# Chapter – I
# Estimation of Water and Wastewater Flow

Before designing proper water works project, it is essential to determine the quantity of water that is required daily. This involves the determination of population and rate of demand. The determination of population is one of the most important factors in the planning, if the project has to serve the community for a certain design period.

In order to determine the section of the sewer, it is essential to know the total quantity of wastewater or sewage that would flow through the sewer. The total flow is divided into two components and these are dry weather flow (DWF) and storm water flow.

**Content**



## 1.1. Various types of water demand

The total water requirement may be divided into following categories.

- Residential or domestic use
- Institutional use
- Public use
- Industrial use
- Water system losses

### *1.1.1. Residential or domestic use*

The residential or domestic use comprises of about 50 % of the total water demand. It includes the water requirements for drinking, cooking, bathing, washing of clothes, utensils and house and flushing water closets. IS: 1172-1957 recommends a per capita water consumption of 135 liters per day. The breakup of domestic demand is given below.

Table 1: Water requirement for domestic purposes (IS1172-1957)

| Sl. No. | Purpose | Amount of water (lpcd) |
|---|---|---|
| 1 | Cooking | 5 |
| 2 | Drinking | 5 |
| 3 | Bathing | 55 |
| 4 | Washing clothes | 20 |
| 5 | Flushing W.C. | 30 |
| 6 | Washing of house | 10 |
| 7 | Washing of utensils | 10 |
| | Total | 135 |

The Manual on Water Supply and Treatment (MWST), Ministry of Urban Development (MUD), New Delhi recommends the following rates for domestic demand.

Table 2: Domestic and non-domestic water demand (MUD)

| Sl. No. | | Description | Amount of water (lpcd) |
|---|---|---|---|
| 1 | a | For communities with population upto 20000 | |
| | b | Water supply through stand post | 40 (min) |
| 2 | | Water supply through house service connection | 70-100 |
| 3 | | For communities with population 20000 to 100000 | 100-150 |
| 4 | | For communities with population above 100000 | 150-200 |

### *1.1.2. Institutional demand*

The Manual on Water Supply and Treatment, MUD recommends the values of water requirements for institutional need as given below.

Table 3: Water for institutional need

| Institution | Water requirement (lpcd) |
|---|---|
| Hospitals<br>No of beds exceeding 100<br>No of beds not exceeding 100 | <br>450 per bed<br>340 per bed |
| Hostels | 135 |
| Hotels | 180 per bed |
| Boarding school | 135 |
| Day school | 45 |
| Restaurants | 70 per seat |
| Air ports and sea ports | 70 |
| Offices | 45 |
| Factories | 45 |
| Junction stations | 70 |
| Intermediate station | 45 |
| Terminal station | 45 |
| Cinema halls and theaters | 15 |

### *1.1.3. Public or civil use*

Water required for public or civil uses may be for the following purposes.

- Road washing (5 lpcd)
- Sanitation – for cleaning public sanitary blocks, flushing sewer etc. (3-5 lpcd)
- Public parks (2-3 liter per sq. meter per day)
- Fire fighting
- Water required for fire fighting is usually known as fire demand.
- It is treated as function of population and may be computed using different formula given below.
    - Kuichling's formula
        - $Q = 3182\sqrt{P}$

          Where, Q = quantity of water in lpm and P = population in thousand

- Buston's formula
    - $Q = 5663\sqrt{P}$
- Freeman's formula
    - $Q = 1136\left(\frac{P}{5} + 10\right)$
- National Board of Fire Underwriters formula
    - $Q = 4637\sqrt{P}\left(1 - 0.01\sqrt{P}\right)$

- The rate of consumption is very high.

### *1.1.4. Industrial uses*

- The quantity of water required depends upon the type of industry.
- For a city with moderate factories, a provision of 20-25% of per capita consumption may be made for this purpose.
- The following table shows the water requirement for specific industry.

Table 4: Industrial water needs

| Industry | Unit of production | Water requirement (kiloliter per unit) |
|---|---|---|
| Automobile | Vehicle | 40 |
| Distillery | Kiloleter of alcohol | 122-170 |
| Fertilizer | 100 Kg | 80-200 |
| Leather | 100 Kg | 4 |
| Paper | 100 Kg | 200-400 |
| Steel | 100 Kg | 200-250 |
| Sugar | 100 Kg | 1-2 |
| Textile | 100 Kg | 8-14 |

### *1.1.5. Water system losses*

- Losses from water distribution system consists of
    - Leakage and overflow from service reservoirs
    - Leakage from main and service pipe connections
    - Leakage and losses on consumer's premises
    - Under registration of supply meter
    - Large leakage or wastages from public taps.
- Losses of water may be taken as 15-20% of the total consumption.

## 1.2. Design Period

- Water supply projects may be designed normally to meet the requirements over a thirty years period after completion.
- The time lag between design and completion of the project should also be taken into account and which should not exceed two to five years depending upon the project size.
- The thirty years period may be modified in regard to certain components of the project depending on their useful life.
- The following table shows the design periods for different components of water supply scheme and sewerage system.

Table 5: Design periods for components of water supply scheme

| Sl. No. | Items | Design period in years |
|---|---|---|
| 1. | Storage by dams | 50 |
| 2. | Infiltration works | 30 |
| 3. | Pumping: | |
| | i. Pump house (civil works) | 30 |
| | ii. Electric motors and pumps | 15 |
| 4. | Water treatment units | 15 |
| 5. | Pipe connection to several treatment units and other small appurtenances | 30 |
| 6. | Raw water and clear water conveying mains | 30 |
| 7. | Clear water reservoirs at the head works, balancing tanks and service reservoirs (overhead or ground level) | 15 |
| 8. | Distribution system | 30 |

Table 6: Design periods for components of water supply scheme

| Sl. No. | Component | Recommended Design Period in years | Clarification |
|---|---|---|---|
| 1. | Collection System i.e. Sewer Network | 30 | The system should be designed for the prospective population of 30 years, as its replacement is not possible during its use. |
| 2. | Pumping Stations (Civil Works) | 30 | Duplicating machinery within the pumping station would be easier/cost of civil works will be economical for full design period. |
| 3. | Pumping Machinery | 15 | Life of pumping machinery is generally 15 years. |
| 4. | Sewage Treatment Plant | 30 | The construction may be in a phased manner as initially the flows may not reach the designed levels, and it will be uneconomical to build the full capacity plant initially. (Refer Chapter 10.2). |
| 5. | Effluent disposal and utilisation | 30 | Provision of design capacities in the initial stages itself is economical. |

## 1.3. Population Forecasting

Following are some of the important methods of population forecasts or population projections.

- Arithmetical mean method
- Incremental increase method
- Geometric mean method
- Decreasing rate method
- Graphical method

### Example on population forecast

Predict the population for the years 1981, 1991, and 2001 from the following census figures of a town by different methods.

| Year | 1901 | 1911 | 1921 | 1931 | 1941 | 1951 | 1961 | 1971 |
|---|---|---|---|---|---|---|---|---|
| Population: (thousands) | 60 | 65 | 63 | 72 | 79 | 89 | 97 | 120 |

### Solution

| Year | Population: (thousands) | Increment per Decade | Incremental Increase | Percentage Increment per Decade |
|---|---|---|---|---|
| 1901 | 60 | - | - | - |
| 1911 | 65 | +5 | - | (5+60) x100=+8.33 |
| 1921 | 63 | -2 | -3 | (2+65) x100=-3.07 |
| 1931 | 72 | +9 | +7 | (9+63) x100=+14.28 |
| 1941 | 79 | +7 | -2 | (7+72) x100=+9.72 |
| 1951 | 89 | +10 | +3 | (10+79) x100=+12.66 |
| 1961 | 97 | +8 | -2 | (8+89) x100=8.98 |
| 1971 | 120 | +23 | +15 | (23+97) x100=+23.71 |
| Net values | 1 | +60 | +18 | +74.61 |
| Averages | - | 8.57 | 3.0 | 10.66 |

*+=increase; - = decrease*

***Arithmetical Progression Method:***

$$P_n = P + ni$$

*Average increases per decade = i = 8.57*

*Population for the years,*

*1981= population 1971 + ni, here n=1 decade*
*= 120 + 8.57 = 128.57*
*1991= population 1971 + ni, here n=2 decade*
*= 120 + 2 x 8.57 = 137.14*
*2001= population 1971 + ni, here n=3 decade*
*= 120 + 3 x 8.57 = 145.71*
*1994= population 1991 + (population 2001 - 1991) x 3/10*
*= 137.14 + (8.57) x 3/10 = 139.71*

***Incremental Increase Method:***

*Population for the years,*

*1981= population 1971 + average increase per decade + average incremental increase*
*= 120 + 8.57 + 3.0 = 131.57*

*1991= population 1981 + 11.57*
*= 131.57 + 11.57 = 143.14*

*2001= population 1991 + 11.57*
*= 143.14 + 11.57 = 154.71*

*1994= population 1991 + 11.57 x 3/10*
*= 143.14 + 3.47 = 146.61*

***Geometric Progression Method:***

*Average percentage increase per decade = 10.66*

$$P_n = P (1+i/100)^n$$

*Population for 1981 = Population 1971 x* $(1+i/100)^n$
*= 120 x (1+10.66/100), i = 10.66, n = 1*
*= 120 x 110.66/100 = 132.8*

*Population for 1991 = Population 1971 x* $(1+i/100)^n$
*=* $120 \times (1+10.66/100)^2$ *, i = 10.66, n = 2*
*= 120 x 1.2245 = 146.95*

*Population for 2001 = Population 1971 x* $(1+i/100)^n$
*=* $120 \times (1+10.66/100)^3$ *, i = 10.66, n = 3*
*= 120 x 1.355 = 162.60*

*Population for 1994 = 146.95 + (15.84 x 3/10) = 151.70*

## 1.4. Variation in Rate of Demand

- The average daily per capita consumption is obtained by dividing the quantity of water supplied during the year by the number of days in the year and the number of persons served.

- This per capita demand varies not only from year to year and from season to season, but more important from day to day and hour to hour.
- In most of the Indian cities, the peak demand occurs in the morning and evening. During the night hours, the consumption is below average.
- The variations are expresses as percentage of the annual average daily consumption. Some common values are as under.
    - ***Maximum seasonal consumption*** is 130% of the annual average daily rate of demand.
    - ***Maximum monthly consumption*** is 140% of the annual average daily rate of demand.
    - ***Maximum daily consumption*** is 180% of the annual average daily rate of demand.
    - ***Maximum hourly consumption*** is 150% of maximum daily consumption.
- Effect of variation in consumption on design
    - A water supply system has several units and design of each unit should match with the hourly, daily and seasonal variations in the demand.
    - The design principles taking into account the effect of variation in the consumption are given below.
        - ***The filter units as well as pumping*** units are designed for ***1.5 times the average daily demand***.
        - ***Distribution mains*** are designed ***for maximum hourly demand of the maximum day***.
        - ***Sedimentation tanks and water reservoirs*** are designed for the ***average daily rate*** of consumption.

## 1.5. Estimation of Sewage Quantity

- To find the **design flow** in **sanitary sewer** the following steps are followed.
    - Select the ***design period***.
    - Forecast the ***design population (P)*** of the area.
    - Find the sewage flow per day by multiplying population with flow per day per capita of sewage. The sewage is taken as ***(70-80)% of average water supply***.
    - Select a ***peak factor (P.F.)*** to find the peak sewage flow (Note. Sewers are designed for peak flow).
    - Calculate the ***allowance for industrial and commercial sewage***.
    - Calculate ***infiltration allowance***.
    - Find the design sewage flow by ***adding Peak Flow, industrial allowance and infiltration flow***.

### *1.5.1. Design period*

- A design period of 30 years (excluding planning and construction period) is recommended for all types of sewers.
- Period between design and construction should be taken as 3 to 6 years depending on size of project.

### *1.5.2. Tributary area*

- The tributary area for any section under consideration has to be marked on the key plan and the area can be measured from the map.

### *1.5.3. Percapita sewage flow*

- Dry weather flow (DWF) is defined as = population x per capita rate of sewage contributed per day
- (or) DWF = (Density of population x Area served by the sewer) x per capita rate of flow
  - Per capita sanitary sewage = 80% of per capita water demand
- Since dry-weather-flow depends on the quantity of water used, and as there are fluctuations in rate of water consumption, there will be fluctuations in dry weather flow hourly or seasonally.

### *1.5.4. Peak factor*

- Sewer is designed for peak flow.
- The peak factor i.e. the ratio of maximum to average flow depends upon contributory population.
- The minimum flow varies from 1/3 to ½ of the average flow.

| Population | Peak factor |
|---|---|
| Upto 20000 | 3.00 |
| 20000 – 50000 | 2.50 |
| 50000 – 750000 | 2.25 |
| above 750000 | 2.00 |

### *1.5.5. Ground water infiltration*

- Estimate of sanitary sewage may include certain flow due to infiltration of groundwater through joints.
- Suggested estimates of groundwater infiltration for sewers laid below ground water table is given.

| Population | Minimum | Maximum |
|---|---|---|
| **liter/Ha.d** | **5000** | **50000** |
| **liter/Km.d** | **500** | **5000** |
| **lpd/manhole** | **250** | **500** |

### *1.5.6. Estimation of Storm Sewage*

- A portion of rainfall that falls on the ground is lost as evaporation and percolation. The remaining flows over the ground surface as storm water.
- The quantity of storm water that goes to the sewers depends on
  - Intensity and duration of rainfall
  - Runoff coefficient
  - Catchment area.

1.5.6.1. Rational Method

$$Q = \frac{AKR}{360}$$

$Q$ = rate of run-off ($m^3/s$)
$A$ = Area of watershed (ha)
$K$ = Run-off coefficient
$R$ = Intensity of rainfall (mm/h)

1.5.6.1.1. Rainfall intensity ($R$)

- The rainfall intensity depends upon frequency and duration of the storm.
- Thus, intensity duration and frequency (IDF) curves are used to find the rainfall intensity.
- An Intensity-Duration-Frequency curve (IDF Curve) is a graphical representation of the probability that a given average rainfall intensity will occur.
- Rainfall Intensity (mm/hr), Rainfall Duration (how many hours it rained at that intensity) and Rainfall Frequency (how often that rain storm repeats itself) are the parameters that make up the axes of the graph of IDF curve.
- An IDF curve is created with long term rainfall records collected at a rainfall monitoring station.

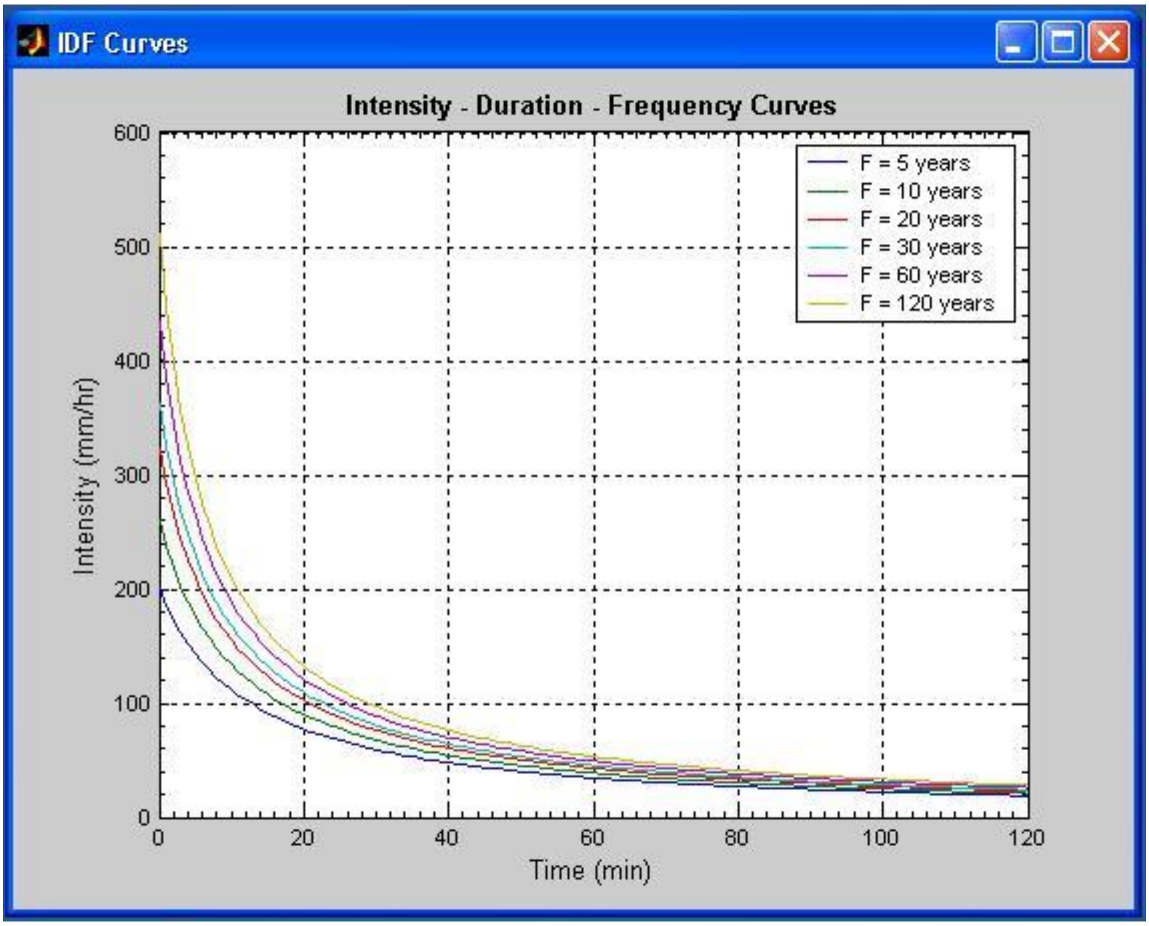


Figure1: Rainfall intensity, duration and frequency curve

$R$ can be computed as follows

$$R = \frac{25.4a}{T+b}$$

Where, $R$ = Intensity of rainfall (mm/h)
$T$ = Time of concentration
For 5-10 min storms, a = 30, b = 10
For 10-100 min storm, a = 40, b = 20

- Time of concentration is the time required for the rainfall to flow over the ground surface from the farthest point in the drainage area to reach the outlet point of that area where the flow is to be estimated.
- Time of concentration (T) = time of entry ($t_e$) + time of flow into the sewer *($t_p$)*
- Time of entry is the time required for the first drop of rain water to flow from the distant point of watershed to the head of the sewer or drain.
- Time of flow in the sewer is the ratio of the length of the sewer to the velocity of flow when running full.

$R$ can also be found by ***British Ministry of Health Formula*** as given below.

$$R = \frac{760}{t+10} \quad for \quad storm \quad duration \quad of \quad 5-20 \quad \text{min}$$

$$R = \frac{1020}{t+10} \quad for \quad storm \quad duration \quad of \quad 20-100 \quad \text{min}$$

Where, $R$ = Intensity of rainfall (mm/h)
$t$ = storm duration (min)

1.5.6.1.2. Run-off coefficient

- It is the fraction of rainfall that enters the storm sewer.
- It depends upon the type of catchment area.
- When the impervious factor is not the same for the entire area, the impervious factor or run-off coefficients of the total area may be calculated as

$$K = \frac{\sum ak}{\sum a} = \frac{\sum ak}{A}$$

Where, $a$ = smaller area with run-off coefficient k
$K$ = run-off coefficient of the total area
$A$ = total area of the catchment

| Nature of area | Run-off coefficients |
| --- | --- |
| Most densely populated built-up portion and roofs | 0.7 to 0.9 |
| Pavements with tightly cemented joints | 0.75 to 0.85 |
| Pavements with open joints | 0.5 to 0.7 |
| Tar Roads | 0.8 to 0.9 |
| Mecadem roads | 0.4 to 0.5 |
| Gravel roads, impaved area, vacant sites | 0.1 to 0.3 |
| Forest lands, parks and gardens | 0.05 to 0.2 |

### *1.5.7. Worked-out example*

A residential town (of leaf shaped) with detached houses has an area of 50 hectares. Its length is 2400 m. A circular combined sewer is to be laid for the area. A velocity of 1 m/s when discharging a maximum rate. The wastewater generation rate is 140 lpcd. Calculate maximum, minimum and average DWF. Duration of storm = 30 min. Find storm discharge. Assume design population = 10000, for paved road time of entry = 10 min and $K$ = 0.8.

Solution of Example

*Calculation of Sanitary Sewage*

Average DWF = population x rate of sewage flow
= 10,000 x 140 =14,000,00 l/d
= 1.4 ml/d
= 16.21 l/s

$Q_{min}$ = 16.21 x (1/3) l/s = 5.40 l/s and
$Q_{max}$ = 3 x 16.21 = 48.63 l/s

*Calculation of Storm Sewage*

Time of entry = 10 min
Time of travel = 40 min
Time of concentration = 50 min
$R$ = 25.4*40/(50+20) = 14.5 mm/h
According to BMHF, $R$ = 1020/(30+10) = 25.5 mm/h
Take higher value for safe side
$Q = AKR/360$ = 50*0.8*25.5/360 = 2.84 $m^3/s$

*Maximum discharge through sewer = 2.84+0.048 =* **2.888 $m^3/s$.**