

Water Supply Engineering

Chapter 7

Reservoirs and Distribution System

Lecture 12 (Week 12)

Reservoirs and Distribution System, System of supply, Clear water reservoirs, Service reservoirs and types, Numerical on capacity determination of service reservoirs

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Learning Objectives:

- Understand types of water supply systems: continuous and intermittent.
- Explain the advantages and limitations of each supply system.
- Describe the function and importance of clear water reservoirs
- Explain the role of service reservoirs in balancing demand and supply.
- Identify different types of service reservoirs used in water supply systems.
- Understand the features and site selection criteria for service reservoirs.
- Perform basic calculations to determine the required capacity of service reservoirs

7. Reservoirs and Distribution System

Reservoirs

Reservoirs are essential components of a water supply system. Their main function is to store treated water before it is distributed to consumers. These structures help to balance the variation between water production and consumption throughout the day. Reservoirs also provide a reserve for emergencies such as firefighting, maintenance shutdowns, or supply interruptions.

Types of Reservoirs:

1. **Clear Water Reservoirs:** These are located at or near the treatment plant and store clean water before it enters the distribution system.
2. **Service Reservoirs (Balancing Reservoirs):** Positioned within the distribution network, these regulate daily fluctuations in demand and supply.

Functions of Reservoirs:

- Equalizing peak demand
- Providing pressure to the distribution network
- Storing water for emergencies
- Assisting in operational flexibility

Reservoirs may be constructed underground, at ground level, or elevated, depending on the terrain and pressure requirements of the distribution system.

Distribution System

The distribution system is a network of pipes and associated components that deliver water from reservoirs to consumers. Its design is crucial for ensuring that water is supplied continuously, safely, and at adequate pressure.

Types of Distribution Systems:

1. **Gravity System:** Uses elevation difference to distribute water. It is cost-effective and requires minimal energy but depends on topography.
2. **Pumping System:** Water is pumped directly into the network. This system is suitable for flat terrains but requires continuous energy input.
3. **Combined System:** A mix of gravity and pumping, often used in areas with variable topography.

Components of a Water Distribution System

A well-designed water distribution system ensures that safe, adequate, and reliable water supply reaches end users efficiently. The key components of a typical distribution system are described below:

1. Service or Distribution Reservoir

- These reservoirs serve as storage units that help balance fluctuations between water supply and consumer demand. They play a critical role in:
 - Maintaining consistent pressure in the distribution network.
 - Acting as a buffer during peak demand or supply interruptions.
 - Supporting emergency water requirements (e.g., during fire outbreaks).

2. Pipe Network

- A system of interconnected pipes forms the backbone of the water distribution system. The main functions include:
 - Transporting treated water from reservoirs to various parts of the community.
 - Ensuring even and efficient distribution across all service zones.

3. Pumps

- Pumps are used to move water from sources or lower elevations to higher elevations or to pressurize the system. Their roles include:
- Lifting water to overhead tanks or elevated reservoirs.
- Maintaining adequate flow and pressure within the network.

4. Valves

- Valves are essential control elements in the distribution system. They help:
- Regulate and isolate the flow of water as needed.
- Enable maintenance work by shutting off specific sections.
- Control pressure and prevent backflow in the system.

5. Service Connections

- These are the individual pipelines that connect the main distribution lines to user premises. They:

- Provide direct water access to residential, commercial, and institutional consumers.
- Usually include meters, stop valves, and sometimes backflow preventers.

6. Meters

- Water meters are installed to:
 - Measure the volume of water supplied to households or specific areas.
 - Support fair billing and monitor usage.
 - Detect leakages or unusual consumption patterns.

7. Fire Hydrants

- These are special fixtures attached to the distribution network, intended for:
 - Providing immediate access to water during fire emergencies.
 - Being strategically located for easy access by fire services.

8. Public Standposts

- Public standposts are communal water delivery points provided in areas without private connections. They:
- Ensure access to clean water for people in underserved or low-income communities.
- Are typically located in public spaces and used by multiple households.

7.1 Supply of water system

❖ Basically, water is supplied to the consumers by two types:

1. Continuous system
2. Intermittent system

7.1.1 Continuous System

- water is supplied to the consumers for all 24 hours of a day from a system of supply

Merit

- Water is available every time hence no need of private storage tank.
- No stagnant in the pipe at any instant hence fresh water is always available.
- Adequate quantity of water is available at any time for fire fighting.
- Lesser pipe sizes are required.

Demerit

- More wastage of water if the people do not possess the civic sense and do not understand the importance of water.
- If there is leakage in the system, large volume of water is wasted because of long duration of flow.
- On repairing supply may be interrupted during supply hours. (Kansakar, 2015)

7.1.2 Intermittent system

- Water is supplied to the consumers only during fixed hours of the day. Common system in Nepal; especially in city of Nepal. (Kansakar, 2015)

Advantages:

- Useful when either sufficient pressure or quantity of water is not available at the source.
- At various distribution zones of the city, water can be supplied by turn.
- Repairing work can be done in non-supply hours.
- Leakage causes less wastes of water because of small duration of flow.

Disadvantages:

- As a whole this system is inconvenience to the consumers because they have to remain alert to collect the water supply.

- People store water during non- supply hours. Consumers needs sufficient storage.
- No water is available for fire fighting in non-supply hours.
- More waste of water when taps left open unknowingly during non supply time.
- It requires bigger sized diameter pipes.
- During non-supply time pressure in the line may fall below atmospheric pressure, which may induce suction of external matter and soil through leak joint.
- Many valves will be required for maintaining flow and extra staff may be required.

Reservoir

- ❖ A tank is used to store water is called reservoir. The storage may be public storage (clear water reservoirs, service reservoirs, balancing reservoir) and private storage (roof tank, underground tanks).

- ❖ This stored water is then supplied to the consumers through system of reservoirs and pipe networks called distribution system.
- ❖ Larger capacity of reservoir will increase its cost.
- ❖ Larger the capacity of reservoir, the better will be the reliability of water supply system.

Purposes:

The reservoirs are necessary for the following purposes:

- To provide a reserve against failure of main or in intermittent systems of supply.
- To balance the fluctuations in the demand.
- To reduce the pressures on the various appliances and installation
- To maintain uniform pressure in the distribution system.
- To meet the emergency demands such as firefighting.

7.2 Clear water reservoirs

Clear Water Reservoirs are crucial components in a water supply system, positioned at the final stage of the water treatment process. Their primary function is to store treated (filtered and disinfected) water before it is distributed to consumers via the service reservoirs or directly through the distribution network.

Location and Construction

- These reservoirs are typically located within or near the water treatment plant, ensuring immediate storage after treatment.
- Depending on the topography and site conditions, they may be constructed partially or fully underground, or sometimes half above and half below ground level.
- Common construction materials include reinforced cement concrete (RCC) and masonry, providing durability and structural strength.

- The reservoir structure is usually divided into two or more compartments. This division allows one part of the reservoir to remain in service while the other undergoes maintenance, cleaning, or repairs, ensuring an uninterrupted water supply.

Function and Operation

- These reservoirs act as intermediate storage units, temporarily holding treated water before it is:
 - Pumped to elevated service reservoirs for gravity-fed distribution, or
 - Directly pumped into pressurized distribution networks.
- The stored water is referred to as clear water because it has passed all stages of purification, including sedimentation, filtration, and disinfection.

Capacity Requirements

- The storage volume of a clear water reservoir should be sufficient to meet 14 to 16 hours of daily water demand. This buffer is essential for:

- Coping with fluctuations in water consumption.
- Ensuring availability during temporary pump shutdowns or power failures.
- Supporting demand during peak usage times.

Additional Considerations

- Access points, ventilation, and manholes must be provided for inspection and cleaning.
- Reservoirs should be covered and sealed to prevent contamination from dust, animals, or unauthorized access.
- Overflow arrangements, drain valves, and scour valves must be installed to ensure operational safety and ease of cleaning.

7.3 Service reservoirs

- ❖ It is used to store the filtered water to meet the widely fluctuating demands from clear water reservoir, to provide storage for firefighting and emergencies and to equalize operating pressures and is constructed before distribution system.

- ❖ Constructed with masonry and RCC. Covered well to avoid contamination.
- ❖ Suitable provisions are made for manholes, access ladders, scour, etc
- ❖ Located near to the community as far as possible to supply water in shortest possible time
- ❖ Elevated types are also popular.
- ❖ These service reservoirs should be designed for balancing, breakdown storage and fire storage. (Dr. B.C Punmia, Er.Ashok Kumar Jain, Dr. Arun K.Jain, 2013)

7.3.1 Purpose and Construction

It serves the following purposes

- a) Balance the fluctuation in demand.
- b) Maintain uniform pressure in distribution system.

- c) Enable convenient pumping hours.
- d) Meet emergency demand like fire.
- e) Improve quality due to storage.
- f) Distribution system becomes economical.
- g) Operation of distribution system becomes very easy.

Construction Aspects:

- Built with durable materials such as RCC to ensure strength and longevity.
- Covered structures are essential to prevent contamination from external sources.
- Designed with practical features like access points, ventilation, and cleaning facilities.
- Capacity planning must account for balancing daily demand, emergency needs, and possible service interruptions.

7.3.2 Types of service reservoirs

Service Reservoir which is well known as distribution reservoir can be classified in following types on different basis:

A. According to situation with respect to ground

- Surface Reservoirs
- Elevated Reservoirs

1. Surface (Ground-Level) Service Reservoirs

Surface reservoirs, also known as **ground or non-elevated reservoirs**, are essential storage structures in a water distribution system. These reservoirs are typically constructed at or below ground level and are often placed on elevated terrain to utilize gravitational flow.

They function as intermediate storage units between water treatment plants and elevated or direct distribution systems, ensuring steady water supply and pressure regulation.

Key Features and Functions

Shape and Location

- Usually rectangular or circular in shape.
- Constructed at natural high elevations or on artificially raised platforms to assist gravitational distribution.
- Their placement at strategic locations minimizes energy requirements for pumping.

Construction Material

- Common materials include brick masonry, stone masonry, plain cement concrete (PCC), and reinforced cement concrete (RCC).

- RCC is particularly preferred for durability, strength, and water-tightness.

Structural Design Considerations

Sidewalls are designed to withstand:

- Internal water pressure when the reservoir is full.
- External soil pressure when the reservoir is empty.

Roof slabs (if covered) are equipped with **ventilators** for air circulation and protection against external contamination.

Underground designs are often chosen for large-capacity reservoirs or in urban settings to save surface space.

Hydraulic Components

- Inlet and outlet pipes regulate water inflow and distribution.
- Overflow pipes maintain the Full Supply Level (FSL) and prevent structural damage from overfilling.

- Washout pipes (typically placed at the lowest point) help in sludge and sediment removal.
- Sluice valves are used for isolating sections during repair or maintenance.
- Air vents prevent vacuum formation and allow air to escape during filling.

Compartments and Maintenance

- Surface reservoirs are often built with two or more compartments to allow continuous operation during cleaning or repair.
- This ensures that part of the reservoir can be in use while the other undergoes scheduled maintenance.

Design Considerations

- **Groundwater Table:** The location and depth of the water table must be accounted for to avoid uplift pressure and seepage.

- **Soil Conditions:** Structural stability depends on soil bearing capacity and drainage characteristics.
- **Accessibility:** Provisions for manholes, ladders, and walkways are essential for inspection and maintenance.

Advantages

- Cost-effective compared to elevated reservoirs for larger capacities.
- Easier to construct and maintain.
- Suitable for locations where natural elevation is available.

2. Elevated Reservoirs (Overhead Water Tanks)

Elevated reservoirs, also known as overhead tanks, are water storage structures built above ground level at a certain height, usually supported on reinforced concrete, masonry, or steel towers.

Their main purpose is to store treated water and distribute it using gravitational force, ensuring reliable supply and pressure to the consumers across the service area.

Shape and Structural Types

These reservoirs can be designed in various shapes based on structural and aesthetic considerations:

Circular: Common due to uniform stress distribution.

Rectangular: Suitable where site conditions favor such design.

Elliptical or Spheroid: Often used for larger capacities with modern aesthetic designs.

Working Mechanism

- Water is pumped from clear water or ground reservoirs to the elevated reservoir.
- From this elevated height, water flows by gravity into the distribution network.

- The height provides sufficient hydraulic head for maintaining pressure throughout the pipeline network, especially in flat terrains.

Components and Accessories

Elevated reservoirs are equipped with several essential accessories for smooth operation, safety, and maintenance:

Component	Function
Inlet pipe	Delivers water from pumping station or surface reservoir.
Outlet pipe	Supplies water to the distribution network.
Overflow pipe	Prevents overflow by allowing excess water to exit when tank is full.

Manhole	Allows access to the tank interior for inspection and cleaning.
Washout pipe	Removes sludge and sediments settled at the bottom during periodic cleaning.
Ventilator	Provides air exchange to avoid vacuum formation and protect water quality.
Ladders & Railings	Ensure safe access for maintenance personnel.
Water level indicator	Displays the current water level for monitoring.
Lightning conductor	Protects the structure from lightning strikes.

Design Considerations

- Elevation height is determined based on the required pressure head and topography of the service area.
- Capacity depends on daily demand, peak consumption, and fire-fighting requirements.
- Structural stability must consider wind loads, seismic forces (especially in seismic zones like Nepal), and water pressure.
- Foundation design must accommodate soil bearing capacity and load from the full tank.

Advantages

- Provides adequate pressure without continuous pumping.
- Efficient water distribution over wide areas.
- Ensures availability during power outages or pump failures.

- Enhances aesthetic appearance when properly designed.

Limitations

- **Construction cost** is higher than ground-level reservoirs.
- Maintenance at heights can be challenging and risky.
- Vulnerable to wind and earthquake forces without proper design

Additional Notes

- In regions with flat terrain or high-rise buildings, elevated reservoirs are essential for maintaining distribution pressure.
- Their presence is common in municipal supply systems, industries, schools, and apartment complexes.
- Modern designs often incorporate smart level sensors and remote telemetry systems for efficient monitoring and automation.

B. According to material of construction

- Stone Masonry Reservoirs
- Brick Masonry Reservoirs
- Ferro Cement Reservoirs
- HDPE Reservoirs
- PVC Reservoirs
- RCC Reservoirs
- Steel Reservoirs

C. According to the shapes

- Rectangular Reservoirs
- Square Reservoirs
- Circular Reservoirs
- Cylindrical Reservoirs
- Spherical Reservoirs

7.4 Numerical on capacity determination of service reservoirs

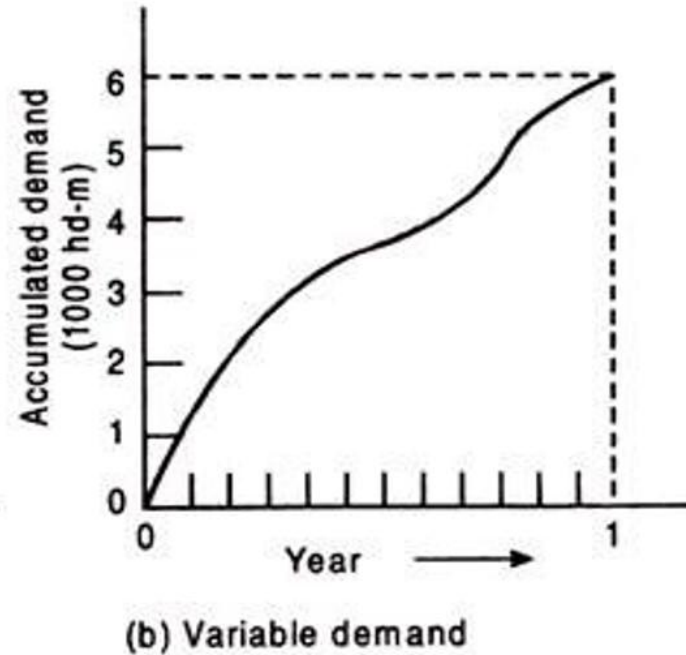
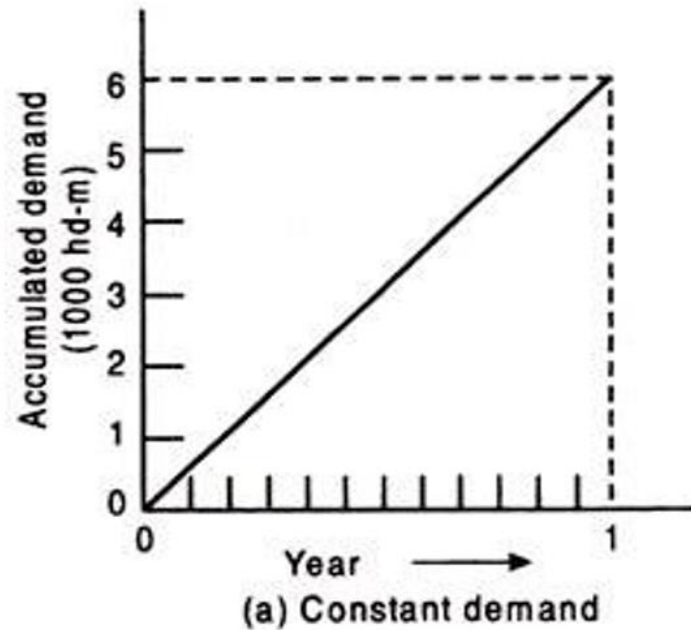
The storage capacity of service reservoir is based on the following three requirements:

- a. Balancing or equalizing reserve**
- b. Breakdown reserve**
- c. Fire reserve**

Balancing reserve:

- Demand of water always keeps on varying from hour to hour, but treated water comes at a constant rate from treatment plant
- Balancing reserve is that quantity of water required that is stored in reservoir for balancing variable water demand

- It is conventionally calculated by means of mass curve or hydrograph indicating hourly rate of consumption and commonly calculated by analytical method
- Microcomputers and calculators are widely used to calculate balancing reserve.



Source: (Kansakar, 2015)

Breakdown reserve

- It is the storage for emergencies such as the failure of pumps, electricity, or any other equipment and time for repairs.
- It is difficult to assess because such breakdown may be minor or it may be major which may take days or weeks to repair hence generally 25% of the total capacity of the reservoir or about 1.5 to 2 times the average hourly supply may be considered as breakdown storage.
- Higher value may be adopted, if the expectation of failure is very high.
- Normally in Nepal this storage is not considered.

Fire reserve

- The water stored in distribution reservoir for firefighting purpose is known as fire reserve.

➤ The amount of fire reserve can be determined from the following expression:

$$R=[F-P]*T$$

where,

R=reserve storage in liters

F= fire demand in liters/minutes;

P=reserve fire pumping capacity in liters/minute;

T= duration of fire in minutes

Q.1.The water demand of a town is 2160 m³/day. The water demand is to be met from the river flowing under gravity to the reservoir. The water is supplied to the consumers from the reservoir by continuous system. Calculate the capacity of balancing reservoir for the consumption pattern as shown in table below.

Hours	Water consumption in %
5.00-7.00	25
7.00-12.00	30
12.00-17.00	15
17.00-19.00	20
19.00-5.00	10

Solution:

Demand to be supplied from reservoir = $2160 \text{ m}^3/\text{day}$

Inflow to the reservoir = $2160/24 = 90 \text{ m}^3/\text{hour}$

Time		Hrs	Water consumption (%)	Supply(m ³) (Hrs*inflow)	Demand(m ³) (Total demand*water consumption)	Surplus (m ³)	Deficit (m ³)
From	To						
5:00	7:00	2	25	180	540(2160*25%)	-	360
7:00	12:00	5	30	450	648	-	198
12:00	17:00	5	15	450	324	126	-
17:00	19:00	2	20	180	432	-	252
19:00	5:00	10	10	900	216	684	-
Total		24	100	2160	2160	810	810

Therefore, capacity of the reservoir =684 m³.

Or, Capacity=Max. cum Surplus+Max. cum Deficict-Total Supply+Total demand

Works Cited

Dr. B.C Punmia, Er.Ashok Kumar Jain, Dr. Arun K.Jain. (2013). *Water Supply Engineering*. New Delhi: Laxmi Publications (P) LTD.

Kansakar, D. B. (2015). *water supply engineering*. kathmandu: Prakash Man Shakya.

Thank You!!!