Building Plumbing System

Introduction

The following report designs the water supply system for a typical residential building on the industrial park. For reference, floor plan of an existing 6-storey building in Bangladesh is used.

Design components:

1. Size of water distribution pipes.
2. Dimension of underground water reservoir.
3. Dimension of overhead water reservoir.
4. Pump capacity.

Considerations:

- Water pressure is 30 psi at public main as was ensured by water distribution network design previously.
- Maximum pressure allowed at any fixture is 50 psi.
- Service pipe length is 70 ft.
- Following the design requirements table (Appendix C-5 Water supply system design requirements (Source: BNBC 2020)), the minimum pressure required for water closets (flush tank), shower heads, lavatories, or kitchen sinks are 55 kPa or 8 psi.
- Fixture units (FU) for:
    - Water closet (flush tank): 5 FU
    - Shower head: 4 FU
    - Lavatory: 2 FU
    - Kitchen sink (private): 2 FU

Assumption:

- Pressure drop for branch is 1 psi.
- Distance between overhead tank and roof is 24 ft.
- Occupancy per unit of a typical floor is 5 people.
- Units per typical floor are 2.

Reference Building

The reference building used for design has the following characteristics:

- 6-storey building. Each storey is 3.048 m or 10 ft.
- Typical floors have 6 bathrooms (with integrated showers), 2 dining rooms, and 2 kitchens. These correspond to 6 water closets, 6 shower heads, $6 + 2 = 8$ lavatories, and 2 kitchen sinks.
- Ground floor and roof is assumed to have 1 water closet, 1 lavatory, and 1 kitchen sink each.
- Every water closet uses flush tank system.

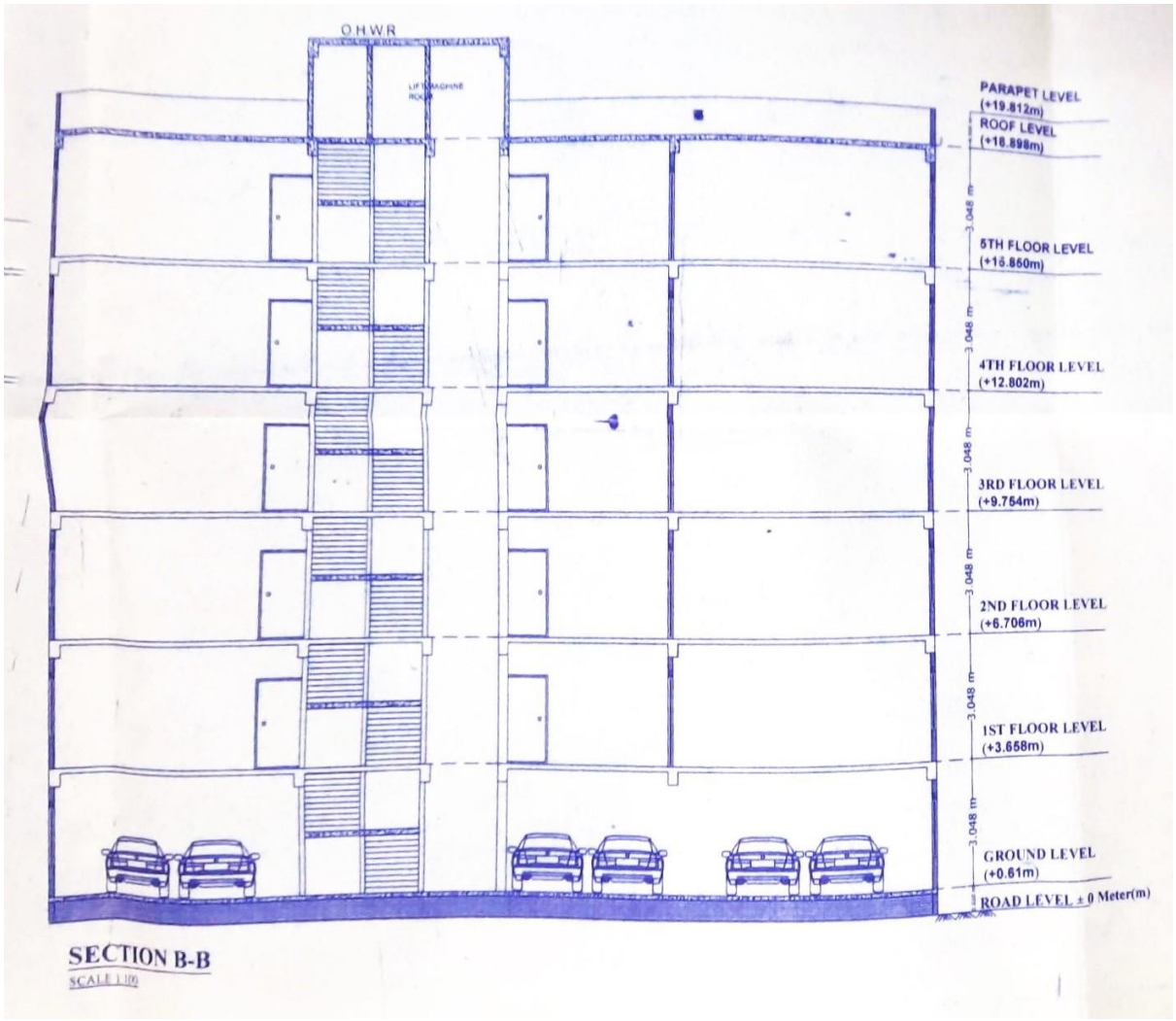


Figure 14 Section view displaying individual floors

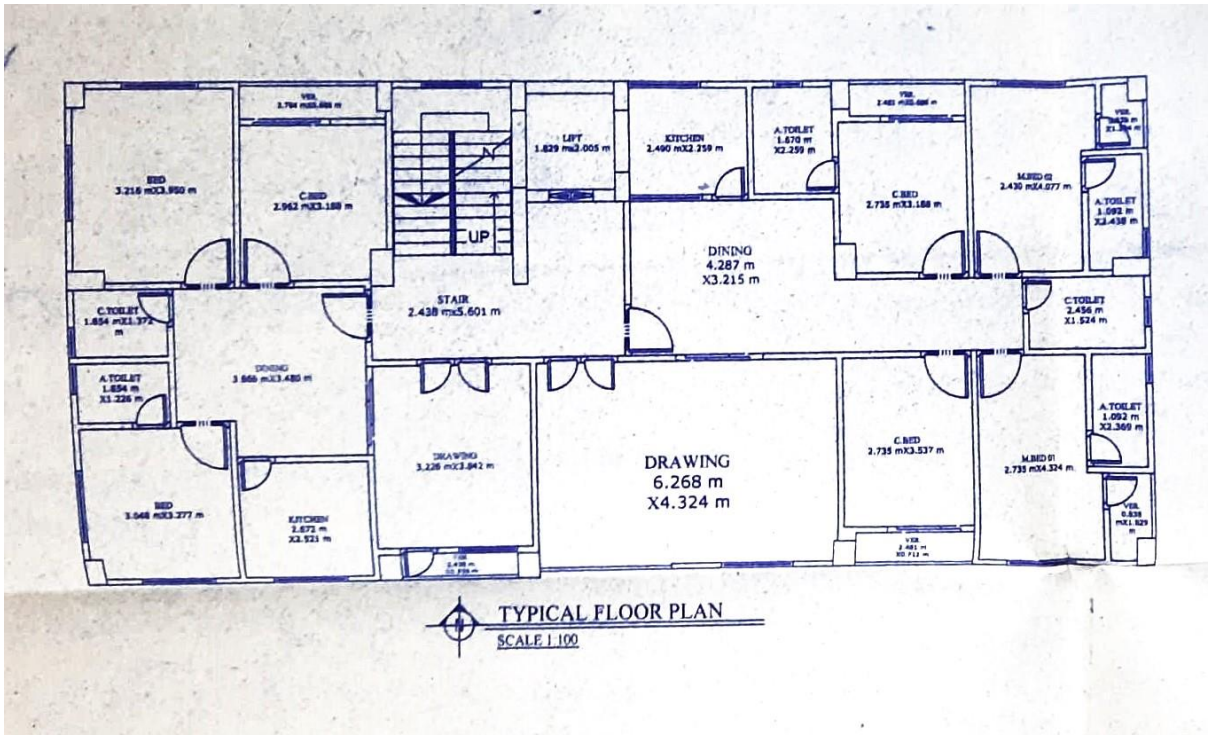


Figure 15 Plan of a typical floor (1st to 5th floor)

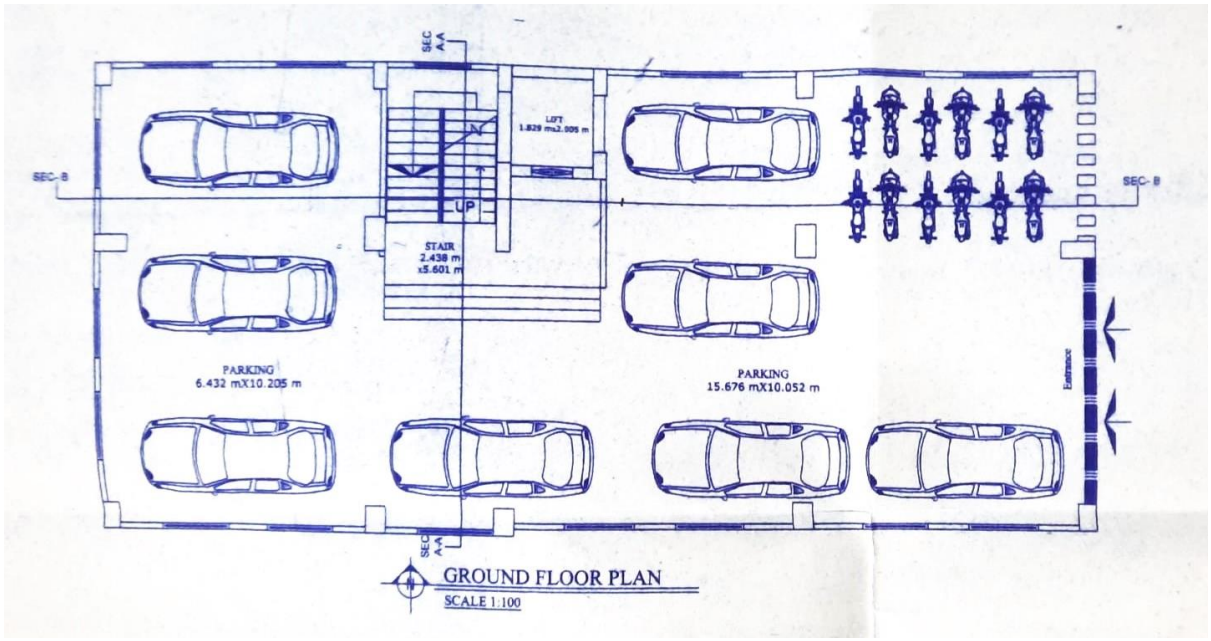


Figure 16 Plan of ground floor

Determination of Zoning

Fixture units:

- Typical floors:
  - 6 water closets: $6 \times 5 = 30$ FU
  - 6 shower heads: $6 \times 4 = 24$ FU
  - 8 lavatories: $8 \times 2 = 16$ FU
  - 2 kitchen sinks: $2 \times 2 = 4$ FU
  - Total: $30 + 24 + 16 + 4 = 74$ FU
- Ground floor and roof:
  - 1 water closet: $1 \times 5 = 5$ FU
  - 1 lavatory: $1 \times 2 = 2$ FU
  - 1 kitchen sink: $1 \times 2 = 2$ FU
  - Total: $5 + 2 + 2 = 9$ FU
- Total FU:
  - 1st to 5th floor level: $5 \times 74 = 370$ FU
  - Ground level + roof: $2 \times 9 = 18$ FU
  - Total: $370 + 18 = 388$ FU

Maximum demand:

For 388 FU, based on demand curve for systems predominantly using flash tanks (Appendix C-1 Estimate curves for demand load based on fixture units), the probable peak demand is determined to be 100 GPM.

Service pipe size:

For iron pipe, based on the pipe friction loss chart (Appendix C-2 Friction loss per 100-ft length of pipe), drop of pressure is:

1. For diameter 3": 1.8 psi/100'
2. For diameter 4": 0.45 psi/100'

The 4" pipe with pressure drop of 0.45 psi/100' will be used tentatively.

From the water meter pressure loss graph (Appendix C-3 Pressure losses in water meter), for 4" pipe, pressure drop is 1 psi.

Upfeed zone:

$$30 = 1 + 1.5(70 + h)(0.45/100) + 0.434h + 8 + 1$$

$$\text{or, } h = 44.3 \text{ ft}$$

Thus, upfeed system would allow water supply to maximum 4 storey, or 3 floors when accounted for underground depth.

Downfeed zone:

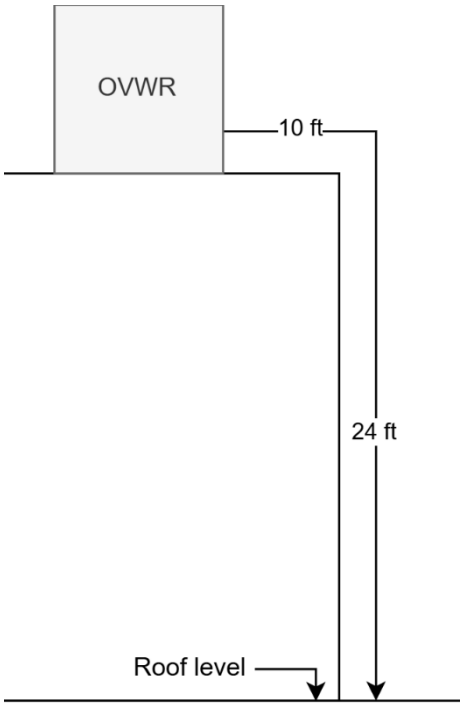
$$50/0.434 - 24 = 91 \text{ ft}$$

Thus, downfeed system would allow water supply to maximum 9 storey.

For this design, downfeed system will be used to supply water across all floors as a combined upfeed + downfeed system is unnecessary here.

Design of Downfeed Zone

Tank to top fixture:



Pressure available for overcoming friction:

$$p = 24 \times 0.434 - 8 - 1 = 1.42 \text{ psi}$$

Permissible drop per 100 ft:

$$\frac{1.42 \times 100}{1.5(24 + 10)} = 2.78 \text{ psi/100'}$$

5th floor to ground floor:

Pressure available for overcoming friction:

$$p = 9 + 10 \times 0.434 - 8 - 1 = 4.34 \text{ psi}$$

Permissible drop per 100 ft:

$$\frac{4.34 \times 100}{1.5 \times 10} = 28.93 \text{ psi/100'}$$

Pipe sizes:

Floor	FU	Accumulated FU	Demand (gpm)	Pipe Length (ft)	Pressure Drop (psi/100')	Pipe Size (in)
Roof	9	388	100	34	2.78	3.0
5th	74	379	95	10	28.93	2.0
4th	74	305	85	10	28.93	2.0
3rd	74	231	70	10	28.93	1.5
2nd	74	157	55	10	28.93	1.5
1st	74	83	38	10	28.93	1.5
Ground	9	9	20	10	28.93	1.5

Overhead Tank

Daily water demand:

- Total occupancy: $5 \times 2 \times 5 = 50$ person
- Per person daily demand: 120 lpcd [Category y_2: < 1500 sft]
- Total domestic demand: $120 \times 50 = 6{,}000$ lpd $= 6\ m^3$
- Tank volume for regular demand: $6/2 = 3\ m^3$ [2×30 mins pumping]
- Demand for firefighting: 1000 lpm $\times 30$ mins $= 30\ m^3$
  See Appendix C-4 Fire protection flow requirements (Source: BNBC 2020)
- Total tank volume: $3 + 30 = 33\ m^3$
- From building section view, the position of overhead tank is above stair.
  Maximum size of OHWR: $(1.8 + 2.4)$ m $\times$ 5.6 m $= 4.2$ m $\times$ 5.6 m
  Actual size: $10' \times 15' = 3.048$ m $\times$ 4.572 m
- Depth of OHWR: $33/(3.048 \times 4.572) = 2.368$ m
- Freeboard: 1 ft $= 0.305$ m
- Total depth of OHWR: $2.368 + 0.305 = 2.673\ m = 8.770\ ft \approx 9\ ft$
- Therefore, dimension: $10' \times 15' \times 9'$

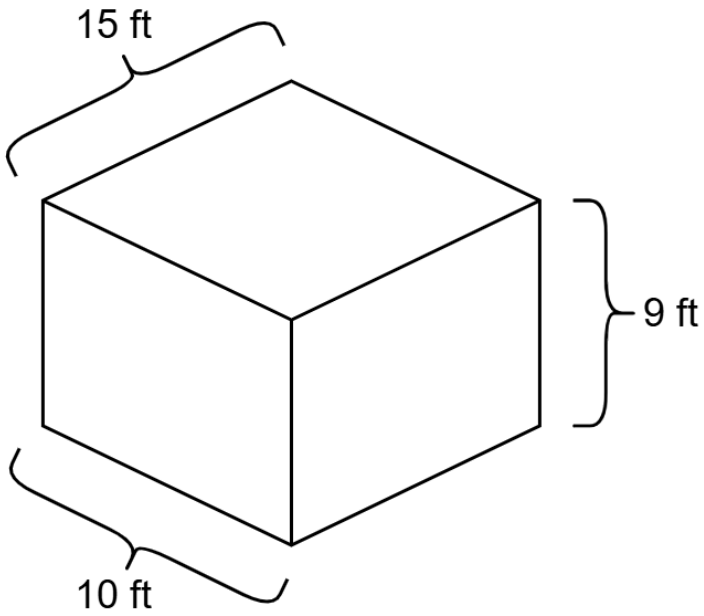


Figure 17 Schematic diagram of OHWR

Underground Water Reservoir

- Daily domestic demand: $6\ m^3$
- Firefighting demand: $30\ m^3$
- Total volume: $6 \times 2 + 30 = 42\ m^3$
- Maximum size of UGWR: $7.37\ \text{m} \times 4.5\ \text{m}$
  Actual size: $20' \times 12' = 6.096\ \text{m} \times 3.658\ \text{m}$
- Depth of UGWR: $42/(6.096 \times 3.658) = 1.883\ \text{m}$
- Freeboard: $0.305\ \text{m}$
- Total depth of UGWR: $1.883 + 0.305 = 2.188\ \text{m} = 7.17\ \text{ft} \approx 8\ \text{ft}$
- Therefore, dimension: $20' \times 12' \times 8'$

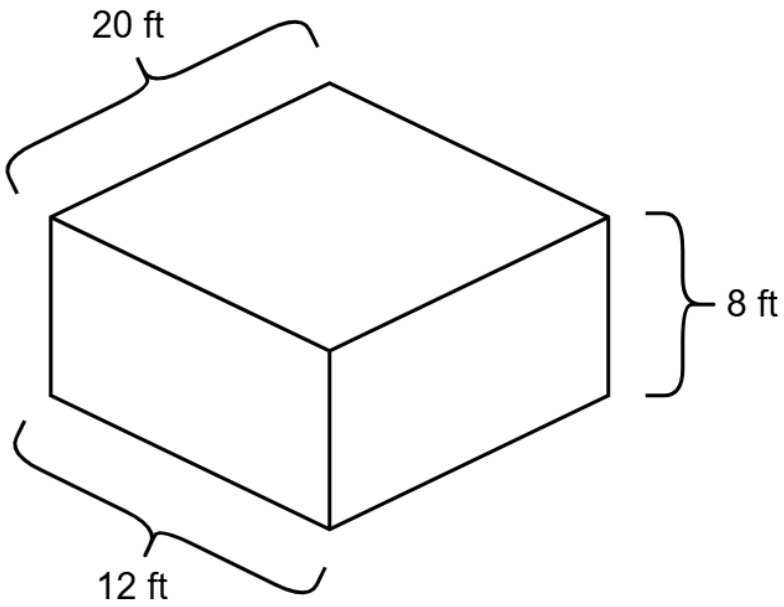


Figure 18 Schematic diagram of UGWR

Pump Capacity

- Water carried per pump: $6{,}000/2 = 3{,}000$ liter/30mins $= 26.42$ gpm
- Assumed velocity: 8 fps
- Corresponding friction loss: 16 psi/100'
- Riser length:
  - L_{static}: $D_{UGWR} + H_{building} + H_{roof-OHWR}$
    $= 8' + 60' + 24' = 92'$
  - $L_{horizontal}$: $L_{UGWR-stair} + L_{raiser-OHWR}$
    $= 24.6' + 10' = 34.6'$
  - L_{total}: $92 + 34.6 = 126.6'$
- Total frictional head, H_L: $L\frac{h_L}{100} + requirements\ at\ OHWR + minor\ loss$
  $= 126.6 \times \frac{16}{100} + 8 + 5 = 33.3$ psi
- Friction head: $33.3 \times \frac{144}{62.4}$ ft
  $= 76.8$ ft
- Velocity head: $\frac{v^2}{2g} = \frac{8^2}{2 \times 32.2} = 0.99$ ft
- Total head, H: $static\ head\ +\ velocity\ head\ +\ friction\ head$
  $= 92 + 0.99 + 76.8 = 169.79$ ft
- Assumed efficiency, E: 65%
- Required capacity of pump: $\frac{HQ}{3960E}$
  $= \frac{169.79 \times 26.42}{3960 \times 0.65}$
  $= 1.74$ HP
  ≈ 2 HP

Appendices

Appendix A Water Demand Design Aids

Table 8.5.1(a): Water Consumption for Domestic Purposes in Residential Buildings (Cities/Big District Towns)

Category	Socio-economic group, Type of Building, Source and Other Facilities	Water Consumption	
		Full Facility (*lpcd*)	Restricted Facility (*lpcd*)
A	**Metropolitan Cities/City Corporation Area/District Towns**		
x	High income group:		
A1	Single family dwelling (with garden and car washing)	260	200
A3	Big multi-family apartment/flat (> 2500 sft)	200	150
y	Middle income group:		
y_1	Officer's qtr./Colony and moderate apartment (< 2000 sft)	180	135
y_2	Small building/staff qtr. and small apartment (< 1500 sft)	---	120
z	Low income group:		
z_1	Junior staff qtr./flat (< 1000 sft) and temporary shade	---	80
z_2	Stand post connection in the fringe area	---	65
z_3	Common yard (stand post) connection in the fringe area	---	50
z_4	Slum dwellers collection from road side public stand post	---	40

Appendix A-1 Residential water consumption (metropolitan & district towns)

Table 8.5.1(d): Domestic Water Requirements for Various other Occupancies and Facility Groups

Class of Occupancy	Occupancy Groups	For Full[a] Facilities (*lpcd*)	For Restricted Facilities (*lpcd*)
A: Residential	A4: Mess, Boarding Houses, Dormitories and Hostels	135	70
	A5: Hotels and Lodging Houses (per bed)	300	135
B: Educational Facilities	B1: Educational Facilities up to Higher Secondary Levels	70	45
	B2: Facilities for Training and above Higher Secondary Education	100	70
	B3: Pre-School Facilities	50	35
C: Institutional	C1: Institution for Care of Children	180	100
	C2: Custodian Institution for Physically Capable Adults	180	100
	C3: Custodian Institution for the Incapable Adults	120	70
	C4: Penal and Mental Institutions for Children	100	60
	C5: Penal and Mental Institutions for Adults	120	70
D: Healthcare Facilities	D1: Normal Medical Facilities (Small Hospitals)	340	225
	Big Hospitals (Over 100 beds)	450	250
	D2: Emergency Medical Facilities	300	135
	Nurses & Medical Quarters	250	135
E: Business	E1: Offices	45	30
	E2: Research and Testing Laboratories	70	45
	E3: Essential Services	70	45
F: Mercantile	F1: Small Shops and Market	45	30
	F2: Large Shops and Market	45	30
	F3: Refueling Station	70	45
G: Industrial Buildings	G1: Low Hazard Industries	40	25
	G2: Moderate Hazards Industries	40	25

Appendix A-2 Non-residential water demand rates (part 1 – educational, institutional & commercial)

Class of Occupancy	Occupancy Groups	For Full[a] Facilities (*lpcd*)	For Restricted Facilities (*lpcd*)
H: Storage Buildings	H1: Low Fire Risk Storage	10	6
	H2: Moderate Fire Risk Storage	10	6
I: Assembly	I1: Large Assembly with Fixed Seats (per seat)	90	45
	I2: Small Assembly with Fixed Seats (per seat)	90	45
	I3: Large Assembly without Fixed Seats[b]	15	10
	I4: Small Assembly without Fixed Seats	15	10
	I5: Sports Facilities	15	10
J: Hazardous Building	J1: Explosion Hazard Building	15	10
	J2: Chemical Hazard Building	15	10
	J3: Biological Hazard Building	10	6
	J4: Radiation Hazard Building	10	6
K: Garage[c]	K1: Parking Garage	15	10
	K2: Private Garage	15	10
	K3: Repair Garage	15	10
L: Utility	L: Utility	10	6
M: Miscellaneous	M1: Special Structures	--[d]	--[d]
	M2: Fences, Tanks and Towers	---	3

Notes:

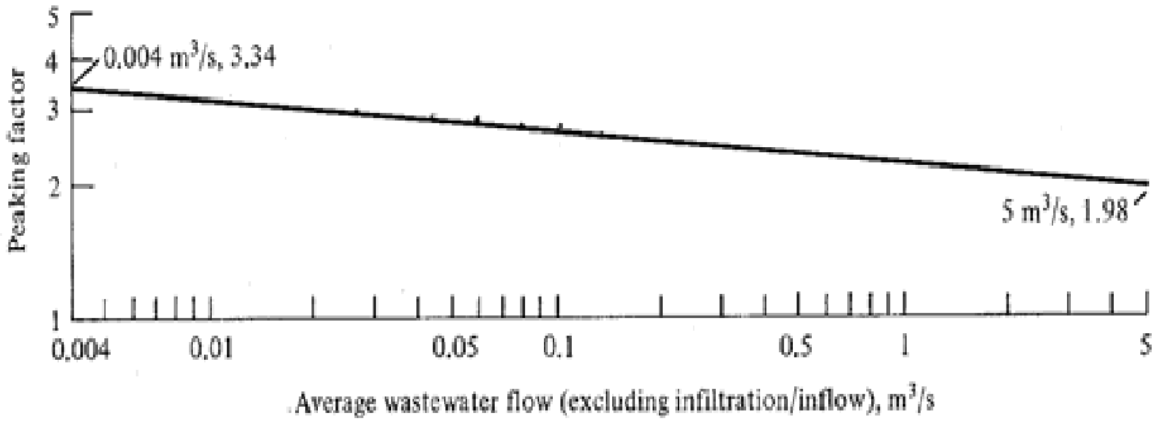
[a] For full facility in occupancy classifications A, B, C and D, the water requirement value includes 25% hot water.

[b] In the case of mosques, the water requirements given above shall be adequate for ablution and other uses of one devotee per prayer. The appropriate LPCD value may be calculated on this basis.

[c] Water requirement for occupancy K is shown as a provision for unknown visitors only.

[d] Water requirement for occupancy M1 shall be assessed considering its nature of use and the similarity in purpose with any of the occupancies mentioned above.

Appendix B Sewer Design Aids



Appendix B-1 Wastewater flow peaking factor curve

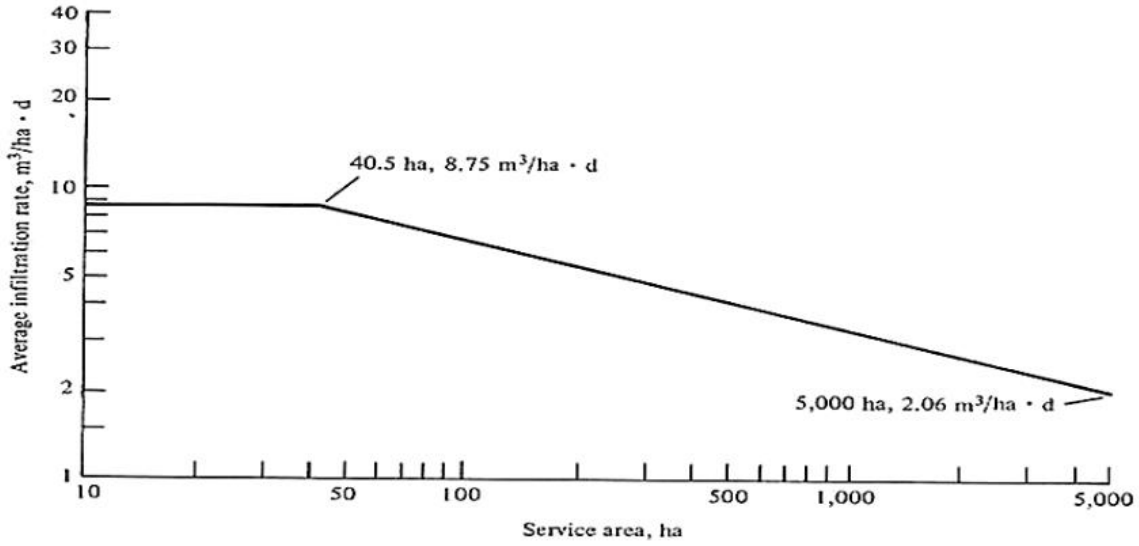


Figure 5 : Average infiltration rate allowance for new sewers. Note: ha × 2.4711 = acre; m³/ha·d × 106.9 = gal/acre·d.

Appendix B-2 Sewer infiltration rate allowances

Table-3: Gravity Sewer Minimum Pipe Slopes

Size in inch (mm)	Slope m/m	
	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 B-3 Minimum slopes for gravity sewers

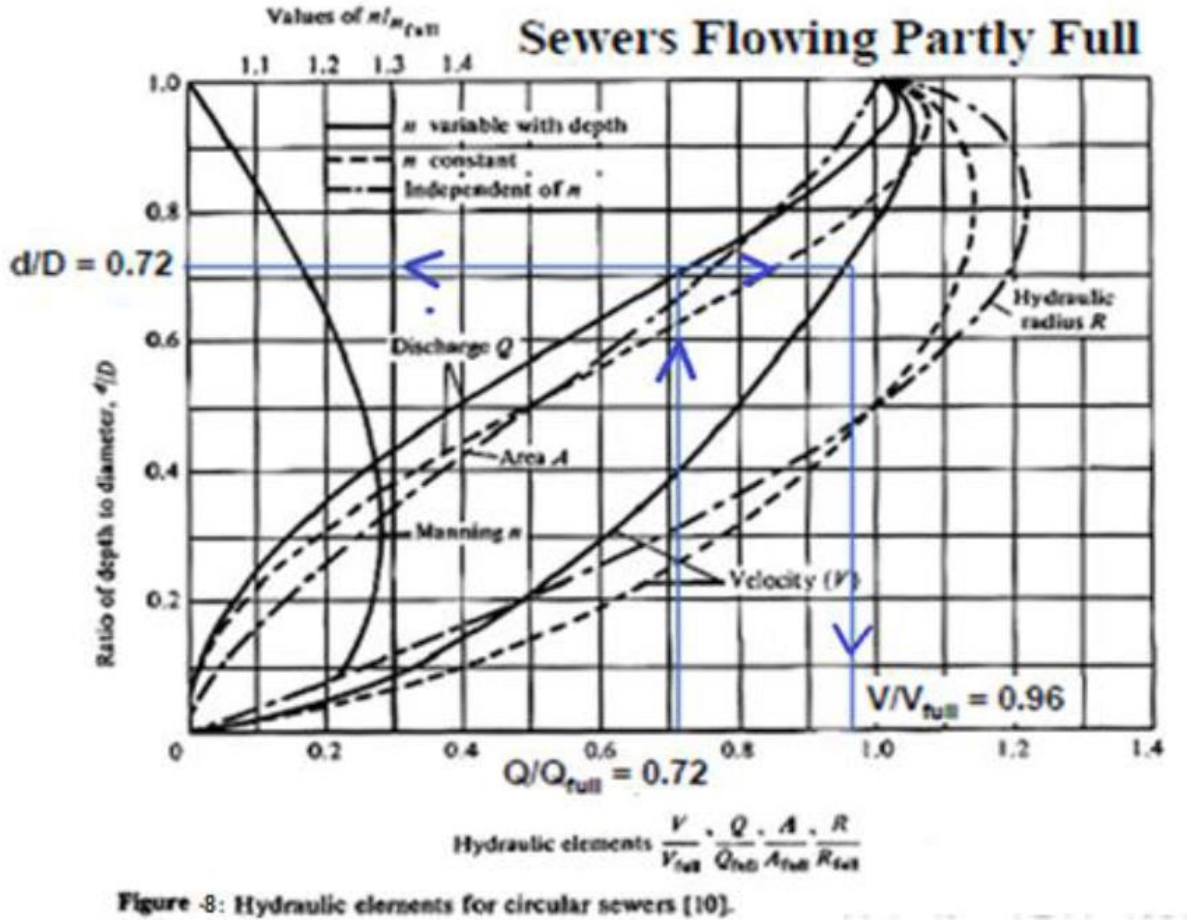
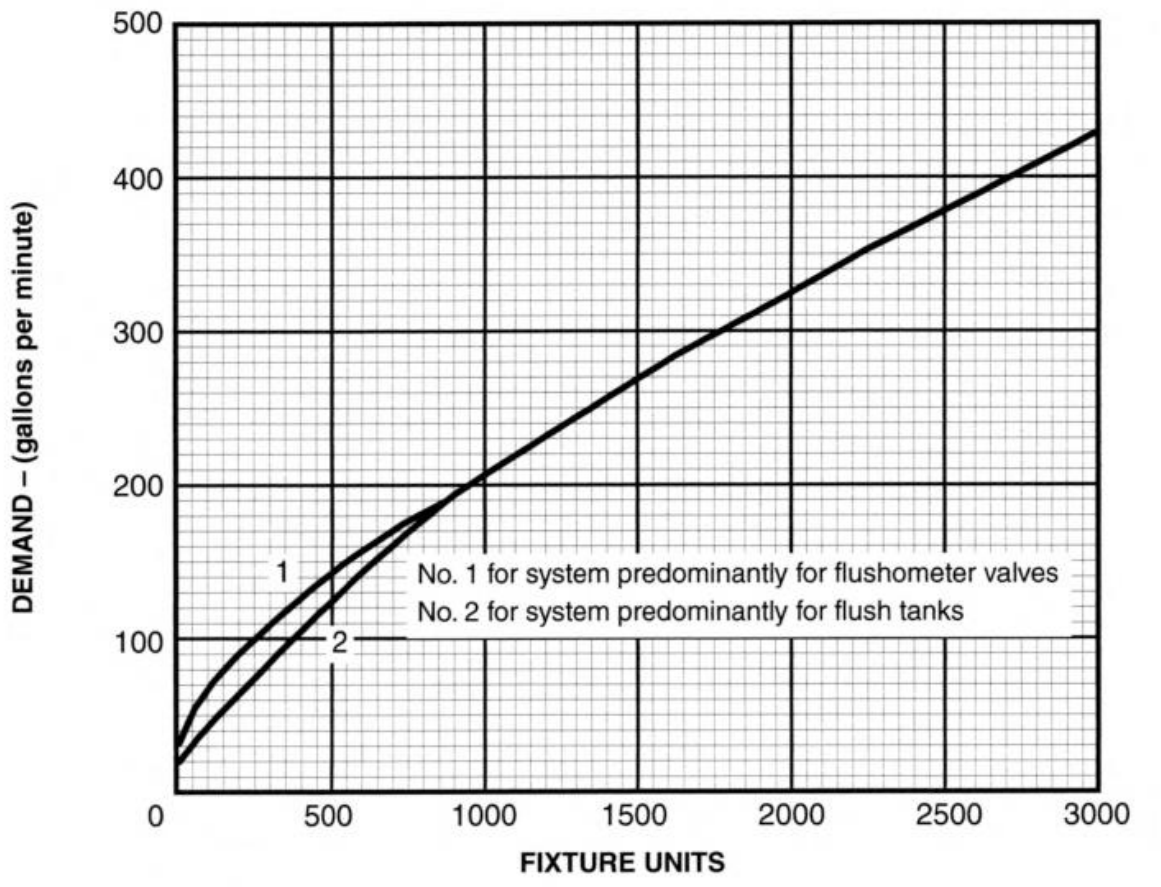


Figure 8: Hydraulic elements for circular sewers [10].

Appendix B-4 Hydraulic elements diagram for circular sewers

Appendix C Plumbing Design Aids



Appendix C-1 Estimate curves for demand load based on fixture units

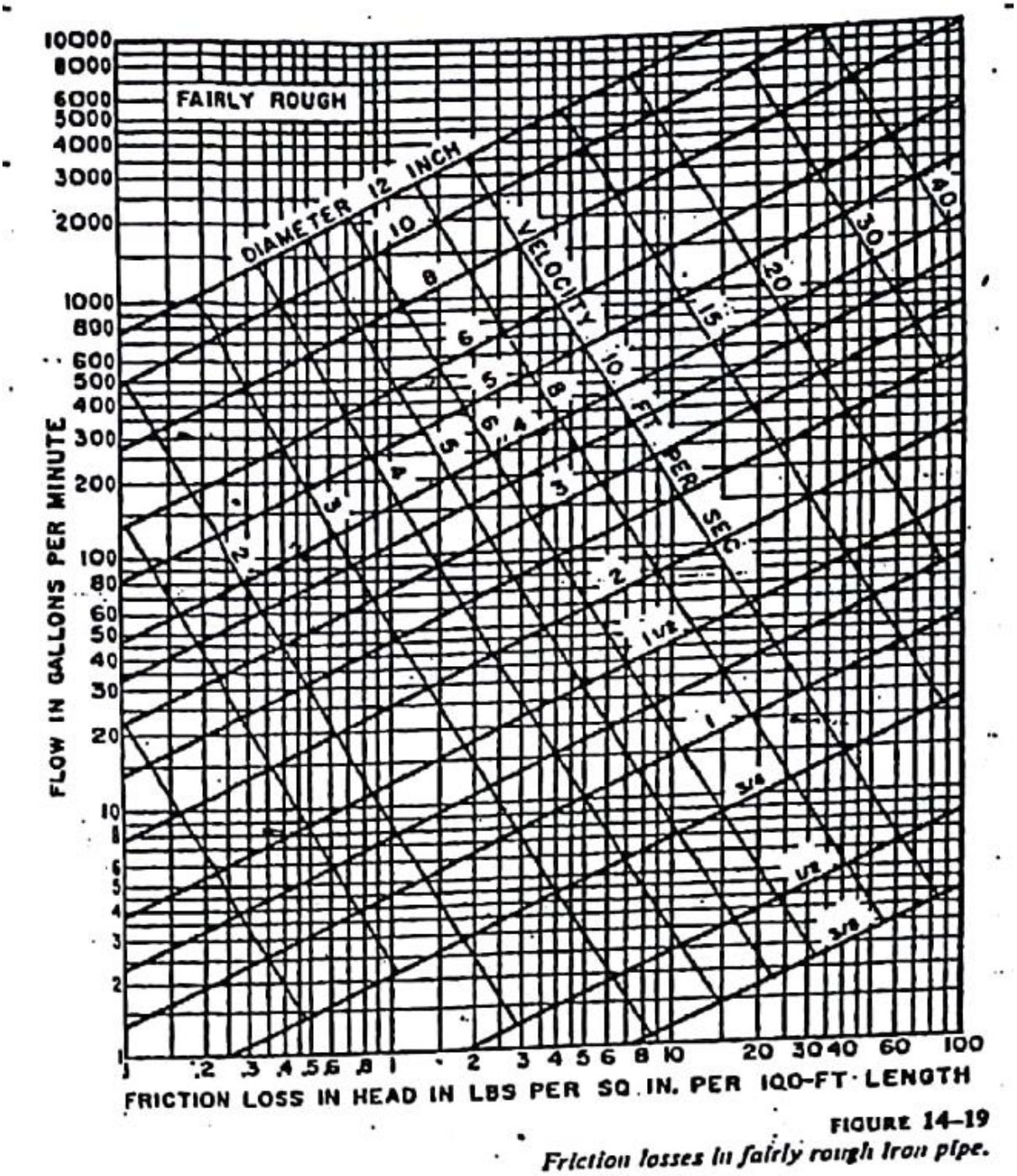
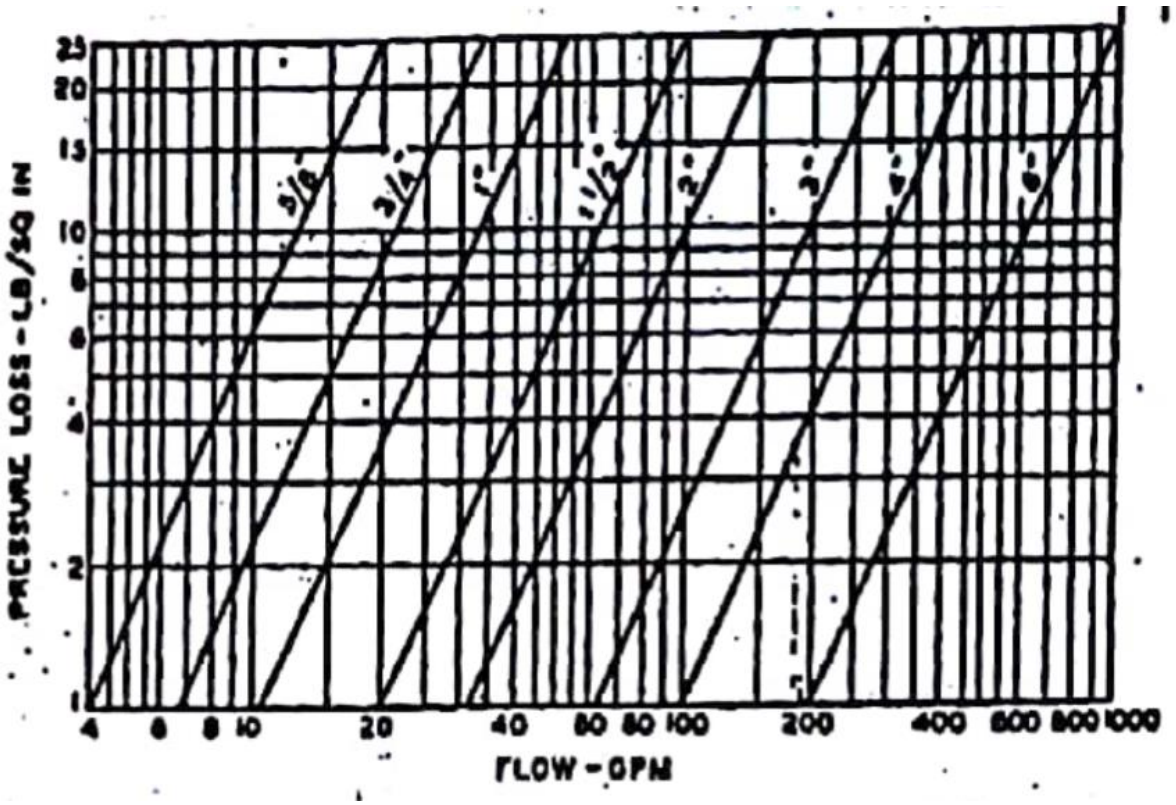


FIGURE 14–19

Friction losses in fairly rough iron pipe.

Appendix C-2 Friction loss per 100-ft length of pipe



Appendix C-3 Pressure losses in water meter

Table 4.4.1: Fire Protection Flow Requirements*

Building Type**	Sprinkler System (litre/min.)	Standpipe and Hose System (litre/min.)	Duration in Minutes for Building Heights		
			Up to 51 m	51 m to 102 m	Above 102 m
Light hazard- I	1000	1000	30	38	45
Light hazard- II	1900	1900	50	62	75
Ordinary hazard- I	2650	1900	75	95	112
Ordinary hazard-II	3200	1900	75	95	112
Ordinary hazard-III	4800	1900	75	95	112

Appendix C-4 Fire protection flow requirements (Source: BNBC 2020)

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		13	55	--
supply size requirement		19	55	--
		25	100	--

5.10.4.2 For 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 shall be maintained at a pressure so that none of their fittings shall are subject to a water head greater than 35 m (345 kPa ≈ 50 psi).

Appendix C-5 Water supply system design requirements (Source: BNBC 2020)