5.13 Gravel Pack Material

Sieve No	Size, mm	% Finer From Graph	Cumulative % Retained	% Retained	Range of % retained
4	4.75	100	0	0	0-8
8	2.36	65	35	35	27-43
16	1.18	20	80	45	37-53
30	0.6	0	100	20	12-28
40	0.425	0	100	0	0
50	0.3	0	100	0	0
100	0.15	0	100	0	0
200	0.075	0	100	0	0

c) Selection of Strainer Size:

To retain 90% of gravel pack material,
Slot = (D10/25.4)*1000; here D10 will be of the gravel pack material
If, D10 = 0.84mm
= (0.84/25.4)*1000=33.07
So, we select 6-inch diameter 40 slot strainer having each opening area of 40/1000 inch.
6-inch diameter envelop of gravel pack material will surround the entire screen.

Strainer Size: 40 slot

6 inch Diameter Envelop of Gravel Pack Material

d)Calculation of Yield of Tube well:
For 40 slot size, 20% opening has been assumed for steel screening).

For 40 slot strainer,

Strainer area= 20% of strainer surface area

= 0.20 x 3.1416 x Diameter x Strainer length

Here, Diameter = 6”, Length = 100’

Assume, Flow velocity = 0.10 fps

Screen Blockage Factor, BF=0 .4(The factor of safety is considered assuming blockage while operation)

So, Yield of a well = (0.2 x 3.1416 x 6/12 x 100 x 0.1) *0.4

= 1.25664 ft^3/s

= 1.25664x $(0.3048)^3$x3600x1000 lph

= 128103 lph

g) Well Number Calculation:

Design considerations:

- For one pump
- In one day
- 5 hours pumping in two shifts

(For Residential & Common Service at Present)

As pumping is for 10 hours per day, Yield = 96077x10=960770 lpd .

More than one well may be required if one well can't meet the demand.

Now, Water demand for that area = 1613829 lpd

No. of tube wells required = 1613829 /960770 = 1.68 ≈ 2.

Table 5.14 Well Number Calculation

Zones	Present Demand (lpd)	Demand after 10 years (lpd)	Demand after 20 years (lpd)
For Residential &Common Services (Same overhead tank)			
Residential	750925	873800	1006800
Common Services	862904	949194	1035485
Total Water Demand	1613829	1822994	2042285
Yield of Well= 96077 lph			
No. of Well Required	1.68	1.90	1.77
	2	2	2
Pumping Hour	10	10	12
For Fire fighting, Administrative & Industrial (Same overhead tank)			
Fire fighting	15012	15012	15012
Industrial	1306844	1568280	1829632
Administrative	33642	37044	40446
Total Water Demand	1355498	1620336	1885090
Yield of Well= 96077 lph			
No. of Well Required	1	.99	1.96
	1	1	2
Pumping Hour	14	17	10

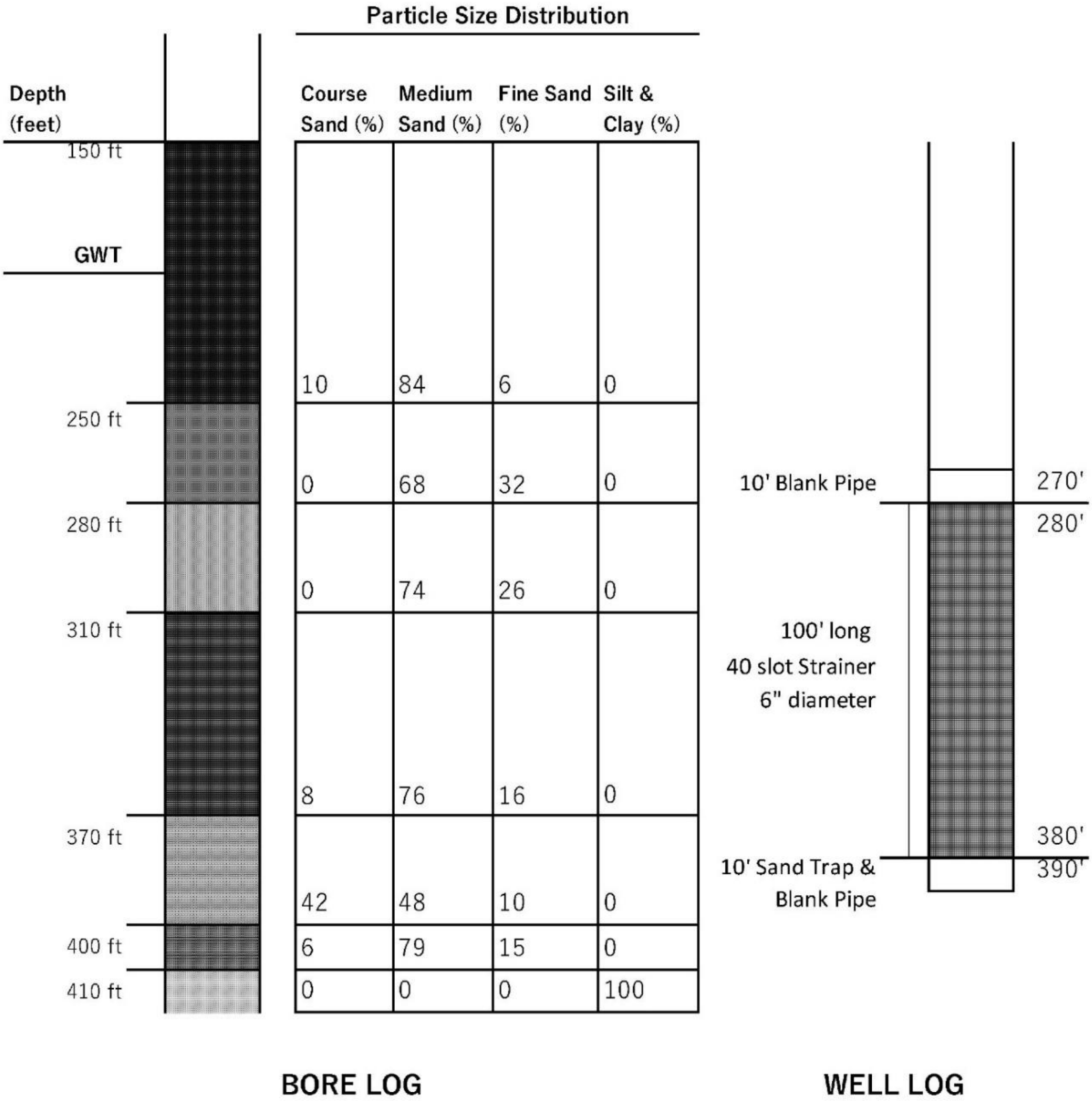


Figure 5. 9 Bore log and Well log

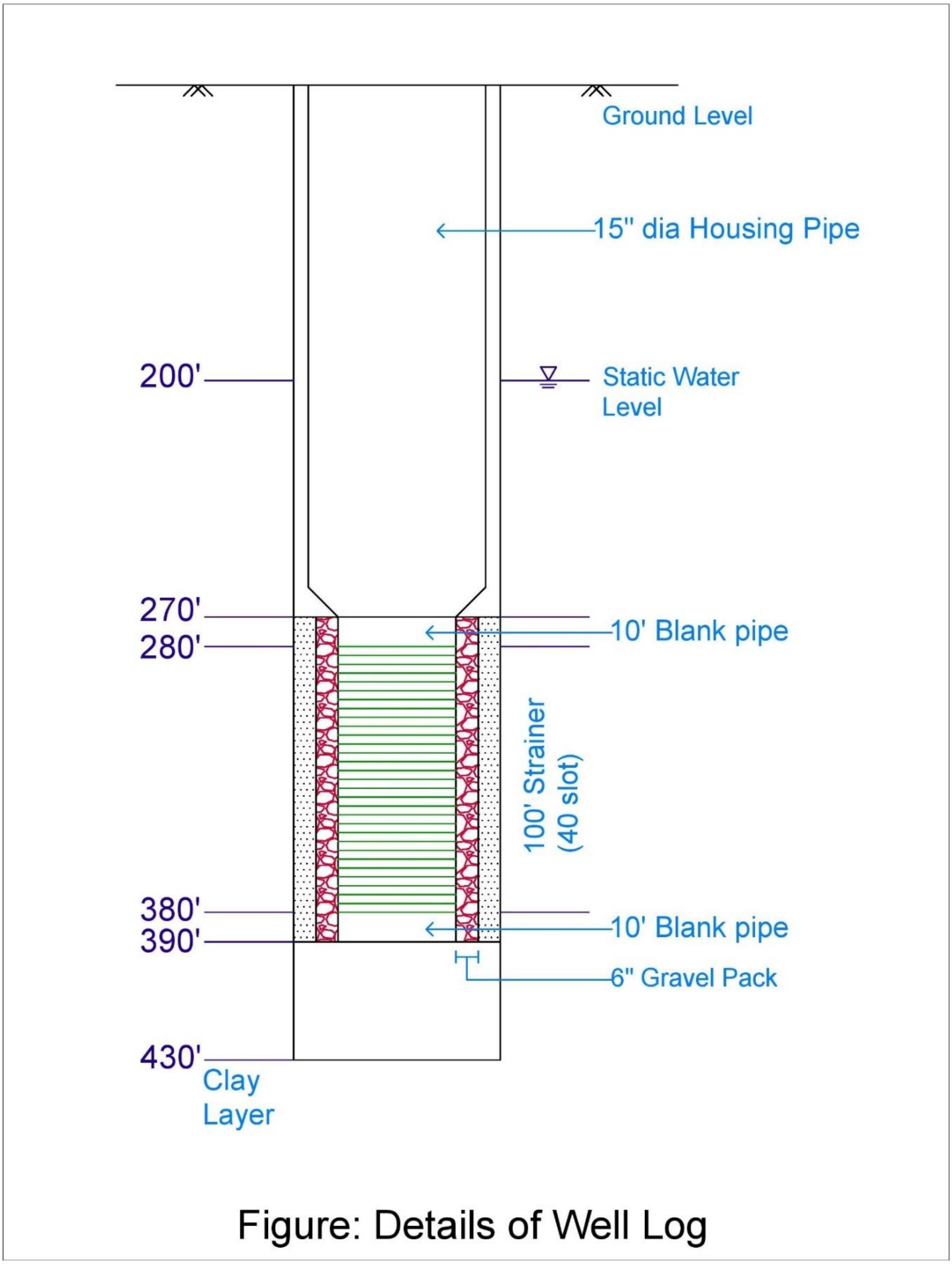


Figure 5. 10 Details of Well log

CHAPTER 6

PUMP STATION VISIT

Water Supply System at BUET

Introduction:

The water supply system of BUET is based on groundwater extraction by pumping process. But nowadays the pumping process is becoming struggling because of lowering of water table. As the water table is going down, high depth boring and high capacity pump will be needed and along with this, a huge amount of cost may be addressed. Lower Water Table results bad quality of water pertaining color problem, odor problem and gets mixed up with silt-clay mixture and metals. Moreover, proper maintenances are also needed to run the system efficiently.

Salient Features of Pumping System of BUET:

- The ground water table in BUET is now at 195 ft & declination 5'/year.
- Revolutions: 3000 RPM
- Submersible pumps are used in the pumping system. (84 HP/ 63kW)
- Pressure Range at which water is pumped: 30-60 psi
- The pumping water table is 300 ft
- 2-4 gate valves are available at every distribution area

Locations of Pumping Stations in BUET:

There are four pumping stations in BUET. At present, three of them are active.

Three active stations are-

- Pumping station near DSW office

- Pumping station at West Palashi
- Pumping station at Azad Quarter

Only inactive station-

- Pumping station at Nazrul Islam Hall

Features of the Active Pumping Station in BUET:

1. Pumping Station near DSW Office:

- Boring Depth: 500 feet
- Lifting Capacity: 2 Cusec
- Lifting Height: It can lift 6 stories high from reservoir tank. Extra pump has been used for 12 story high ECE building.
- Pump Capacity: 84 HP
- Pump Operating hour: 8 hours (from 2.00 p.m. to 10:00 p.m.) • Boring Depth: 450 feet.

Figure 6. 1 Ampere and Voltmeter

Figure 6. 2 Housing pump (pumping station near DSW office)

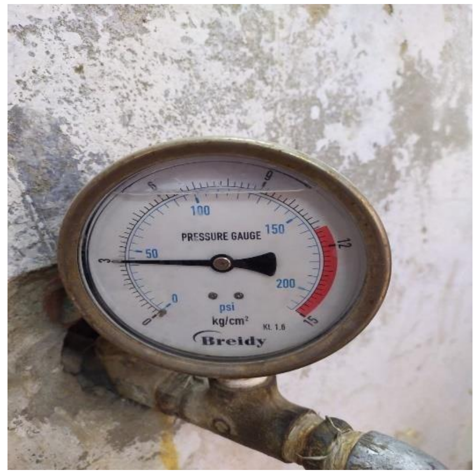


Figure 6. 3 Pressure gauge

Figure 6. 4 Suction pump

Reference:

MD. Jamal Uddin.
Designation: Senior Pump Driver.

2. Pumping Station at West Palashi:

- Boring Depth:500 ft**.**
- Pump Lifting Capacity: 2 Cusecs
- Pumping Operating Hour: 6 hours (from 8:00 a.m. to 2:00 p.m.)
- Housing Pipe:
- Diameter of Housing Pipe: 18 inch
- Depth of Housing Pipe: 300 ft
- Comment: The housing pipe is used as the same reason. Some sorts of supports can be adopted to brackets on the pump housing to support the weight of the pipes, ejector or jet in the well.
- Diameter of Strainer: 6 in
- Depth of Strainer: 80 ft.
- Comment: Strainer is used to bring water from its surrounding area which is free from stone; in this case, it is act as a filter. There is 4 strainers with 20 ft length of each strainer

Figure 6. 5 Ampere meter and Voltmeter

- Suction Pipe:
- Diameter of Suction Pipe: 6 inch • Depth of Suction Pipe: 250 ft.

Figure 6. 6 Suction pipe

- Water pressure:
- Maximum Water Pressure Before Being Turned Off: 60 psi
- Disinfection: Chlorinator present at every pump
- Amount of Chlorine: Chlorine level applied at 0.2 kg/hour or 10 Cl_2 – PPD.
- Revolutions: 5000 RPM
- <u>Comments:</u> Currently the quality of pumped water is quite good & due to this reason no treatment is needed at this moment.

Figure 6. 7 Disinfection and Water supply lines

- Reference:

MD. Rafiqul Islam.

Designation: Senior Pump Driver.

3. Pumping Station at Azad Quarter:

- Boring Depth:480 ft**.**
- Pump Lifting Capacity: 1.5-2 Cusec
- Pumping Operating Hour: 21 hours (from 1:00 a.m. to 10:00 p.m.)

- Housing Pipe:
- Diameter of Housing Pipe: 20 inches
- Depth of Housing Pipe: 340 ft
- Comment: The housing pipe is used as the same reason. Some sorts of supports can be adopted to brackets on the pump housing to support the weight of the pipes, ejector or jet in the well. It is not possible to get pumps at depth more than 300 feet.
- Strainer:
- Diameter of Strainer: 8 inches
- Depth of Strainer: 120 ft

Figure 6. 8 Ampere and voltage meter

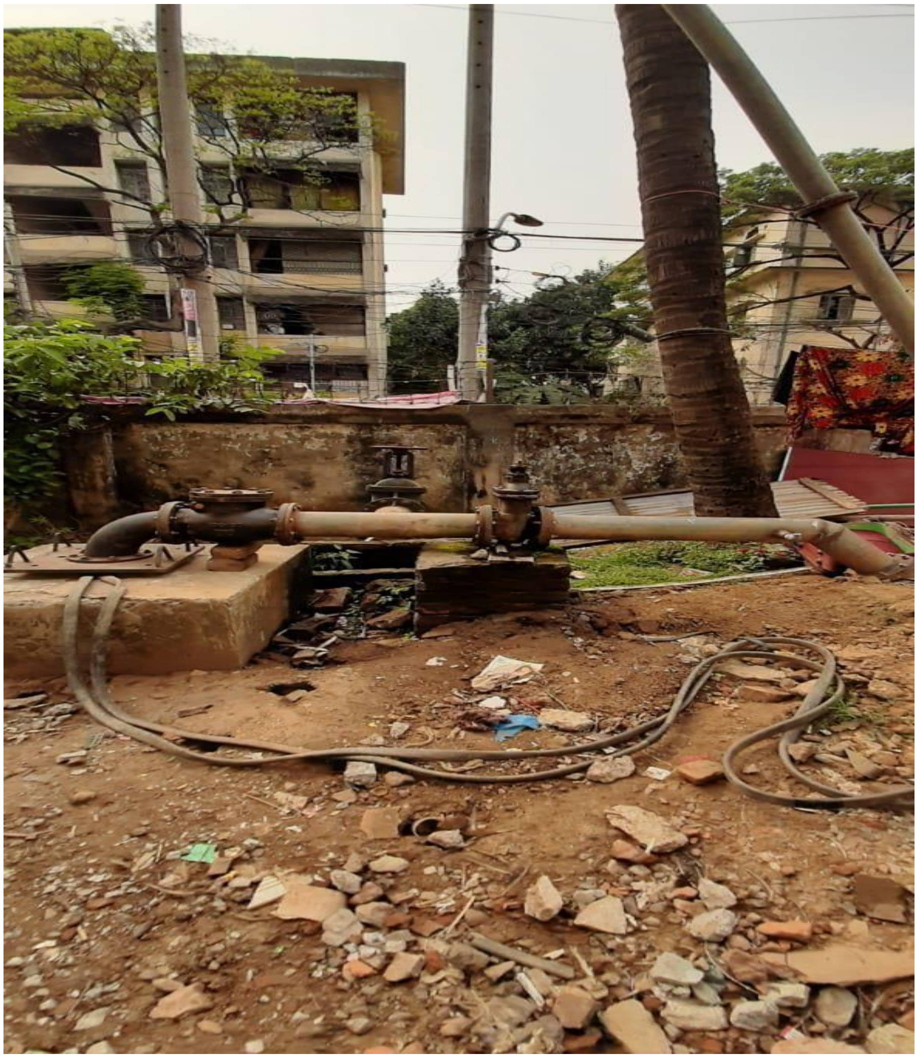


Figure 6. 9 Location of Housing Pipe & Suction pipe

- Reference:

MD. Sohag Howladar.
Designation: Senior Pump Driver.

4. Pumping Station at Nazrul Islam Hall:

- Current Condition: Out of Service

Figure 6. 10 Nazrul Islam Hall Pump Station

Figure 6. 11 Nazrul Islam Hall Pump Station

Reconnaissance

Figure 6. 12 Reconnaissance

Figure 6. 13 Reconnaissance

Conclusion:

- The report represents a basic briefing about the daily water supply procedure of BUET area. By observing the declination of water table by the time being, it can be concluded that if water table declines at this rate, existing pumping station may become very hard and inoperative.

- By examining the present condition, it can be said that when water can't be uplifted by using existing pumping stations if the water table goes down approximately more than 50 ft from the current position.

- Installation of extra pumps can be an alternative solution to increase the supply but it will take a large amount of costing thus is less feasible.

- High depth boring is also a good option for future but it is not economic enough and water quality at this higher depth is very poor.

- Existing defective pumps should be removed and in their place new pumps can be installed. Specially the pump situated in Nazrul Islam Hall should be brought under proper repairment and maintenance

- From the pump drivers it was found that in 2007 the GWT was at a depth of 130 ft, which is currently at 195 ft. Also it is not possible with the current available technology in BUET to pump water from a depth greater than 300 ft. So, at the current declination rate of

5ft/year, these Pump stations will provide service for the next 20 years.

- Finally, the wastage of water must be reduced and strictly controlled. It is a good alternative if the dependency on groundwater can be lessen.

CHAPTER 7

PUMP CAPACITY AND SCHEDULING

Determination of Pump Capacity

Introduction:

Design of any water supply system includes pumps and necessary equipment's design, storage reservoirs design and various pipes designing that convey water to the consumers. Design of pumping devices includes:

1) Determining Pump Capacity
   - Working Horse Power
   - Breaking Horse Power
2) Pumping Schedule

Terminology Used in Pumping

Before designing pumping device some terminology have to be known. These are described in a whole in below

Head

Hydraulic energy expressed as height of column of liquid above a datum. Minor losses, Kinetic Energy or Velocity Head are expressed as Potential Energy or Static Head.

hm = (kV2)/2g +hv
Hstat = HD+Hs (for lift suction head)
Hstat = HD-Hs (for flooded suction)

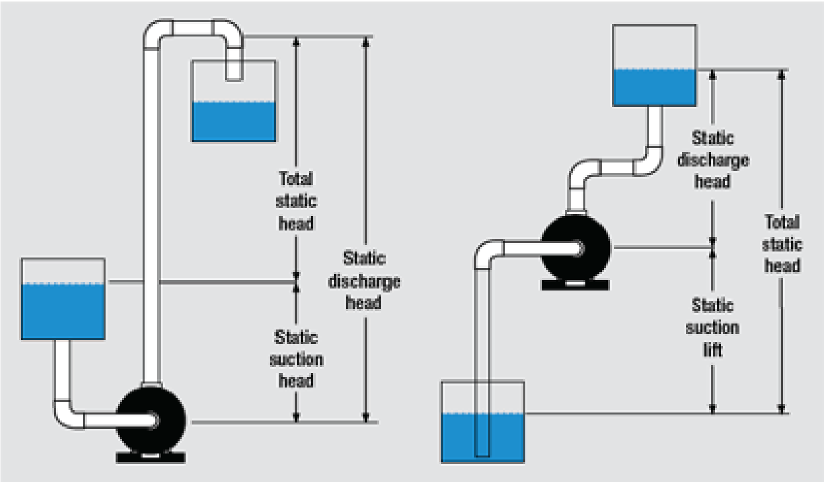


Figure 7. 1 Sketch for pump total static

a)Flooded Suction Head	b) Lift Suction Head

Total Dynamic Head (TDH)
Total dynamic head is the total energy barrier that must be overcome before the
water can be lifted by a pump. The TDH for a pump is the net energy imposed into the water by the pump.

TDH= (Discharge Energy- Suction Energy)
TDH= Hstat + hf + hm

Capacity
It is the volumetric flow of a liquid through a pump. The capacity of a pump is dependent on the total TDH and pump characteristics.
The relationship between TDH and pump capacity is shown in a **Pump Characteristics Curve**

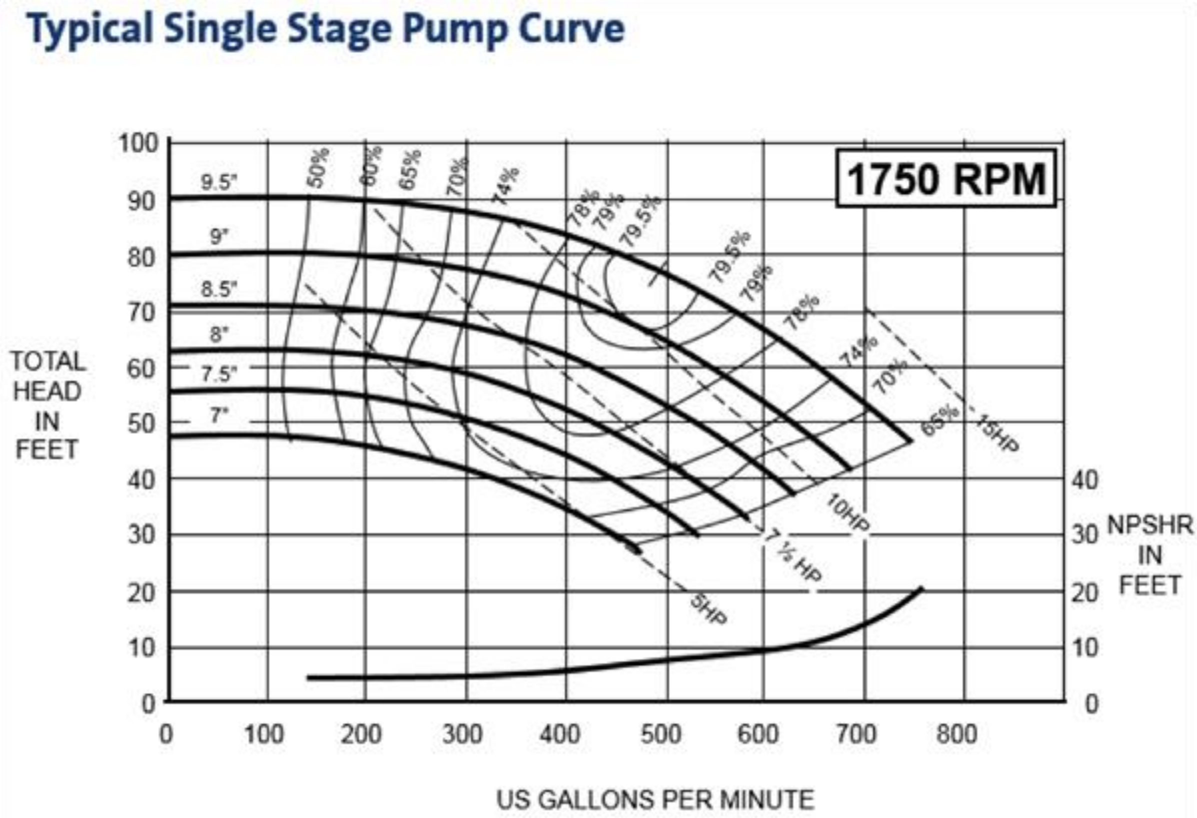


Figure 7. 2 Pump Characteristics Curve

Power and Efficiency
The Output Power is the power produced by the pump and is often referred to as Water Power. The Input Power is the power applied by a driver and always exceeds the Output Power. This is also called Break Power or Break Horse Power.

Pw = K'Q(TDH)ɤ
Ep = Pw/Pp x 100

Pw = Output Power (water power) of the pump, kW (HP)

K’ = Constant depending on the units of expression
E
p = Pump Efficiency, Usually 70-90%
P
p = Power input to the pump

Pumps Commonly Used in Water Works
Kinetic
- Centrifugal
- Peripheral or Recessed Impeller

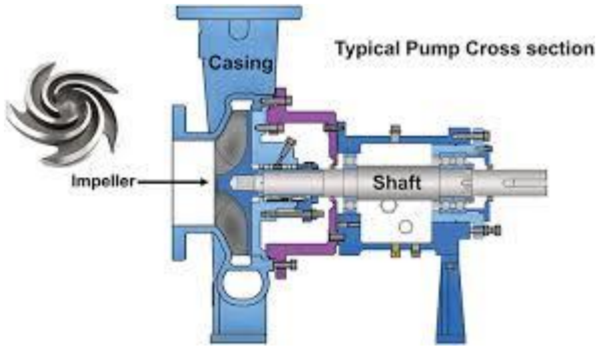


Figure 7. 3 Typical Pump Cross Section

We are using submersible pump here because of:
i) Greater boring depth can be ensured by using submersible pump and bends in the boring don’t cause complete failure of the operation.
ii) No shaft are used in submersible pump and motor can be placed below the water.

Methodology
The whole plan area is divided into two zones. Zone-1 is for industrial area and zone-2 is the combination of residential and commercial area. The number of well/pump required for each zone at present, after 10 years and after 20 years was calculated in the previous assignment.

Assumptions

Velocity of water supply = 3 fps
Maximum Building Height=60 ft
pump efficiency = 75%
Height of the rooftop tank=15 ft

Data Analysis and Calculation:
We know: Working Horse Power, WHP = $\frac{HQ}{3960}$
Where, H = Total head or lift of the pump (ft)
Q = Yield of well in gpm (Gallon per minute)
Again, Breaking Horse Power, BHP = $\frac{WHP}{\eta}$
Where, η = pump efficiency = 75%
Now, Total Head, H = Static head + Velocity head (h_v) + Friction head (h_f)
Static head = Suction head (h_s) + Delivery head (h_d)
In our industrial village submersible pump is considered & for submersible

pump, suction head (h_s) = 0
Now, Delivery head, h_d = Static water level + Maximum building height = 200'+ 60' = 260'

Velocity head, $h_v = \frac{V^2}{2g} = \frac{3^2}{2\times32}$ = 0.140625'

Friction head, h_f = 10% of maximum pipe length
= 10% of (Maximum horizontal distance + Maximum height of the building + Height of the rooftop tank)

For Pump-1: h_f = 10% of (137.58'+471.67'+131.33' + 60' + 15') = 81.56'
For Pump-2: h_f = 10% of (87.08'+266.25'+562.08'+131.33'+ 60' + 15') = 112.17'
For Pump-3: h_f = 10% of (150.58'+1032'+274.33'+151.83' + 60' + 15') = 168.37'
For Pump-4: h_f = 10% of(110.58'+720.83'+597.42'+151.83' + 60' +15')= 165.57'

Therefore, for pump-1; Total Head, H = $h_s + h_d + h_v + h_f$
= 0' + 260' + 0.140625' + 81.56'
= 341.7'

Yield of well, Q = 96077 lph = $\frac{96077}{227.13} gpm$= 423 gpm (1 gpm =227.13 lph)

So, for pump-1; Working Horse Power (WHP) = $\frac{HQ}{3960}$
= $\frac{341.7\times423}{3960}$
= 36.5 HP

So, for pump-1; Breaking Horse Power (BHP) = $\frac{WHP}{\eta}$
= $\frac{36,5}{0.75}$ HP
= 48.67 HP
=49 HP

Similarly WHP and BHP for other pumps are calculated.

Pump	**WHP (HP)**	**BHP (HP)**
Pump-1	36.5	49
Pump-2	40	53
Pump-3	46	61
Pump-4	45.5	61

Table 7.1: Pump Capacity.

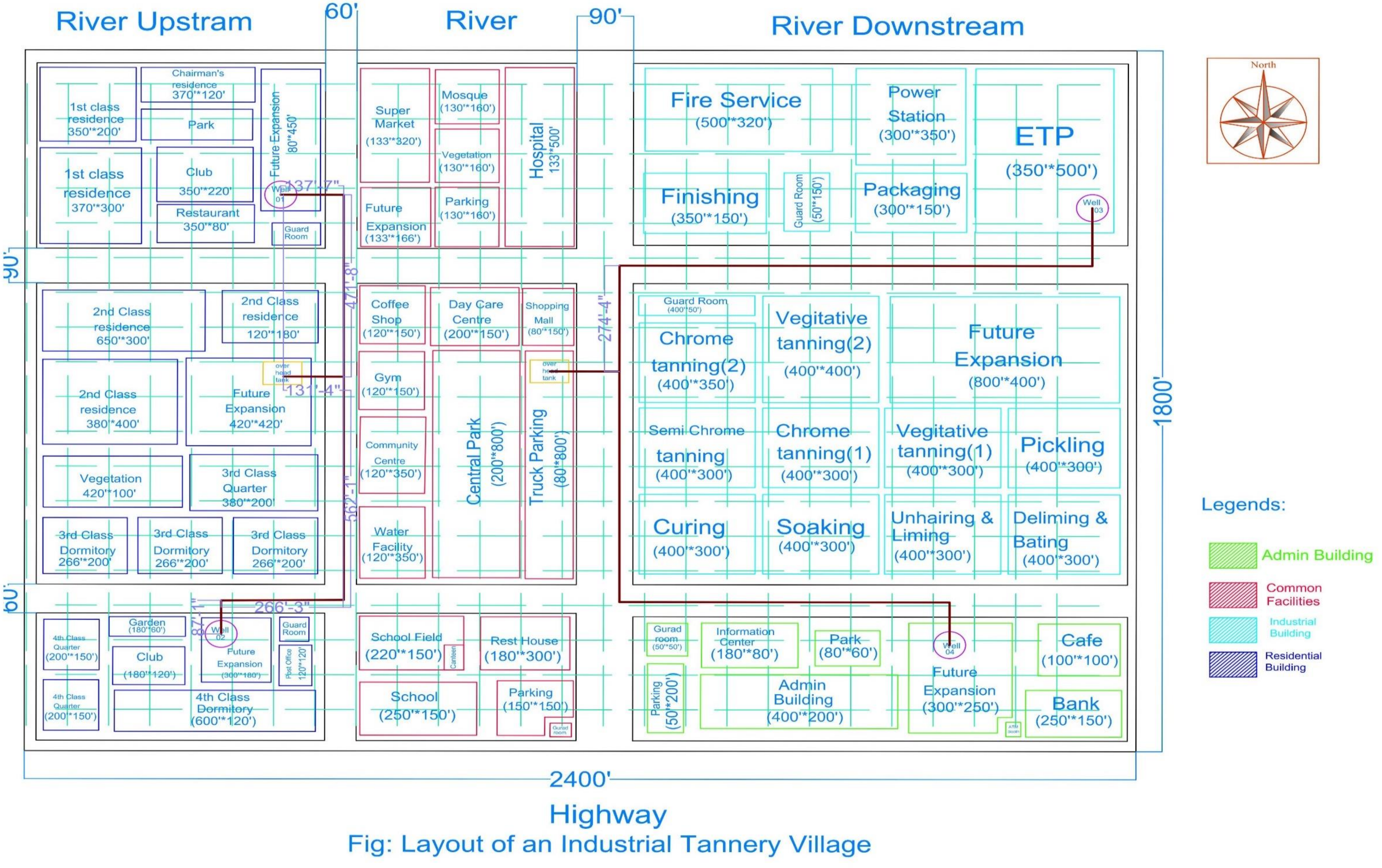


Figure 7. 4 Location of Wells in Tannery Village

_DETERMINING PUMPING SCHEDULE

Methodology

a) The total present and future water demand for each zone is calculated in Chapter before.
b) Pumping Charts is prepared according to this demand and pumping hour.
c) In every pumping schedule, fire demand adequacy has been ensured.

Method of Supply

1. Continuous supply
2. Intermittent supply

Continuous supply is always better because

- In intermittent supply, during non-supply hours distribution lines may suffer partial vacuum, sucking in contaminated water from nearby sewer pipes running close to water distribution lines.
- Consumption is well metered in continuous supply
- Constant supply for firefighting can be maintained

Method of Distribution:

- **System with direct pumping**

o Power failure means collapse of system
o Difficult to maintain required pressure in the line under varying rate of consumption

- **System with pumping and storage**

o Economic operation but high initial cost
o Required pressure can be maintained in the line under varying water consumption

Here we have followed System with Pumping and Storage for Distribution purpose.

Table 7.2 Well Number Calculation

Zones	Present Demand (lpd)	Demand after 10 years (lpd)	Demand after 20 years (lpd)
For Residential &Common Services			
Residential	750925	873800	1006800
Common Services	862904	949194	1035485
Total Water Demand	1613829	1822994	2042285
Yield of Well= 96077 lph			
No. of Well Required	1.68	1.90	1.77
	2	2	2
Pumping Hour	10	10	12
For Fire fighting, Administrative & Industrial			
Fire fighting	15012	15012	15012
Industrial	1306844	1568280	1829632
Administrative	33642	37044	40446
Total Water Demand	1355498	1620336	1885090
Yield of Well= 96077 lph			
No. of Well Required	1	.99	1.96
	1	1	2
Pumping Hour	14	17	10

Table 7.3 Pumping schedule for present demand in Residential Zone				
Time Schedule	Water Demand (in 1000 litre)	Total Supply (from pump 1) (in 1000 litre)	Storage (in 1000 litre)	Remarks
			35	No Pumping Req.
6AM-7AM	20	96	111	Pump-1 ON
7AM-8AM	39	96	168	Pump-1 ON
8AM-9AM	47	0	121	No Pumping Req.
9AM-10AM	51	96	166	Pump-1 ON
10AM-11AM	53	0	113	No Pumping Req.
11AM-12PM	50	96	159	Pump-1 ON
12PM-1PM	40	0	119	No Pumping Req.
1PM-2PM	33	96	182	Pump-1 ON
2PM-3PM	32	0	150	No Pumping Req.
3PM-4PM	27	0	123	No Pumping Req.
4PM-5PM	25	0	98	No Pumping Req.
5PM-6PM	32	0	66	No Pumping Req.
6PM-7PM	36	96	126	Pump-1 ON
7PM-8PM	42	96	180	Pump-1 ON
8PM-9PM	38	0	142	No Pumping Req.
9PM-10PM	35	0	107	No Pumping Req.
10PM-11PM	29	0	78	No Pumping Req.
11PM-12AM	25	0	53	No Pumping Req.
12AM-1AM	22	96	127	Pump-1 ON
1AM-2AM	19	0	108	No Pumping Req.
2AM-3AM	16	0	92	No Pumping Req.
3AM-4AM	13	0	79	No Pumping Req.
4AM-5AM	9	0	70	No Pumping Req.
5AM-6AM	14	0	56	No Pumping Req.
Total	751			

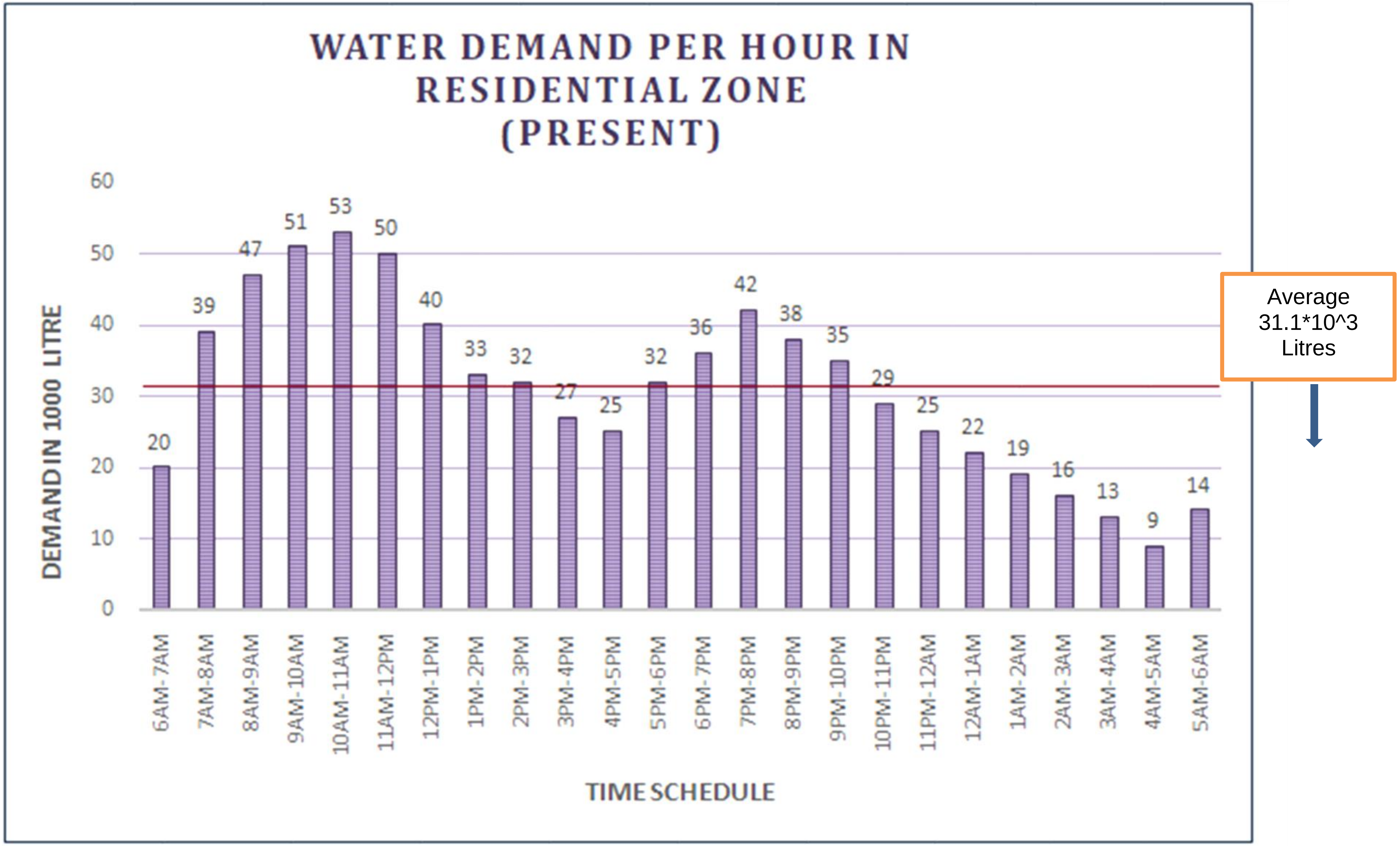


Figure 7. 5 Water demand per hour in residential zone (present)

Table 7.4 Pumping schedule for demand after 10 years in Residential Zone				
Time Schedule	Water Demand (in 1000 litre)	Total Supply (from pump 1) (in 1000 litre)	Storage (in 1000 litre)	Remarks
			38	No Pumping Req.
6AM-7AM	23	96	111	Pump-1 ON
7AM-8AM	46	96	161	Pump-1 ON
8AM-9AM	55	0	106	No Pumping Req.
9AM-10AM	60	96	142	Pump-1 ON
10AM-11AM	62	0	80	No Pumping Req.
11AM-12PM	59	96	117	Pump-1 ON
12PM-1PM	47	96	166	Pump-1 ON
1PM-2PM	39	0	127	No Pumping Req.
2PM-3PM	37	0	90	No Pumping Req.
3PM-4PM	32	0	58	No Pumping Req.
4PM-5PM	29	96	125	Pump-1 ON
5PM-6PM	37	0	88	No Pumping Req.
6PM-7PM	42	96	142	Pump-1 ON
7PM-8PM	49	0	93	No Pumping Req.
8PM-9PM	44	96	145	Pump-1 ON
9PM-10PM	41	0	104	No Pumping Req.
10PM-11PM	34	0	70	No Pumping Req.
11PM-12AM	29	96	137	Pump-1 ON
12AM-1AM	26	0	111	No Pumping Req.
1AM-2AM	22	0	89	No Pumping Req.
2AM-3AM	19	0	70	No Pumping Req.
3AM-4AM	15	0	55	No Pumping Req.
4AM-5AM	11	0	44	No Pumping Req.
5AM-6AM	16	0	28	No Pumping Req.
Total	874			

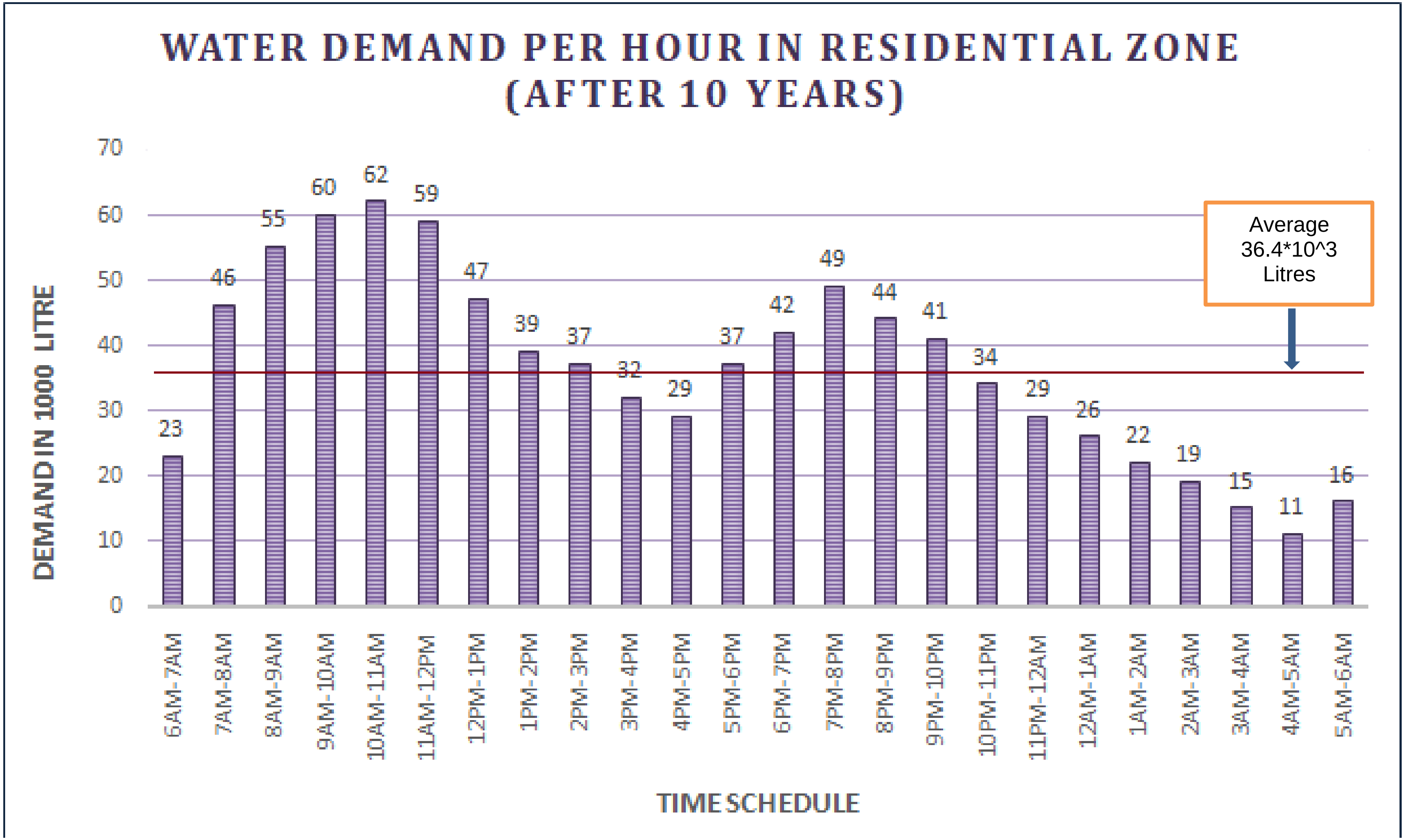


Figure 7. 6 Water demand per hour in residential zone (after 10 years)

Table 7.5 Pumping schedule for demand after 20 years in Residential Zone				
Time Schedule	Water Demand (in 1000 litre)	Total Supply (from pump 1) (in 1000 litre)	Storage (in 1000 litre)	Remarks
			42	No Pumping Req.
6AM-7AM	27	96	111	Pump-1 ON
7AM-8AM	53	96	154	Pump-1 ON
8AM-9AM	63	0	91	No Pumping Req.
9AM-10AM	69	96	118	Pump-1 ON
10AM-11AM	71	96	143	Pump-1 ON
11AM-12PM	67	96	172	Pump-1 ON
12PM-1PM	54	0	118	No Pumping Req.
1PM-2PM	44	0	74	No Pumping Req.
2PM-3PM	43	96	127	Pump-1 ON
3PM-4PM	36	96	187	Pump-1 ON
4PM-5PM	34	0	153	No Pumping Req.
5PM-6PM	43	0	110	No Pumping Req.
6PM-7PM	49	96	157	Pump-1 ON
7PM-8PM	57	96	196	Pump-1 ON
8PM-9PM	51	0	145	No Pumping Req.
9PM-10PM	47	0	98	No Pumping Req.
10PM-11PM	39	0	59	No Pumping Req.
11PM-12AM	34	96	121	Pump-1 ON
12AM-1AM	30	96	187	Pump-1 ON
1AM-2AM	26	0	161	No Pumping Req.
2AM-3AM	22	0	139	No Pumping Req.
3AM-4AM	18	0	121	No Pumping Req.
4AM-5AM	12	0	109	No Pumping Req.
5AM-6AM	19	0	90	No Pumping Req.
Total	1008			

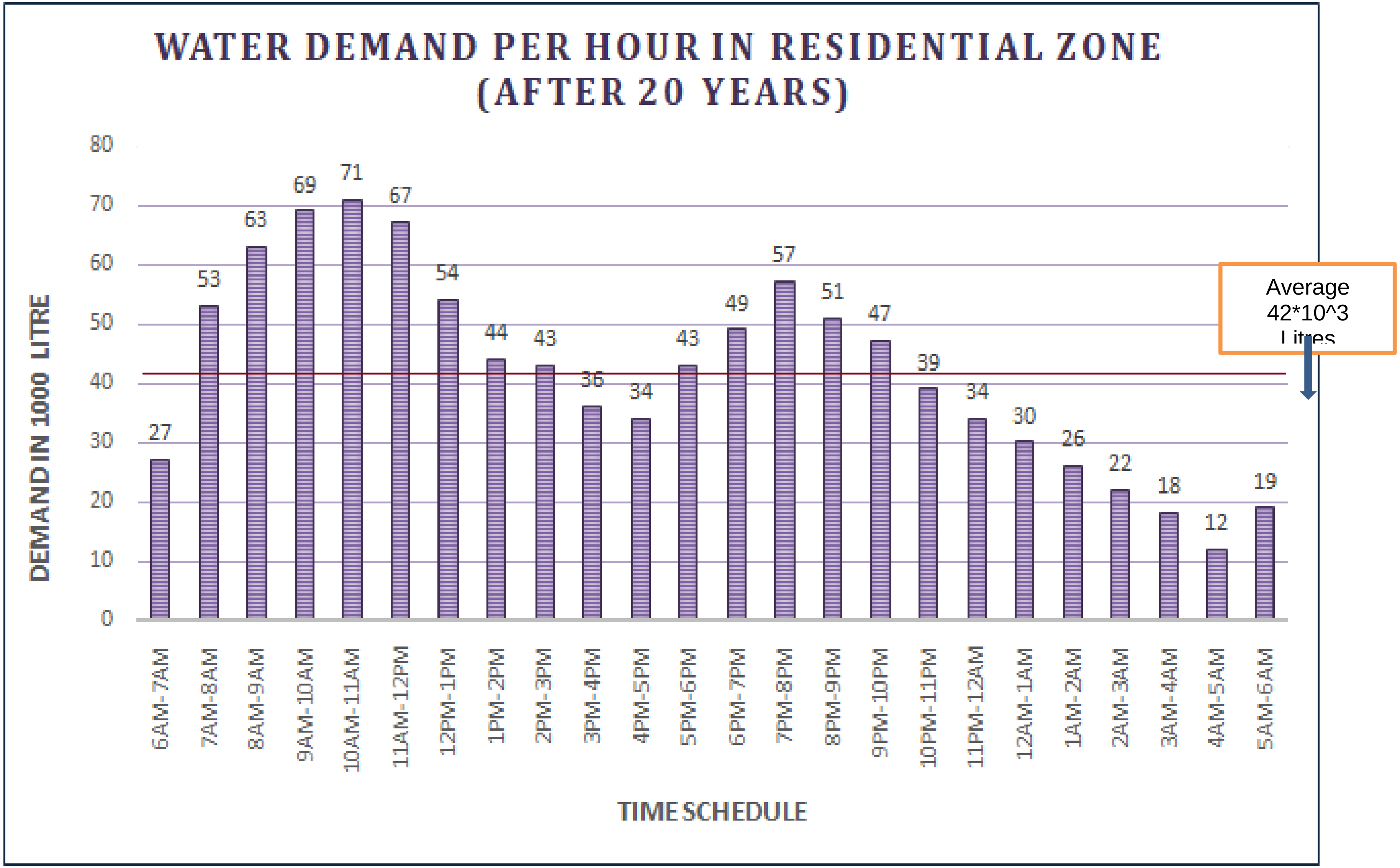


Figure 7. 7 Water demand per hour in residential zone (after 20 years)

Table 7.6 Pumping schedule for present demand in Commercial Zone				
Time Schedule	Water Demand (in 1000 litre)	Total Supply (from pump 2) (in 1000 litre)	Storage (in 1000 litre)	Remarks
			29	No Pumping Req.
6AM-7AM	14	96	111	Pump 2 ON
7AM-8AM	64	96	143	Pump 2 ON
8AM-9AM	69	96	170	Pump 2 ON
9AM-10AM	71	96	195	Pump 2 ON
10AM-11AM	78	0	117	No Pumping Req.
11AM-12PM	57	0	60	No Pumping Req.
12PM-1PM	59	96	97	Pump 2 ON
1PM-2PM	69	96	124	Pump 2 ON
2PM-3PM	58	96	162	Pump 2 ON
3PM-4PM	48	0	114	No Pumping Req.
4PM-5PM	43	0	71	No Pumping Req.
5PM-6PM	37	96	130	Pump 2 ON
6PM-7PM	30	96	196	Pump 2 ON
7PM-8PM	27	0	169	No Pumping Req.
8PM-9PM	25	0	144	No Pumping Req.
9PM-10PM	21	0	123	No Pumping Req.
10PM-11PM	20	0	103	No Pumping Req.
11PM-12AM	16	0	87	No Pumping Req.
12AM-1AM	15	0	72	No Pumping Req.
1AM-2AM	11	0	61	No Pumping Req.
2AM-3AM	11	0	50	No Pumping Req.
3AM-4AM	8	0	42	No Pumping Req.
4AM-5AM	7	0	35	No Pumping Req.
5AM-6AM	4	0	31	No Pumping Req.
Total	862			

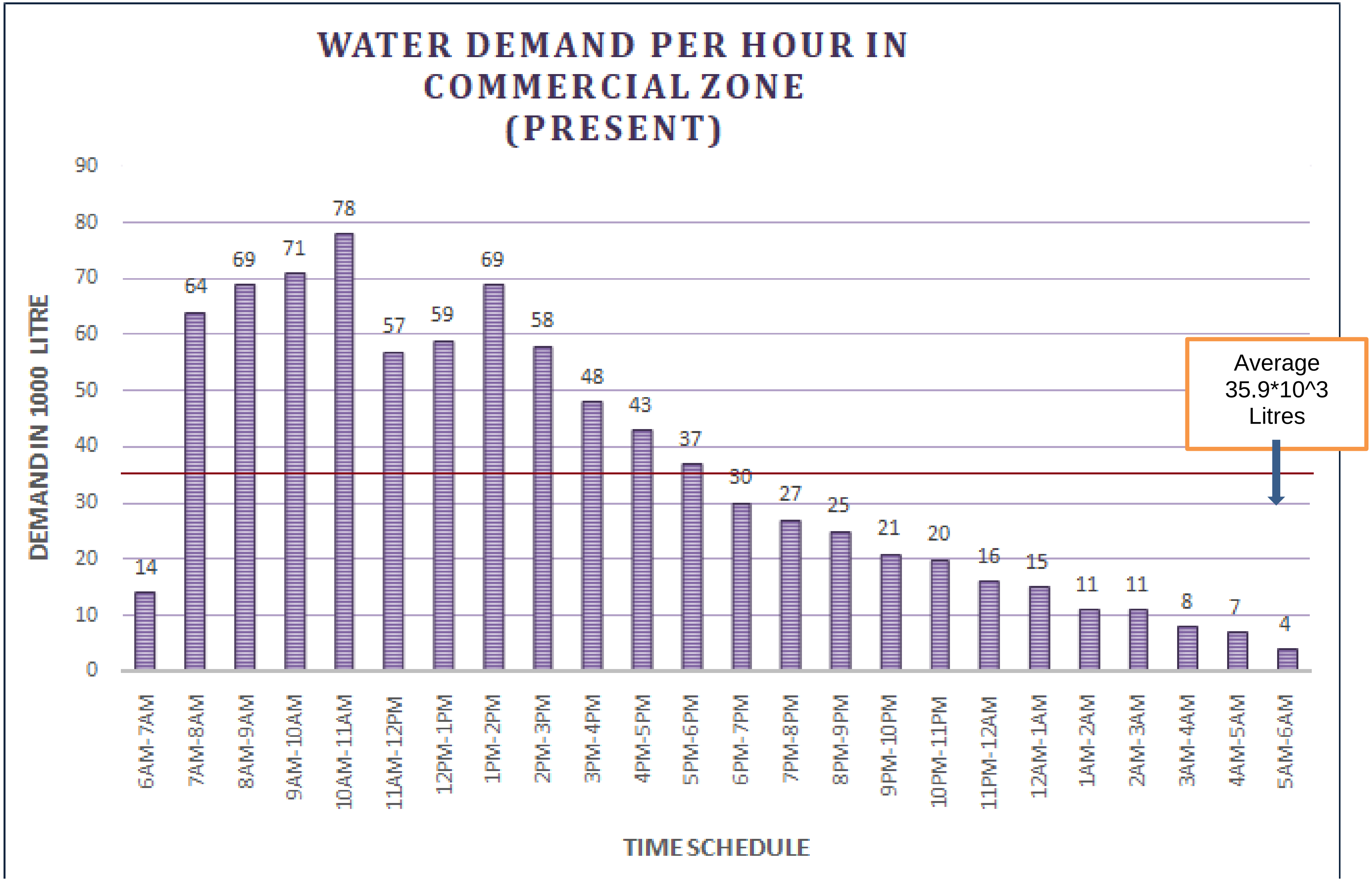


Figure 7. 8 Water demand per hour in commercial zone (present)

Table 7.7 Pumping schedule for demand after 10 years in Commercial Zone				
Time Schedule	Water Demand (in 1000 litre)	Total Supply (from pump 2) (in 1000 litre)	Storage (in 1000 litre)	Remarks
			29	No Pumping Req.
6AM-7AM	14	96	111	Pump 2 ON
7AM-8AM	65	96	142	Pump 2 ON
8AM-9AM	70	96	168	Pump 2 ON
9AM-10AM	72	96	192	Pump 2 ON
10AM-11AM	79	0	113	No Pumping Req.
11AM-12PM	58	96	151	Pump 2 ON
12PM-1PM	60	96	187	Pump 2 ON
1PM-2PM	70	0	117	No Pumping Req.
2PM-3PM	59	96	154	Pump 2 ON
3PM-4PM	49	0	105	No Pumping Req.
4PM-5PM	44	96	157	Pump 2 ON
5PM-6PM	38	0	119	No Pumping Req.
6PM-7PM	31	96	184	Pump 2 ON
7PM-8PM	27	0	157	No Pumping Req.
8PM-9PM	26	0	131	No Pumping Req.
9PM-10PM	21	0	110	No Pumping Req.
10PM-11PM	20	0	90	No Pumping Req.
11PM-12AM	16	0	74	No Pumping Req.
12AM-1AM	15	0	59	No Pumping Req.
1AM-2AM	12	0	47	No Pumping Req.
2AM-3AM	11	0	36	No Pumping Req.
3AM-4AM	8	0	28	No Pumping Req.
4AM-5AM	7	0	21	No Pumping Req.
5AM-6AM	4	0	17	No Pumping Req.
Total	876			

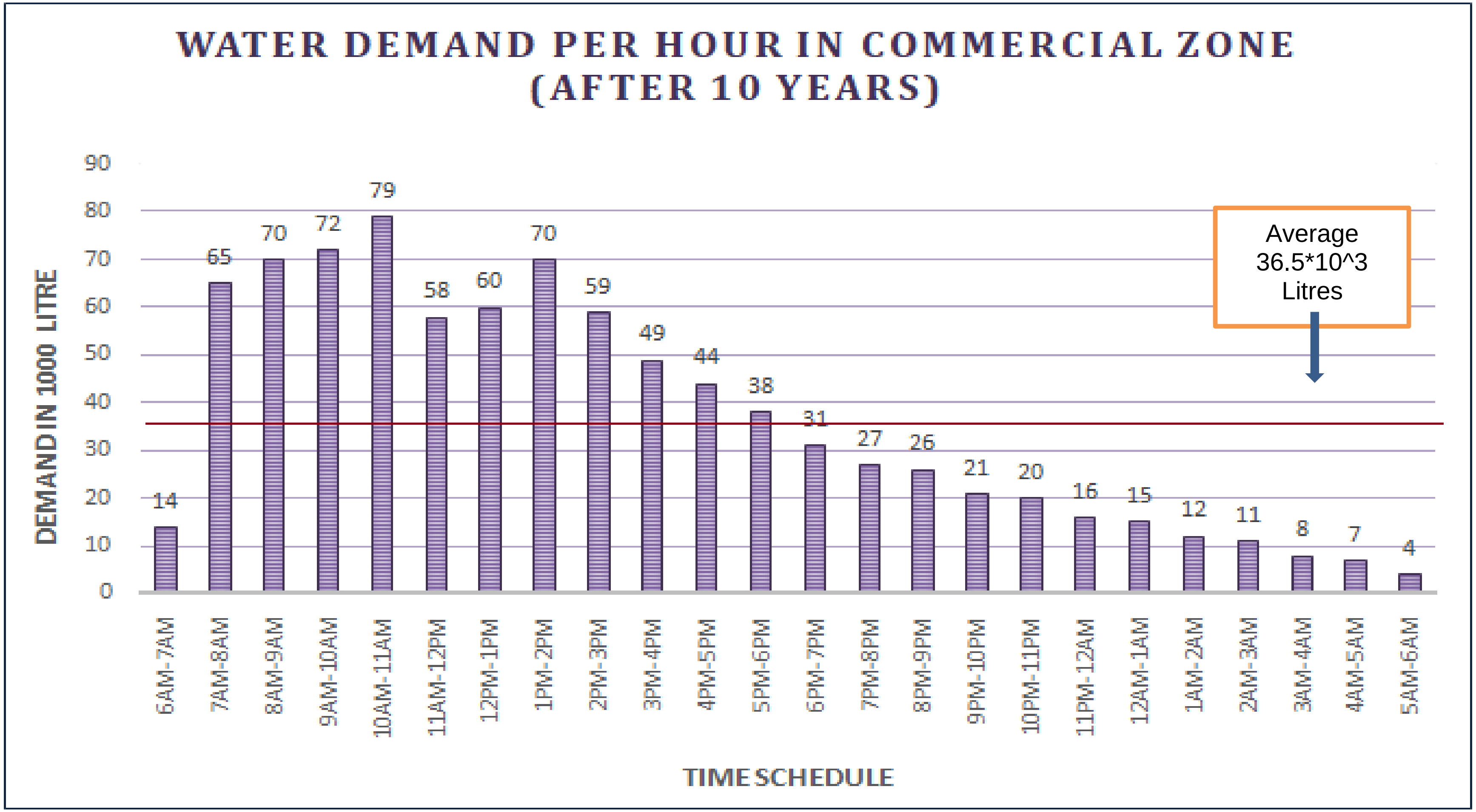


Figure 7. 9 Water demand per hour in commercial zone (after 10 years)

Table 7.8 Pumping schedule for demand after 20 years in Commercial Zone				
Time Schedule	Water Demand (in 1000 litre)	Total Supply (from pump 3) (in 1000 litre)	Storage (in 1000 litre)	Remarks
			31	No Pumping Req.
6AM-7AM	16	96	111	Pump 2 ON
7AM-8AM	75	96	132	Pump 2 ON
8AM-9AM	81	96	147	Pump 2 ON
9AM-10AM	83	96	160	Pump 2 ON
10AM-11AM	91	96	165	Pump 2 ON
11AM-12PM	67	96	194	Pump 2 ON
12PM-1PM	69	0	125	No Pumping Req.
1PM-2PM	80	96	141	Pump 2 ON
2PM-3PM	68	96	169	Pump 2 ON
3PM-4PM	56	0	113	No Pumping Req.
4PM-5PM	51	96	158	Pump 2 ON
5PM-6PM	44	0	114	No Pumping Req.
6PM-7PM	35	0	79	No Pumping Req.
7PM-8PM	31	96	144	Pump 2 ON
8PM-9PM	30	0	114	No Pumping Req.
9PM-10PM	25	0	89	No Pumping Req.
10PM-11PM	23	0	66	No Pumping Req.
11PM-12AM	19	0	47	No Pumping Req.
12AM-1AM	18	0	29	No Pumping Req.
1AM-2AM	13	96	112	Pump 2 ON
2AM-3AM	13	0	99	No Pumping Req.
3AM-4AM	9	0	90	No Pumping Req.
4AM-5AM	8	0	82	No Pumping Req.
5AM-6AM	4	0	78	No Pumping Req.
Total	1009			

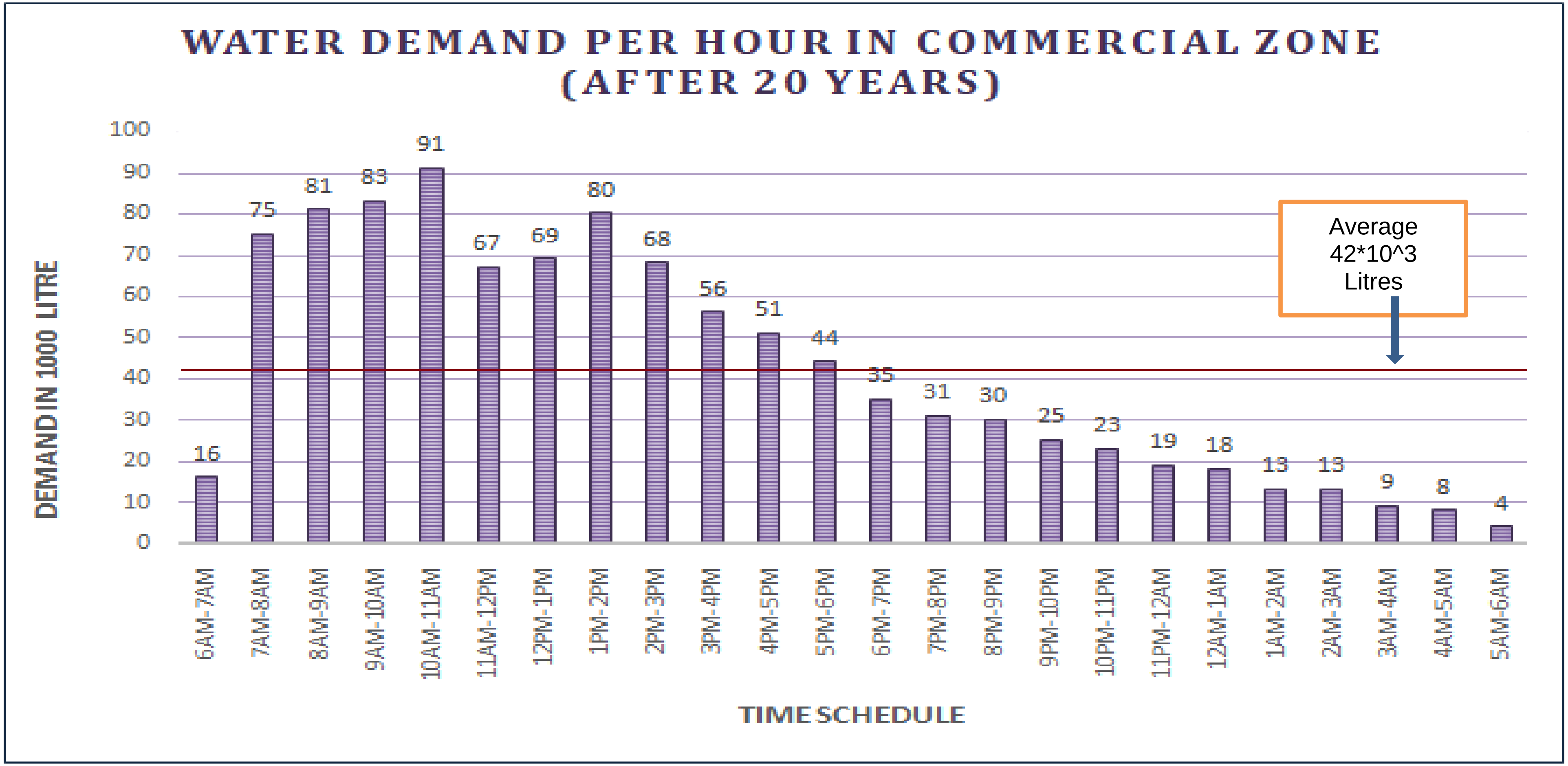


Figure 7. 10 Water demand per hour in commercial zone (after 20 years)

Table 7.9 Pumping schedule for present demand in Industrial Zone				
Time Schedule	Water Demand (in 1000 litre)	Total Supply (from pump 3) (in 1000 litre)	Storage (in 1000 litre)	Remarks
			28	No Pumping Req.
6AM-7AM	13	96	111	PUMP 3 ON
7AM-8AM	75	96	132	PUMP 3 ON
8AM-9AM	86	96	142	PUMP 3 ON
9AM-10AM	108	96	130	PUMP 3 ON
10AM-11AM	92	96	134	PUMP 3 ON
11AM-12PM	86	96	144	PUMP 3 ON
12PM-1PM	78	96	162	PUMP 3 ON
1PM-2PM	73	96	185	PUMP 3 ON
2PM-3PM	67	0	118	No Pumping Req.
3PM-4PM	11	0	107	No Pumping Req.
4PM-5PM	13	0	94	No Pumping Req.
5PM-6PM	62	0	32	No Pumping Req.
6PM-7PM	75	96	53	PUMP 3 ON
7PM-8PM	105	96	44	PUMP 3 ON
8PM-9PM	89	96	51	PUMP 3 ON
9PM-10PM	86	96	61	PUMP 3 ON
10PM-11PM	78	96	79	PUMP 3 ON
11PM-12AM	74	96	101	PUMP 3 ON
12AM-1AM	59	0	42	No Pumping Req.
1AM-2AM	7	0	35	No Pumping Req.
2AM-3AM	5	0	30	No Pumping Req.
3AM-4AM	4	0	26	No Pumping Req.
4AM-5AM	3	0	23	No Pumping Req.
5AM-6AM	4	0	19	No Pumping Req.
Total	1353			

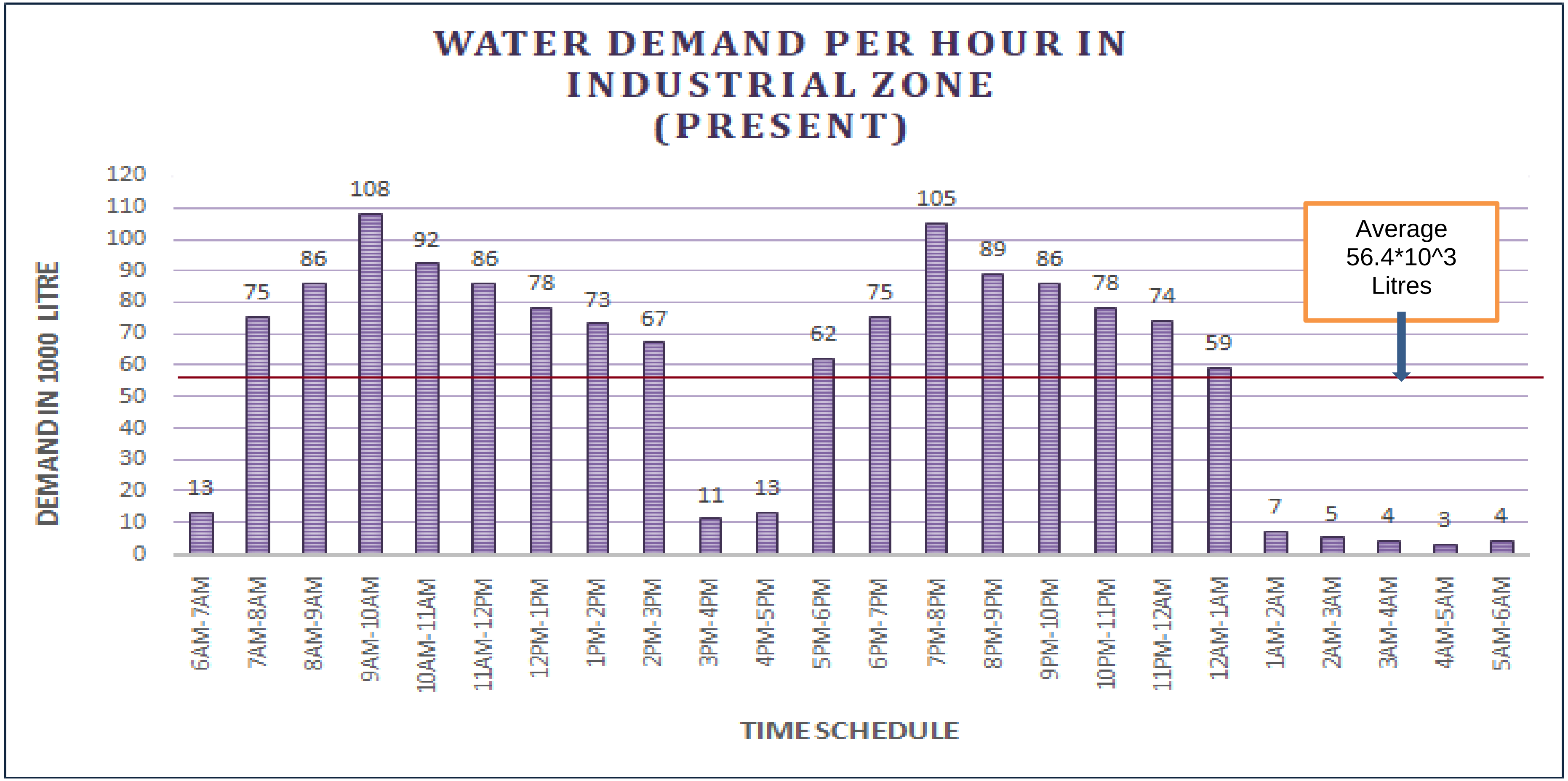


Figure 7. 11 Water demand per hour in industrial zone (present)

Table 7.10 Pumping schedule for demand after 10 years in Industrial Zone				
Time Schedule	Water Demand (in 1000 litre)	Total Supply (from pump 3) (in 1000 litre)	Storage (in 1000 litre)	Remarks
			31	No Pumping Req.
6AM-7AM	16	96	111	PUMP 3 ON
7AM-8AM	90	96	117	PUMP 3 ON
8AM-9AM	103	96	110	PUMP 3 ON
9AM-10AM	129	96	77	PUMP 3 ON
10AM-11AM	109	96	64	PUMP 3 ON
11AM-12PM	103	96	57	PUMP 3 ON
12PM-1PM	93	96	60	PUMP 3 ON
1PM-2PM	87	96	69	PUMP 3 ON
2PM-3PM	81	96	84	PUMP 3 ON
3PM-4PM	13	96	167	PUMP 3 ON
4PM-5PM	16	0	151	No Pumping Req.
5PM-6PM	74	0	77	No Pumping Req.
6PM-7PM	90	96	83	PUMP 3 ON
7PM-8PM	126	96	53	PUMP 3 ON
8PM-9PM	106	96	43	PUMP 3 ON
9PM-10PM	103	96	36	PUMP 3 ON
10PM-11PM	93	96	39	PUMP 3 ON
11PM-12AM	89	96	46	PUMP 3 ON
12AM-1AM	71	96	71	PUMP 3 ON
1AM-2AM	8	0	63	No Pumping Req.
2AM-3AM	6	0	57	No Pumping Req.
3AM-4AM	5	0	52	No Pumping Req.
4AM-5AM	4	0	48	No Pumping Req.
5AM-6AM	5	0	43	No Pumping Req.
Total	1620			

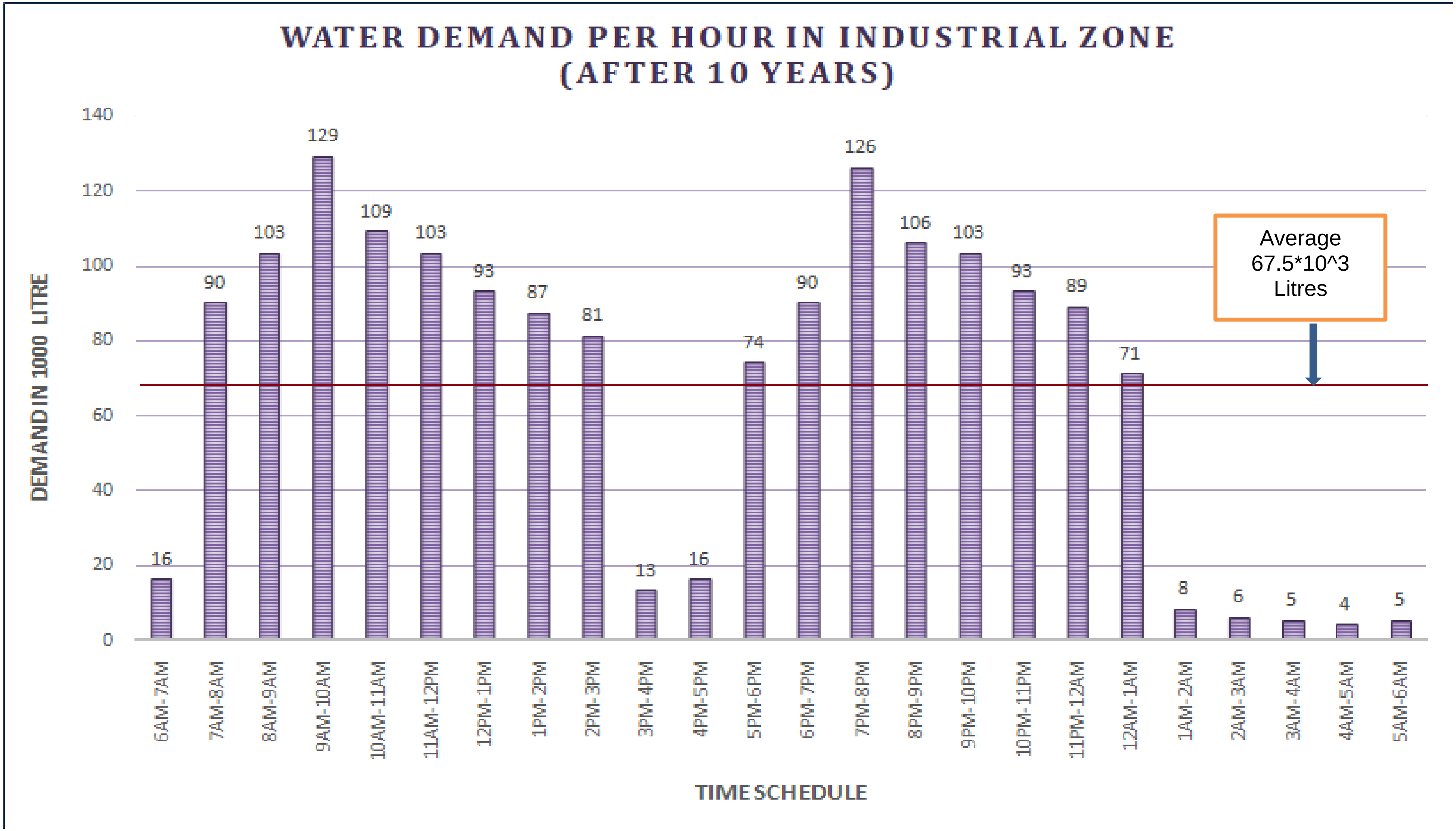


Figure 7. 12 Water demand per hour in industrial zone (after 10 years)

Table 7.11 Pumping schedule for demand after 20 years in Industrial Zone				
Time Schedule	Water Demand (in 1000 litre)	Total Supply (from pump 3 & 4) (in 1000 litre)	Storage (in 1000 litre)	Remarks
			34	No Pumping Req.
6AM-7AM	19	96	111	PUMP 3 ON
7AM-8AM	105	96	102	PUMP 3 ON
8AM-9AM	120	96	78	PUMP 3 ON
9AM-10AM	150	96	24	PUMP 3 ON
10AM-11AM	127	192	89	PUMP 3+ PUMP 4
11AM-12PM	120	192	161	PUMP 3+ PUMP 4
12PM-1PM	109	0	52	No Pumping Req.
1PM-2PM	101	96	47	PUMP 3 ON
2PM-3PM	94	96	49	PUMP 3 ON
3PM-4PM	15	0	34	No Pumping Req.
4PM-5PM	19	0	15	No Pumping Req.
5PM-6PM	86	96	25	PUMP 3 ON
6PM-7PM	105	96	16	PUMP 3 ON
7PM-8PM	146	192	62	PUMP 3+ PUMP 4
8PM-9PM	124	192	130	PUMP 3+ PUMP 4
9PM-10PM	120	96	106	PUMP 3 ON
10PM-11PM	109	96	93	PUMP 3 ON
11PM-12AM	103	96	86	PUMP 3 ON
12AM-1AM	82	96	100	PUMP 3 ON
1AM-2AM	9	0	91	No Pumping Req.
2AM-3AM	7	0	84	No Pumping Req.
3AM-4AM	6	0	78	No Pumping Req.
4AM-5AM	4	0	74	No Pumping Req.
5AM-6AM	5	0	69	No Pumping Req.
Total	1885			

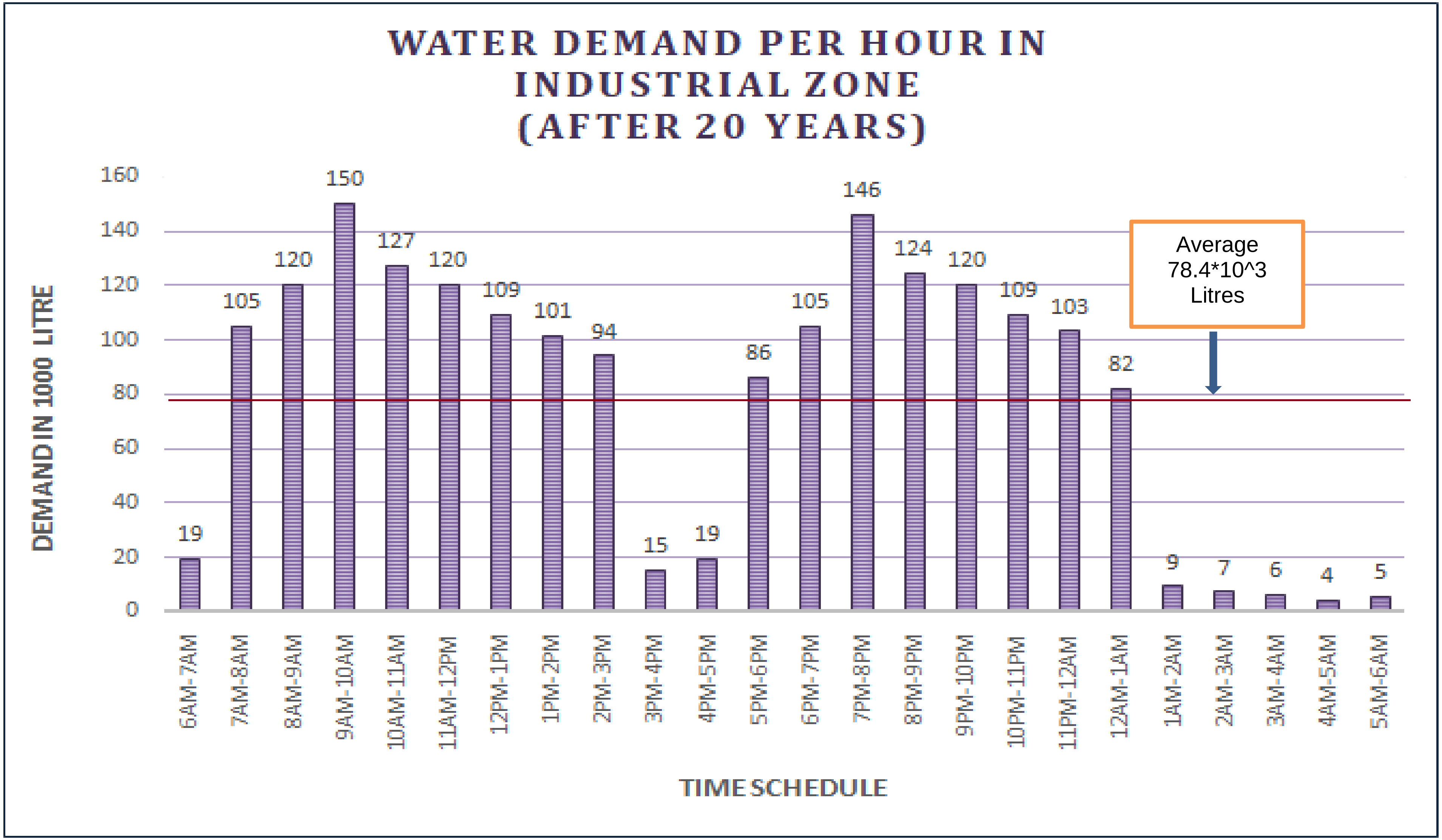


Figure 7. 13 Water demand per hour in industrial zone (after 20 years)

CHAPTER 8

WATER DISTRIBUTION NETWORK

Objective:

The main objective of Water Distribution Systemis to deliver water to consumer with appropriate quality, quantity and pressure. Distribution system is used to describe collectively the facilities used to supply water from its source to the point of usage. Another purpose of water distribution system is to supply water at convenient point and time and reasonable cost.

The transmission of water from the source (or sources) to the various consumers is usually done in two stages:

(1) Distribution :

This term is generally used to describe the system of bigger (or trunk) mains, reservoirs and, in some situations, pumping systems

(2) Reticulation:

Reticulation refers to the interconnected pipe network through which water finally reach to the consumers.

Requirements of Good Distribution System

- Water quality should not get deteriorated in the distribution pipes.
- It should be capable of supplying water at all the intended places with sufficient pressure head.
- It should be capable of supplying the requisite amount of water during fire fighting while maintaining acceptable pressures for normal service.
- The layout should be such that no consumer would be without water supply, during the repair of any section of the system.
- All the distribution pipes should be preferably laid one meter away or above the sewer lines.
- It should be fairly water-tight as to keep losses due to leakage to the minimum.

Pressure in the distribution system

Proper water line pressure ensures enough supply for customers and for firefighting, while protecting treated water from ingress of untreated groundwater. Minimum pressure for domestic flow during peak demand should be at least 30 psi. Fire hydrant should be operated at 40 psi, at least 10 psi at low pressure condition. Maximum 100 psi pressure is acceptable in small low-lying areas. Otherwise pressure reducing valve has to be used.

Layouts of Distribution Network

The distribution pipes are generally laid below the road pavements, and as such their layouts generally follow the layouts of roads. There are, in general, four different types of pipe networks; any one of which either singly or in combinations, can be used for a particular place.

1) Branched Network - Dead End System

2) Looped network –
a. Grid Iron System
b. Ring System
c. Radial System

Branched/ Dead-end System

It comprises a transmission main starting from service reservoir or source and laid along the main road with sub-mains branching off from the main along other roads joining the main road. It is suitable for old towns and cities having no definite pattern of roads.

Assumptions

- A transmission main serving residential and a part of common services zone was laid out along the main road.
- Quantity flowing in each section of the network was taken from the peak daily demand previously calculated.
- Proper water line pressure ensures enough supply for customers and for firefighting. Water distribution system was designed to maintain operating pressures within the system between 40 and 75 psi.
- Maximum 100 psi pressure is acceptable in small low-lying areas. Otherwise pressure reducing valve has to be used.
- Velocity (v) assumed here to be around 3 fps to calculate pipe size.

Steps for designing branched network

1. The areas of the zone 2 (residential and 55% of common services) and the branched networks provided in different residential and common services were shown in the layout.
2. Then the estimated peak flows at different points were found from the water demand calculation and then flow through each section of the network was found.
3. Pipe size for each section was found using the equation Q= Av. Velocity (v) was assumed to be 1m/s or 3 fps.
4. The frictional head loss was found by using the equation, Head loss, $h_f = 4fLv^2/2gD$, where, f = friction factor, L = Length of pipe v = velocity = 3 fps, g = acceleration of gravity = 32.2 fps^2 D = Diameter provided So, pressure loss in psi = h_f (ft) x 62.4 (lb/ft^3) /144
5. Then pressure requirement at the furthest point from the source was checked. Then the terminal pressure head taking the change in the elevation of the pipe into account was determined.
6. In case of a difference between the calculated terminal pressure and the permissible pressure.

Sample Calculation

Sample Calculation of Pipe Section 6-5 (Mainly 3rd class Residents)
From (**Table**: **Residential Water Demand Calculation**), we can find the water to be supplied to the corresponding path 6-5 are,

Peak Demand after 20 years for 3rd class residents (apartment) = 390000 lpd
Peak Demand after 20 years for 3rd class residents (dormitories) = 33950 lpd

So, along the path **6-5** water to be supplied will be the summation of the above two numerical values.

Water Supply along Path 6-5 = 390000 + 33950 lpd = 423950 lpd

Determination of Pipe Diameter
Supply: 0.17 cusec
Length: 120.33 ft
Area of the pipe: Q = AV,
Where, Q = Supply (cusec)
A = area of the pipe
V = Velocity = 3 fps
A = Q/V = (.17/3)*144 = 0.06 sq. ft
A = pi*D^2/4
D_{req}= 0.27 ft = 3.24 in
$D_{provided}$ = 4 in
Calculation for Frictional head loss For Path 2-6-5
Head loss, h_f = 4fLv_2/2gD,
Where, f = friction factor,
L = Length of pipe
v = velocity = 3 fps,
g = acceleration of gravity = 32.2 fps_2
D = Diameter provided
For 6-5,
h_f = 2.04 ft,

=>Head loss in psi = 2.04* 62.4/144 = 0.88 psi

For 2-6,

h_f = 1.98 ft,

=>Head loss in psi = 1.98* 62.4/144 = 0.86 psi

Total head loss in this path = 0.88 + 0.86 psi = 1.74 psi

Height from tank = 80 ft = 24.38 m

Available pressure from tank = h*rho*g = 24.38 *1000* 10 = 243840 Pa = 35 psi

Available pressure = (35-1.74) psi = 33.26 psi > 30 psi

So, OK.

Table 8.1 Diameter of pipes for supply of water to residential zone and common services

Node	Peak demand (LPD)	Length (ft)	Peak Demand (cusec)	Area (sq ft)	Dia (required), ft	Dia (required), inch	Dia (provided), inch	Dia (provided), ft	Head Loss, hf (ft)	Head Loss, hf (psi)
2,3 (submain)	1025427	138.5	0.42	0.14	0.42	5.04	6	0.5	1.55	0.67
3,4	163925	54	0.07	0.02	0.17	2.04	3	0.25	1.21	0.52
3,10	861502	138.5	0.35	0.12	0.39	4.68	5	0.42	1.84	0.8
10,11	395616	336.17	0.16	0.05	0.26	3.12	4	0.33	5.69	2.47
10,13	465886	156.92	0.19	0.06	0.28	3.36	4	0.33	2.66	1.15
13,12	155325	70	0.06	0.02	0.16	1.92	2	0.17	2.3	1
13,14	310561	225.59	0.13	0.04	0.23	2.76	3	0.25	5.04	2.18
2,6 (submain)	3163303	265.63	1.3	0.43	0.74	8.88	9	0.75	1.98	0.86
6,5	423950	120.33	0.17	0.06	0.27	3.24	4	0.33	2.04	0.88
6,7	2739353	307.63	1.12	0.37	0.69	8.28	9	0.75	2.29	0.99
7,8	2341440	346.17	0.96	0.32	0.64	7.68	8	0.67	2.89	1.25
7,9	397913	280.17	0.16	0.05	0.26	3.12	4	0.33	4.75	2.06

Table 8.2 Check for available pressure

Path	Node	Length (ft)	hf (psi)	Total Loss (psi)	Available Pressure (psi)	Comment
1	2,3	138.5	0.67	1.19	33.81	OK
	3,4	54	0.52			
2	2,3	138.5	0.67	3.94	31.06	OK
	3,10	138.5	0.8			
	10,11	336.17	2.47			
3	2,3	138.5	0.67	3.62	31.38	OK
	3,10	138.5	0.8			
	10,13	156.92	1.15			
	13,12	70	1			
4	2,3	138.5	0.67	4.8	30.2	OK
	3,10	138.5	0.8			
	10,13	156.92	1.15			
	13,14	225.59	2.18			
5	2,6	265.63	0.86	1.74	33.26	OK
	6,5	120.33	0.88			
6	2,6	265.63	0.86	3.1	31.9	OK
	6,7	307.63	0.99			
	7,8	346.17	1.25			
7	2,6	265.63	0.86	3.91	31.09	OK
	6,7	307.63	0.99			
	7,9	280.17	2.06			

Branch Network

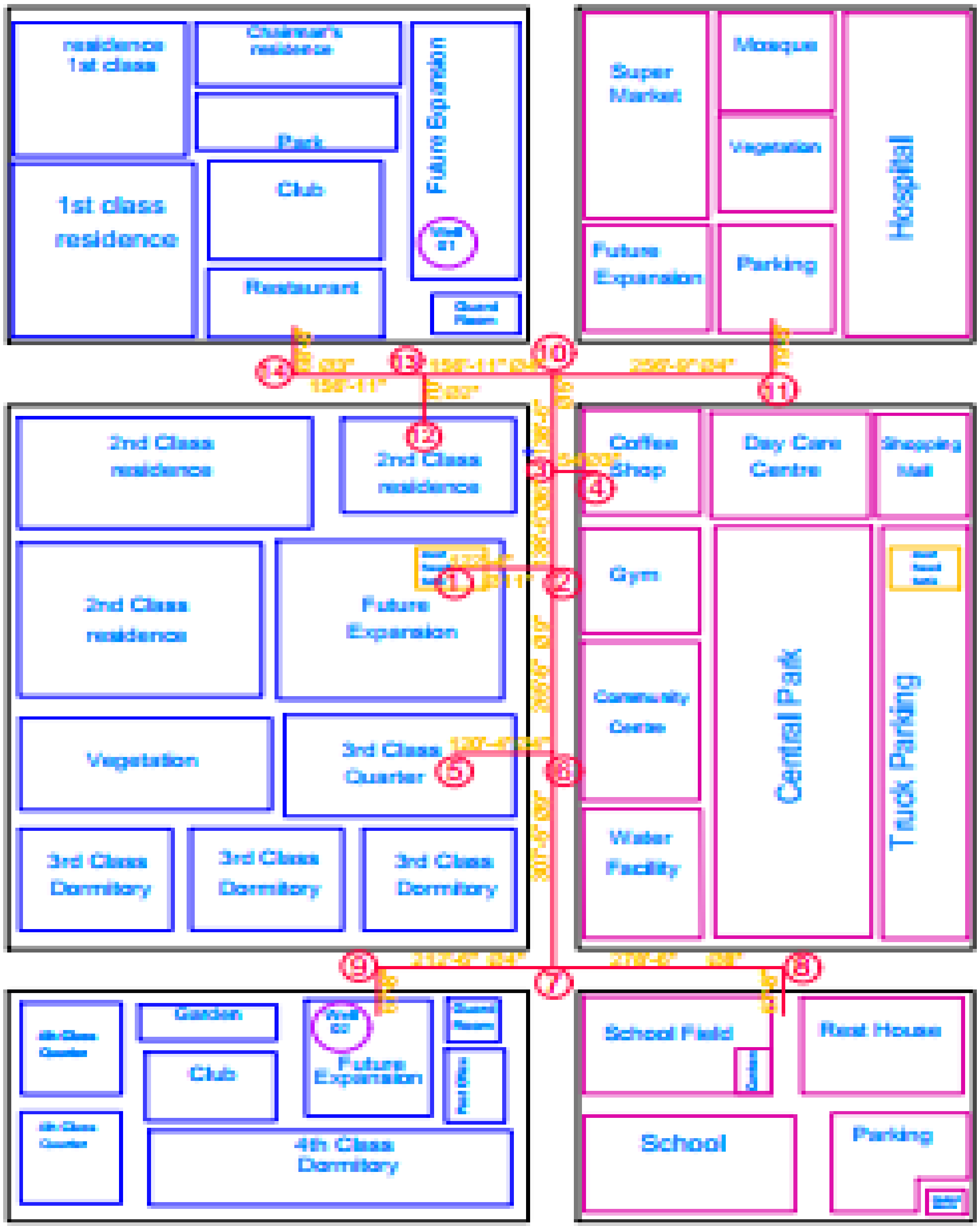


Figure 8. 1 Branch Network

Looped Network

Looped distribution network is an improvement over the dead-end system. Here the ends of mains and sub-mains are connected. This network is suitable for a well-planned developed area with a definite pattern of road network.

Assumptions

- A loop network is used for whole industrial unit.
- Grid-Iron system was used for supplying water in loop.
- In the looped network following conditions were satisfied:
  1. Flow entering into a junction must equal the flow leaving it.
  2. Algebraic sum of head loss in a closed loop will be zero.
- Hardy Cross method of approximation was used to calculate flow of water in each pipe section.
- For the calculation of head loss, we have used HAZEN WILLIAMS EQUATION.

Hardy Cross Method Approximations

In any looped network following two conditions must be satisfied:

1. Flow entering into a junction must equal the flow leaving it.
2. Algebraic sum of head loss in a closed loop will be zero.

The Hazen-William equation for hardy cross method is $H = kQ^x$

Where,

H = Head loss

k = is a constant depending on length, diameter and roughness of the pipe as well as fluid property. Here, we are assuming k = 1

Q = Assumed flow in the pipe

X = 1.85 for Hazen-Williams equation

Steps for designing looped network

1. Reasonable rates of flow were assumed in each pipe of the network such that inflow equals outflow at each junction.
2. In each loop the head loss, H and the H/Q ratio were found for all pipes.
3. With due attention to sign, $\sum H$ was found around each circuit.
4. For the same circuit, $\sum H/Q$ was found without considering sign.
5. Correction Δ was applied to each loop where $\Delta = -\sum H / x \sum (H/Q)$.
6. When the sign of Δ is negative, we decreased the clockwise flow and increased the counter clockwise flow. When the sign is positive '+' increase clockwise flows and decrease counterclockwise flows. Pipes that are common to two loops require double correction.
7. With adjusted flow the process was repeated for second approximation.
8. After the flow is corrected for each loop, pipe size was determined using head loss determination diagram (**Figure:**).

Sample Calculation

Calculation for Pipe 1-2 and Common Pipe 2-4:

Determination of In and Out Flow for the Total network:

At out-flow node 2, the total outflow consists of water supply from the contribution area of Fire service, Power station, Packaging, Chrome tanning, 2nd Vegetative tanning, Soaking and Curing zone.

For Fire service, Water Supply = 9072 lpd

For Power station, Water Supply = 346 lpd

For Packaging, Chrome tanning, 2nd Vegetative tanning, Soaking and Curing zone , Water Supply

= 1280742 lpd
Total Water Out-Flow at Node 2 = 1290160 lpd
= 53757 lph = 14.9 lps
Similarly, Out-Flow at Node 3, 4, 5 are 6.4, 0.6, 0.7 lps
Now The In-Flow at Node 1 is the summation of out-flow at this 4 node.
In-Flow at Node 1 = 14.9+6.4+0.6+0.7 = 22.5 lps
The following Table shows the overall information of in-out flow at each node
is presented below:

Table 8.3 Determination of Inflow and Outflow at Each Nodes

Nodes	**Distributed Area**	**Water Supply at Distributed Area**	**Water Inflow Outflow at Each Node**		
		Lpd	**lpd**	**lph**	**lps**
2	Fire Service	9072	1290160	53757	14.9
	Power Station	346			
	Packaging	1280742			
	Chrome Tanning				
	Vegetative Tanning (2)				
	Soaking				
	Curing				
	Semi Chrome Tanning				
	Finishing				
3	ETP	1229	550119	22921.6	6.4
	Pickling	548890			
	Delimming and Bating				
	Vegetative Tanning (1)				
	Unhairing and Limming				
5	Admin Building	40446	48740	2030.83	0.6
	Information Center				
	Guard Room				
	Park	8294			
4	Café	36000	57600	2400	0.7
	Bank	21600			
1	Total In-flow		1946619	81109	22.5

The Inflow-Outflow at each node is represented in the following figure showed as:

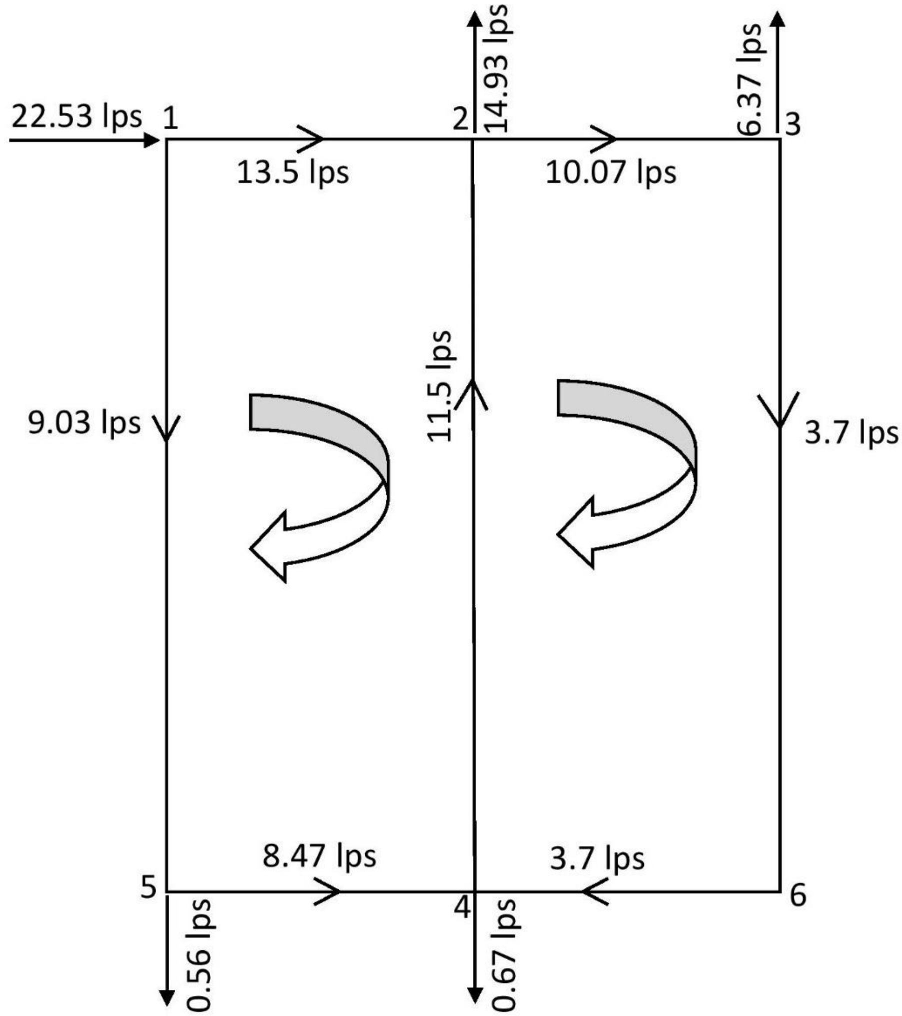


Figure 8. 2 Inflow and Outflow at different Nodes

Figure: Inflow and Outflow at different Nodes

After determining each flow at every node, flow has been assigned in every path randomly and trial has been done.

Trial 1:

Pipe 1-2:
Pipe Length 194 m

K = 1
Flow, Q_0 = 13.5 lps = 0.0135 m^3/s

Head loss for pipe 1-2, $H_0 = kQ^x$

Here, K= is a constant depending on length, diameter and roughness of the pipe as well as fluid property.

Q= Assumed Flow in the pipe
x= 1.85 for Hazen-Williams Equation

Here, we are assuming k=1 and so H_0= $1*(0.0135)^{1.85}$ m = 0.0003 m
Absolute H_0 = 0.0003 m
Ratio of H_0/Q_0 for pipe 1-2 = 0.0258

Pipe 2-4:

Length =376.3 m

Assumed Q_0 = -11.50 lps. (As flow of direction is anti-clockwise)
= -0.0115 m^3/s

Head loss for Pipe 2-4 = $-1 *(0.0115)^{1.85}$= -0.0003 m
H_0/Q_0 = 0.0225

As this pipe is common, we have to consider both the loops.

Similarly, Values of H_0 for Pipe 4-5 and 5-1 were found
Now, Summation of H_0 = -0.0002 m

Similarly, values for H_0/Q_0 for pipe 4-5, 5-1 were found.
Now summation of H0/Q0 = 0.0838

Now, for loop 1, $\Delta_1 = - \sum H_0/x \sum (H_0/Q_0)$ = 0.00144 m^3/s

When the sign is positive '+' increases clockwise flows and decrease counterclockwise flows.

So now Corrected flow for Pipe 1-2=0.0135 + 0.00144 = 0.01494 m^3/s

Corrected flows for other Pipe path is calculated as similar and shown in the table attached (Table)

For Loop 2:
Flow for Pipe 2-3, Q_0 = 10.07 lps = 0.01 m^3/s
Head Loss for Pipe 2-3, H_0 = 0.0002 m

Similarly, Values of H_0 for Pipe 3-6, 6-4 and 4-2 were found
Now, Summation of H_0 = 0.00052 m

Ratio of H_0/Q_0 for pipe 2-3 = 0.0201
Similarly, values for H_0/Q_0 for pipe 3-6, 6-4, 4-2 were found.
Now summation of H_0/Q_0 = 0.1

Now, for loop 2, $\Delta_2 = - \sum H_0/x \sum (H_0/Q_0)$ = -0.0047 m^3/s
So, For Pipe 2-3 corrected Q in loop 2 = $Q_0 - \Delta_2$
= 0.01-0.0047 = 0.0053 m^3/s
= 5.3 lps

For Pipe 4-2 corrected Q in loop 2 = $Q_0 + \Delta_2 - \Delta_1$ = 0.0115-0.0047-0.00144 = 0.0053 m^3/s
= 5.3 lps

Final Corrected flows for other pipe path is shown in the table attached (**Table**)
Trial 2: Same procedure was repeated. As the correction Δ value was found to be close to zero (shown in table), it can be said that desired accuracy was attained after Trial 2.

Figure : Final Flow in Every pipe

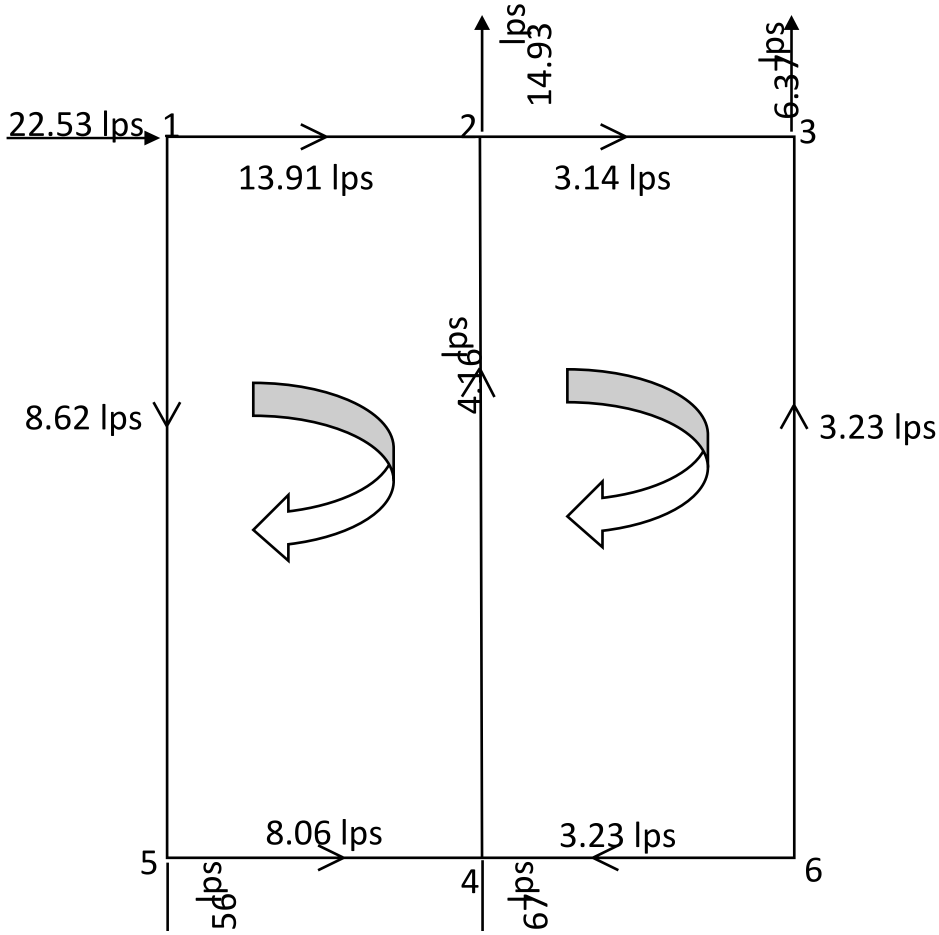


Figure 8. 3 Final Flow in Every pipe

Diameter or Size Selection:
After we got the corrected Q_0 we determined pipe diameter from head loss determination diagram and obtained value from graph was multiplied by 1.2 as the roughness coefficient value is equal to 120 for this graph.

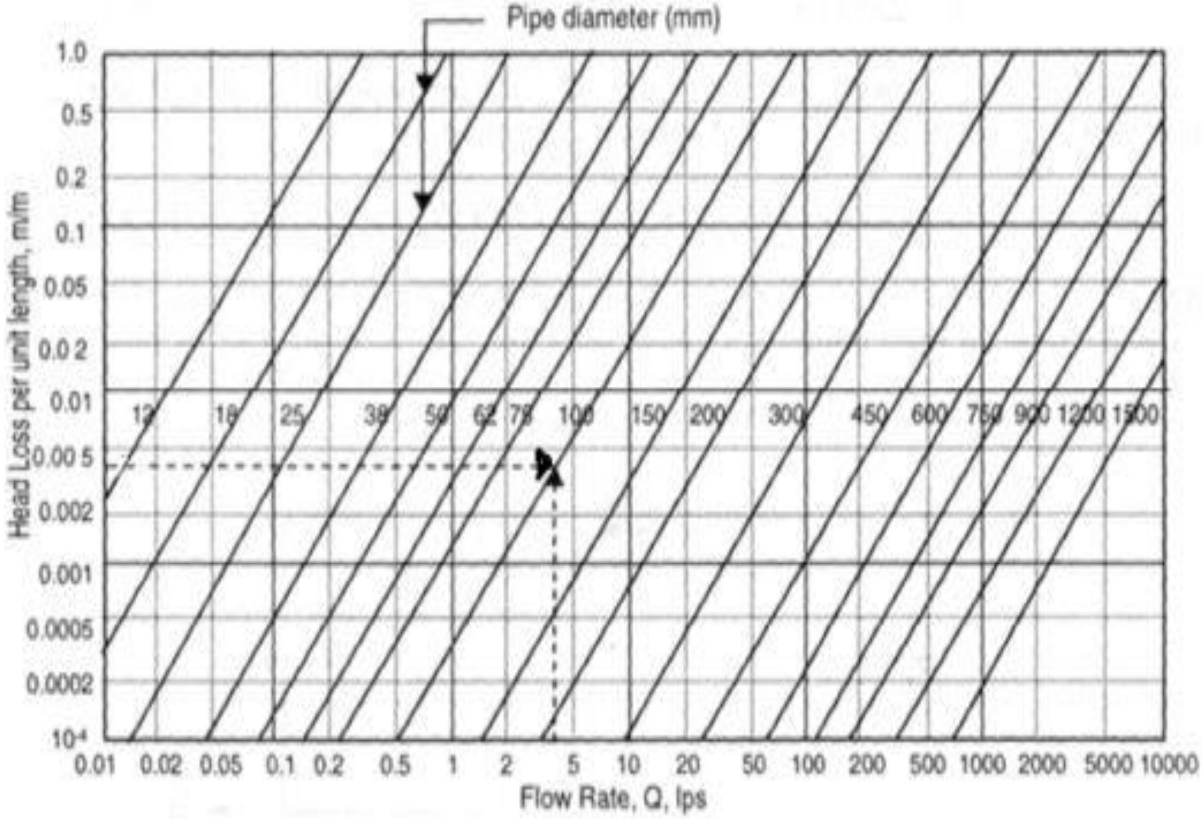


Figure 7.6: Head Loss Determination Curve (For Roughness Coefficient C = 120)

Figure 8. 4 Head Loss determination Curve (for roughness coefficient C=120)

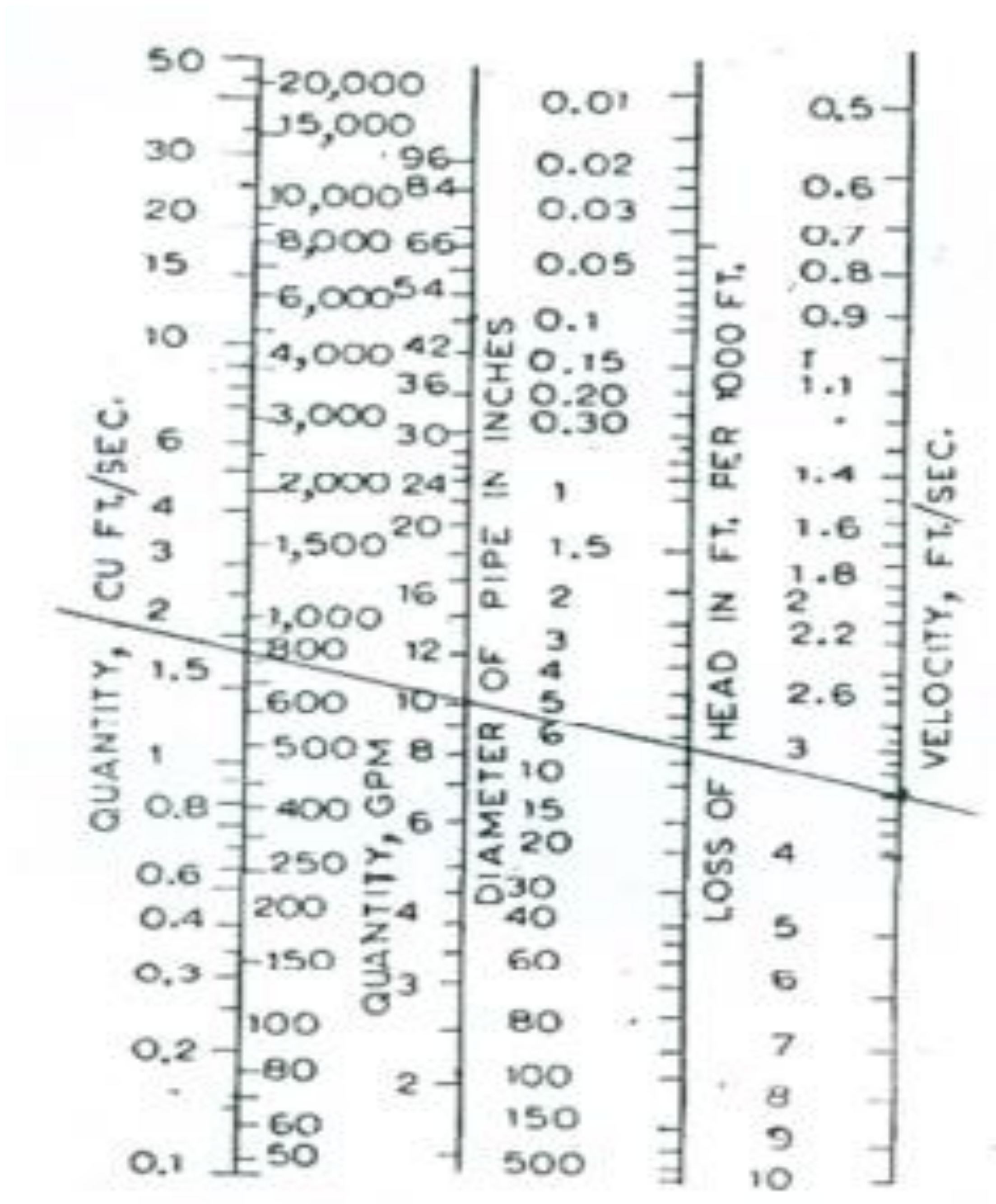


Figure 8. 5 Nomograph for Hazen-William Equation (For C = 100)

Figure: Nomograph for Hazen-William Equation (For C = 100)

Table 8.4 Loop network design (trial 1)

Trial 1	Pie	length (ft)	lengt h (m)	k	Qo (lps)	Qo (m^3/s)	Ho (m)	Ho/L(m/m)	Ho/Qo	Δ	Corrected Qo (m^3/s)	Correcte d Qo (lps)
Loop 1	1_2	636.33	194.0	1	13.50	0.0135	0.0003	0.0000018	0.0258	0.001	0.0149	14.93596
	2_4	1234.5	376.3	1	-11.50	-0.0115	-0.0003	-0.0000007	0.0225	0.006	-0.0053	-5.31864
	4_5	636.33	194.0	1	-8.47	-0.0085	-0.0001	-0.0000008	0.0173	0.001	-0.0070	-7.03404
	5_1	1234.5	376.3	1	-9.03	-0.0090	-0.0002	-0.0000004	0.0183	0.001	-0.0076	-7.59404
Sum							-0.0002		0.0838			

Trial 1	Pipe	length (ft)	lengt h (m)	k	Qo (lps)	Qo (m^3/s)	Ho (m)	Ho/L(m/m)	H0/Qo	Δ	Correcte d Qo (lps)	Corrected Qo (lps)
Loop 2	2_3	641.2 5	195.5	1	10.07	0.0101	0.00020	0.0000010	0.020 1	-0.005	0.0053	5.324600 8
	3_6	1234. 5	376.3	1	3.70	0.0037	0.00003	0.0000001	0.008 6	-0.005	-0.0010	-1.045399
	6_4	641.2 5	195.5	1	3.70	0.0037	0.00003	0.0000002	0.008 6	-0.005	-0.0010	-1.045399
	4_2	1234. 5	376.3	1	11.50	0.0115	0.00026	0.0000007	0.022 5	-0.006	0.0053	5.318642 6
	Sum						0.00052		0.059 7			

Table 8.5 Loop network design (trial 2)

Trial 2	Pipe	length (ft)	length (m)	k	Q_o **(lps)**	Qo (m^3/s)	Ho (m)	Ho/L(m/m)	H0/Qo(m/(m3/s))	Δ (m3/s)	Corrected Q_o **(m^3/s)**	Corrected Q_o **(lps)**
Loop 1	1_2	636.33	194.0	1	14.94	0.0149	0.0004	0.0000022	0.0281	-0.001	0.0139	13.9129
	2_4	1234.5	376.3	1	-5.32	-0.0053	-0.0001	-0.0000002	0.0117	0.001	-0.0042	-4.15514
	4_5	636.33	194.0	1	-7.03	-0.0070	-0.0001	-0.0000005	0.0148	-0.001	-0.0081	-8.0571
	5_1	1234.5	376.3	1	-7.59	-0.0076	-0.0001	-0.0000003	0.0158	-0.001	-0.0086	-8.6171
Sum							0.0001		0.0703			

Trial 2	Pipe	length (ft)	length (m)	k	Qo (lps)	Qo (m^3/s)	Ho (m)	Ho/L(m/m)	H0/Qo	Δ	Corrected Qo (m^3/s)	Corrected Qo (lps)
Loop 2	2_3	641.25	195.5	1	5.32	0.0053	0.000062	0.00000032	0.0117	-0.002	0.0031	3.1380401
	3_6	1234.5	376.3	1	-1.05	-0.0010	-0.000003	-0.00000001	0.0029	-0.002	-0.0032	-3.23196
	6_4	641.25	195.5	1	-1.05	-0.0010	-0.000003	-0.00000002	0.0029	-0.002	-0.0032	-3.23196
	4_2	1234.5	376.3	1	5.32	0.0053	0.000062	0.00000016	0.0117	-0.001	0.0042	4.1551396
	Sum						0.000118		0.0292			

Table 8.6 Diameter calculation for loop network

	Pipe	length (ft)	length (m)	Corrected Q_o **(lps)**	Diameter(mm),C=120
Loop 1	1_2	636.33	194.0	13.91	900
	2_4	1234.5	376.3	-4.16	900
	4_5	636.33	194.0	-8.06	900
	5_1	1234.5	376.3	-8.62	900

	Pipe	length (ft)	length (m)	Corrected Qo (lps)	Diameter(mm),C=120
Loop 2	2_3	641.25	195.5	3.14	750
	3_6	1234.5	376.3	-3.23	1500
	6_4	641.25	195.5	-3.23	1200
	4_2	1234.5	376.3	4.16	900

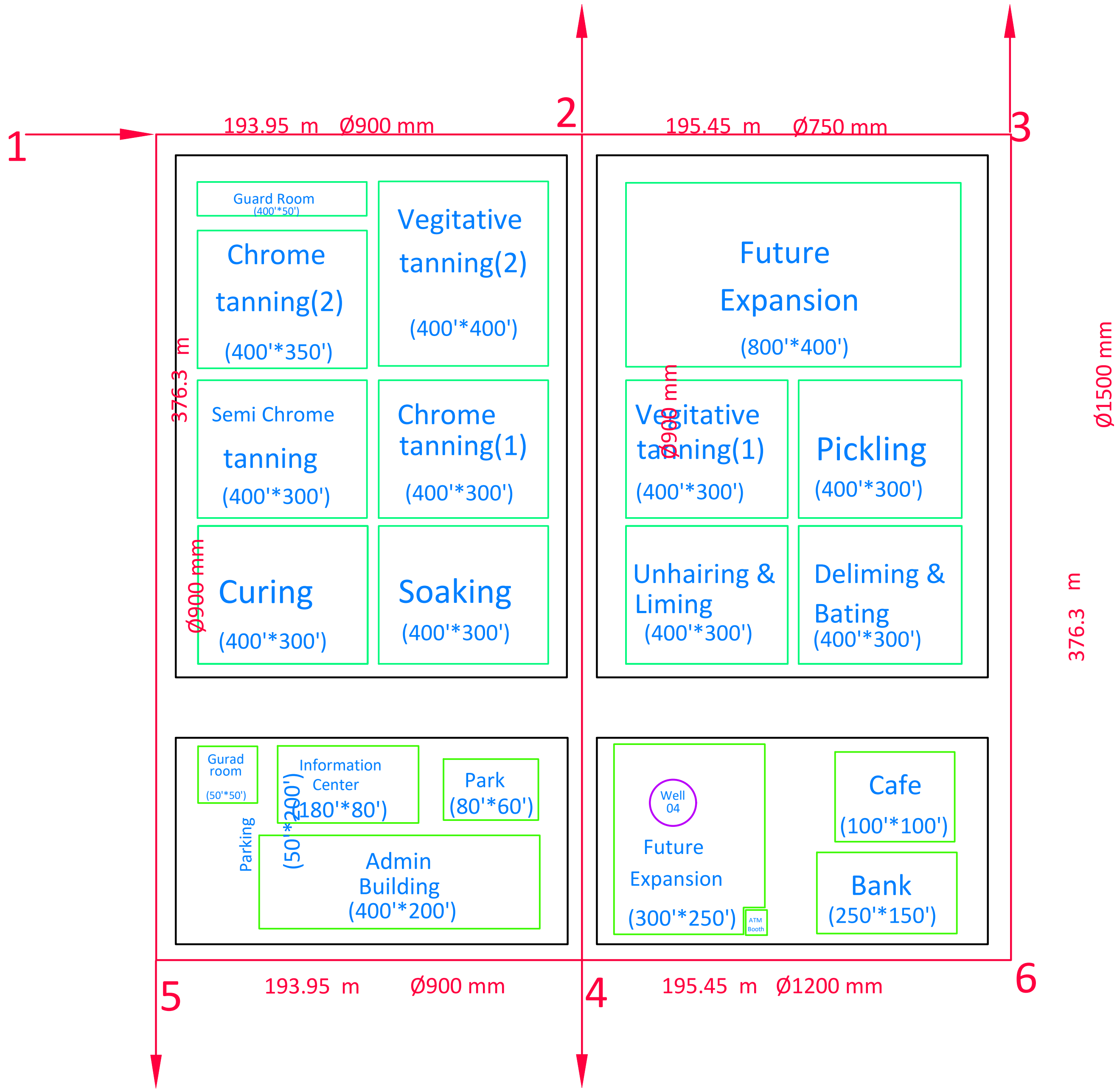


Figure 8. 6 Loop Network

CHAPTER 9

DESIGN OF SEWER SYSTEM

Objective

Sewer system plays a vital role in the economic development. Sewers are must for the drainage of waste water. In order to have an effective sewage system the sewers should be properly designed and more care should be taken in finding the invert levels otherwise whole design may get wrong. Sewers are designed for the drainage of waste water coming from houses, industries, streets, runoff etc. to protect the environment and people from serious diseases, as more than 50 diseases spread from sewage. So for a good living, the sewers should be properly designed and the sewage should be treated properly before discharging it into the river. An optimal design of sewer system is one which minimizes the total cost that includes the cost of pipes, cost of manholes, and cost of laying and jointing of pipes, which should meet certain specification in relation to discharge, velocity etc., and any other alternative design for the same hydraulic conditions. The smallest feasible diameter and the minimum slope, so as to lay the pipe as close as possible to the surface are considered as optimal. Hence, a life cycle cost analysis of the pipes of different pipe materials and diameter is to be performed for selecting appropriate pipe material and an optimal design for a sewer network.

The basic functional elements of a conventional sewerage system include-

a) House connections- collect wastewater from houses
b) Network of sewer systems- for collection and conveying the wastewater
c) Treatment plant- for processing the wastewater, and
d) Receiving environment (water or land) for disposal of the treated wastewater.

Classification

e) Depending on the type of sewage carried by the conveyance system, sewage collection can be categorized into three types-

1. **Separate Sewer System:** Sanitary sewage and storm waste are collected and conveyed separately through two different systems. Storm water can be discharged without treatment; only sanitary sewage is treated but very costly option.
2. **Combined Sewer System:** Both sanitary sewage and storm water are collected and carried together through a single set of sewers. Economical, large size makes it easy to clean but however increases waste load in treatment plant, difficulties in maintaining minimum flow during dry season.

3. **Partially Combined or Partially Separate System:** Only one set of sewers is laid to carry sanitary sewage as well as storm water during low rainfall. During heavy rainfall excess storm water is carried separately e.g., through open drains to natural channels.

Again, based on hydraulic characteristics and purpose, sanitary wastewater collection systems further categorized as – gravity, pressure and vacuum system. Gravity system is most common where wastewater is transported by gravity.

In a conventional sewerage system wastewater from house connections are conveyed to lateral or branch sewers. Main sewers are used to convey sewage from one or more lateral sewers to trunk sewers or to interceptor sewers.

Trunk Sewers

Trunk sewers are large sewers that are used to convey wastewater from main sewers to treatment or other disposal facilities, or to large intercepting sewers. In our project we will mainly design the trunk sewer.

Components of Wastewater of Industrial Village

1. Domestic (Sanitary) wastewater
2. Industrial wastewater
3. Infiltration
4. Storm water (Excluded in this project)

Conveyance capacity allowance must be made for groundwater infiltration and unavoidable inflows. Estimation of "design flow" is important because it ultimately determines the sizes of the sewers to be provided.

Basic Design Considerations:

Hydraulic Design Equation

The Manning equation is commonly used for sewer design. Roughness co-efficient "n"in Manning's equation should not be less than 0.013 for new sewers made of PVC, Vitrified clay or concrete.

- Pipe sections should not be less than 5 feet long
- For new constructions assume first class construction with true and smooth inside surfaces.

Pipe Sizes

- Consider minimum pipe size 8 inches (200mm). However, if wastewater volume is low pipe size at least 6 inch is allowed.
- Smallest sewers should be larger than the building sewer connections in general use in the area • Most common size of building connection is 6 inches but connections of 5 and 4 inches have been used successfully in some areas

Flow Velocities

During design two critical velocities are considered – i) Self cleansing velocity –

- It is the minimum velocity required to be attained at least once in a day to prevent solid deposition along sewer.
- Minimum allowable velocity is 2 ft/sec (0.6 m/sec) at one-half full or full depth. If access for cleaning is difficult, the minimum velocity should be 3 ft/sec (1 m/sec).

ii) Non-scouring velocity

- It is the maximum limit of velocity to prevent scouring/ damage to sewer wall by solids in wastewater.
- Its value depends on the
- Maximum allowable velocity:

- 2.5-3.0 m/sec for concrete sewer
- 3.0-3.5 m/sec for vitrified sewer
- 2.0-2.5 m/sec for brick sewer
- 3.5-4.0 m/sec for cast iron sewer

Sewer Pipe Slopes

The following table shows the minimum gravity sewer pipe slopes based on manning's equation with a minimum velocity of 0.6 m/s. Where practicable steeper slopes should be used.

Table 9.1: Gravity Sewer Minimum Pipe Slopes

Size in inch (mm)	Slope m/m
	n = .0.013
8 (200)	0.0033
10 (250)	0.0025
12 (300)	0.0019
15 (375)	0.0014
18 (450)	0.0011
21 (525)	0.0009
24 (600)	0.0008
27 (675)	0.0007
30 (750)	0.0006
36 (900)	0.0004

Manholes

The number of manholes must be adequately spaced so that the sewers can be easily inspected and maintained.

Manhole Size and

Spacing Size:

- Manholes in small sewers are usually about 4 feet in diameter when the sewers have circular cross sections
- In large sewers, larger manholes may be required to accommodate larger cleaning devices

Spacing:

- Sewers < 24 in (600mm) - Place manholes at intervals not greater than 350 ft (100m).
- Sewers 27 – 48 in (700-1200mm) - Place manholes at intervals not greater than 400 ft (120m). • Sewers > 48 in (1200 mm) - Manholes may be placed at greater intervals depending on local conditions like breaks in grade, location of street intersections, etc.

In addition place manholes –

- Abrupt changes in horizontal direction or slope
- Pipe size change locations

Pipe Diameter Determine

Manning's equation,
Pipe Diameter, D (m) = 1.548 [nQ/ √S]^0.375

Here,

Q = Cumulative Flow (m^3/s) n = Manning roughness

coefficient (an empirical, dimensionless constant)

S = pipe slope, m/m or dimensionless

Average Wastewater Flows:

Category	% of avg. water demand
Industrial	90
Residential	70
Institutional	70
Commercial	70

Peak wastewater flows

Components of waste water flow include:

1. Peak flows from residential, institutional and commercial zone
2. Peak discharge of industrial waste water
3. Peak infiltration allowance (use fig-5)

Peak factors for industrial, institutional and commercial wastewater is given in table:

Peak Factors for Different Facilities	
Category	**Peak Factor**
Industrial	2.1
Institutional	3.1
Commercial	1.8

Peak factor for residential wastewater:

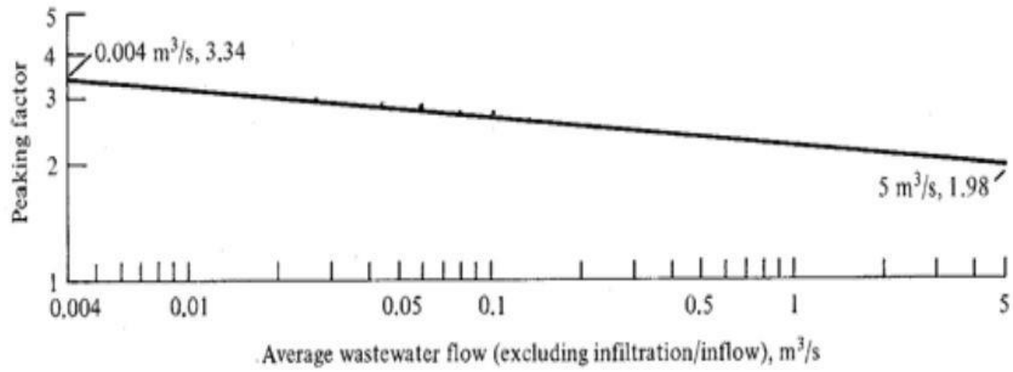


Figure 8. 7 Peaking Factor for Residential Wastewater Flows

Figure 8.7: Peaking Factor for Residential Wastewater Flows

Infiltration to Sanitary Sewer Systems

Groundwater/percolating water in the subsurface entering a sewer system through-defective pipes, leaking pipe joints, cracked manhole walls etc.

Calculation/ estimation of infiltration for new construction can be obtained using the following figure:

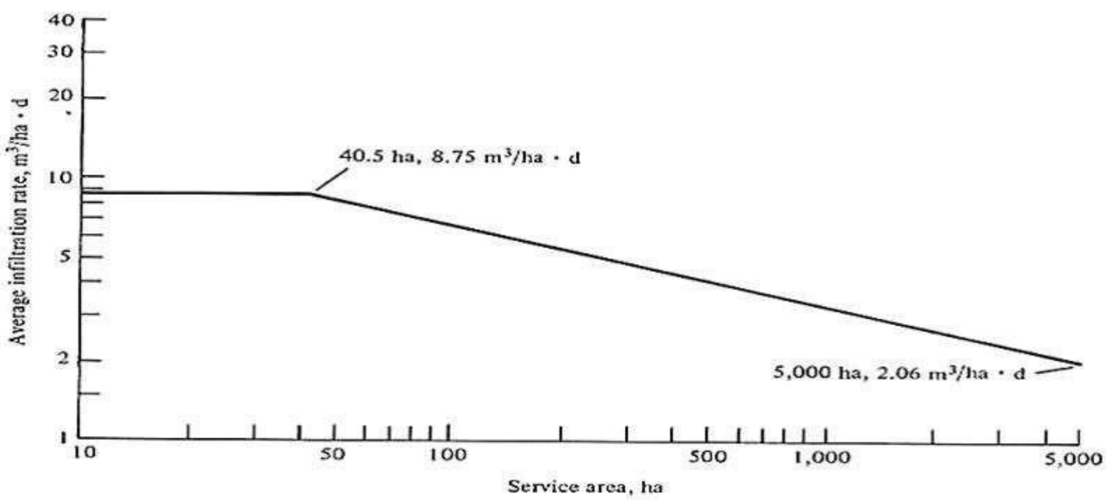


Figure 5 : Average infiltration rate allowance for new sewers. Note: ha × 2.4711 = acre: m^3/ha·d × 106.9 = gal/acre·d.

Figure 8. 8 Average infiltration rate allowance for new user

Steps of Sewer System Design

At first, we have collected the contour map for our design area. The area is getting lowered towards the river. Then the junctions (nodes) of branch sewers/main sewers with the Trunk sewer is marked and identified in layout. The trunk sewer starts from the road between bank and administrative building, has a right angle turn while passing the industrial zone and stops at ETP. The plan is shown in Figure.

We have divided the plan into 8 feeder areas. The six areas are shown in Figure. From these areas sanitary wastewater and infiltration occurs in sewer system and its quantity increases cumulatively towards ETP.

We have previously calculated the supply water demand for each of these areas. Now average wastewater is calculated by assuming that a portion of these supply water will be returned to sanitary sewer system. The assumption table with percentages of average wastewater in each category is given before.

The peak wastewater flow can be obtained by multiplying the avg. wastewater with peak factors included in the table. The total calculation of peak wastewater flow is given later in table.

The total infiltration for each area is calculated by using the figure shown in table. Combining the peak wastewater flow and infiltration cumulatively we get the design wastewater flow (table 8.6).

Now we will design the trunk sewer. At first, we have to consider the slope of pipe. Initially we will provide the natural slope of soil.

We will use n = 0.013 (for new concrete pipe)

From Manning's equation [8-10],

Pipe diameter, D (m) = 1.548*[n*Q/√S]0.375

We have to use the next larger diameter (Dactual) from table, if the calculated diameter pipe doesn't exist.

By using the above , equation with Dactual we have to calculate Qfull. We have to calculate Vfull using Manning's equation [8-11],

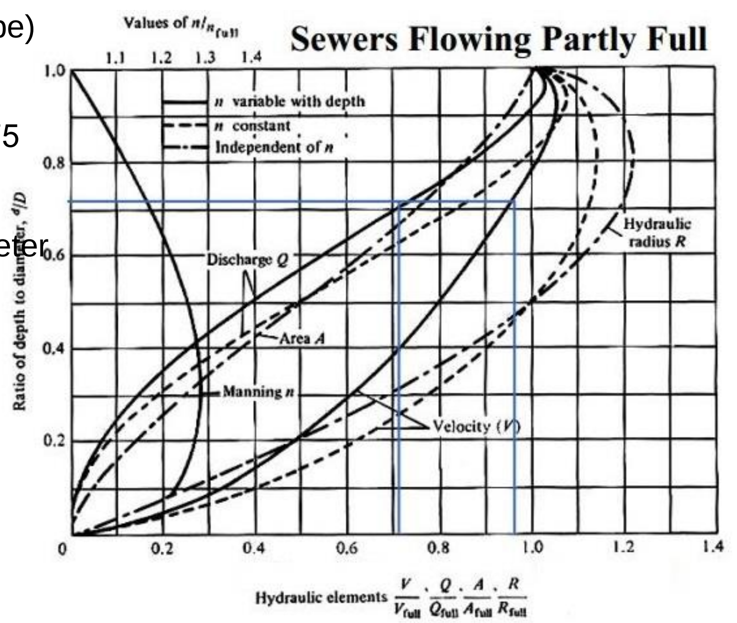


Figure: Hydraulic Element Diagram for Circular Sewer

Figure 8. 9 Hydraulic element diagram for circular sewer

Vfull = 1/n*(D/4)2/3S1/2

Then by calculating Q/Qfull,

From hydraulic elements diagram [8-12], we get d/D and V/Vfull, and then V. We have to check this velocity against minimum velocity (0.6 m/s) and non-scouring velocity (2 m/s). If not satisfactory, then we have to give trial again with changed slope and diameter. The pipe diameters with slope is shown in table 8.6.

Now we have to draw the longitudinal pipe profile (Table 8.7). From available contour diagram of the area, Ground surface elevation at each node along the trunk sewer trench line is calculated. Sewer crown and invert level is important in drawing.

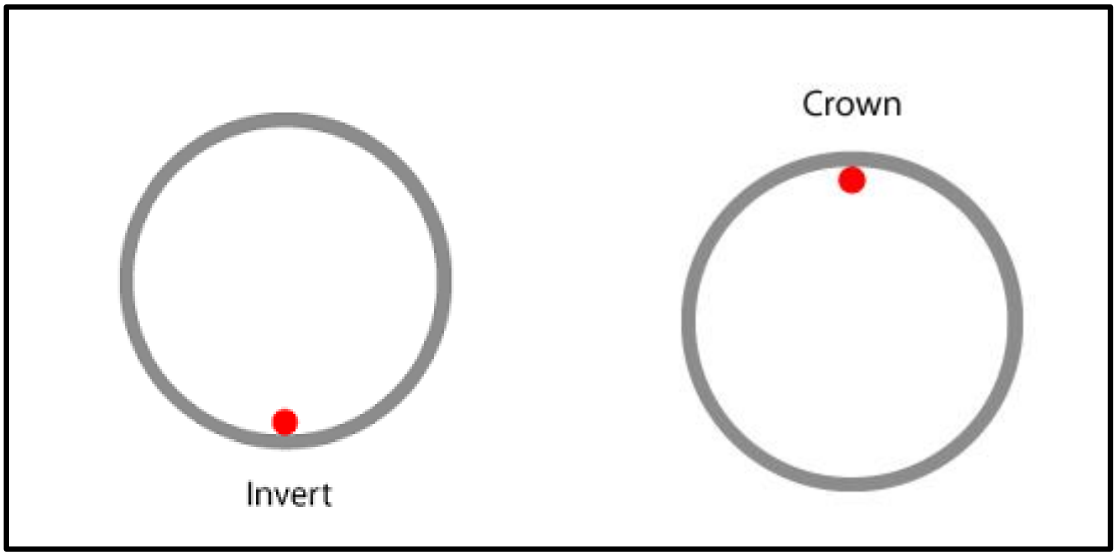


Figure 8. 10 Invert and Crown level of pipe

Sewer crown = Ground elevation – Cover – Pipe thickness

Sewer invert = Crown – Pipe diameter

The manhole locations are determined in table . The number of manholes must be adequately spaced so that the sewers can be easily inspected and maintained. As our sewers are less than 600mm diameter so manhole spacing should not be more than 100 m

In figure the longitudinal profile of sewer is shown with ground surface RL, pipe plan view, crown and invert level and manhole positions.

Sample Calculation

Here we will show all calculations for the pipe 2.
Its feeder area is A2, Length 125 m.

(a)Calculation of Peak wastewater

For A2 area, average supply water demands are 37700 lpd (1st class quarter), 18000 lpd (Restaurant) (From Table).
Previously mentioned wastewater percentages of supply water is 70% for both residential and commercial zone. The peak factor for 1st class quarter is 3.1 and for common services they are 1.8.

So, Peak wastewater (without inflow),
For 1st class quarter =37700 *0.7*3.1 = 84448 lpd

For Restaurant = 2025*0.7*1.8 = 22680 lpd

Flow from pipe 1 =161101 lpd
Total cumulative flow = 161101+84448+22680 = 268229 lpd = 0.011369175 m3/s

For A2, total area 2.8 hectare, from graph average infiltration rate = 8.75 m3/hectare-day and

So, total cumulative infiltration = 8.75*2.8/ (24*3600)
= 0.0003 m3/s

So, total peak wastewater rate = .0003+.011369175 = 0.0117 m3/s

(b) Pipe diameter calculation

From contour map,

The ground elevation

at upper end = 30.48 m,

at lower end = 29.98 m.

Line length = 100 m

So,

Natural slope = (30.48-29.98)/100 = 0.0065

Assuming a slope 0.0075 for pipe laying,

From Manning's equation,

Pipe diameter, D= 1.548*[n*Q/√S]0.375=1.548*[0.013*.0.0024/√0.0075]^0.375 *1000 =

79 mm

The next larger pipe diameter (available) is 200 mm

So, using this as Dactual,

Qfull= [D/1.548]^(1/0.375)* √S/n =
(1/0.013)*(3.14*0.25*(200*0.001)^2)*((200*0.001/4)^(2/3))*(0.0075)^0.5 = 0.028 m3/sec

Now, Q/Qfull = 0.0024/0.028 = 0.08625

From Hydraulic element graph,

for Q/Qfull = 0.08625,

d/D = 0.21 ,

V/Vfull= 0.67,

Now from Manning's equation,

Vfull= 1/n*(D/4)2/3S1/2 = (1/0.013)*((200*0.001/4)^(2/3))*(0.0075)^0.5 = 0.904 m3/sec

So, V = 0.67*0.904 = 0.606 m/s, 0.6 < V <2,

So, Pipe diameter is OK.

(c) Calculation of Longitudinal Profile

Pipe slope= 0.007,

Pipe length = 150 m,

Pipe diameter = 200 mm,

Crown level of lower end of pipe 1 is 27.68 m

So, Crown level at upper end of pipe 2 = 27.38 m

Invert level at upper end of pipe 2 = 27.38 -0.2 = 27.18m

Cover at upper end = 2.25 m

Fall in sewer = 0.007*150 = 1.05 m

GL at lower end = 29.23 m

Crown level at lower end of pipe 2 = 26.33 m

Invert level at upper end of pipe 2 = 27.38 -0.2 = 27.18m

Cover at lower end= 29.23-26.33-(200*0.001)-0.05=18.7-16.50-0.05 = 2.15 m > 2 m (OK)
So, Pipe 2 design is ok So, Pipe 2 design is ok.

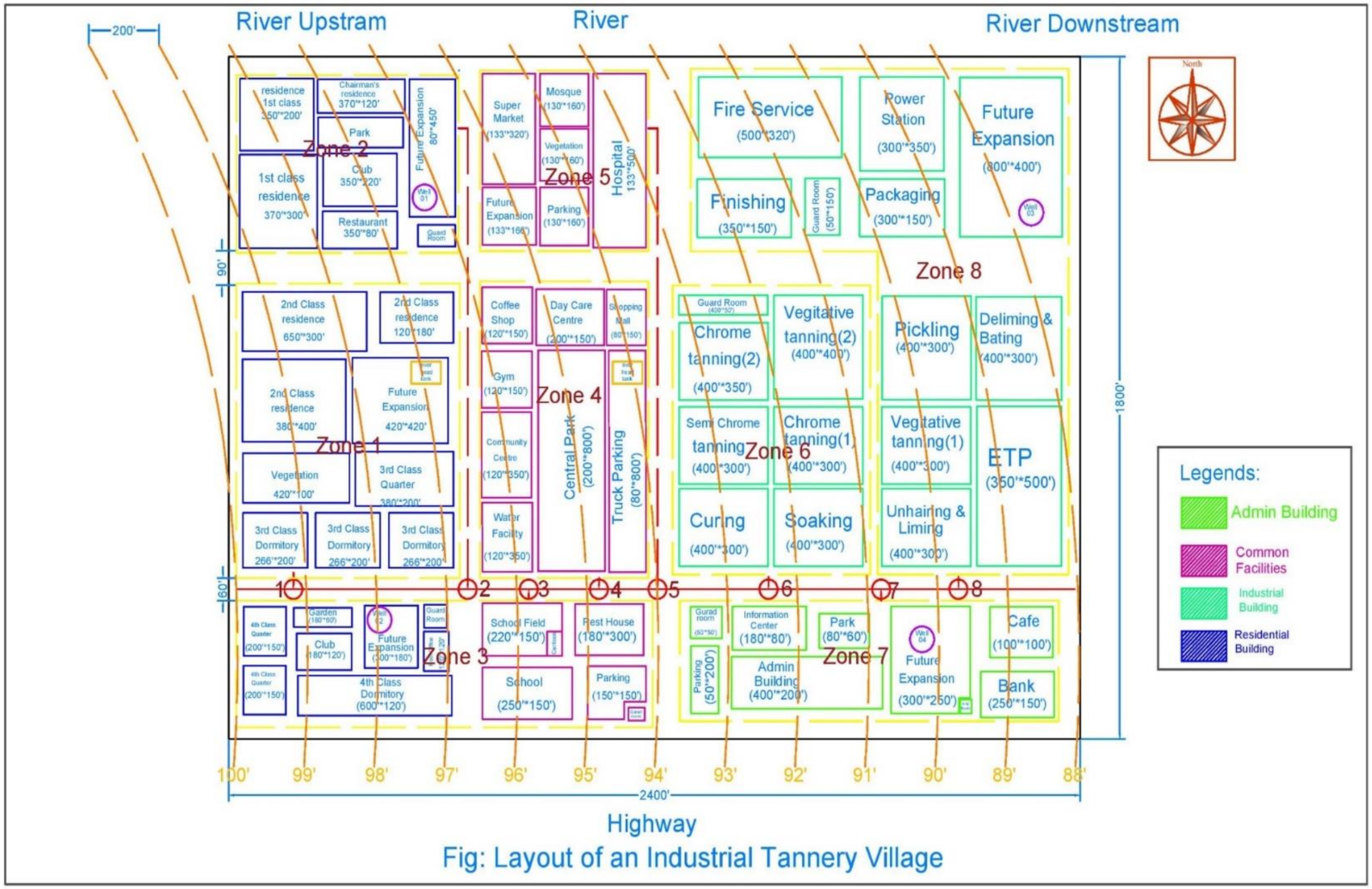


Figure 8. 11 Location of trunk sewer

Table 9.1. Wastewater Calculation (excluding Infiltration)

Node	Contributing Area Number	Area Description	Average Demand	Wastewater Percentage	Average Wastewater	Peak Factor	Peak Wastewater	Wastewater Flow	
			lpd		lpd		lpd	lpd	m3/s
1	A1	2nd Class Residence	60,660	70	42,462	3.1	131,632	162,051	0.001945
		3rd Class Dormitory	13,580	70	9,506	3.1	30,419		
2	A2	1st Class Quarter	37,700	70	26,390	3.2	81,809	104,489	0.001254
		Restaurant	18,000	70	12,600	1.8	22,680		
3	A3	Parking	2,074	70	1,452	1.8	2,613	425,744	0.005109
		4th Class Residence	110,960	70	77,672	3.1	240,783		
		School	144,720	70	101,304	1.8	182,347		
4	A4	Gym	603	70	422	1.8	760	14,151	0.000170
		Park	2,074	70	1,452	1.8	2,613		
		Parking	2,074	70	1,452	1.8	2,613		
		Shopping Mall	6,480	70	4,536	1.8	8,165		
5	A5	Hospital	40,800	70	28,560	1.8	51,408	74,887	0.000899
		Mosque	10,080	70	7,056	1.8	12,701		
		Market	6,480	70	4,536	1.8	8,165		
		Parking	2,074	70	1,452	1.8	2,613		
6	A6	Chrome Tanning	352,080	90	352,080	2.1	739,368	739,368	0.008872
		Vegetative Tanning							
		Soaking							

		Curing							
7	A7	Parking	2,074	70	1,452	1.8	2,613	125,524	0.000867
		Admin Building	40,446	70	28,312	4	113,249		
		Bank	5,400	70	3,780	1.8	6,804		
8	A8	Fire Service	2,268	70	1,588	1.8	2,858		
		Power Station	86	70	60	1.8	108	2,208	0.000026
		Pickling	430	90	387	2.1	813		
		ETP	309	90	278	2.1	584		
		Vegetative Tanning	372	90	335	2.1	703		

Table 9.2. Cumulative Wastewater Flow (Including Infiltration)								
Node	Contributing Area	Area		Average Infiltration Rate	Total Cumulative Infiltration		Wastewater Flow (Excluding Infiltration)	Wastewater Flow (Including Infiltration)
		square m.	hectare	m3/hectare-day	m3/day	m3/sec	m3/s	m3/s
1	A1	46,435	4.6	8.75	40.631	0.0005	0.017382355	0.0179
2	A2	27,786	2.8	8.75	24.313	0.0003	0.011396175	0.0117
3	A3	37,188	3.7	8.75	32.540	0.0004	0.024345636	0.0247
4	A4	35,187	3.5	8.75	30.789	0.0004	0.014381479	0.0147
5	A5	21,404	2.1	8.75	18.729	0.0002	0.009656917	0.0099
6	A6	40,278	4.0	8.75	35.243	0.0004	0.009656917	0.0101
7	A7	32,207	3.2	8.75	28.181	0.0003	0.009656917	0.0100
8	A8	92,091	9.2	8.75	80.580	0.0009	0.009656917	0.0106

Line	Infiltration (m^3/s)	Waste water (m^3/s)	Total Wastewater(m^3/s)	Slope	Exact Pipe diamter (mm)	Actual Pipe diameter (mm)	Q (full) (m^3/s)	Q/Qfull	d/D	V/V_full	V_full (m^3/s)	V (m^3/s)	Remarks
1	0.0005	0.001944617	0.0024149	0.0075	79	200	0.028	0.086246	0.21	0.67	0.904	0.60568	OK
2	0.0008	0.003198485	0.0039501	0.007	97	200	0.027	0.146302	0.28	0.76	0.873	0.66348	OK
3	0.0012	0.008307408	0.0095293	0.007	134	200	0.027	0.352938	0.4	0.85	0.873	0.74205	OK
4	0.0020	0.008477221	0.0104508	0.0065	141	200	0.026	0.401954	0.42	0.95	0.842	0.7999	OK
5	0.0032	0.009375863	0.0125714	0.007	149	200	0.027	0.465606	0.5	1	0.873	0.873	OK
6	0.0052	0.018248279	0.0234174	0.0066	191	200	0.027	0.86731	0.72	1.12	0.848	0.94976	OK
7	0.0084	0.019114979	0.0274796	0.006	206	250	0.046	0.597382	0.58	1.06	0.938	0.99428	OK
8	0.0135	0.019141477	0.0326751	0.006	220	250	0.046	0.710329	0.62	1.09	0.938	1.02242	OK

Table 9.3: Pipe Diameter Calculation

						Sewer invert Elevation(RL),(m)		Ground Elevation (RL), (m)		Cover Above the pipe,(m)	
Line	length (m)	Slope	Diameter (mm)	Fall in Sewer (m)	Invert drop(mm)	Upper End	Lower End	Upper End	Lower End	Upper End	Lower End
1	100	0.0075	200	0.75	0	28.23	27.48	30.48	29.98	2	2.25
2	150	0.007	200	1.05	0	27.18	26.33	29.98	29.23	2.25	2.65
3	55	0.007	200	0.385	0	26.21	25.825	29.23	28.955	2.65	2.88
4	60	0.0065	200	0.39	0	25.72	25.33	28.955	28.655	2.88	3.075
5	50	0.007	200	0.35	0	25.22	24.87	28.655	28.405	3.075	3.285
6	100	0.0066	200	0.66	0	24.51	23.85	28.405	27.905	3.285	3.805
7	100	0.006	250	0.6	50	23.52	22.92	27.905	27.405	3.805	4.185
8	70	0.006	250	0.42	0	22.7	22.41	27.405	27.055	4.185	4.345

Table 9.4: Calculation of Pipe Profile

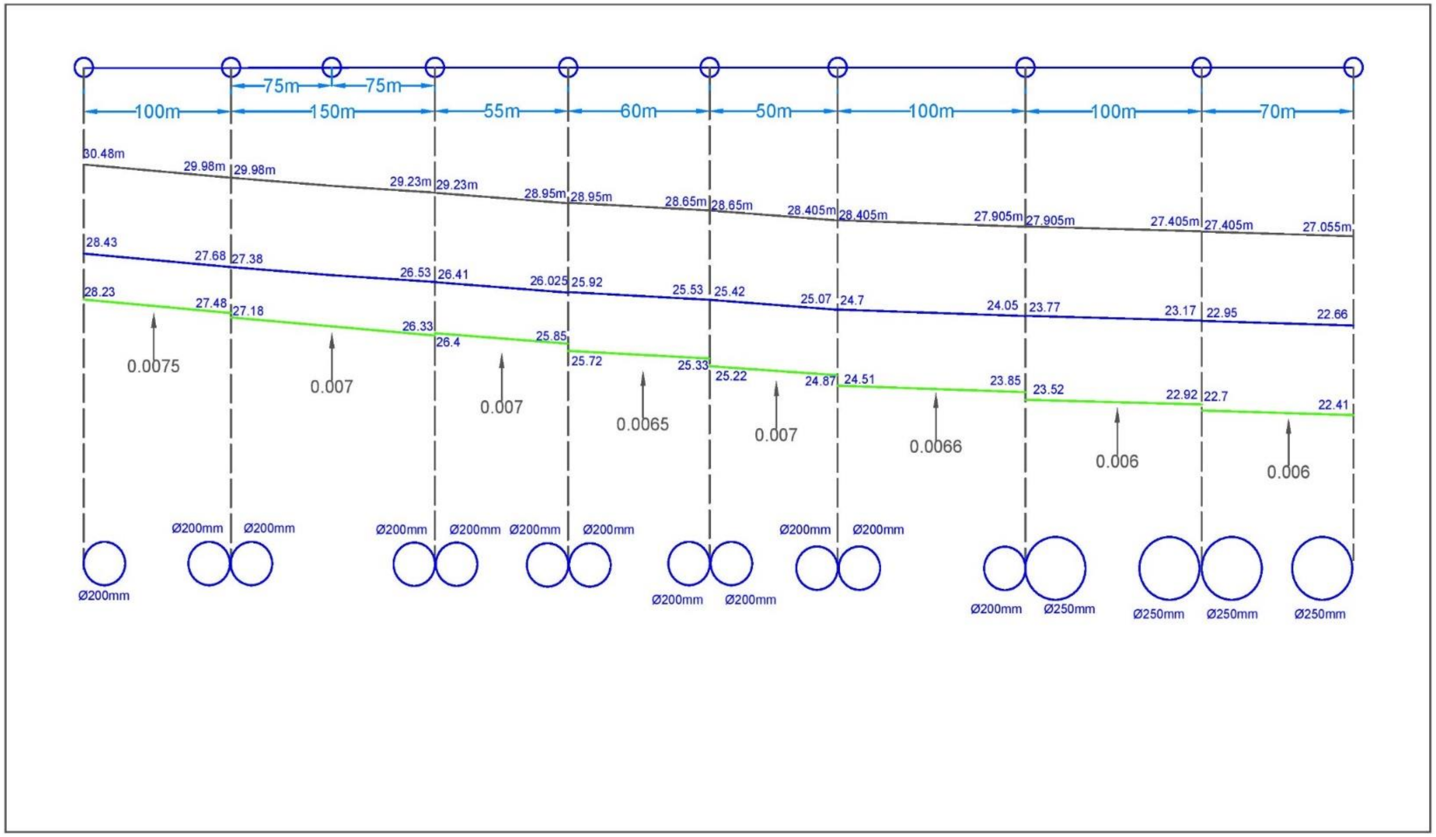


Figure 8. 13 Longitudinal Profile of Trunk Sewer

CHAPTER 10

DESIGN OF PLUMBING AND DRAINAGE

Objective

The objective of the chapter is to design components of water supply system and drainage system of seven storied building. For the design of water supply system down feed water supply is considered. The design components; size of water distribution pipes, size of underground water reservoir and overhead water tank, riser size and pump capacity are calculated for the building. The elements like drainage pipes, building drains and sewers, including connections, devices and other appurtenances are designed for building drainage system.

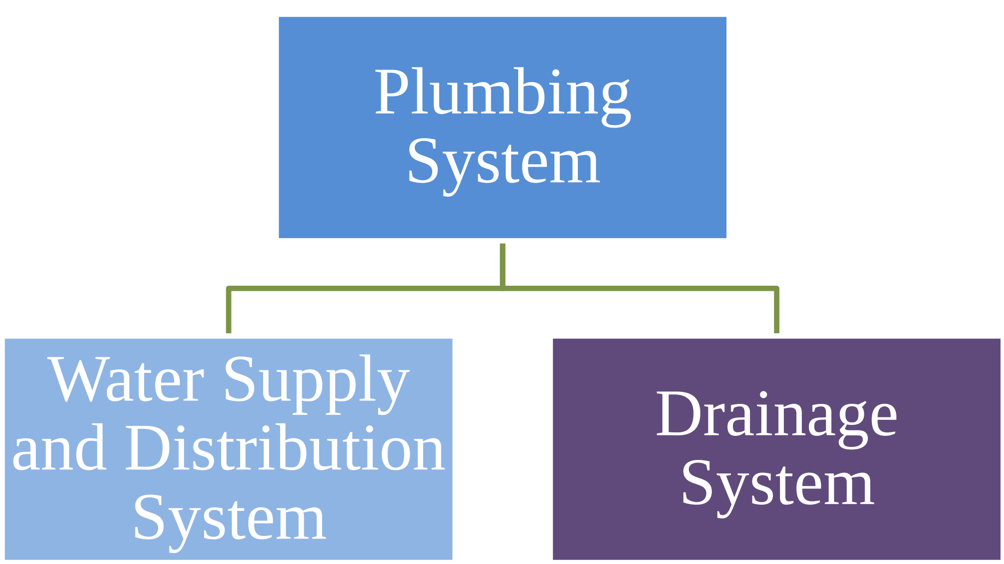
Plumbing

The plumbing includes the practice, materials, and fixtures used in the installation., maintenance, extension, and alteration of all piping, fixtures, appliances, and accessories in connection with sanitary drainage or storm drainage facilities, the venting system and the public or private water supply systems within or adjacent to any building, structure, or conveyance.

Major Elements of plumbing system

The plumbing system includes-

- Water supply and distribution pipes: riser, up feed or down feed distribution pipes, underground water reservoir (UGWR) and overhead (OH) tank.
- Plumbing fixtures and traps,
- Soil, waste and vent pipes,
- Building drains and building sewers, including-their respective connections, devices, and appurtenances within the property lines of the premises. **(It is excluded in our design)**



DESIGN OF WATER SUPPLY AND DISTRIBUTION SYSTEM

Water Distribution in a Building

Water distribution in to building can be done in many way

1. Upfeed distribution

Simple upfeed
– Water fed to fixtures in a building only by the incoming pressure of the supply water.
– This method is good for buildings up to 5 to 6 stories high.
Pumped upfeed
– Water fed to the fixtures in a building by increasing the pressure of the supply water using additional pumps.

2. Down Feed Distribution

– Uses pumps to deliver water to a rooftop storage tank of the building.
– The water in the storage tank feeds fixtures below due to the force of gravity.
– Commonly one roof top tank is used to distribute water to whole building. For tall building intermediate tank (s) are often used to supply water at different levels.
– If main does not have sufficient pressure to carry water to OH tank, underground water reservoir (UGWR) is provided to store water from main and deliver to the overhead tank.

As the designated building is 7 storied, so we have chosen Down Feed Distribution.

Design of Down Feed Water Supply System

Design Components

1. Sizing of Water Distribution Pipes within the Building
2. Dimensions of UGWR
3. Dimensions of OH tank
4. Determination of size of riser
5. Calculation of Pump capacity

Design steps

A. Sizing of Water Distribution Pipes within the Building
B. Calculation of Dimension of Underground Water Reservoir
C. Calculation of Dimension of Overhead Water Tank
D. Design of Riser Pipe and Pump
E. Calculation of pump capacity

A. <u>Sizing of Water Distribution Pipes within the Building</u>

The design of the consumers' pipes or the supply pipe to the fixtures is based on:
a) The number and kind of fixtures installed;
b) The fixture unit flow rate; and
c) The probable simultaneous use of these fixtures.

The rates at which water is desirably drawn into different types of fixtures are known. These rates become whole numbers of small size when they are expressed in fixture unit. The fixture units for different sanitary appliances or groups of appliances are given in the **Table- 8.5.4** [9-1].

The design steps are described below:

1. Drawing the sketch of the main lines, risers and branches serving different fixtures at different water use points in the building.
2. Determining the number and types of fixture that will be required on the basis of the **Table- 8.6.1**[9-2] or as per design requirement.
3. The demand weight of different fixture units is computed in terms of water supply fixture unit (**wsfu**) either using **Table – 8.5.4** or from **Table- P1** [9-3].
4. As the total down feed zone is supplied by more than one pipe, the total peak demand is calculated for individual down feed zone using the procedure below-
5. It should be noted that the possibility of all water supply taps in any system in domestic and commercial use will draw water at the same time are extremely remote. Designing the water mains for the gross flow will result in bigger and uneconomical pipe mains and is not necessary. Therefore the peak demand load (or maximum probable flow) in liter per minute may be estimated with the data obtained in step-3 either using
a) **Fig.-P1** (Hunter curve) [9-4] or
b) From **Table-8.5.5** [9-5] or
c) On the basis of occupancy classification specified in **Table - 8.5.1**. [9-6]
In our calculation Hunter curve is used.

6. The equivalent length calculation:

The length of the main lines, risers and branches from elevation & floor plan is determined.
The equivalent length of different fittings may be estimated on the basis of the data presented in the **Table-P2 (a), Table-P2 (b**) and **Table-P2(c)** [9-7].
The total equivalent length is the sum of the equivalent lengths of all pipes and fittings.

7. Pressure at fixture:
In a down feed water distribution system (roof tank supply), static pressure due to gravity increases with increasing floor height (4.32 psi or 0.3 Bar per floor of 10 ft. height at non flow condition). Therefore, water distribution pipe in a building should be maintained at a pressure so that none of their fittings are subject to a water head greater than 35 m (approximately 50 psi).
The distribution system should be maintained at a pressure not less than those specified in **Table- 8.5.6**[9-8] during peak demand period.

Average available pressure loss (kPa) $F_p = P \pm 9.8H - f$ (+ve for down-feed supply)
Where
F_p = Average available pressure loss (kPa) per meter of equivalent length of pipe
P = Pressure (kPa) in the water main OR zero for overhead gravity storage tank.
H = Difference (m) in elevation between storage tank and the fixture under consideration.
f = Pressure loss (kPa) through water meter or such other fittings plus pressure (kPa) required to produce adequate flow through the fixture under consideration in down-feed system.

8. Selection of pipe size:

Commercially available standard sizes of pipes are only to be used against the sizes arrived at by actual design. Therefore, several empirical formulae are used, even though they give less accurate results.
The Hazen and William's formula and the charts based on the same may be used without any risk of inaccuracy in view of the fact that the pipes normally to be used for water supply are of smaller sizes. Nomograph of Hazen and William's equation has been provided in **Figure-P4** [9-9].
For this using peak demand and available pressure loss determine pipe size from **Figure-P4**.

B. Calculation of Dimension of Underground Water Reservoir

For water supply system with inadequate pressure to feed plumbing fixtures or balancing roof tank, the building premises usually have a ground (or underground) tank to store water most commonly below stair case. The water from the ground tank is then boosted up to the roof tank to feed plumbing fixtures.

- Calculate total daily demand for the building using **Table - 8.5.1** (or total demand obtained in step-5 in determination of pipe size in topic-A)
- Water is stored in underground water reservoir with extra one day reserve for emergency requirements.

Therefore total capacity of Under Ground Reservoir (Q) = 2 x Total daily demand of water (m^3).

- UGWR is usually provided below stair case. So the surface area of the tank depends on the area available below stair case.

Say, the dimension is e.g., surface area, (A) = 20’ x 12’.
Water depth H_1 = Q/A.

- Using a thumb rule of 10:1, i.e., a 10 story building will require 10' foundation thus 10' depth of U/G reservoir can be provided.

This height should include height obtained in step-5 + 6” to 12” freeboard
Total height = H_1 + Free board (6 -12 inch)

- Finalize the dimensions of the tank.

C. Calculation of Dimension of Overhead Water Tank

In addition to daily water consumption, an overhead water reservoir is used to store water in case of emergency such as fire or power cutoff.

1. Assume reasonable pumping schedule to pump water from UGWR to the overhead tank. e.g., if 1 hour pumping twice daily, tank volume needed
V_1 = total daily demand (m^3)/2.

2. For calculating of water requirement for fire -fighting, use **Table 4.4.1[9-10].**
Therefore, V_2 = fire-fighting rate (m3/min) * 30 min.

3. Therefore capacity of the tank = $V_1 + V_2$

4. Calculate appropriate dimensions for the tank.

5. In addition to height obtained in step- 4 a freeboard of 10” - 12’’ should be provided.

Note: To provide sufficient pressure, the bottom of the tank must be elevated sufficiently above the highest floor water fixtures.

D. Design of Riser Pipe and Pump

Riser pipes are used to convey water from the underground water reservoir to overhead tank and a pump is required so that the water can flow upward through the riser pipe.
1. Total amount of water carried by the riser each time of pumping to OH tank (gpd) = total daily demand/ pumping frequency
Say 3000 gallon is carried by the riser each time of 1 hour pumping to OH tank
Therefore, Q = 50 gpm
2. Assume velocity 8-10 fps
3. Using **Fig. - P4**, determine pipe size (d) and head loss (h_L) (psi/100 ft)

E. Calculation of pump capacity

1. Total length of riser (L) = total building height (10 ft per floor) + 10' from UGWR + OH tank inlet height above top roof surface.

2. Total Frictional head $H_L = (h_L * L)/100$ + 8 psi required pressure at the O/H tank + 5 psi minor loss due to bend

3. Frictional head in ft $L_h = H_L *144 /62.2$

4. Total Head, H = Static head + Velocity head + Friction head

Pump capacity = HQ/ (3960 E).
Assume E = 60-65%

Calculation

- **Calculation of water demand of a building (10 story)**

From plan of the building, we see there are 4 apartments in each floor and total 40 apartments in the building. Each apartment consists of 2 toilets, 1 kitchen.
We assume the fixtures in these rooms are as:

Room	Fixtures	FU
Toilet	Flash tank+ wash basin+ shower head	3+5+1=9
Kitchen	Kitchen sink+ tap	2+1=3

[Values of FU are taken from Table 8.5.4 and Table P1]

Total FU in 1 apartment= 2 toilets + 1 kitchen = 2×9+3=21
Total FU in the building= 40×21= 840

For 840 FU, demand = 700 L/min ***[from the Hunter Curve]***
=185 gpm

Apartment size is approximately < 1500 sq. ft
From **Table 8.5.1 (a),** category b2;
Water consumption= 120 lpcd (restricted facility)
We assume, ***no. of family members in each apartment= 5***
Now, water consumption in each apartment = 5×120 = 600 lpd
Water consumption in whole building= 600 lpd × 40 = 24000 lpd
= 6340 gpd

- **Calculation of dimensions of underground water reservoir**

Capacity of this reservoir will be 2×24000 lpd = 48000 lpd
= 1694 cft = 1700 cft
If reservoir is placed under staircase, we assume its area 18 ft*12 ft
Hence height of reservoir = (1700)/ (18×12) = 7.87 ft
We provide height 8.5 ft (7.56 inch free board)

Using a thumb rule of 10:1, 10 story building will require 10' foundation thus 10' depth of U/G reservoir can be provided.

Dimensions of the reservoir is 18 ft × 12 ft × 8.5 ft

- **Calculation of dimensions of overhead water reservoir**

We assume 1 hour pumping and twice in a day.
6340/2 = 3170 gal/ hour
3170 gal= 3170*3.785/28.317 cft = 424 cft

Considering from **Table 4.4.1, building type light hazard 1 (occupancy group A2), standpipe and hose system,**
Flow requirement= 1000 liter/min
For 30 min duration,
Water volume= 30×1000= 30000 liter
=1059cft
Total volume of water required= 1059+424 =1483 cft
We provide area of 20 ft× 10 ft

Hence depth= (1483)/ (20×10) = 7.4 ft

We provide depth of 8 ft (with approximately 7 inch free board)
Dimensions of the overhead reservoir is 20 ft × 10 ft × 8 ft

Overhead tank is on 25 ft above from roof.

- **Design of Riser Pipe**

Water flow 3170 gal/hour =52.83 gpm
Assuming velocity 10 ft/sec,
From Fig. - P4, 1.5" diameter riser is provided
The corresponding head 550 ft/1000 ft
Head loss, h_L= 550*0.433 =238 psi/ 1000ft

- **Design of Pump**

Total length of riser (L) = total building height 100 ft+8.5 ft (from UGWR)+ OH tank inlet height above top roof surface 33 ft = 141.5 ft
Total Frictional head H_L = 238/1000*141.5 psi + 8 psi (required pressure at the O/H tank) + 5 psi (minor loss due to bend) = 47 psi

Frictional head in ft, L_h = H_L ×144 /62.2 = (47×144)/62.4 = 109 ft

Velocity Head = $v^2/2g$ = 10^2/ (2×32) = 1.56 ft

Total Head, H = Static head (L) + Velocity head + Friction head (L_h)
= 141.5' + 1.56' + 109'= 252 ft

We assume pump efficiency= 60%

HP of the pump = HQ/ (3960 E)

$$= \frac{252 \times 52.53}{3960 \times .6}$$

= 5.6 HP

Hence we provide a pump of 6 HP

- **Calculation for Design of Down feed Zone Pipes**

Two down feed zones are selected, with the first down feed pipe supplying water to top 5 floors and the second down feed pipes to rest of the bottom floors and basement.

Sample Calculation for 9th floor:
FU in 9th floor = 84
Accumulated FU = 84+84+84+84+84 = 420 FU
From Fig.-P1, Demand flow = 111 gpm
Horizontal length of pipe = 75 ft
Vertical length of pipe = 25+5+4=34 ft
Total Length= 75+34= 109 ft
Difference (m) in elevation between storage tank and the fixture under consideration (H)= 34/3.28= 10.36 m

Available pressure per equivalent length of pipe (kPa) = 9.8*10.36-55-7 = 39.5 kPa
Loss of head (ft/1000 ft) = {(39.5/109)*1000}/2.98 = 121.86 ft

From Fig.-P4,

Using Demand flow = 111 gpm and Loss of head (ft/1000 ft) 121.86 ft, Pipe dia = 2.5 in

Drainage System

A drainage system (drainage piping) includes all the piping within public or private premises, which conveys sewage, rain water, or other liquid wastes to a legal point of disposal, but does not include the mains of a public sewer system or a private or public sewage treatment or disposal plan.

Major Elements of Building Drainage System

1. Drainage pipes
- Soil pipes
- Waste pipes
- Vertical pipes are known as stacks (soil / waste / vent)

2. Traps
- Placement
- Depth of trap seal
- Cleaning

3. Vents
- Purpose - ventilate plumbing system & prevent foul gases from drainage system to enter the building
- Vent stack size

Building Drainage Systems

For the design and installation for drainage piping, one of the following building drainage systems can be adopted:

1. Single stack system
2. one-pipe system, and
3. two-pipe system

Single stack system

- The fixtures in each floor are connected to a single stack without any trap ventilation pipe work.
- Single stack system usually used with 100 mm diameter stack for buildings up to 5-storey height.

Two-pipe system:

- A discharge pipe system comprising two independent discharge pipes - one conveying soil directly to the sewer, the other separately conveys the silage from kitchen and bath directly to the drain through a trapped gully.
- The system may also consist of ventilating pipes.

We will use Two-pipe system as our building is more than 5 storied.

Design Steps

1. To estimate the total load weight (DFU) carried by a soil or waste pipe, the relative load weight for different kinds of fixtures using Table 8.6.14. Table 8.6.15 provides an approximate rating of those fixtures not listed in Table 8.6.14.

2. Slope: Design the building drains and sewer to discharge the peak simultaneous load weight flowing half-full with a minimum self-cleansing velocity of 0.75 m per second. However, flatter gradient may be used if required but the minimum velocity should not be less than 0.6 m per second. Again, it is undesirable to employ gradients giving a velocity of flow greater than 2.5 m per second. (However, for your design - use the minimum slope mentioned in the previous section).

3. The maximum number of fixture units that may be connected to a given size of building sewer, building drain, horizontal branch or vertical soil or waste stack should be as provided in Tables 8.6.16 and 8.6.17. Using the load factor unit as obtained in step-1, calculate size of horizontal branches or vertical soil or waste stack(s) from Table-8.6.16

4. Determination of vent pipes: Vents are normally sized by using the "Developed Length" (total linear footage of pipe making up the vent) method. Determine the size of vent piping from its length and the total of the fixture units connected in accordance with Table 8.6.21. Compare with minimum size requirement and select the appropriate size.

Assumptions

1. The discharge from water closet is carried by the soil pipe.
2. The discharge from shower and wash basin is carried by waste stack pipe.

3. Vent stack height continued at least 5 feet above roof.
4. Water closet has minimum 2” vent.
5. Individual vents from any other fixture shall not be less than 1 1/4 inches
6. Connections of pipes should be at 45° angles
7. Cleanouts should be provided every 50 ft of horizontal length
8. Cleanouts also should be provided at all stack bottoms

Calculation

Table 10.1

		DFU	No of fixtures	No. of stories	Total DFU	Trap size(mm)
Toilet	Water closet	3	2	10	60	50
	Wash basin	1	2	10	20	30
	Shower head	2	2	10	40	40
Kitchen	Kitchen sink	2	1	10	20	40

1 Stack for 2 Toilets
1 Stack at each end of the Building (Total = 2)

From **Table 8.6.14,**

DFU for water closet =3
DFU for Shower head =2
DFU for Wash basin =1

Total DFU for water closet =
DFU unit value *No. of Fixtures*No. of Storey =
3*2*10 = 60

Total DFU for Shower head = 2*2*10 = 40

Total DFU for Wash basin = 1*2*10 = 20

Trap Size From Table 8.6.15,

Water Closet= 50mm
Shower head = 40mm

Wash basin = 30mm

Table 10.2 Pipe Size Calculation

Soil Waste Pipe Size				
Water closet	branch numbers	Load factor(from table 8-6-14)	Size,mm(from table 8.6.16)	Soil waste pipe(mm)
	1	3	40	50
	2	6	50	
Waste Water Pipe Size				
	branch numbers	Load factor(from table 8-6-14)	Size,mm(from table 8.6.16)	waste water pipe(mm)
wash basin	1	1	30	50
Shower head	2	3	50	
Bathtub with Shower head	3	5	50	
wash basin	4	6	50	

Size of Soil and Waste Pipe and Stack

Max. Fixture units connected to soil pipe = 6

Max. Fixture units connected to waste pipe = 6

From **Table 8.6.21,**

Size of Soil pipe = 50mm
Size of Waste pipe =50mm
Fixtures unit connected to soil stack = 60
Fixtures unit connected to waste stack =40+20 = 60

Size of Soil Stack = 100mm

Size of Waste Stack = 75mm

	Total fixture unit	Diameter, mm from table 8.6.21	Maximum development length of vent(m)	slope from table 8.6.22(mm/m)
Soil stack	60	100	228.5	20
Waste stack	60	75	189	20

Size and Length of Vent Pipe
Size of Soil/ Waste Stack = 100mm

From **Table 8.6.21,**

Total Fixtures connected to soil stack =60

Size of Soil Vent = 40mm

Total Fixtures connected to waste stack = 60

Size of Waste Vent = 75mm

1 stack for 1 Toilet and 1 Kitchen (with Basement)

From **Table 8.6.14,**

DFU for water closet = 3
DFU for Shower head =2
DFU for Wash basin =1
DFU for Kitchen Sink = 2
DFU for Basement Wash basin = 1
DFU for Basement Water Closet = 3

Total DFU for water closet =
DFU unit value *No. of Fixtures*No. of Storey
= 3*1*10 =30
Total DFU for Shower head = 2*1*10 =20
Total DFU for Wash basin = 1*1*10= 10
Total DFU for Kitchen Sink = 2*1*10= 20
Total DFU for Basement Wash basin = 1*1*10 = 10

Total DFU for Basement Water Closet = 3*1*10 = 30

Trap Size

From **Table 8.6.15,**

Water Closet= 50mm
Shower head = 40mm
Wash basin = 30mm
Kitchen Sink = 40mm
Basement Wash basin = 30mm
Basement Water Closet = 50mm

Table 10.2 Pipe Size Calculation

Soil Waste Pipe Size				
	branch numbers	Load factor(from table 8-6-14)	Size,mm(from table 8.6.16)	Soil waste pipe(mm)
Water closet (apartments)	1	3	40	40
Water closet (basement)	1	3	40	

Waste Water Pipe Size				
	branch numbers	Load factor(from table 8-6-14)	Size,mm(from table 8.6.16)	waste water pipe(mm)
Bathtub with Shower	1	2	40	50
Wash basin	2	3	50	
Kitchen sink	3	5	50	
Wash basin (basement)	1	1	30	

Size of Soil and Waste Pipe and Stack

Max. Fixture units connected to soil pipe = 3
Max. Fixture units connected to waste pipe = 5

From **Table 8.6.21,**

Size of Soil pipe = 40mm
Size of Waste pipe = 50mm
Fixture unit connected to soil stack = 30+30 = 60
Fixture unit connected to waste stack = 20+10+20+10 = 60

Size of Soil Stack = 100mm
Size of Waste Stack = 75mm

	Total fixture unit	Diameter ,mm from table 8.6.21	Maximum development length of vent(m)	slope from table 8.6.22(mm/m)
Soil stack	60	100	228.5	20
Waste stack	60	75	189	20

Size and Length of Vent Pipe

Size of Soil Stack = 100 mm

Total Fixtures connected to soil stack =60

From **Table 8.6.21,**

Size of Soil Vent = 40mm
Size of Waste Stack = 75mm

Total Fixtures connected to waste stack = 60

Size of Waste Vent = 75mm

1 stack for 1 Toilet and 1 Kitchen

From **Table 8.6.14,**

DFU for water closet = 3
DFU for Shower head =2
DFU for Wash basin =1
DFU for Kitchen Sink = 2

Total DFU for water closet =
DFU unit value *No. of Fixtures*No. of Storey
= 3*1*10 =30
Total DFU for Shower head = 2*1*10 =20
Total DFU for Wash basin = 1*1*10= 10
Total DFU for Kitchen Sink = 2*1*10= 20

Trap Size

From **Table 8.6.15,**

Water Closet= 50mm
Shower head = 40mm
Wash basin = 30mm
Kitchen Sink = 40mm

Table 10.4 Pipe Size Calculation

Soil Waste Pipe Size				
	branch numbers	Load factor(from table 8-6-14)	Size,mm(from table 8.6.16)	Soil waste pipe(mm)
Water closet (apartments)	1	3	40	40
Water closet (basement)	0	0	0	

Waste Water Pipe Size				
	branch numbers	Load factor(from table 8-6-14)	Size,mm(from table 8.6.16)	waste water pipe(mm)
Bathtub with Shower	1	2	40	50
Wash basin	2	3	50	
Kitchen sink	3	5	50	

Size of Soil and Waste Pipe and Stack

Max. Fixture units connected to soil pipe = 3
Max. Fixture units connected to waste pipe = 5

From **Table 8.6.21,**

Size of Soil pipe = 40mm
Size of Waste pipe = 50mm
Fixture unit connected to soil stack = 30
Fixture unit connected to waste stack = 20+10+20 = 50

Size of Soil Stack = 100mm
Size of Waste Stack = 75mm

	Total fixture unit	Diameter, mm from table 8.6.21	Maximum development length of vent(m)	slope from table 8.6.22(mm/m)
Soil stack	30	100	298.5	20
Waste stack	50	75	207	20

Size and Length of Vent Pipe

Size of Soil Stack = 100 mm
Size of Vent Pipe = 100mm

Total Fixtures connected to soil stack = 30

Table 8.6.21,

Size of Soil Vent = 40mm
Size of Waste Stack = 75mm

Total Fixtures connected to waste stack = 50

Size of Waste Vent = 75mm

1 stack for 1 Toilet

1 Stack at each end of the Building (Total = 2)

From **Table 8.6.14,**

DFU for water closet = 3
DFU for Shower head =2
DFU for Wash basin =1

Total DFU for water closet =
DFU unit value *No. of Fixtures*No. of Storey
= 3*1*10 =30
Total DFU for Shower head = 2*1*10 =20
Total DFU for Wash basin = 1*1*10= 10

Trap Size

From **Table 8.6.15,**

Water Closet= 50mm
Shower head = 40mm
Wash basin = 30mm

Table 10.5 Pipe Size Calculation

Soil Waste Pipe Size				
Water closet	branch numbers	Load factor(from table 8-6-14)	Size,mm(from table 8.6.16)	Soil waste pipe(mm)
	1	3	40	40

Waste Water Pipe Size				
	branch numbers	Load factor(from table 8-6-14)	Size,mm(from table 8.6.16)	waste water pipe(mm)
wash basin	1	1	30	50
Bathtub with Shower head	2	3	50	

Size of Soil and Waste Pipe and Stack

Max. Fixture units connected to soil pipe = 3
Max. Fixture units connected to waste pipe = 3

From **Table 8.6.21,**
Size of Soil pipe = 40mm
Size of Waste pipe = 50mm
Fixture unit connected to soil stack = 30
Fixture unit connected to waste stack = 10+20 = 30

Size of Soil Stack = 100mm
Size of Waste Stack = 75mm

	Total fixture unit	Diameter ,mm from table 8.6.21	Maximum development length of vent(m)	slope from table 8.6.22(mm/m)
Soil stack	30	100	298.5	20
Waste stack	30	75	207	20

Size and Length of Vent Pipe

Size of Soil Stack = 100 mm
Size of Vent Pipe = 100mm

Total Fixtures connected to soil stack = 30

Table 8.6.21,
Size of Soil Vent = 40mm
Size of Waste Stack = 75mm

Total Fixtures connected to waste stack = 30

Size of Waste Vent = 75mm

1 stack for 1 Kitchen

1 Stack at each end of the Building (Total = 2)

From **Table 8.6.14,**

DFU for Kitchen Sink = 2

Total DFU for water closet =
DFU unit value *No. of Fixtures*No. of Storey

Total DFU for Kitchen Sink = 2*1*10= 20

Trap Size

From **Table 8.6.15,**

Kitchen Sink = 40mm

Table 10.6 Pipe Size Calculation

Waste Water Pipe Size				
	branch numbers	Load factor(from table 8-6-14)	Size,mm (from table 8.6.16)	waste water pipe(mm)
kitchen sink	1	2	40	40

Size of Soil and Waste Pipe and Stack

Max. Fixture units connected to waste pipe = 2

From **Table 8.6.21,**

Size of Waste pipe = 40mm
Fixture unit connected to waste stack = 20
Size of Waste Stack = 75mm

	Total fixture unit	Diameter, mm from table 8.6.21	Maximum development length of vent(m)	slope from table 8.6.22(m m/m)
Waste stack	20	75	247	20

Size and Length of Vent Pipe

Size of Vent Pipe = 100mm

From **Table 8.6.21,**

Size of Waste Stack = 75mm
Total Fixtures connected to waste stack = 20
Size of Waste Vent = 75mm

Table 10.7: Design of down feed zone pipes

	Floor	FU	Acc. FU	Demand flow (GPM)	Vertical Length (ft)	Max horizontal Length(ft)	Water Column (ft)	Available pressure per equivalent length of pipe (kPa)	Loss of head (ft/1000 ft)	Pipe dia (in)
Zone 1	9	84	420	111	34	75	34	39.58537	121.8686222	2.5
	8	84	336	93	10	75	44	69.46341	195.8812662	2.5
	7	84	252	77	10	75	54	99.34146	258.4190818	2
	6	84	168	61	10	75	64	129.2195	311.9586505	1.5
	5	84	84	44	10	75	74	159.0976	358.3116999	1
Zone 2	4	84	420	111	74	75	84	188.9756	398.834177	2
	3	84	336	93	10	75	94	218.8537	434.5610947	2
	2	84	252	77	10	75	104	248.7317	466.2961781	1.5
	1	84	168	61	10	75	114	278.6098	494.6730516	1
	GF	84	84	44	10	75	124	308.4878	520.1979779	1

Figure 8.14: Typical Floor Plan of a Building

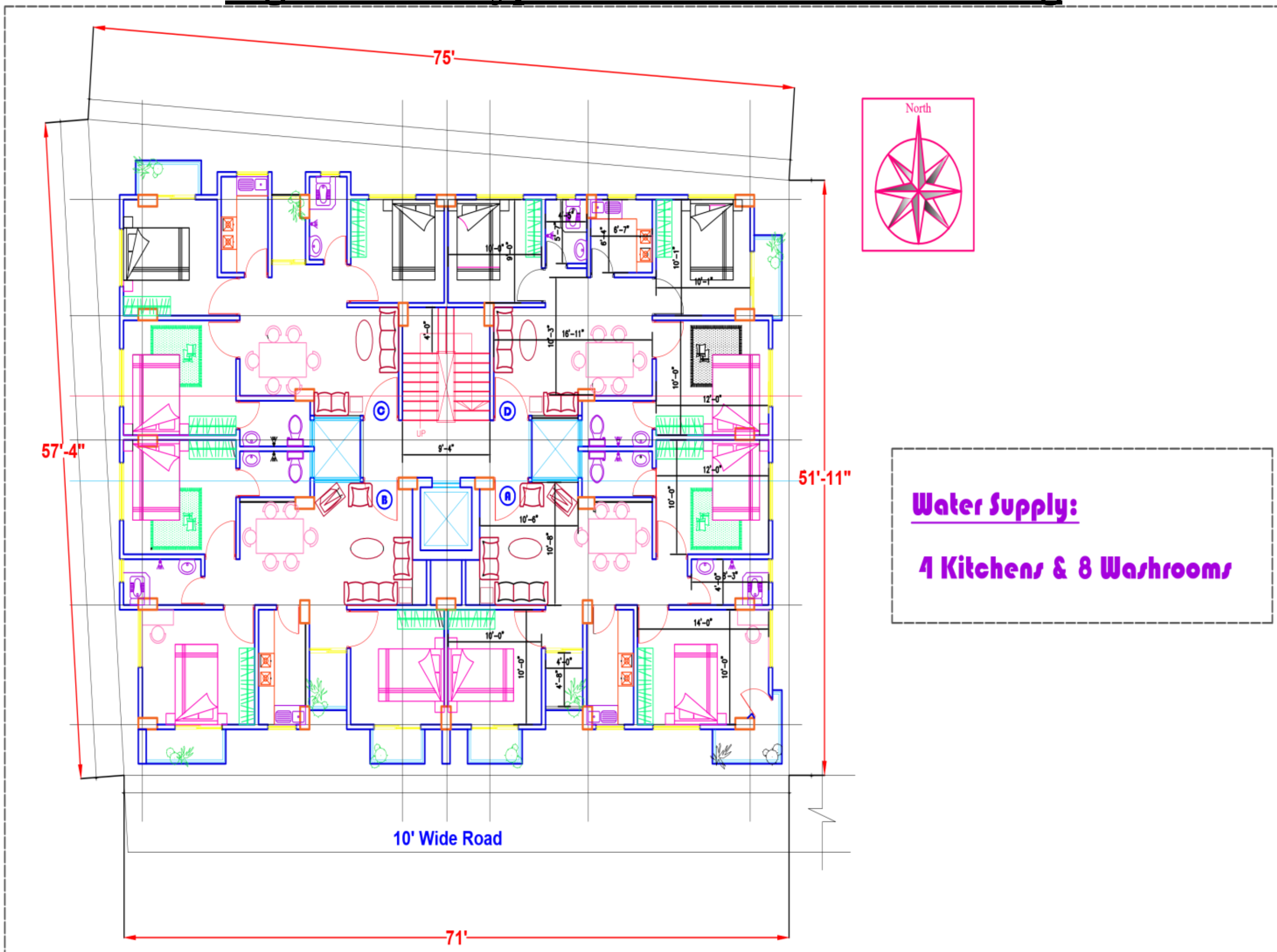


Figure 8. 14 Typical floor plan of building

Figure 8.15: Water Plumbing Network

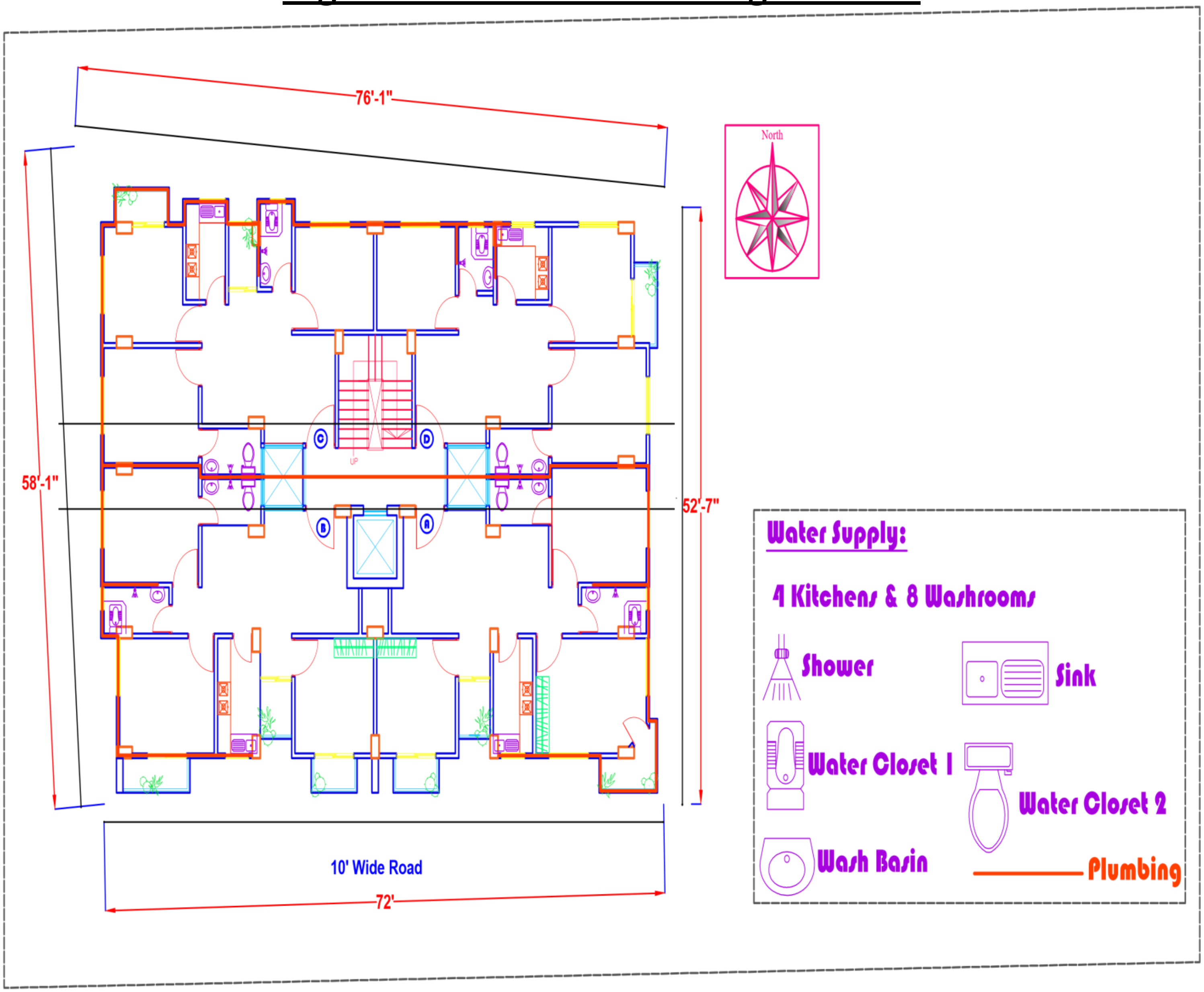


Figure 8. 15 Water Plumbing Network

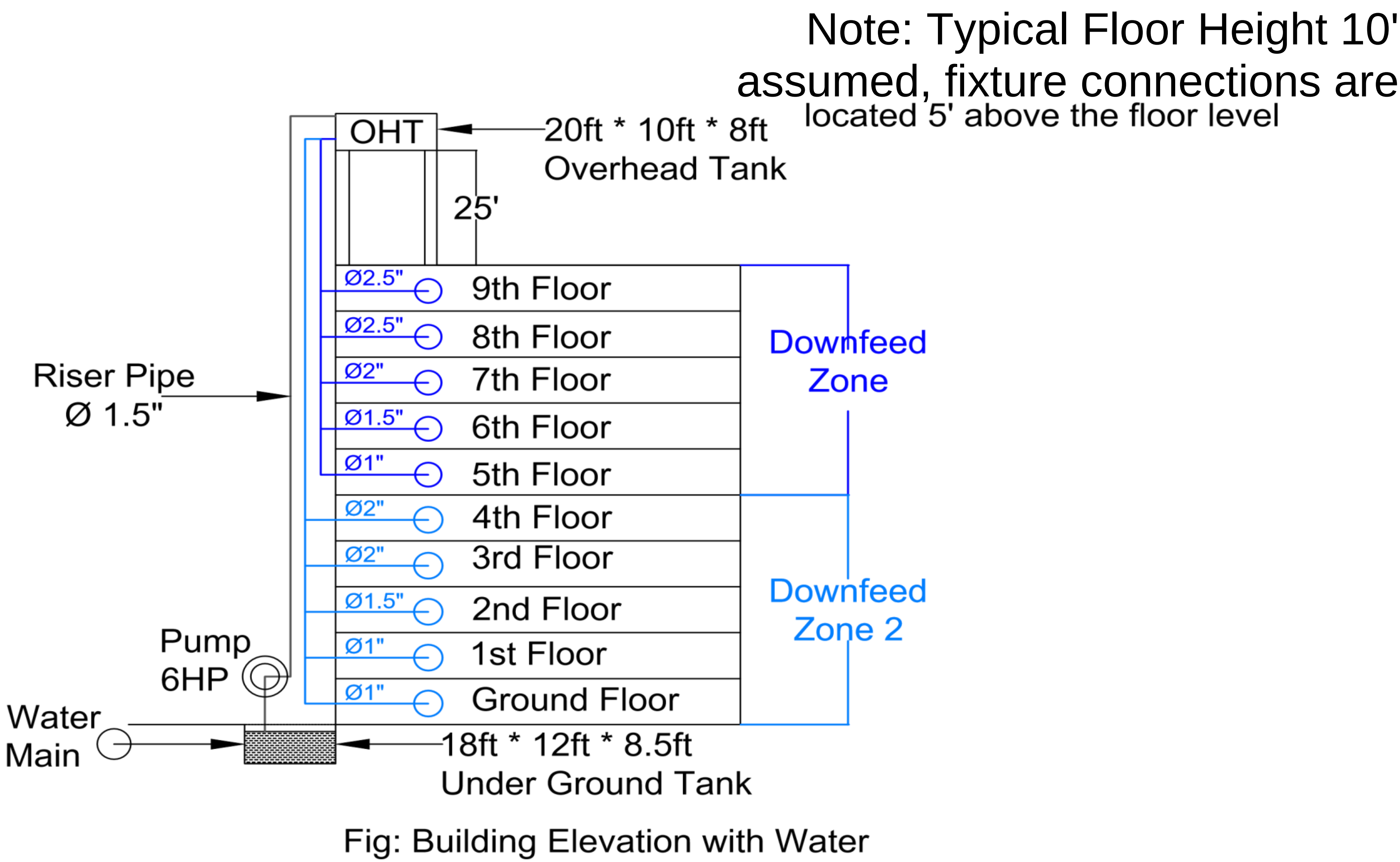


Figure 8. 16 Building elevation with water

Figure : Drainage System of Building

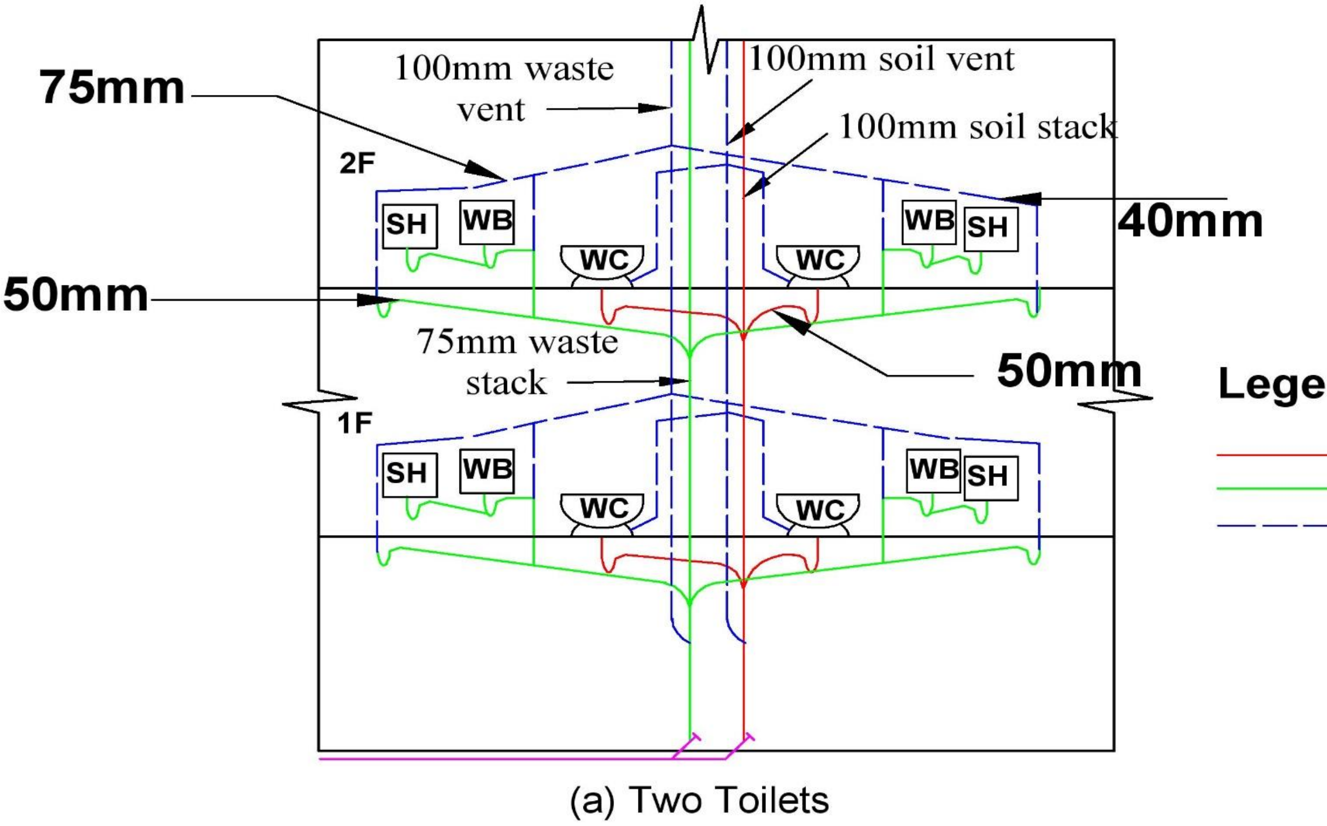
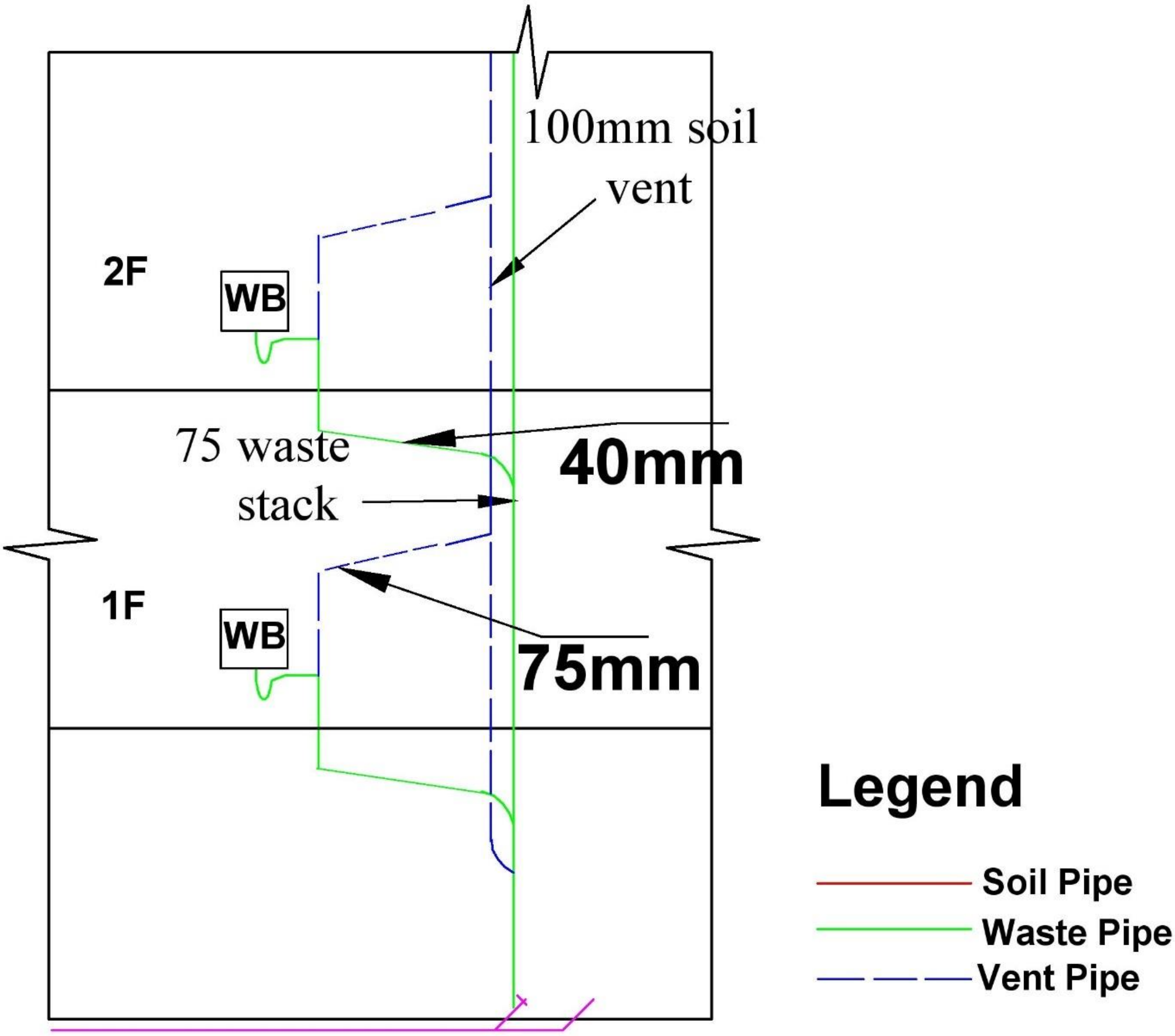
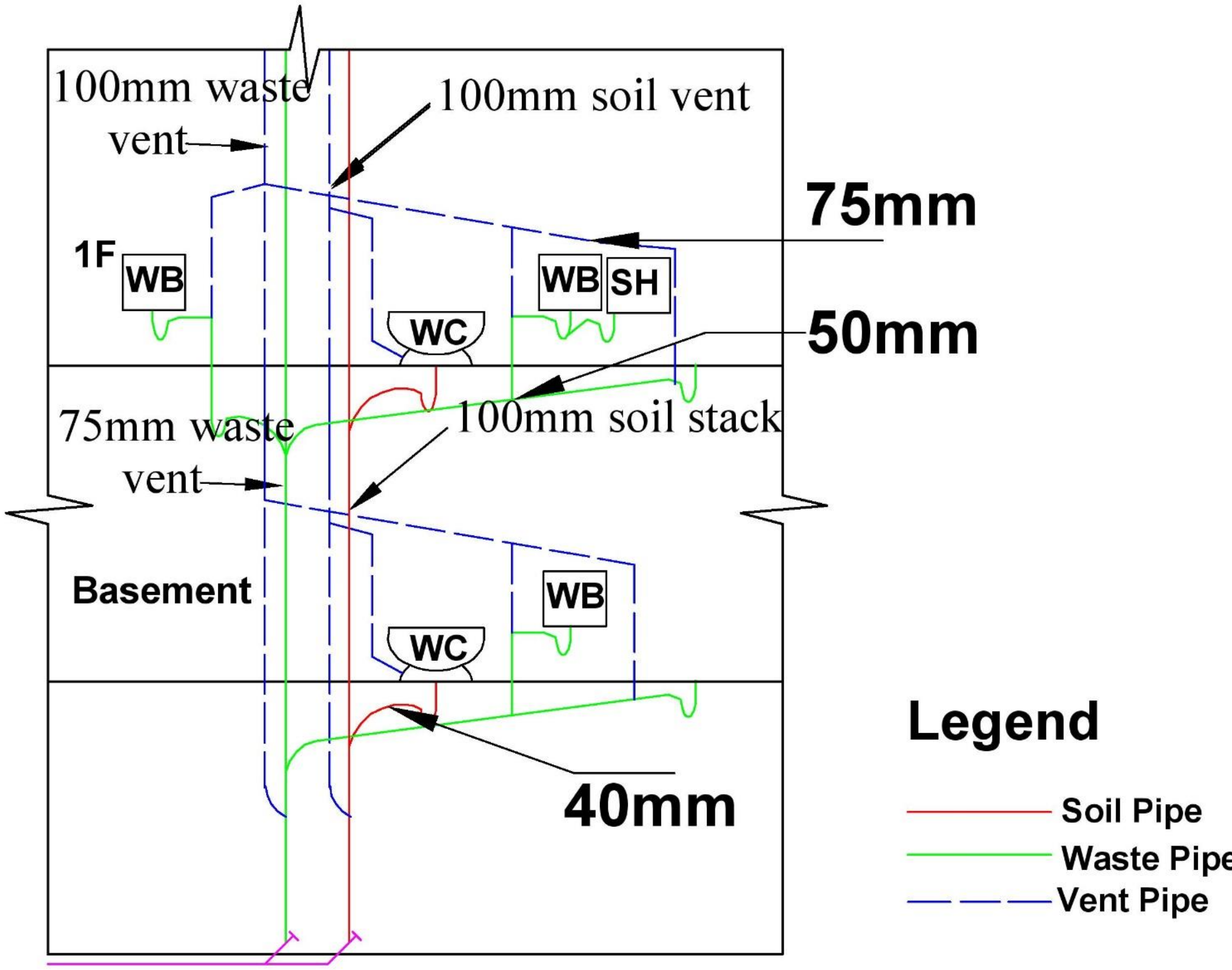


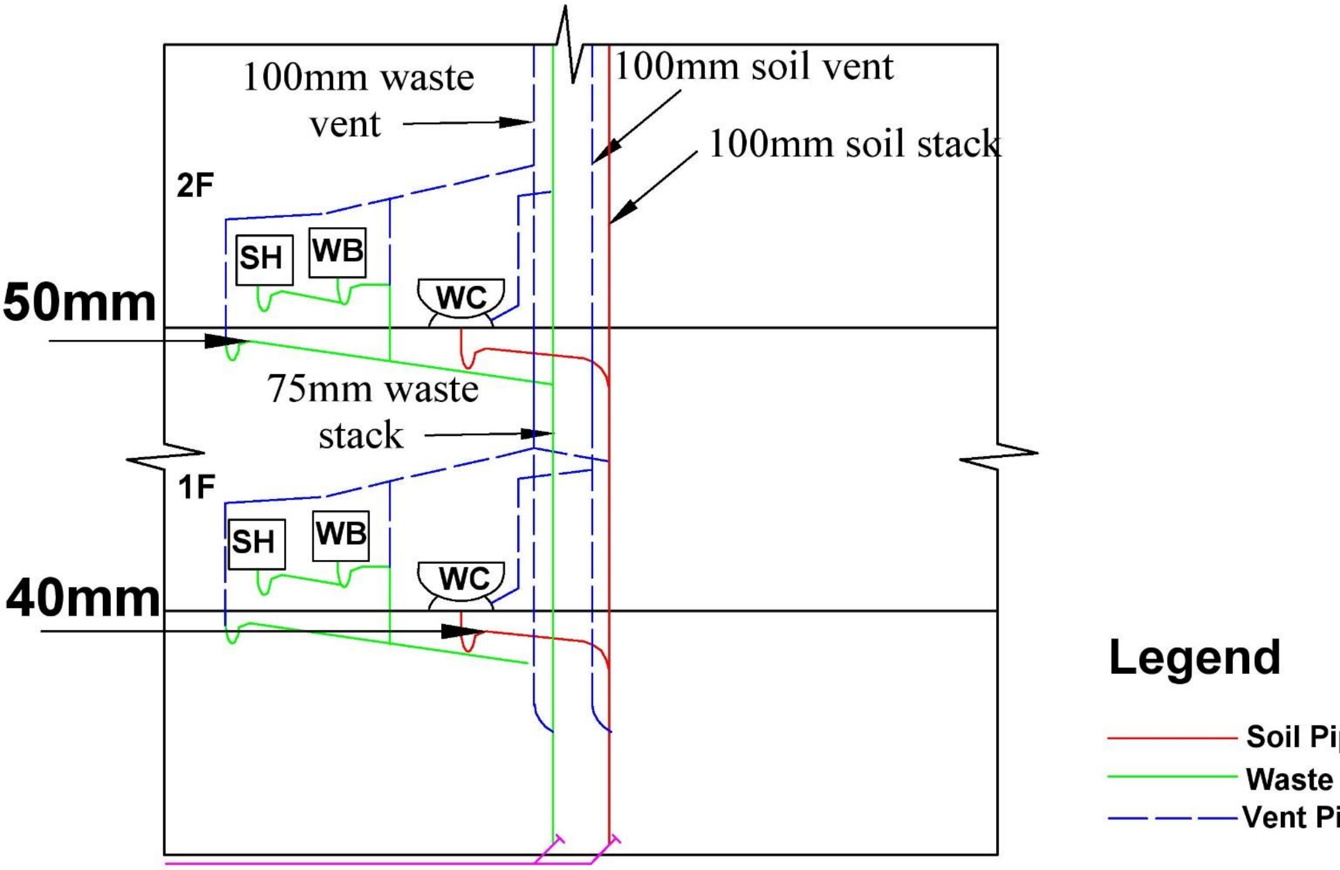
Figure 8. 17 Drainage system of buiding



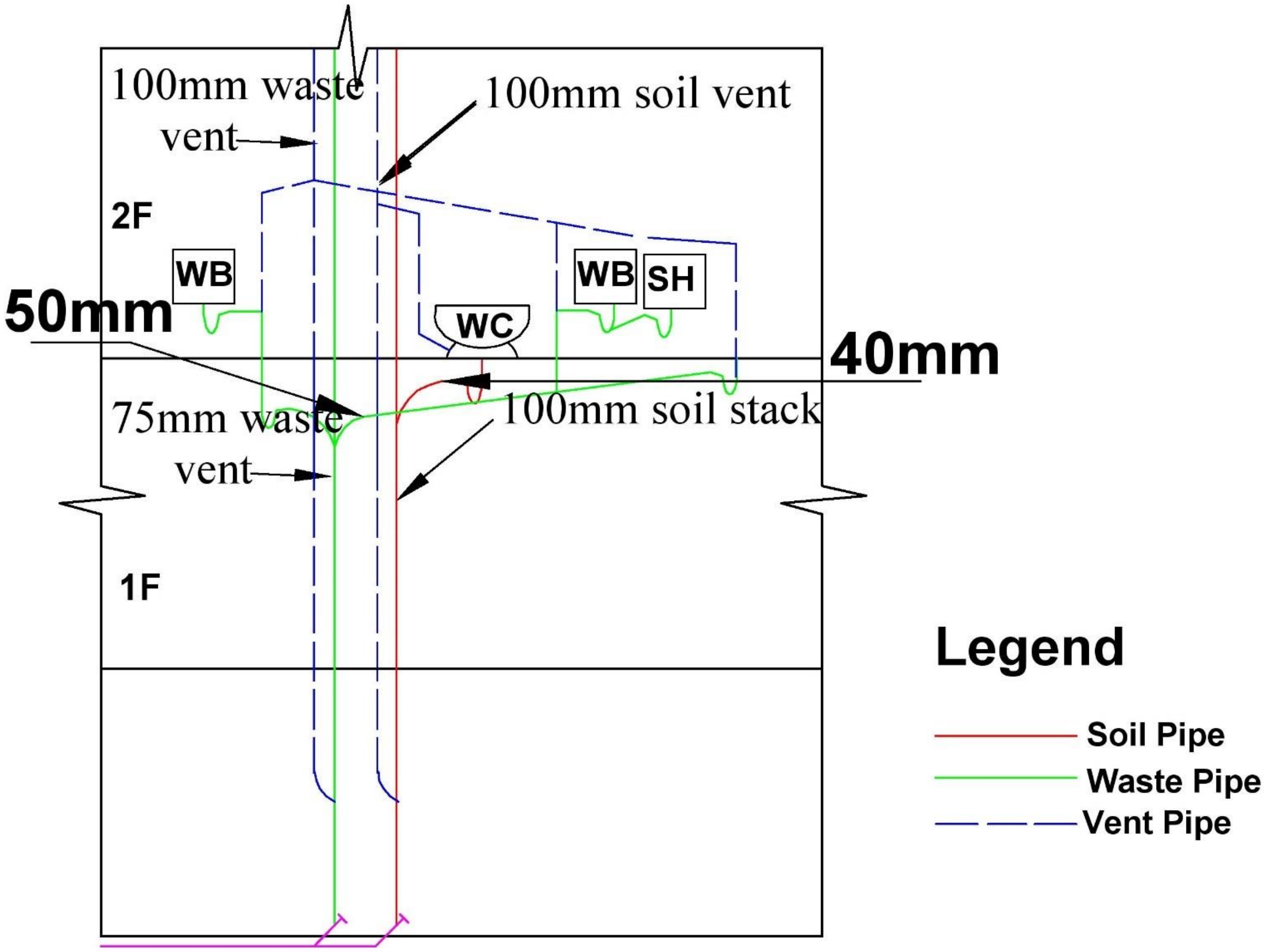
(b)Wash Basin at kitchen



(c) Toilet and Kitchen with Basement



(d) Single Toilet



(e) Toilet and Kitchen(Without Basement)

CHAPTER 11

APPENDIX

Appendix A

Appendix A.1

MIT Soil Classification Table

MIT Classification	Soil Grain Size
Silt/Clay	< 0.06 mm
Fine Sand	0.06 – 0.20 mm
Medium Sand	0.20 – 0.60 mm
Coarse Sand	0.60 – 2.00 mm
Fine Gravel	>2.00 mm

Appendix A.2

Recommended Screening Length

Aquifer Thickness	Recommended Screening Length (% of water bearing depth)
<25'	70
25'-50'	75
>50'	80

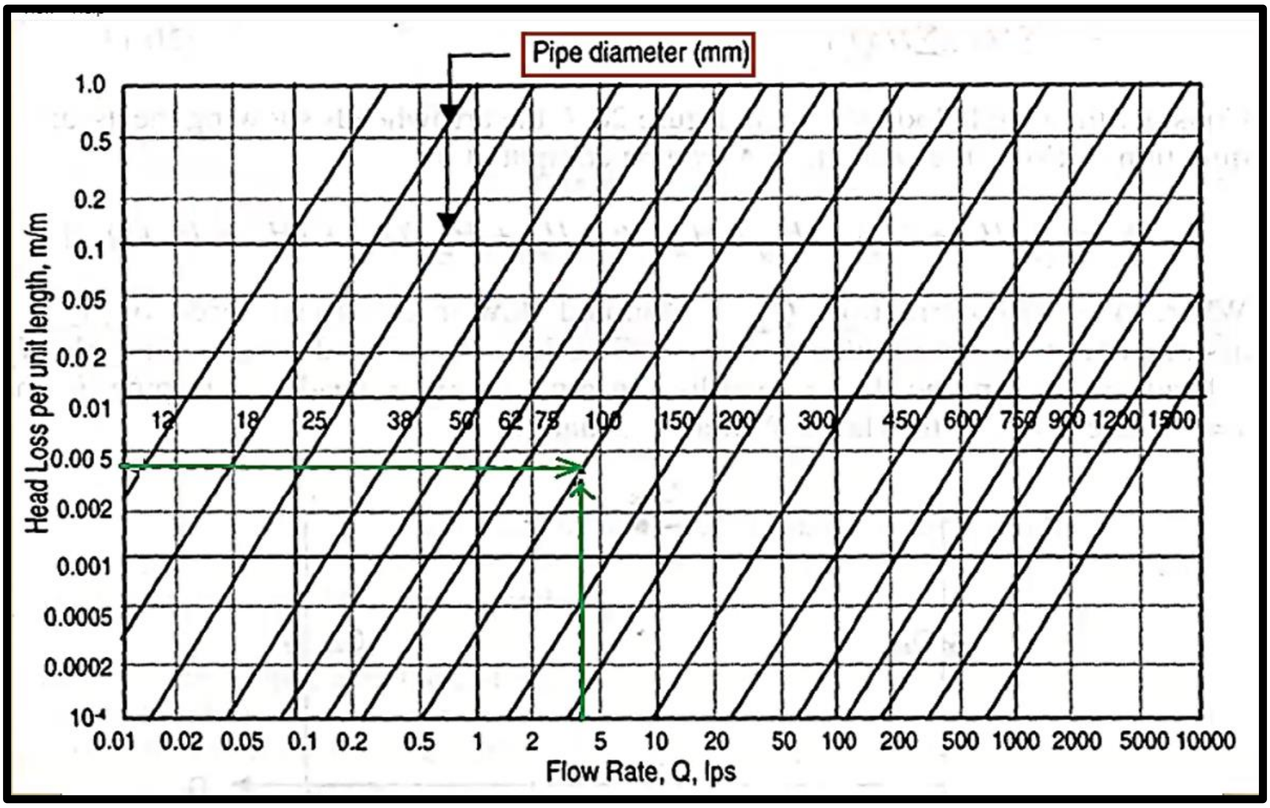
Appendix A.3

Calculation table for gravel pack materials

Depth	Sieve No	Sieve Size (mm)	% Fine	D_{30}	D30(multiplied by 5.72 for gravel pack material)	From graph	% of fine for gravel pack	% retained
300-320 ft	#4	4.75	100	0.22	1.2584	27.17	100	0
	# 8	2.36	100			13.4992	84	16
	# 16	1.18	100			6.7496	23	77
	# 30	0.6	99.2			3.432	6	94
	# 40	0.425	83			2.2695	3	97
	# 50	0.3	51.2			1.695	2	98
	# 100	0.15	12.7			0.8985	1	99
	# 200	0.075	2.8			0.4485	0	100
	Pan		0			0		

Appendix B

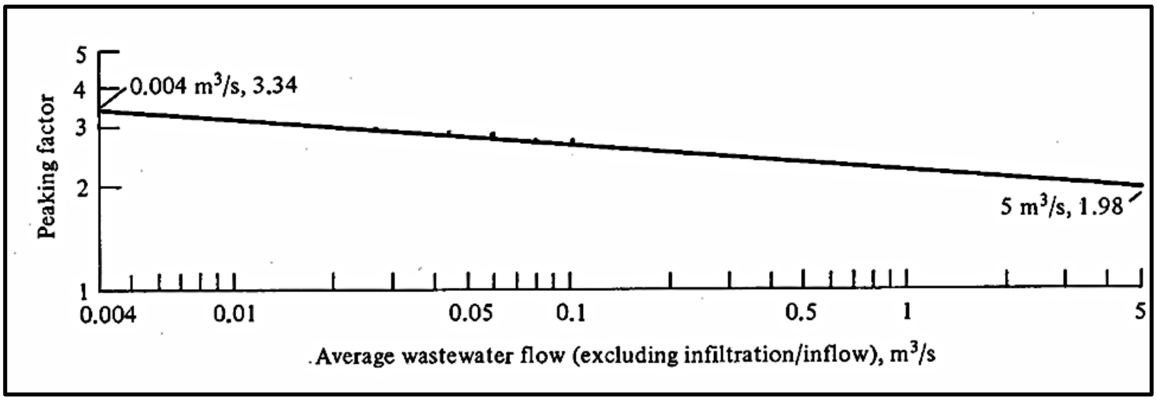
Head loss determination diagram (for roughness co-efficient, C = 100)



Appendix C

Appendix C.1

Peaking Factor for Residential Wastewater Flows



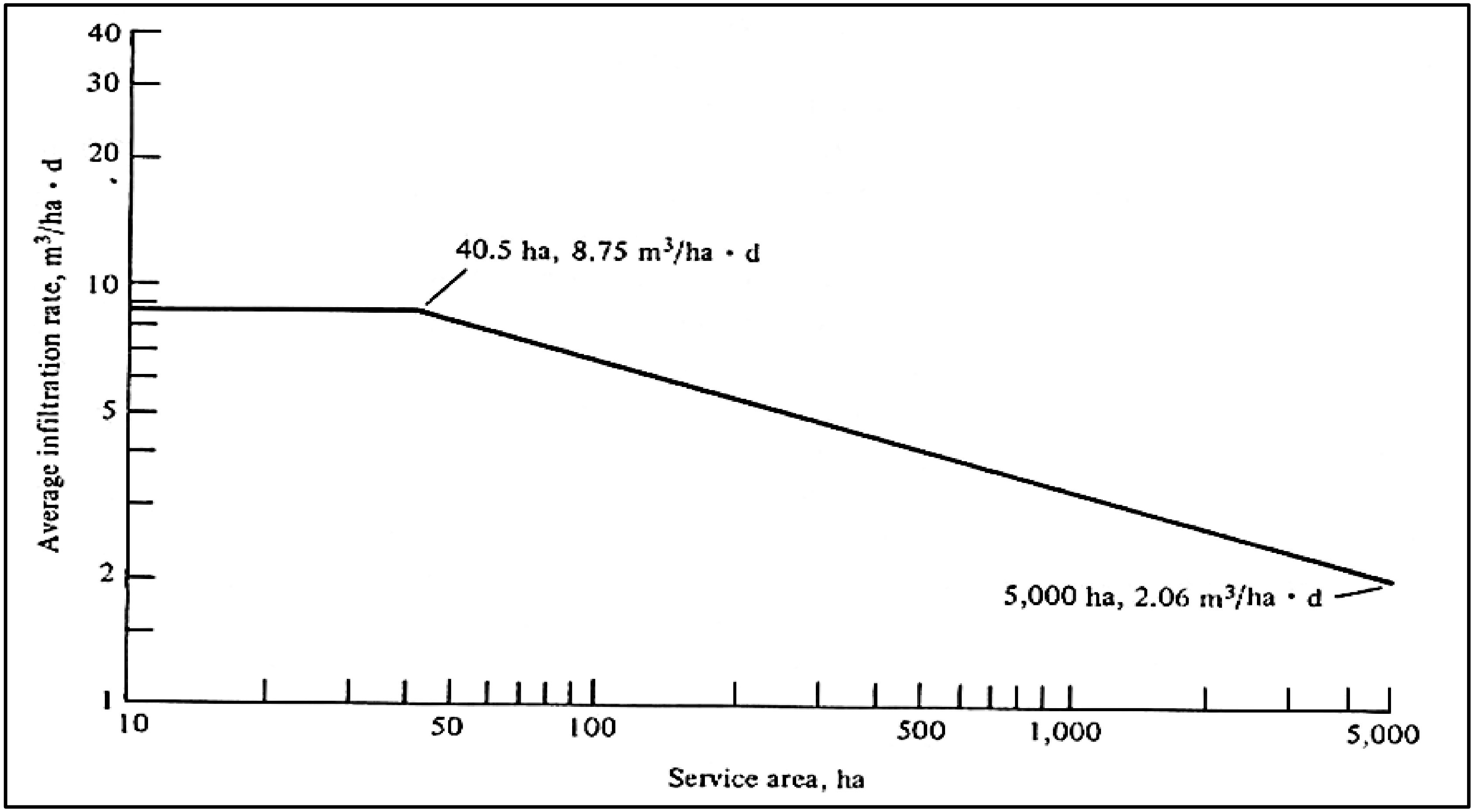
Appendix C.2

Table: Gravity sewer minimum pipe slopes

Size in inch (mm)	Slope	
	n = 0.013	n = 0.015
8 (200)	0.0033	0.0044
10 (250)	0.0025	0.0033
12 (300)	0.0019	0.0026
15 (375)	0.0014	0.0019
18 (450)	0.0011	0.0015
21 (525)	0.0009	0.0012
24 (600)	0.0008	0.0010
27 (675)	0.0007	0.0009
30 (750)	0.0006	0.0008
36 (900)	0.0004	0.0006

Appendix C.3

Average infiltration rate allowance to new users



Appendix D

Appendix – D.1

Table: Fixture Unit for different Types of Fixtures with Inlet Pipe Diameter

Sl No.	Type of Fixture	Fixture Unit (FU) As Load Factor	Minimum Size of Fixture Branch, mm
1	Ablution Tap	1	15
2	Bath tub supply with spout	3	15
3	Shower Stall Domestic	2	15
4	Shower in Group per head	3	15

5	Wash Basin (Domestic Use)	1	15
6	Wash Basin (Public Use)	2	15
7	Wash Basin (Surgical)	2	15
8	Kitchen Sink (Domestic Use)	2	15/20
9	Washing Machine	3	15/20
10	Drinking Fountain	0.5	15

Appendix – D.2

Table: Water Supply Fixture Unit (wsfu) Values for Various Plumbing Fixtures

Fixture or group	Supply Control	wsfu		
		Cold	Hot	Total
Bath group	Flush tank	4.5	3	6
Bath group	Flush valve	6	3	8
Bathtub	Faucet	1.5	1.5	2
Bidet	Faucet	1.5	1.5	2
Combination	Faucet	2	2	3
Kitchen sink	Faucet	1.5	1.5	2

Laundry tray	Faucet	2	2	3
Laundry	Faucet	1.5	1.5	2
Pedestal urinal	Flush valve	10	-	10
Restaurant sink	Faucet	3	3	4
Service sink	Faucet	1.5	1.5	2
Shower head	Mixing Valve	3	3	4
Stall or wall urinal	Flush tank	3	-	3
Stall or wall urinal	Flush valve	5	-	5
Water closet	Flush tank	5	-	5
Water closet	Flush valve	10	-	10

** Fixture with both cold and hot water supplies, the weight for maximum separate demands may be considered 75% of total wsfu.*

Appendix – D.3

Table- 8.5.1(a): Water Consumption for Domestic Purposes (Cities/Big District Towns) [In Residential Buildings]

Cat	Socio-economic group, Type of Building & Other Facilities	Water Consumption	
A	*Big Cities / City Corporation Area / Big District Towns (Population > 0.5 million)*	Full Facility (lpcd)	Restricted Facility (lpcd)
a	High income group:		
a1	Single Family Dwelling with Garden & Car washing	260	200
a2	Big Multi -Family Apartment /Flat (> 2500 sft)	200	150
b	Middle income group:		
b1	Officer's Qrt./Colony & moderate Apartment (< 2000 sft)	180	135
b2	Small building/Staff Qrt. & small Apartment (< 1500 sft)	---	120
c	Low income group:		
c1	Junior staff Qrt. /flat (< 1000 sft) & temporary shade	---	80
c2	Stand post connection in the fringe area	---	65
c3	Common yard (stand post) connection in the fringe area	---	50
c4	Slum dwellers collection from road side public stand post	---	40

Table- 8.5.1(b): Water Requirement for Domestic Purposes (District Towns/Upazilas/Urban growth Centres) [In Residential Buildings]

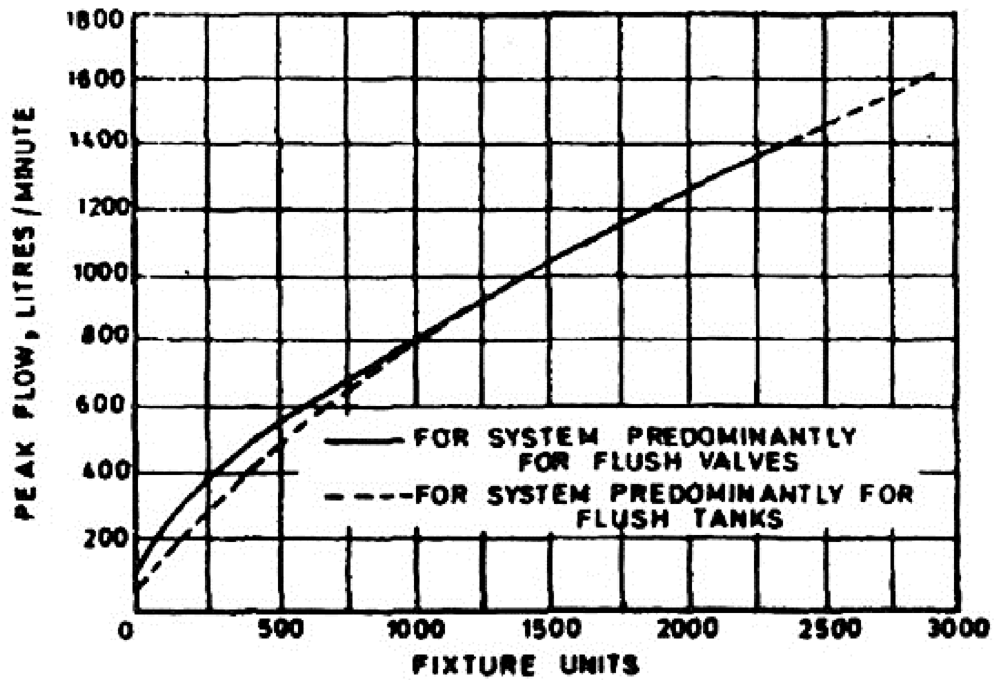
Cat	Socio-economic group, Type of Building & Other Facilities	Water Consumption	
B	*Small District Towns/ Upajilas & Urban Growth Centre (Population > 0.1 million)*	Full Facility (lpcd)	Restricted Facility (lpcd)
a	Middle in come group:		
a1	Single Family Dwelling with Garden	---	150
a2	Officer's Qrt./Colony & moderate Apartment (< 2000 sft)	---	135
a3	Small building/Staff Qrt. & small Apartment (< 1500 sft)	---	120
b	Low income group:		
b1	Junior staff Qrt. /flat (< 1000 sft) & temporary shade	---	80
b2	Private Stand post connection in the fringe area	---	65
b3	Common yard (stand post) connection in the fringe area	---	50
b4	Slum dwellers collection from road side public stand post	---	40

Table- 8.5.1(c): Water Requirement for Domestic Purposes (Village Areas and Small Communities) [In Residential Buildings]

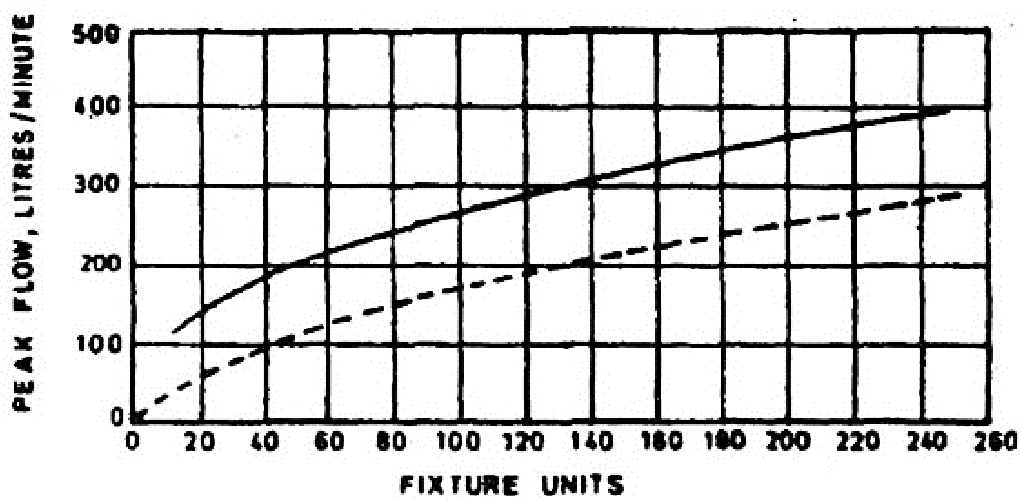
Cat	Socio-economic group, Type of Building & Other Facilities	Water Consumption	
C	Village Areas /Small Community from hand tubewell, dugwells , ponds & rivers (Non piped water supply system)	Full Facility (lpcd)	Restricted Facility (lpcd)

e 8.5.1(d): Domestic Water Requirements for various others Occupancies and Facility Groups

Class of Occupancy	Occupancy Groups	For Full [a] Facilities (lpcd)	For Restricted Facilities (lpcd)
Occupancy A: Residential	A1: Mess, Hostels, or Boarding House A2: Minimum Standard Housing A3: Hotels or Lodging House (Per bed) A4: Hotel (up to 4 Star) A5: Hotels (up to 5 Star) A6: Gardening and Sprinkling A7: Car Washing	135 - 300 180 320	70 70 135 — —
Occupancy B: Educational	B1: Educational Facilities B2: Preschool Facilities	70 50	45 35
Occupancy C: Institutional	C1: Institution for Children's Care C2: Custodian Institution for Capable C3: Custodian Institution for Incapable C4: Penal and Mental Institution	180 180 120 120	100 100 70 70
Occupancy D: Health Care	D1: Normal Medical Facilities/ Small Hospitals D2: Big Hospitals (Over 100 beds) D3: Emergency Medical Facilities D4: Nurses & Medical Quarters	340 450 300 250	225 250 135 135
Occupancy E: Assembly	E1: Large Assembly with Fixed Seats (per seat) E2: Small Assembly with Fixed Seats (per seat) E3: Large Assembly without Fixed Seats [b] E4: Small Assembly without Fixed Seats E5: Sports Facilities	90 90 8 8 8	45 45 5 5 5
Occupancy F: Business and Mercantile	F1: Offices F2: Small Shops and Markets F3: Large Shops and Markets F4: Garage and Petrol Stations F5: Essential Services F6: Restaurant	45 45 45 70 70 70	30 30 30 45 45 50
Occupancy G: Industrial	G1: Low Hazard Industries G2: Moderate Hazards Industries	40 40	25 25
Occupancy H: Storage	H1: Low Fire Risk Storage H2: Moderate Fire Risk Storage	10 10	6 6
Occupancy J:	J1: Explosive Hazard Building	8	5



1A Estimate Curves



——— For system predominantly for flush valves

- - - - - For system predominantly for flush tanks

1B Enlarged Scale Curves

Appendix D.5

Table: Probable Simultaneous Demand

No. of Fixture Units	System with Flush Tanks Demand (Based on Fixture Units)		System with Flush Valves Demand (After Hunter)	
	Unit Rate of Flow[1])	Flow in Litre per Minute	Unit Rate of Flow1)	Flow in Litre per Minute
(1)	(2)	(3)	(4)	(5)
20	2.0	56.6	4.7	133.1
40	3.3	93.4	6.3	178.4
60	4.3	121.8	7.4	209.5
80	5.1	144.4	8.3	235.0
100	5.7	161.4	9.1	257.7
120	6.4	181.2	9.8	277.5
140	7.1	201.0	10.4	294.5
160	7.6	215.2	11.0	311.5
180	8.2	232.2	11.6	328.5
200	8.6	243.5	12.3	348.3
220	9.2	260.5	12.7	359.6
240	9.6	271.8	13.1	370.9
300	11.4	322.8	14.7	416.2
400	14.0	396.4	17.0	481.4
500	16.7	472.9	19.0	538.0
600	19.4	549.3	21.1	597.5
700	21.4	606.0	23.0	651.3
800	24.1	682.4	24.5	693.7
900	26.1	739.0	26.1	739.0
1000	28.1	795.7	28.1	795.7

[1] Unit rate of flow= Effective fixture units.

Table- 8.5.1(a): Water Consumption for Domestic Purposes (Cities/Big District Towns) [In Residential Buildings]

Cat	Socio-economic group, Type of Building & Other Facilities	Water Consumption	
A	*Big Cities / City Corporation Area / Big District Towns (Population > 0.5 million)*	Full Facility (lpcd)	Restricted Facility (lpcd)
a	High income group:		
a1	Single Family Dwelling with Garden & Car washing	260	200
a2	Big Multi -Family Apartment /Flat (> 2500 sft)	200	150
b	Middle income group:		
b1	Officer's Qrt./Colony & moderate Apartment (< 2000 sft)	180	135
b2	Small building/Staff Qrt. & small Apartment (< 1500 sft)	---	120
c	Low income group:		
c1	Junior staff Qrt. /flat (< 1000 sft) & temporary shade	---	80
c2	Stand post connection in the fringe area	---	65
c3	Common yard (stand post) connection in the fringe area	---	50
c4	Slum dwellers collection from road side public stand post	---	40

Table- 8.5.1(b): Water Requirement for Domestic Purposes (District Towns/Upazilas/Urban growth Centres) [In Residential Buildings]

Cat	Socio-economic group, Type of Building & Other Facilities	Water Consumption	
B	*Small District Towns/ Upajilas & Urban Growth Centre (Population > 0.1 million)*	Full Facility (lpcd)	Restricted Facility (lpcd)
a	Middle in come group:		
a1	Single Family Dwelling with Garden	---	150
a2	Officer's Qrt./Colony & moderate Apartment (< 2000 sft)	---	135
a3	Small building/Staff Qrt. & small Apartment (< 1500 sft)	---	120
b	Low income group:		
b1	Junior staff Qrt. /flat (< 1000 sft) & temporary shade	---	80
b2	Private Stand post connection in the fringe area	---	65
b3	Common yard (stand post) connection in the fringe area	---	50
b4	Slum dwellers collection from road side public stand post	---	40

Table- 8.5.1(c): Water Requirement for Domestic Purposes (Village Areas and Small Communities) [In Residential Buildings]

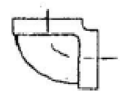
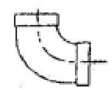
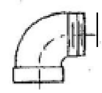
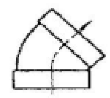
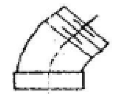
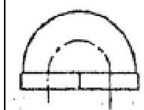
Cat	Socio-economic group, Type of Building & Other Facilities	Water Consumption	
C	Village Areas /Small Community from hand tubewell,	Full Facility	Restricted Facility

Table 8.5.1(d): Domestic Water Requirements for various others Occupancies and Facility Groups

Class of Occupancy	Occupancy Groups	For Full [a] Facilities (lpcd)	For Restricted Facilities (lpcd)
Occupancy A: Residential	A1: Mess, Hostels, or Boarding House A2: Minimum Standard Housing A3: Hotels or Lodging House (Per bed) A4: Hotel (up to 4 Star) A5: Hotels (up to 5 Star) A6: Gardening and Sprinkling A7: Car Washing	135 - 300 180 320	70 70 135 --- ---
Occupancy B: Educational	B1: Educational Facilities B2: Preschool Facilities	70 50	45 35
Occupancy C: Institutional	C1: Institution for Children's Care C2: Custodian Institution for Capable C3: Custodian Institution for Incapable C4: Penal and Mental Institution	180 180 120 120	100 100 70 70
Occupancy D: Health Care	D1: Normal Medical Facilities/ Small Hospitals D2: Big Hospitals (Over 100 beds) D3: Emergency Medical Facilities D4: Nurses & Medical Quarters	340 450 300 250	225 250 135 135
Occupancy E: Assembly	E1: Large Assembly with Fixed Seats (per seat) E2: Small Assembly with Fixed Seats (per seat) E3: Large Assembly without Fixed Seats [b] E4: Small Assembly without Fixed Seats E5: Sports Facilities	90 90 8 8 8	45 45 5 5 5
Occupancy F: Business and Mercantile	F1: Offices F2: Small Shops and Markets F3: Large Shops and Markets F4: Garage and Petrol Stations F5: Essential Services F6: Restaurant	45 45 45 70 70 70	30 30 30 45 45 50
Occupancy G: Industrial	G1: Low Hazard Industries G2: Moderate Hazards Industries	40 40	25 25
Occupancy H: Storage	H1: Low Fire Risk Storage H2: Moderate Fire Risk Storage	10 10	6 6
Occupancy J: Hazardous	J1: Explosive Hazard Building J2: Chemical Hazard Building	8 8	5 5
Occupancy K[c]	K1: Private Garage & Special Structure	8	5

TABLE- P2(a): FITTING LOSSES IN EQUIVALENT METRE OF PIPE

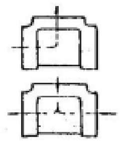
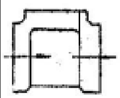
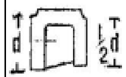
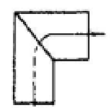
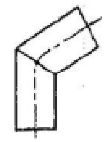
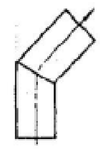
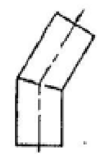
Screwed, Welded, Flanged, Flared and Brazed Connections

Nominal Pipe OR TUBE SIZE (mm)	SMOOTH BEND ELBOWS					
	90° Std*	90° Long Rad.**	90° Street*	45° Std*	45° Street*	180° Std*
						
10	0.43	0.27	0.70	0.21	0.34	0.70
13	0.49	0.31	0.76	0.24	0.40	0.76
19	0.61	0.43	0.98	0.27	0.49	0.98
25	0.79	0.52	1.25	0.40	0.64	1.25
32	1.01	0.70	1.71	0.52	0.92	1.71
38	1.22	0.79	1.92	0.64	1.04	1.92
50	1.53	1.01	2.50	0.79	1.37	2.50
63	1.83	1.25	3.05	0.98	1.59	3.05
75	2.29	1.53	3.66	1.22	1.95	3.66
88	2.75	1.80	4.58	1.43	2.23	4.58
100	3.05	2.04	5.19	1.59	2.59	5.19
125	3.97	2.50	6.41	1.98	3.36	6.41
150	4.88	3.05	7.63	2.41	3.97	7.63
200	6.10	3.97	-	3.05	-	10.07
250	7.63	4.88	-	3.97	-	12.81
300	9.15	5.80	-	4.88	-	15.25
350	10.37	7.02	-	5.49	-	16.78
400	11.59	7.93	-	6.10	-	18.91
450	12.81	8.85	-	7.02	-	21.35
500	15.25	10.07	-	7.93	-	24.71
600	18.30	12.20	-	9.15	-	28.67

** = R/D approximately equal to 1, ** = R/D approximately equal to 1.5*

TABLE- P2(b): FITTING LOSSES IN EQUIVALENT METRE OF PIPE

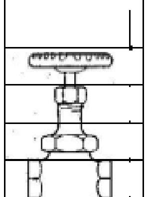
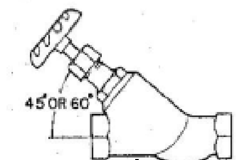
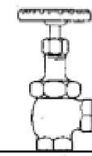
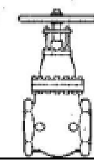
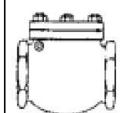
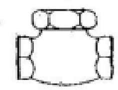
Screwed, Welded, Flanged, Flared and Brazed Connections

Nominal Pipe OR TUBE SIZE (mm)	SMOOTH BEND TEES				METRE ELBOWS			
	Flow-Thru	Straight-Thru Flow			90° Ell	60° Ell	45° Ell	30° Ell
	Branch	No Reduction	Reduced ¼	Reduced ½				
								
10	0.82	0.27	0.37	0.43	0.82	0.34	0.18	0.09
13	0.92	0.31	0.43	0.49	0.92	0.40	0.21	0.12
19	1.22	0.43	0.58	0.61	1.22	0.49	0.27	0.15
25	1.53	0.52	0.70	0.79	1.53	0.64	0.31	0.21
32	2.14	0.70	0.95	1.01	2.14	0.92	0.46	0.27
38	2.44	0.79	1.13	1.22	2.44	1.04	0.55	0.34
50	3.05	1.01	1.43	1.53	3.05	1.37	0.70	0.40
63	3.66	1.25	1.71	1.83	3.66	1.59	0.85	0.52
75	4.58	1.53	2.14	2.29	4.58	1.95	0.98	0.61
88	5.49	1.80	2.44	2.75	5.49	2.23	1.22	0.73
100	6.41	2.04	2.75	3.05	6.41	2.59	1.37	0.82
125	7.63	2.50	3.66	3.97	7.63	3.36	1.83	0.98
150	9.15	3.05	4.27	4.88	9.15	3.97	2.14	1.22
200	12.20	3.97	5.49	6.10	12.20	5.19	2.75	1.56
250	15.25	4.88	7.02	7.63	15.25	6.41	3.66	2.20
300	18.30	5.80	7.93	9.15	18.30	7.63	3.97	2.44
350	20.74	7.02	9.15	10.37	20.74	8.85	4.58	2.75
400	23.79	7.93	10.68	11.59	23.79	9.46	5.19	3.05
450	25.93	8.85	12.20	12.81	25.93	11.29	5.80	3.36
500	30.50	10.07	13.42	15.25	30.50	12.51	6.71	3.97
600	35.08	12.20	15.25	18.30	35.08	14.95	7.63	4.88

** = R/D approximately equal to 1, ** = R/D approximately equal to 1.5*

TABLE- P2(c): VALVE LOSSES IN EQUIVALENT METRE OF PIPE

Screwed, Welded, Flanged and Flared Connections

Nominal	GLOBE	60° – Y	45° – Y	ANGLE*	GATE	SWING CHECK**	LIFT CHECK
Pipe OR TUBE SIZE (mm)							
10	5.19	2.44	1.83	1.83	0.18	1.53	
13	5.49	2.75	2.14	2.14	0.21	1.83	
19	6.71	3.36	2.75	2.75	0.27	2.44	Globe &
25	8.85	4.58	3.66	3.66	0.31	3.05	Lift
32	11.59	6.10	4.58	4.58	0.46	4.27	Vertical
38	13.12	7.32	5.49	5.49	0.55	4.88	Lift
50	16.78	9.15	7.32	7.32	0.70	6.10	Same as
63	21.05	10.68	8.85	8.85	0.85	7.63	Globe
75	25.62	13.12	10.68	10.68	0.98	9.15	Valve**
88	30.50	15.25	12.51	12.51	1.22	10.68	
100	36.60	17.69	14.34	14.34	1.37	12.20	
125	42.70	21.66	17.69	17.69	1.83	15.25	
150	51.85	26.84	21.35	21.35	2.14	18.30	
200	67.10	35.08	25.93	25.93	2.75	24.40	
250	85.40	44.23	32.03	32.03	3.66	30.50	Angle
300	97.60	50.33	39.65	39.65	3.97	36.60	Lift
350	109.8	56.43	41.18	41.18	4.58	41.18	Same as
400	125.05	64.05	54.90	54.90	5.19	45.75	Angle
450	140.3	73.20	61.00	61.00	5.80	50.33	Valve
500	158.6	83.88	71.68	71.68	6.71	61/00	
600	186.05	97.60	80.83	80.83	7.63	73.20	

* = *These loses do not apply to valves with needle point type seat,*

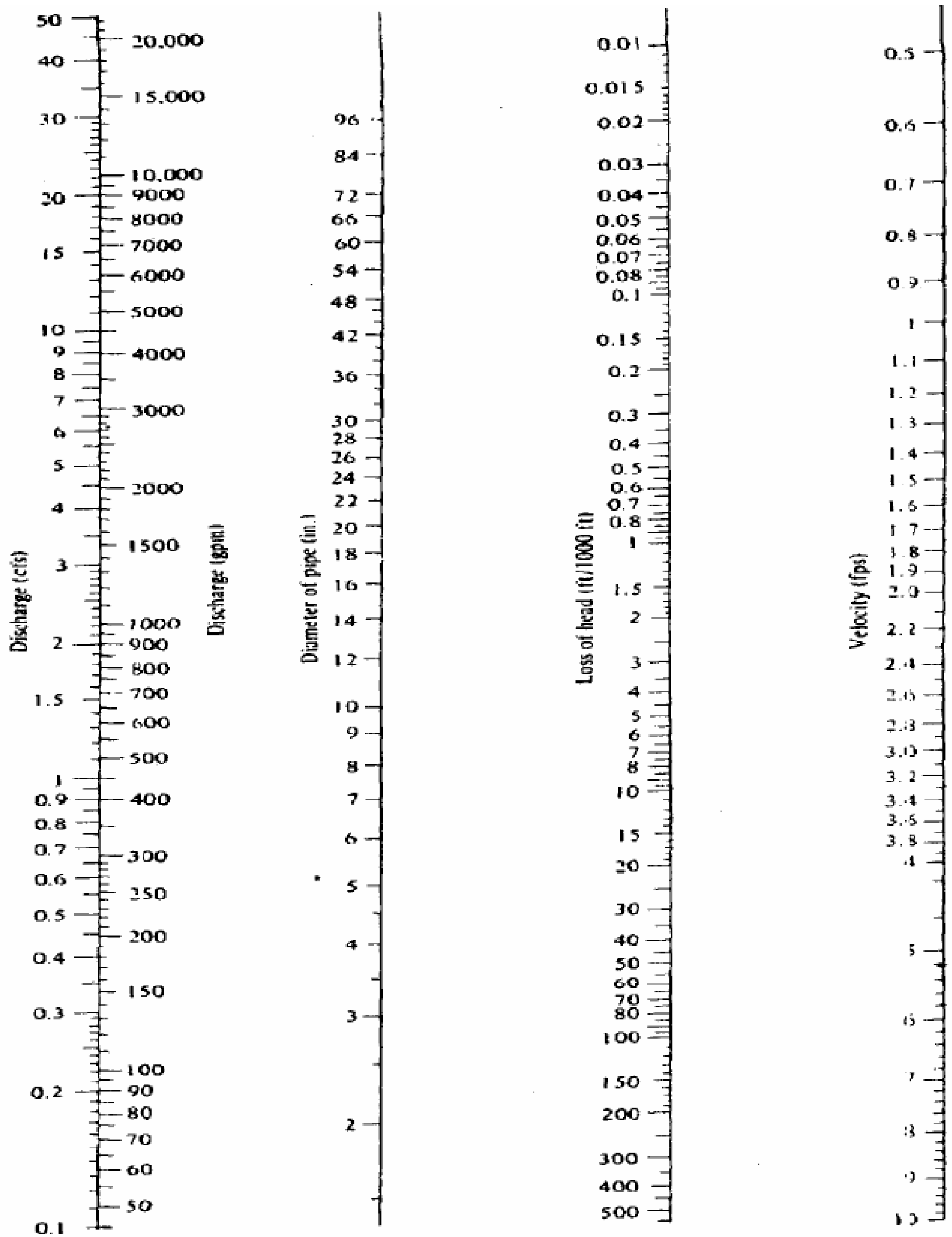
* * = *Losses also apply to the in-line, ball type check valve.*

Appendix-D.8

Table 8.5.6: Water Supply System Design Requirements

Fixture	Supply Control	Minimum Size of Supply Pipe (mm)	Required Flow Pressure (kPa)	Required Flow Rate (lpm)
Bathroom group	Flush tank	-	55	--
Bathroom group	Flushometer valve	-	55	--
Bathtub	Faucet	13	55	15.1
Clothes washer		13	55	--
Combination fixture	Faucet	13	55	--
Dishwashing machine		13	55	10.4
Drinking fountain	Faucet	13	55	2.8
Kitchen sink	Faucet	13	55	9.5
Laundry tray	Faucet	13	55	15.1
Wash basin	Faucet	19	55	--
Pedestal urinal	Flush tank	13	55	56.8
Pedestal urinal	Flushometer valve	19	100	56.8
Restaurant sink	Faucet	19	55	--
Service sink	Faucet	13	55	11.4
Shower head	Mixing valve	13	55	11.4
Water closet	Flush tank	19	55	11.4
Water closet	Flushometer tank	19	55	6.1
Water closet	Flushometer valve	25	100	132
For fixture not listed here but maximum supply size requirement		13 19 25	55 55 100	-- -- --

Note: 1 psi = 6.895 kPa (1 kPa = 0.145 psi), 1 gallon = 3.785 liter


Discharge (cfs)
50
40
30
20
15
10
9
8
7
6
5
4
3
2
1.5
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Discharge (gpm)
20,000
15,000
10,000
9000
8000
7000
6000
5000
4000
3000
2000
1500
1000
900
800
700
600
500
400
300
250
200
150
100
90
80
70
60
50
Diameter of pipe (in.)
96
84
72
66
60
54
48
42
36
30
28
26
24
22
20
18
16
14
12
10
9
8
7
6
5
4
3
2
Loss of head (ft/1000 ft)
0.01
0.015
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.1
0.15
0.2
0.3
0.4
0.5
0.6
0.7
0.8
1
1.5
2
3
4
5
6
7
8
10
15
20
30
40
50
60
70
80
100
150
200
300
400
500
Velocity (fps)
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4
5
6
7
8
9
10

Appendix – D.10

Table 4.4.1: Fire Protection Flow Requirements

Building Type	Sprinkler System (l/min.)*	Standpipe and hose System (l/min.)*	Duration** (minute, min.)
Light hazard- I	1000	1000	30
Light hazard- II	1900	1900	50
Ordinary hazard- I	2650	1900	75
Ordinary hazard - II	3200	1900	75
Ordinary hazard - III	4800	1900	75

Notes:
Values will be for one riser serving floor area of 1000 m^2.

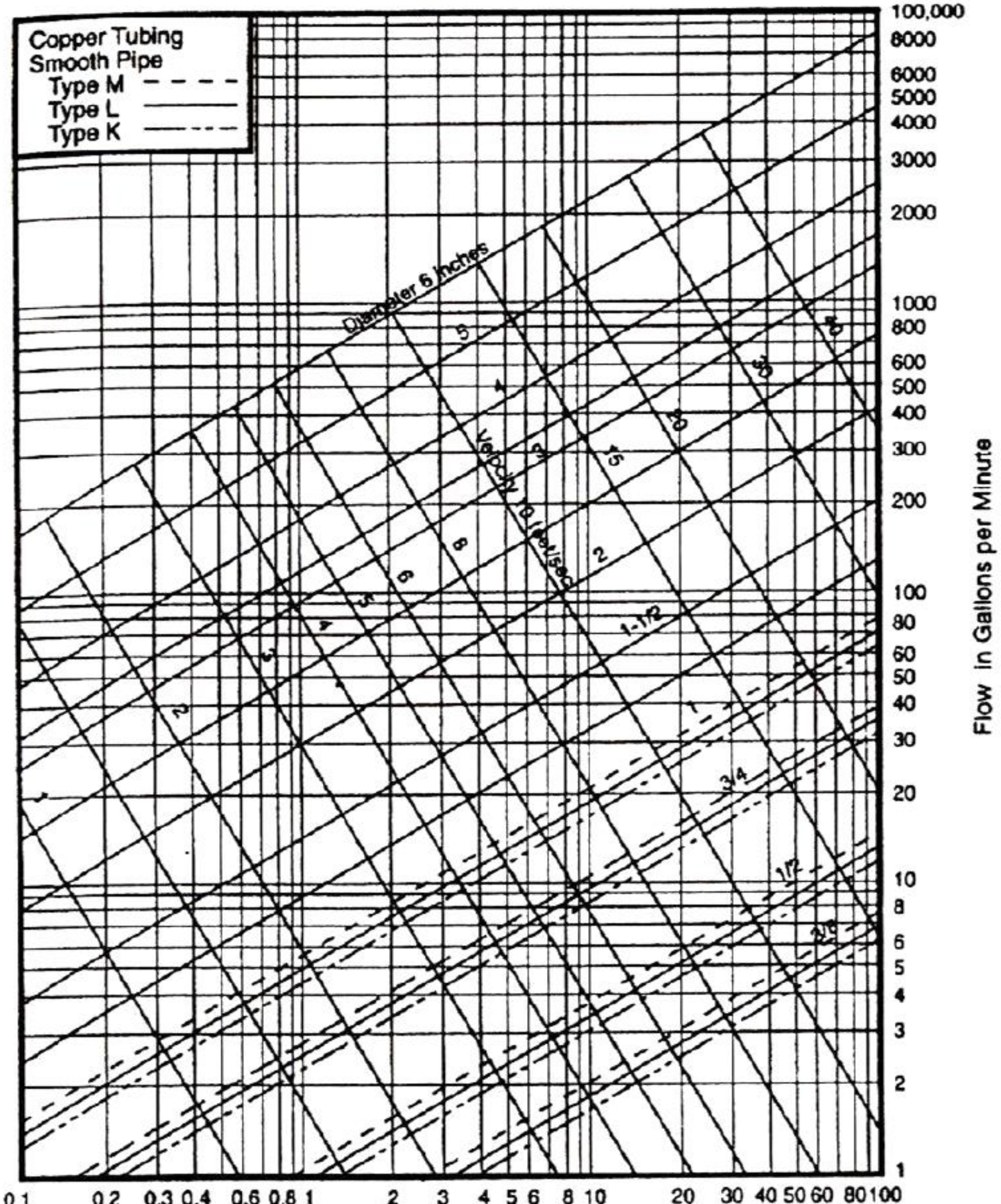
* *These durations shall be for a building up to the height of 51 m. For greater height of 51-102 m and above 102 m, the duration will be 1.25 times and 1.5 times of the specified values respectively.

Light hazard - I :Occupancy groups, A1, A2, A4
Light hazard - II : Occupancy groups, A3, A6, A7, A8, B, C, D, E2, E4, E7, F1 & F2

Ordinary hazard – I : Occupancy groups, E1, E3, E5, F3, F4, F5, F6, F7, G1 & G4

Ordinary hazard- II :Occupancy groups, G2 & H1
Ordinary hazard- III :Occupancy groups, G3 & H2

Extra hazard : Occupancy group, J - pressure and flow requirement for this group shall be determined by
Fire Department but shall not be less than required value for Ordinary hazard-III


Copper Tubing
Smooth Pipe
Type M
Type L
Type K
Diameter 6 inches
5
4
3
2
1-1/2
1
3/4
1/2
3/8
Velocity 10 feet/sec
8
6
5
4
3
2
15
20
30
40
Flow in Gallons per Minute
100,000
8000
6000
5000
4000
3000
2000
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
0.1 0.2 0.3 0.4 0.6 0.8 1 2 3 4 5 6 8 10 20 30 40 50 60 80 100

Appendix D.12

Table 8.6.14: Fixture Units for Different Sanitary Appliances or Groups

Type of Fixture	Fixture Unit Value as Load Factors
One-bathroom group consisting of water closet, wash basin and bath tub or shower stall:	
a) Flush Tank water closet	3
b) Flush-valve water closet	6
Bathtub*	2
Bidet	2
Combination sink and tray (drain board)	2
Drinking fountain	0.5
Floor traps†	1
Kitchen sink, domestic	2
Wash basin, ordinary‡	1
Wash basin, surgeon's	2
Shower stall, domestic	2
Shower (group) per head	3
Urinal, wall hung	4
Urinal, stall	4
Water closet, tank operated	3
Water closet, valve operated	6

* A shower head over a bath tub does not increase the fixture unit value.

† Size of floor trap should be determined by the area of surface water to be drained.

‡ Wash basin with 32 mm and 40 mm trap have the same load value

Table 8.6.16 – Maximum Number of Fixture Units that can be connected to Branches and Stacks

Diameter of Pipe (mm)	Maximum Number of Fixture Units that can be connected			
	Any Horizontal Fixture Branch	One Stack of 3 Stories in Height or 3 Intervals	More than 3 Stories in Height	
			Total for Stack	Total at One story Branch Interval
30	1	2	2	1
40	3	4	8	2
50	6	10	24	6
65	12	20	42	9
75	20	30	60	16
100	160	240	500	90
125	360	540	1100	200
150	620	960	1900	350
200	1400	2200	3600	600
250	2500	3800	5600	1000
300	3900	6000	8400	1500
375	7000	b	b	b

[a] Does not include branches of the building sewer.

[b] Sizing load based on design criteria

TABLE 8.6. 21: Size and Length of Vent Stacks and Stack Vents

Soil or Waste Stack (mm)	Total Fixture Unit (FU) Connected to fixture	Maximum Development Length of Vent (m)* for Diameter (mm) of Vent Pipes										
		30	40	50	65	75	100	125	150	200	250	300
30	2	9										
40	8	15	45.5									
40	10	9	30.5									
50	12	9	22.5	61								
50	20	8	15	45.5								
65	42		9	30.5	91.5							
75	10		12.	45.5	109.5	317						
75	21			33.5	82	247						
75	53			28.5	70	207						
75	102			26	64	189						
100	43		5	10.5	26	76	298.5					
100	140		9.5	8	19.5	61	228.5					
100	320		8	7	16.5	52	195					
100	540		7.5	6.5	15	45.5	176.5					
125	190				8.5	25	97.5	301.5				
125	490				6.5	19	76	231.5				
125	940				5.5	16	64	204				
125	1400				4.5	15	58	180				
150	500					10	39.5	122	305			
150	1100					6.5	30.5	94.5	237.5			
150	2000					6	25.5	79	201			
150	2900						23.5	73	183			
200	1800						9.5	29	73	286.5		
200	3400						7	22	58	219.5		
200	5600						6	19	48.5	186		
200	7600						5.5	17	42.5	170.5		
250	4000							9.5	23.5	94.5	292.5	
250	7200							7	18	73	225.5	
250	11000							6	15.5	61	192	
250	15000							5.5	14	55	173.5	
300	7300								9.5	36.5	116	286.5
300	13000								7	28.5	91.5	219.5
300	20000								6	24	76	186
300	26000								5.5	22	70	152.5
375	15000									12	39.5	94.5
375	25000									9.5	29	73
375	38000									8	24.5	61
375	50000									7	22.5	55