Quantity of sewage

Quantity of sewage depends on Dry weather flow and storm water.

Dry weather flow: Domestic and industrial wastewater (Base flow) including inflow, infiltration and exfiltration.

Infiltration and exfiltration depends on:

(a) subsoil water level (b) length of sewer (c) nature and type of soil through which sewer laid (d) size of sewer.

- Nature of industries
- Sanitary and industrial sewage is derived from water supply so it has a relationship with amount of water consumption. Generally 70-80% of water consumption is taken as wastewater for domestic purposes. For industrial purposes per unit production caused generation of wastewater will be multiplied by the total product can be taken. If the production information is not available then a flow of 3734 m³/km²-day has to be taken.
- similarly, storm water can be calculated either by Rational method or by soil conservation services techniques.
Waste Water flow pattern for 24 hours

SEWAGE FLOW / QUANTITY

Two controlling factors in design of sewer: Maximum and Minimum rate of sewage. Maximum for design purpose and minimum for controlling of sediment:

Variation in Sewage Flow

Like water supply flow varies from time to time. Since sewers must be able to accommodate the maximum flow, the variation in sewage flow need to be studied.

- The variation of maximum, average and minimum is sometime great and need a particular multiplying factor known as Peak factor and is defined as \( \text{Peak/average flow rate} \); for residential area
- \( P.F \) or \( M = 1 + \frac{14}{(4 + \sqrt{P})} \) (in thousands);
- According to WASA (water and sanitary Agency) \( M = 2.3 \times \text{average flow} \). In normal conditions \( M = 4 \) for laterals; 2.5 for main and trunk and 2.0 for combined sewer
## WASA Criteria

<table>
<thead>
<tr>
<th>Average flow (m³/d)</th>
<th>Peak Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2500</td>
<td>4.0</td>
</tr>
<tr>
<td>2500 to 5000</td>
<td>3.4</td>
</tr>
<tr>
<td>5000 to 10000</td>
<td>3.1</td>
</tr>
<tr>
<td>25000 to 50000</td>
<td>2.7</td>
</tr>
<tr>
<td>50000 to 100000</td>
<td>2.5</td>
</tr>
<tr>
<td>100000 to 250000</td>
<td>2.3</td>
</tr>
<tr>
<td>250000 to 500000</td>
<td>2.15</td>
</tr>
<tr>
<td>&gt; 5000000</td>
<td>2.08</td>
</tr>
</tbody>
</table>

- **Significance of Avg. or min flows:**

  Used in design of sewage pumping stations.

  Used to investigate velocities in sewers during low flow period.

## Problem

The residential area of a city has a population density of 15000 persons/km² and an area of 120000 m². If average water consumption is 400 litres per capita day. Find the average and maximum sewage flow in m³/day.

Pop. Density = 15000 per/km²
Area = 120000 m²
Avg. Water Consumption = 400 lpcd
Total population = \( 15000 \times 120000 / (1000)^2 = 1800 \) persons
Avg. Sewage flow = \( 1800 \times 400 \times (80/100) = 576000 \) l/day = 576 m³/day

Peak factor:
\[
M = \frac{1 + 14/(4 + \sqrt{P})}{(in \ thousands)}
\]
\[
M = \frac{1 + 14/(4 + \sqrt{1.80})}{3.62}
\]
Max sewage flow = 3.62 x 576 = 2085.12 m³/day = 1.448 m³/sec
Problem

Calculate the size and slope of a sanitary trunk sewer serving a population of 0.4 million. Use peak flow as 2.3. Water consumption is estimated to be 300 lpcd. Pipe used is RCC. Take infiltration as 10% of average sewage flow.

Solution: water supply = Population \( \times \) per capita demand = 0.4 \( \times \) 1000000 \( \times \) 300 = 120000 \( \mbox{m}^3 \) / day = 1.388 \( \mbox{m}^3 / \mbox{sec} \)

Dry weather flow:

Average Sewer flow = 1.388 \( \times \) 80/100 = 1.11 \( \mbox{m}^3 / \mbox{sec} \) = 96000 \( \mbox{m}^3 / \mbox{day} \)

Peak Factor (WASA) = 2.3

Peak Flow = 2.3 \( \times \) 96000 = 220800 \( \mbox{m}^3 / \mbox{day} \); Infiltration = 10/100 \( \times \) 96000 = 9600 \( \mbox{m}^3 / \mbox{day} \)

Design Flow = Peak Flow + infiltration = 220800 + 9600 = 230400 \( \mbox{m}^3 / \mbox{day} \) = 2.67 \( \mbox{m}^3 / \mbox{sec} \)

Dia of sewer:

\[ Q = AV = 230400 \times 1 / 24 \times 60 \times 60 = A \times 0.6 \Rightarrow A = 4.45 \mbox{ m}^2 \Rightarrow \mbox{Diameter} = 2.38 \mbox{ m} ; \mbox{ Slope of sewer:} \]

\[ V = 1/n R^{2/3} S^{1/2} \Rightarrow 0.6 = 1/0.013 \times (2.38/4)^{2/3} (S)^{1/2} \Rightarrow S = 1.2157 \times 10^{-4} \Rightarrow S = 0.0001215 \mbox{ mm} \]

Sewage flow storm water

- 1: Rational Formula
- The simplest formula used for a catchment area \( \geq 0.5 \mbox{ km}^2 \leq 3.0 \mbox{ km}^2 \). The general form of Rational formula is \( Q = 0.0028 C I A \) where \( Q = \mbox{peak discharge in} \mbox{ m}^3 \mbox{sec}^{-1} ; C = \mbox{Runoff coefficient based on surface storage, infiltration and evaporation less for pervious and more for impervious terrain} ; I = \mbox{rainfall intensity in} \mbox{ mm hr}^{-1} ; \mbox{ A = catchment area in hectares} \).
- For impervious surfaces \( C = 0.175t^{1/3} \) or \( C = t / (8+t) \)
  
  For pervious surfaces \( C = 0.3xt/(20+t) \) where \( t \) is the duration of storm in minutes.

  Assumptions:
  (i) The maximum runoff rate to any design location is a function of the average rate of rainfall during time of concentration, and
  (ii) The Max. rate of rainfall occurs during time of concentration.
Sewage flow storm water

2: Time of concentration method

Time of concentration is defined as the flow time from the most remote point in the discharge area to the point under consideration. Time of concentration consists of two parts.

(i) Inlet or overland flow time \( (T_i) \): the time taken by water to flow overland from the critical point up to the point where it enters the drain. A number of factors like rainfall intensity, surface slope and roughness, flow distance, infiltration capacity and depression storage affect flow inlet time.

Mathematically \( T_i = \frac{0.885 \times L^3}{H^{0.385}} \) where \( T_i \) = Inlet time in hours; \( L \) = length of overflow in km from critical point to drain mouth and \( H \) = total fall of level from critical point to the mouth of drain in meters.

(ii) The channel flow time \( (T_f) \): The time taken by water to flow in the drain channel from the mouth to the considered point. \( T_f = \frac{\text{Length of drain}}{\text{velocity of drain}} \).

Time of concentration \( T_c = T_i + T_f \)

Example

A watershed to contribute an urban storm drainage is 50 hectares, of which 30 ha. having C value of 0.36 with 7% slope, and 20 ha. of 0.5 with 3% slope. The length of run is 720 meters. Calculate peak runoff if rainfall intensity is 15 cm/hour. Velocity of flow is 1.2 m/s.

Given Information: Area = 50 hectares of which 30 ha. Having C = 0.36 and 20 ha = 0.5 I= 15 cm/hr.

Required : Peak Discharge

Solution: The weighted value of \( C = (30 \times 0.36/50) + (20 \times 0.5/50) = 0.415 = 0.416 \)

Time of concentration = Length of run/ velocity = \( \frac{720}{1.2 \times 60} \) = 10 minutes

Rational formula for peak discharge \( Q = 0.0278 \times C \times I \times A = 0.0278 \times 0.416 \times 15 \times 50 = 8.65 \text{ m}^3/\text{sec} \) Answer
STORM WATER SEWAGE: SOIL CONSERVATION SERVICES (SCS) TECHNIQUE:

Soil conservation techniques is based on Curve Number (CN), which is a runoff coefficient and depends on soil type, antecedent moisture. Hydrological soil group are classified as A, B, C & D.

Group A **Lowest runoff potential.** It consists of deep, well to excessively drained sands or gravels with very little clay and silt, also deep, rapidly permeable soil. The infiltration rate is very high, and minimum or no runoff occur from this hydrological group.

Group B **Moderately low runoff potential.** Such group is mostly sandy soil with less deeper than group A. It also less aggregated than A. It consists of moderately deep; moderately well to drained coarse soil. This group of soil have less average infiltration and more runoff than Group A.

Group C **Moderately high runoff Potential:** It consists of shallow soil and soil containing considerable clay and colloids. This group has below average infiltration than group D but more than B. The runoff concentration for such soil is more as compared to B but less than D.

Group D **Highest runoff Potential:** This group include mostly clay of high swelling properties. This cause the infiltration rate minimum and high runoff. This group also include some shallow soil with nearly impermeable sub horizon near the surface causing to minimize the infiltration and resulting of more runoff.

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Problems

Problem #13.1: A residential urban area has the following proportions of different land use; roofs 25%; asphalt pavement 14%; concrete sidewalk, 5%; gravel driveways, 7% grassy lawns with average soil and little slope, 49%. Compute an average runoff coefficient using the values in Table 13-2.

- **Solution**
- **Types of surface** | %age | C value | Product
  - roofs | 25% | 0.70-0.95 | 0.175-0.2375
  - Asphalt pavement | 14% | 0.85-0.90 | 0.119-0.1260
  - Concrete sidewalk | 5% | 0.85-0.90 | 0.0425-0.045
  - Gravel driveways | 7% | 0.05-0.10 | 0.0035-0.007
  - Grassy lawns | 49% | 0.13-0.17 | 0.0637-0.0833

Total 100 0.4037-0.4988
Average C = 0.45125
Problem#13.5

• A watershed of 4,000,000 m² has a present CN of 70 and an average slope of 3%. Development will modify 70% of the hydraulic length, increase the impervious area to 40%, and increase CN to 80. Compute the present and future peak discharge from a 100mm 24-hr storm.

Given information: Area = 4,000,000 m²; CN = 70; Slope = 3% Modification caused area = 70% CN = 80 Rainfall = 100mm-24hr storm

Required: Present and future Peak discharge

Solution: Peak discharge with CN 70 and 100 mm = 33.3 mm/24hr

So Peak discharge = 4,000000 * 33.3 mm/m/1000mm * 1/24hr * hr/60mint*mint/60 secs = 1.542 m³/sec

- Development  %  CN  Product
  70 80 5600
  30 70 2100

Average CN = 7700/100 = 77

By Interpolation (X-X₁/ X₂-X₁) = (Y-Y₁/ Y₂-Y₁) => (77-75) / (80-75) = (Y-41.8)/(51.0-41.8)

= 2/5 = Y- 41.8/9.2 = 9.2*2 = 5Y -209 =Y => 18.4+209/5 = 227.4/5 = Y => 45.48 mm

Total Peak discharge = 4,000000 m² * (45.48 mm/1000 mm/m) * (1/24hr*hr/60 minutes* minutes/60 secs) = 2.106 m³ sec⁻¹ Answer

Steps or stages for Design of sewer

Preliminary Investigation
Design consideration/formulation of design criteria
Actual design
Preparation of drawing and BOQ
Subsequent modifications.

Preliminary Investigation
It includes: If map of the area is not already available the first step is to carry out survey to draw the map of project area. Different details are marked on the map like Streets; Railway Lines; Streams
Locations of underground utilities like gas, water mains etc.
Establish benchmarks throughout the area and make down profiles. Soil conditions should be investigated for the type of stratum, location of water table, presence of any underground rock etc.
Collection of rainfall data.
Study of the natural slopes of area and selection of suitable disposal point.
**DESIGN CONSIDERATIONS / FORMULATIONS OF DESIGN CRITERIA**

Sanitary sewer = Peak flow + over flow + infiltration + Industrial flow – exfiltration

Sewers are designed on the basis of open channel flow.

\[ V = \frac{1}{n} R^{2/3} S^{1/2} \]  
(Manning’s Formula); Where,

- \( V \) = Velocity, m/s;  
- \( n \) = Coefficient of roughness  
- \( R \) = Hydraulic mean depth = \( \frac{\text{Area}}{\text{wetted perimeter}} \)  
- \( S \) = Slope of sewer

**Minimum Velocities:** Minimum velocities are also called self-cleansing velocities. It must be maintained in sewers to avoid deposition of suspended solids and subsequent choking due to the presence of solids in sewers.

Sanitary Sewers = 0.6 m/s (Organic Particular S.G = 1.61)  
Storm Sewers = 1 m/s (Inorganic particulars S.G = 2.65)  
Partially Combined = 0.7 m/s

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**Design Equation**

**Maximum Velocities**

A limit on higher velocity is imposed due to abrasive character of solids in wastewater. Other reason is that there will be higher slope of sewer and result in more execution. The maximum velocity depend on the nature of materials from which sewer has to be constructed. In likely areas we have to provide more slope due to natural slopes. Maximum velocity must be less than 2.4 m

The upper limit of velocity in set by screening action of a sewage are depend on limiting of sewer.

<table>
<thead>
<tr>
<th>Nature of Sewers</th>
<th>Non Scouring Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthen channel</td>
<td>0.60 – 1.20</td>
</tr>
<tr>
<td>Brick lined sewer</td>
<td>1.50 – 2.40</td>
</tr>
<tr>
<td>Cement line sewer</td>
<td>2.40 – 3.00</td>
</tr>
<tr>
<td>Stone ware sewer</td>
<td>3.00 – 4.50</td>
</tr>
</tbody>
</table>

Generally 2.4 m/s is used for of sewers
**PREPARATION OF DRAWINGS AND BOQ**

**Minimum Size of Sewer**

225mm is taken as minimum size (WASA, PHED). Choking do not take place even with bigger are usually thrown into sewer through man holes etc. (Examples: shrubs, bricks etc).

Minimum Cover is taken as 1 meter of the sewers to avoid damage from live loads coming on sewers.

**PREPARATION OF DRAWINGS AND BOQ:**

Typical drawings include:

- Sewer points;
- Manholes;
- Disposal Station;
- Sewer profiles or L-Sections

**SUBSEQUENT MODIFICATIONS:**

Mostly done due to some unforeseen incident, to accommodate some additional demand / requirement of the client etc. there may be several other reasons.

---

**Design flow in Sanitary Sewer**

To find the design flow in sanitary sewers the following steps are followed:

1. Forecast the design population (P) of the area.

2. Find the sewage flow per day by multiplying population with flow per capita of sewage. The sewage is taken as (70 – 80) % of average water supply. If \( q \) is average per capita per day water consumption of water then \( Q_{avg} = \text{Average Sewage Flow} = (0.7 \rightarrow 0.8) \times P \times q \)

3. Select a peaking factor (P.F) to find the peak sewage flow according to Population by formula

\[
M = 1 + \frac{14}{(4 + VP)} \]

If population is not given then use WASA guidelines according to which Laterals M= 4; 2.5 for main and trunk and 2.0 for combined. The peak discharge = \( Q_{peak} = (P.F) (Q_{avg}) \)

4. Calculate the allowance for industrial and commercial sewage at a rate of 3734 m³ / km² / day.

5. Calculate infiltration from average sewage flow as given by WASA. \( Q_{inf} = (0.05 \text{ to } 0.1) Q_{avg} \)

6. Find the design sewage flow by adding peak flow, industrial allowance and infiltration flow.

\[
Q_{design} = Q_{peak} + Q_{inf} + Q_{inf}
\]

Normally Manning’s formula is used for design of sanitary sewer which is:

\[
V = \frac{l}{n (R)^{1/2}} S
\]

Where \( V \) = Velocity of sewage flow  \( R \) = Hydraulic radius  \( S \) = Slope of sewer  \( n \) = roughness coefficient
SEWER FLOWING PARTIALLY FULL

It is necessary to determine velocity and depth of sewage in a pipe when it is flowing only partially full. For this, use of the graph will allow quick computation of the hydraulic elements of partially filled circular sewer. For using this graph, it is necessary to find first the conditions when a sewer is flowing full. Then by calculating the ratio of any two known hydraulic elements, the others can be found.

SIGNIFICANCE OF PARTIAL FLOW STUDY

Conditions during partial flow must frequently be determined in combined / partially combined sewers due to the following reasons:-

1. To investigate velocities during dry weather flow to eliminate possibilities of deposits occurring in pipes.
2. Knowledge of depth of flow is of value in designing sewer intersections. Large sewer should be brought together at elevations so that water may not back up into the other.

Note: Sewers flowing partially full is more important in combined sewers then in partially combined but we also study it for partially combined sewer.

Problem

A 915 mm circular combined sewer is laid on a slope of 0.003 and it is flowing full. Manning’s n=0.013 what will be the velocity and depth of flow when sewer is carrying 0.142m³/s discharge? Let d/D = 0.3 and Va/Vf = 0.6

Solution

\[ D = 915 \text{ mm}; \quad S = 0.003; \quad n = 0.013 \]
\[ V_{\text{full}} = \frac{1}{n} R^{2/3} S^{1/2} = \frac{1}{0.013} \left( \frac{915}{4 \times 1000} \right)^{2/3} \left( 0.003 \right)^{1/2} = 1.276 \text{ m/s} \]

\[ Q = AV = \frac{\pi}{4} \times (0.915)^2 \times 1.276 = 1.036 \text{ m}^3/\text{s} \]
\[ Q_a = 0.142 \text{ m}^3/\text{s} \]
\[ \frac{Q_a}{Q_f} = 0.142/1.036 = 0.137 \approx 0.14 \]
\[ d/D = 0.3 \quad d = 0.3 \times 915 = 274.5 \text{ mm} \]
\[ d = 274 \text{ mm} \]
\[ D = 915 \text{ mm} \]

\[ V_a/V_f = 0.6 \quad V_a = 0.6 \times 1.576 = 0.946 \text{ m/s} \]
SEWER PIPES

Any types of pipes can be used for sewage flow that has to be used in water supply. As water supply flow is usually full and having high velocity. Therefore a good quality of pipeline has to be used. In case of sewage as the flow is mainly by gravity therefore even low quality of pipe can be used. The common types of pipes that has to be used are PVC; AC; RCC and PCC. CI and steel pipes are used under unusual loading condition. Also when sewer acts as a force main (water is under pressure – due to natural slope there is no gravity flow).

PCC Pipes: Normally used for small storm drains and sanitary sewers. Specifications used are ASTM.

<table>
<thead>
<tr>
<th>Size</th>
<th>100mm ~ 610mm (4“ ~ 24”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>I II III</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>Wall A B C</td>
</tr>
<tr>
<td>Thin</td>
<td>Weakest Strongest</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>Thin Normally Thick</td>
</tr>
</tbody>
</table>

R.C.C Normally used for sanitary and combined sewers.

<table>
<thead>
<tr>
<th>Size</th>
<th>225mm ~ 4570mm (9“ ~ 180”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Available in five classes</td>
</tr>
<tr>
<td></td>
<td>I II III IV V</td>
</tr>
<tr>
<td>Weakest</td>
<td>Normally used Strongest</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>Wall A B C</td>
</tr>
<tr>
<td>Thin</td>
<td>Normally used Thick</td>
</tr>
</tbody>
</table>

Sewer Construction

Following are the steps:

1. Marking of sewer lines (done with chalk powder to demarcate the correct alignment of sewers)
2. Excavation of Trenches
   Min width of trenches = 1.5D + 300. where D = diameter in mm
3. Bracing of Trenches (Optional)
   Usually done when the trench become very deep on strata is very loose. Bracing avoid caving in of trench walls thus preventing accidents etc. Dewatering (optional) Done when sewer is to be laid under water table
4. Laying and Jointing of Pipes
5. Backfilling
   Manual backfilling up to 0.75 meter. Afterwards with tractor or other machine
6. Construction of Appurtenances (Accessories)
**STRENGTH OF R.C.C PIPE**

Three edge bearing test is used to measure the strength of R.C.C pipes. Load is applied on Pipe to produce a load crack of 0.25mm crack

Strength of the pipe is expressed as KN/linear max

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**SEWER BEDDINGS**

If sewers are simply laid by placing the pipe barrel on the flat trench bottom, the pipe will not be able to support a load significantly greater than the THREE EDGE BEARING TEST.

However, if the bedding trenches at least the “LOWER QUADRANT” of the sewer and bad material is care fully tamped around the sides of pipe, the supporting strength of pipe significantly increase.

LOAD FACTOR express the increase in strength and numerically \( L.F = \frac{\text{Load carrying capacity}}{3} \)

Various bedding normally used by PHED & WASA (Pakistan) along with their load factors are shown below.

- **Class C Bedding**
  - LF = 1.5
  - LF = 3

- **Class B Bedding**
  - LF = 1.9

- **Class A Bedding**
  - LF = 1.9
Sewer Testing for leakage

- Sewer that has been laid and jointed are tested for water tight joints and for correct straight alignment as follows

- **Test for leakage (Water test):** The sewer are tested to ensure that no leakage through their joints occurs after giving a sufficient time to these joints for proper setting. For this purpose the sewer pipe sections are tested between manhole to manhole under a test pressure of about 1.5 m of water head.

  In order to carryout this test on a sewer line between two manholes, the lower end of sewer is first plugged. Water is now filled in the manhole at the upper end and is allowed to flow through the sewer line. The depth of water in the manhole is maintained to be testing head at least of 1.5 m. The sewer line is watched by moving along the trench and the joints which leaks are to be repaired. The leaking pipe if any will also be replaced .

- **Sewer Testing for straightness:** The straightness of a sewer pipe can be tested placing a mirror at one end of the sewer line and a lamp at the other end. If the pipe line is straight, the full circle of light will be observed. However if the pipe line is not straight, the mirror will indicate any obstruction in the pipe barrel.

- Any obstruction present in the pipe can be tested by throwing a smooth ball in the inner diameter of pipe at the upper end of sewer. In the presence of obstruction ball will not reach to the lower end, while in absence will reached to lower end.