# 3 COLLECTION AND DISTRIBUTION OF WATER

Collection and distribution of water deals with the transport of water from the source through the treatment plant to the consumers. It requires intake structures, transmission lines, distribution pipe networks and other essential accessories.

## 3.1 Surface water Intakes

Intakes are provided whenever water is withdrawn from surface sources such as a lake, a river or a reservoir. The structure should enable withdrawal of the best quality water as well as exclusion of fish, floating and suspended matters from getting into the conveyance system.

***Types of intakes***

Table 3.1 represents the different types of intake structures, their description and applicability.

***Table 3.1*** Intake structures for surface water sources

| Type | Description | Conditions for applicability |
|---|---|---|
| Floating intakes | ▪ Barge-type structure that floats on the water surface and anchored to a fixed pier so that horizontal movements are prevented<br>▪ inexpensive can be fabricated offsite and assembled onsite<br>▪ withdraw water from a fixed depth below the water surface | Suitable in water sources with unsuitable geological conditions and little variation in water surface elevation |
| Submerged intakes | ▪ Cribs with its top covered by a cast iron grating<br>▪ simple, easy, and relatively inexpensive to construct<br>▪ draw water from a fixed elevation near the bottom where poor quality water is usually located | Streams or lakes that have relatively little change in water surface elevation throughout the year |
| Tower intakes<br>▪ Wet intake<br>▪ Dry intake | ▪ Tower structures located offshore into rivers, lakes or reservoirs<br>▪ Withdraw optimum water quality through multiple gates<br>▪ more expensive to construct and less accessible than shore intakes | Large projects on rivers or reservoirs with large water level fluctuations |
| Shore intakes | ▪ Concrete structures open on the water side<br>▪ May use multiple gates to withdraw optimum quality water<br>▪ more expensive than floating or submerged structures | ▪ Lakes and reservoirs with deep shorelines |
| Pier intakes | ▪ Pile supported steel or concrete platform on which different equipment such as pump, valves, etc. rest<br>▪ Withdraw water from fixed level | ▪ Lakes or rivers where the water depth at the shoreline is too shallow for a shore intake |

### Surface-Water Intakes

Towers are common for lakes and reservoirs (Figure 3-2) with fluctuating water levels, or variations of water quality with depth. Orts at several depths permit selection of the most desirable water quality any season of the year.

A submerged intake consists of a rock-filed crib or concrete block supporting and protecting the end of the withdrawal pipe (Figure 3-3).

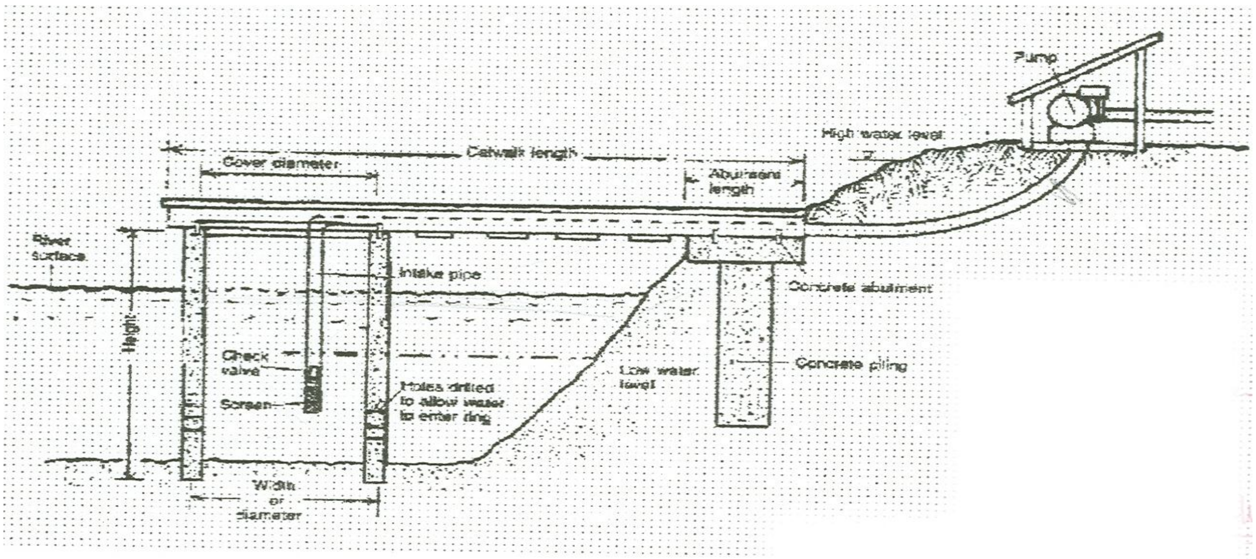


**Figure 3-1** Typical river intake structure with sump

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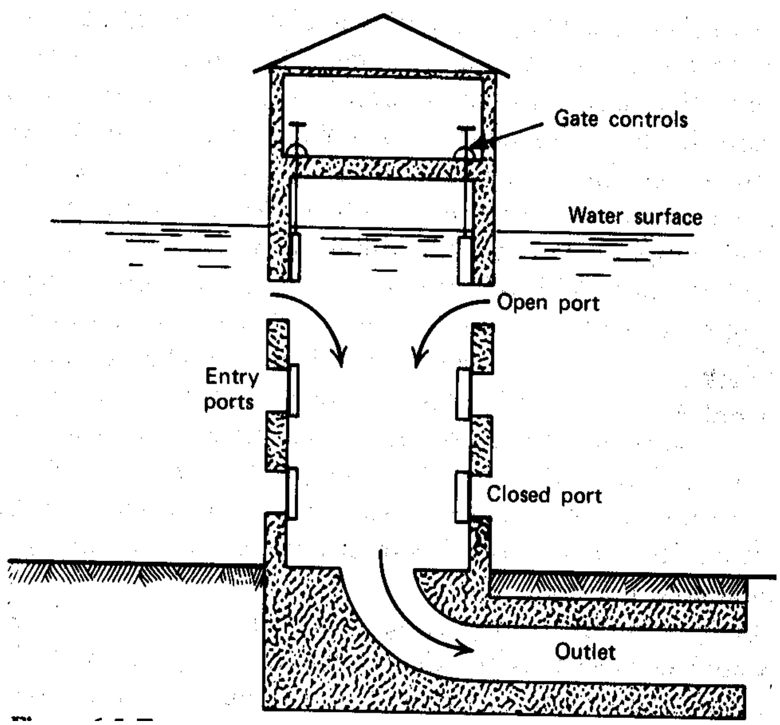



**Figure 3-2** Tower intake structure

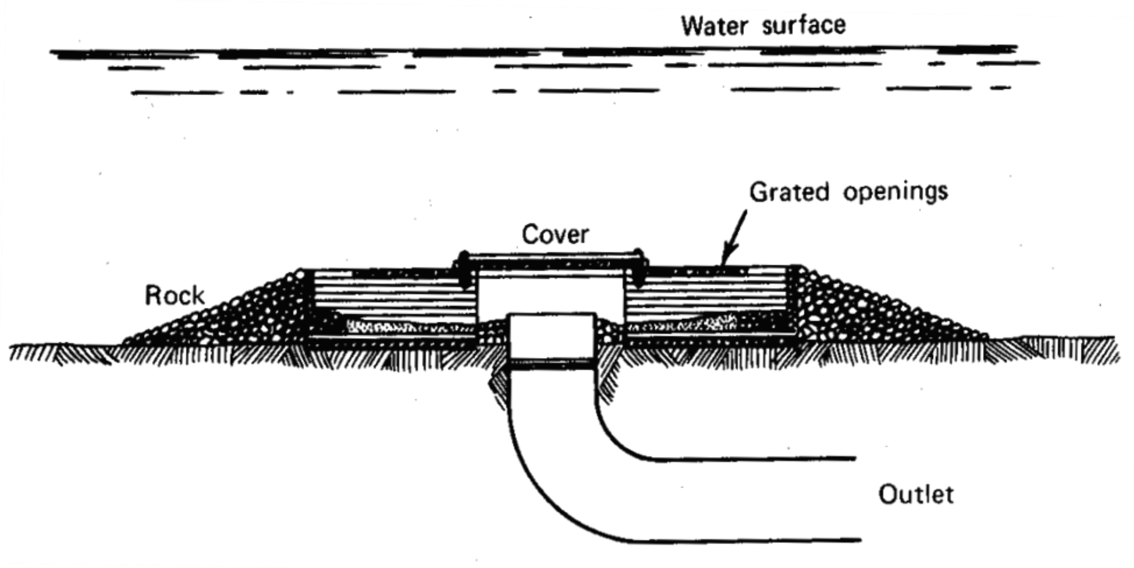



**Figure 3-3** submerged crib intake used for both river and lake sources

**Location of intake structures**

To locate the positions of intakes, the following factors need to be considered

- Avoid locations that are near wastewater discharge points and pollution hazard is likely as well as areas with poor water circulation.
- Select locations that enable withdrawal of water from a range of levels- lowest to highest levels.
- Magnitude and direction of stream or current velocities should be such that they do not affect the function and stability of the intake structure. The limiting velocity should be 0.6 m/s and avoid locating a river intake at the *curved* part of the river.
- Reliable access roads and power sources should be available to facilitate operation and maintenance of the intake structure
- The site for intakes should be near to treatment plant
- Sites that interfere with navigation requirements, if any, should not be considered
- Locations that result in major environmental impacts should be avoided

Design considerations for intake structures and the parameters of design include:

- Design capacity = Q max-day
- Intake velocity should be ≤ 8 cm/s so that suspended matters and fishes do not enter into the conveyance system. Too low velocities that require large intake ports should also be avoided.
- The vertical positions of top and bottom intake ports should be such that good quality water is withdrawn. Locate the top intake port at a distance not less than 2 m from the normal water level and the bottom port at least 1 m above the bottom.
- Major parameters of design:
    - Size and layout of the intake port(s)
    - Layout and bar arrangement of coarse screens

    - Location and size of fine screen
    - Head losses in the intake port, coarse and fine screens
    - A check on the stability of the intake structure

**Intake Design**

Factors to be considered in design

- Location
- Accessibility
- Pump safety (Cavitation)
- Location of LWL

An intake generally consists of a conduit with some protective screens at open end and gates or valves for regulating the flow.

- Inlet pipe
    - Location below lowest W.L. in the stream should be ≈ 1m but above stream bed ≈ from 0.3 to 0.5 m
    - Size, diameter determined based of head loss and velocity
    - Material (PVC, GS, …)
- Strainers
    - Type (mesh either cylindrical or bell-mouth type)
    - Entrance velocity should be 0.15 to 0.30m/s
    - Perforation diameter from 6 to 12mm
    - Cross-sectional area ≈ 2a (a=effective area of the strainer i.e. flow area)
- Sump
    - Bottom elevation of sump
    - Volume of sump is determined by the detention time. Higher detention time means larger volume. A detention time of at least 20min is recommended. Maintenance requirement of also governs the size of the sump. At least two sumps have to be provided to avoid interruption of service.
    - Distance from river
    - Height (total i.e. including a freeboard about 0.5m)
    - Location of the bottom of the sump should be > 1.5m below the stream level or > 1m below stream bed.
- Suction pipe
    - Size, length of the pipe should be determined considering cavitation requirement. Recommended velocity in the suction pipe is 1 to 1.5m/s.
    - Material (cost and availability)
- Pump
    - Characteristics (Q & H)
    - Type of pump
- Valves
    - Purpose (flow control, pressure control, ventilation, flushing)
    - Pressure
    - Location of foot valve should be about 0.6m above the bottom of the sump.
- Access
    - Length, width
    - Capacity

## 3.2 Water Conveyance systems

Conveyance systems serve the purpose of conveying water from the source through treatment plants to the distribution areas. Open channels such as canals, aqueducts, tunnels, etc. or pressure conduits can be used for this purpose.

## 3.3 Pipelines and appurtenances

***Pipelines***

Pipes could be of different types that include cast iron pipe, ductile cast iron pipe, steel pipe, plastic pipe and concrete pipe. The selection of pipe materials is based on such criteria as carrying capacity, strength, ease of transportation and handling, availability, quality of water, and cost (initial and maintenance).

*Cast iron pipes*: are mostly used in water supply schemes. These are highly resistant to corrosion, strong but brittle, usually offer a long life, and reasonably maintenance free. Cast iron pipes are manufactured in lengths of 2.5 m to 5.5 m. Cast iron pipes are joined together by means of Bell and Spigot threaded or flanged joints. These pipes have the advantages of easy jointing, withstanding high internal pressure, long life and less corrosion. But they are very heavy and difficult to transport, because due to brittleness they break or crack easily.

*Steel pipe:* It is occasionally used for main lines and at such places where pressures are high and pipe diameter is large. Steel pipes are strong, have very light weight and can withstand higher pressure than cast iron pipes. They are cheap, easy to construct and can be easily transported than cast iron pipes. The disadvantage of these pipes is that they cannot withstand external loads. If partial vacuum is created by emptying a pipe rapidly, the pipe may collapse or distorted. These pipes are much affected by corrosion and are costly to maintain. The joints in steel pipes can be made by welding or riveting.

*Cement-lined cast iron pipes*: When the water contains corrosive elements, the cast iron pipes are lined with cement to protect them against corrosion. They have very small coefficient of friction than unlined cast iron pipes.

*Plastic pipes*: Nowadays plastic pipes are becoming more and more because of their corrosion resistance property, light weight and economy. Rigid (unplasticized) uPVC pipes are widely used for water services, internal/external water supply systems and water mains. It is stronger and can withstand much higher pressure for a given wall thickness. Generally uPVC is resistant to most inorganic acids, alkaline and salts, as well as many organic chemicals.

*Concrete pipes:* These pipes may be plain, reinforced or prestressed pipes. Plain concrete pipe may be used at such places when water does not flow under pressure. These pipes are joined by Bell and Spigot joints. They are corrosion resistant and more suitable to resist external loads.

*Asbestos cement pipe:* These are manufactured from a mixture of cement and asbestos fiber. Asbestos cement pipes are very light and therefore can be easily handled and transported. They can be easily cut, fitted, drilled, tapped and joined. These pipes are very smooth and are not affected by corrosive materials, and hence have good carrying capacity. Nowadays they are not used due to health issues related to asbestos fiber which is suspected to cause cancer.

***Pipe Joints***: for the facilities in handling, transporting and placing in position, pipes are manufactured in small lengths of 2 to 6 meters. These small pieces of pipes are then joined together after placing in position, to make one continuous length of pipeline. Available pipe joints include *bell-and-spigot*, *push-on*, *mechanical*, *flanged*, *vectualic coupling, and dresser coupling.* Figure 3.4 represents alternative joints for castiron pipes.

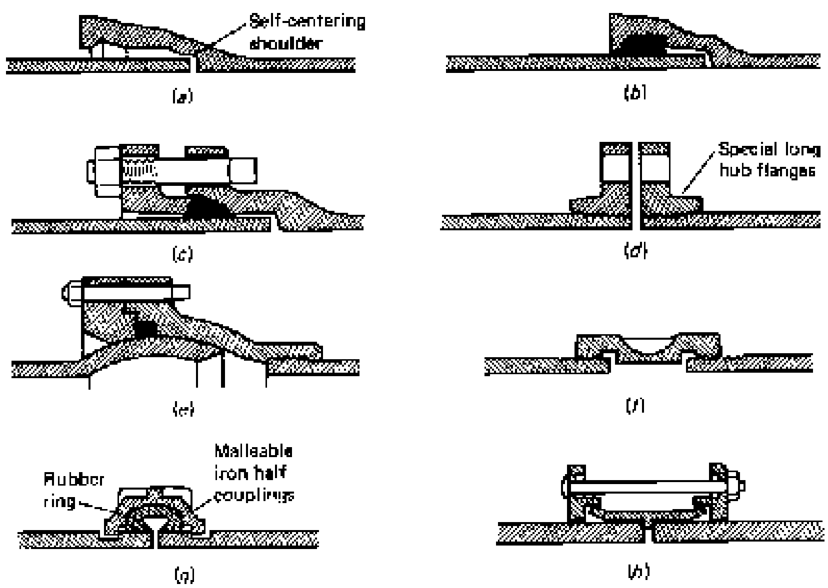



**Fig. 3.4** Cast-iron pipe joints (a) Bell-and-spigot (b) push-on (c) mechanical (d) flanged (e) ball (f) threaded (g) victualic coupling (h) dresser coupling

## ***<u>Appurtenances</u>***

Commonly used appurtenances include valves, backflow preventers, surge controls, and hydrants

### Valves

Valves are installed throughout water systems, treatment plants, pumping stations, pipe networks, and storage reservoirs. Their purpose is to isolate segments of a pipeline, to regulate rate of flow, to control pressure, and to allow release or entry of air from pipe system. Factors to be considered in the selection of valves include purpose and operation, capacity required, head loss and rate of flow, cost, availability, etc. The locations of all valves should be clearly marked on as-built plans, and described in relation to readily identifiable landmarks or prominent physical features, so that they can be easily found in the field. All valves should be protected by suitable valve boxes (usually cast iron, concrete, or high-density plastic) and located so that they will not be affected by normal street or highway maintenance operations. Valves are classified by function as follows.

1. ***Shutoff valves***. These are the most abundant valves in a water system and are used to stop the flow of water through a pipeline. Pipe networks are sectionalized by installation of shutoff valves so that any area affected by a main break or pipe repair can be isolated with a minimum reduction in service and fire protection. Depending on the district within the city and size of the water mains, valve spacings in the distribution area range from 150 to 370m. Ideally, a minimum of three of the four pipes connected at a junction are valved. The pipe connecting a fire hydrant to a distribution main contains a valve to facilitate hydrant repair. In treatment plants and pumping stations, shutoff valves are installed in inlet, outlet, and by-pass lines so that the valves and pumps can be removed for maintenance and repair.

   Gate valves and butterfly valves are the commonly used shutoff valves. A gate valve has a solid sliding gate that moves at right angles to the direction of flow by a screw-operated stem. Gate valves are widely available, relatively low in cost, create very little head loss in the fully open position, and effectively stop flow in the fully closed position. They are, however, of only limited value for throttling or controlling flow and, therefore, not usually used for such purposes.

   A butterfly valve has a movable disk that rotates on a spindle or axle set in the shell. The main disadvantage of a butterfly valve result from the disk always being in the flow stream, restricting the use of pipe-cleaning tools. On the other hand the advantages of this valve are tight shutoff, low head loss, small space requirement, and throttling capabilities.

2. ***Check valves.*** A check valve is a semiautomatic device that permits water flow in only one direction. It opens under the influence of pressure and closes automatically when flow ceases. Usual installations are in the discharge pipes of centrifugal pumps to prevent backflow when the pump is not operating, and in conjunction with altitude valves in connections between storage reservoir and the distribution networks.
3. ***Altitude valves***. Altitude valves are used to automatically control the flow into and out of an elevated storage tank or standpipe to maintain desired water level elevations. These valves are usually placed in a valve pit adjacent to the tank riser. Altitude valves can be of different types that include double-acting sequence valve, single-acting type, or differential altitude valve.
4. ***Air-release and vacuum valves***. Air can enter a pipe network from a pump drawing air into the suction pipe, through leaking joints, and by entrained or dissolved gases being released from the water. Air pockets increase the resistance to the flow of water by accumulating in the high points of distribution piping, in

valve domes, and fittings, and in discharge lines from pump. Air-release valves are installed at these locations to discharge the trapped air. Valves are also needed to protect pipelines from collapse as they are emptied, by allowing air to enter the pipes. Vacuum valves are used for this purpose. Combinations of air release-vacuum valves are available. Air release and vacuum valves are normally not needed within interconnected grid portions of distribution systems.

5. ***Scour or blow-off valves***. These are valves provided either at dead ends or lowest points in the mains to remove sand or silt that might have deposited in the pipeline.
6. ***Pressure reducing valves (PRV)***. Occasionally, topography will be such that excessive pressures result in low-lying regions of the distribution system. In such cases, pressure reducing valves can be quite useful (Fig. 3.5). They operate automatically to throttle flow to maintain the desired downstream pressure as long as the upstream pressure is sufficient. For small systems, it is generally best to avoid using pressure-reducing valves on distribution lines if at all possible. Pressure reducing valves are frequently used on individual water service lines to protect house plumbing and appliances such as water heaters.

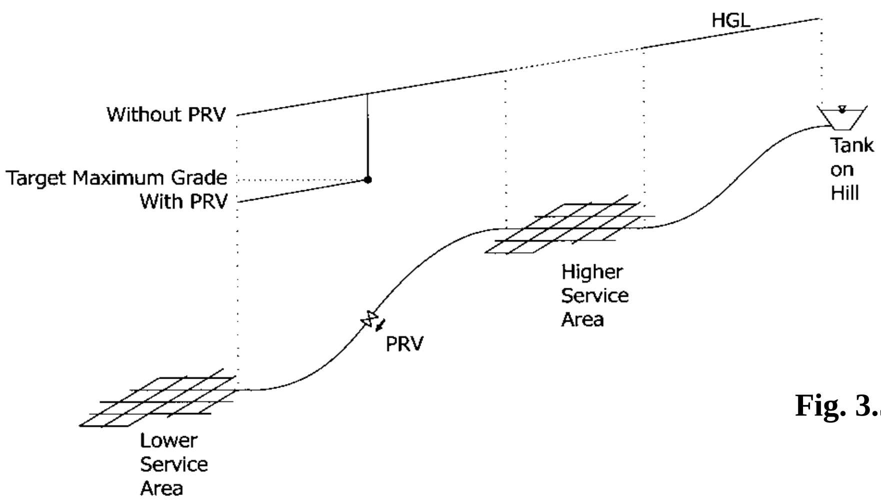



**Fig. 3.5**

7. ***Pressure sustaining valves (PSV).*** This type of valve can be used to prevent a drop in the upstream hydraulic grade line or pressure due to unregulated flow as shown in the fig. 3.6.

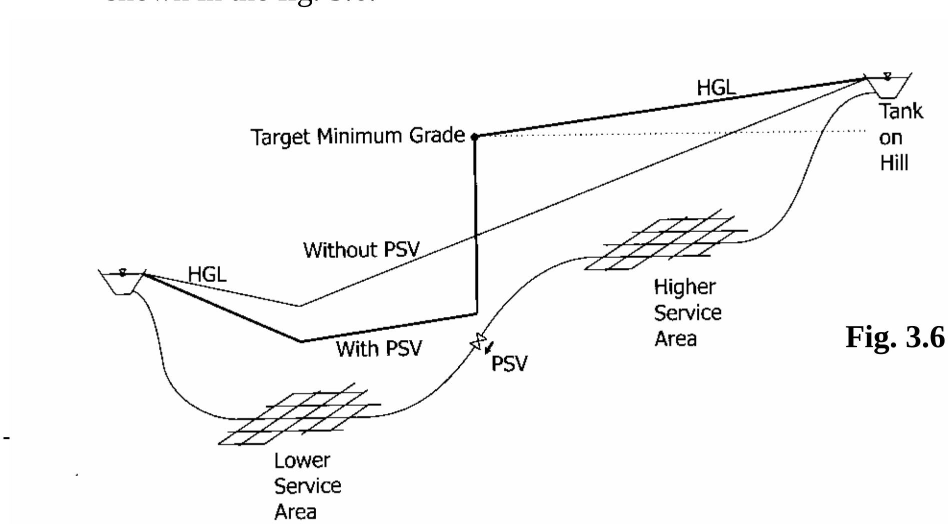



**Fig. 3.6**

8. ***Surge-control devices.*** Velocity changes caused by closure of a valve or variations in pumping rates may result in transient pressure waves that travel through the piping system. Propagation of these waves could be prevented by the uses of quick-opening and slow-closing valves (e.g. globe valves), surge towers or hydropneumatic tanks.

**Backflow preventers**

The water in a distribution system must be protected against contamination from backflow through customer service lines and other system outlets. A cross-connection refers to an actual or potential connection between a potable water supply and an industrial or residential source of contamination. By practicing cross-connection control through enforcement of a plumping code and inspection of back flow preventers in service connections, a municipal utility can ensure against distribution contamination under foreseeable circumstances.

Back siphonage is a backflow resulting from negative or reduced pressure in the supply piping. It can also result from a break in a pipe, repair of a water main at an elevation lower than the service point, and reduced pressure from the suction side of booster pumps. In contrast, back pressure causes reversal of flow when the pressure in a customer's service connection exceeds the pressure in the distribution main supplying the water.

Air-gap separation is the simplest method used to prevent backflow into the supply pipe. Household water supplies are usually isolated from the public-water supply system by air gap separation using a storage tank in the attic or on the roof of the dwelling (see Fig. 3.7). Available mechanical backflow preventers include atmospheric-vacuum breaker, pressure-vacuum breaker, double check valve, and reduced-pressure-principle device. The one selected depends on the type of installation and the hazard involved if backflow occurs. For direct water connections subject to back pressure, only the reduced-pressure-principle backflow preventer is considered adequate as an alternate to an air gap separation. For applications not subject to back pressure. Vacuum breakers can be installed. The atmospheric-vacuum breaker is used in flush valve toilets.

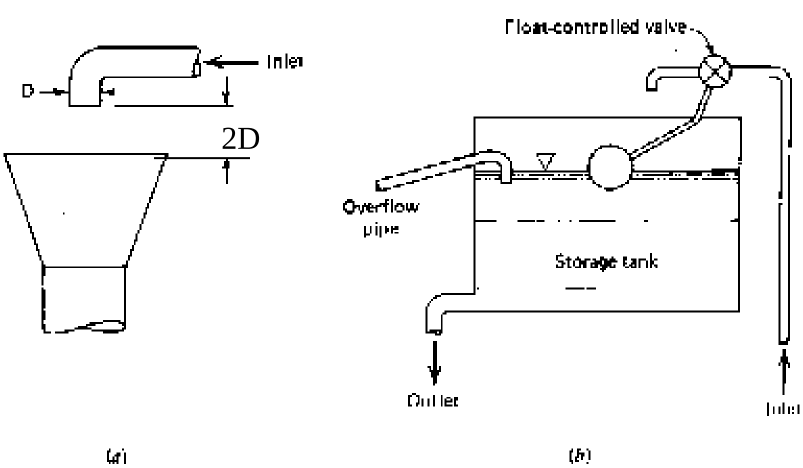



*Fig. 3.7 Air-gap separation to prevent backflow into the supply pipe. (a) Minimum recommended air gap is twice the diameter of the supply pipe. (b) Storage tank with air-gap separation and overflow pipe to prevent overfilling the tank if supply valve fails to close tightly.*

**Hydrants**

Hydrants provide access to underground water mains for the purposes of extinguishing fire, washing down streets, and flushing out water mains. They are installed along streets behind a curb line a sufficient distance, usually 0.6m, to avoid damage from overhanging vehicles. The pipe connecting a hydrant to a distribution main is normally not less than 150mm in diameter and includes a gate valve allowing isolation of the hydrant for maintenance purposes. A firm gravel or broken rock footing is necessary to prevent settling and to permit drainage of water from the barrel after hydrant use.

## 3.4 Distribution systems

Depending upon the level of the source of water and the city, topography of the area, and other local considerations, the method of distribution may be gravitational system, pumping without storage, and pumping with storage.

***Gravitational system*****:** In this system, water from a high-level source is distributed to the consumers at the lower level, by the mere action of gravity without any pumping. This method is the most economical and reliable since no pumping is involved at any stage. However, it needs a lake or a reservoir as a source of supply. Such a system can be adopted for cities situated at foothills, and a source of supply is available somewhere in the hill at sufficient elevation. High pressure for fire fighting may require use of motor pumping trucks, and pressure zones may need to be set to prevent excessive pressures in the low-lying areas. The gravitational system is designed so as to leave only the minimum permissible pressure to the consumers.

***Pumping without storage****:* In this system the treated water is directly pumped into the distribution mains without storing it anywhere (Fig. 3.8). High lift pumps are required and have to operate at variable speeds so as to meet the variable water demand. A continuous attendance or sophisticated control systems are needed to ensure the desired flow in the distribution system. This method is, therefore, generally not recommended as a distribution system since it provides no reserve flow in the event of power failure and pressures fluctuate substantially with variations in flow. Systems of this kind have the advantage of permitting increased pressure for fire fighting, although individual users must then be protected by pressure reducing valves.

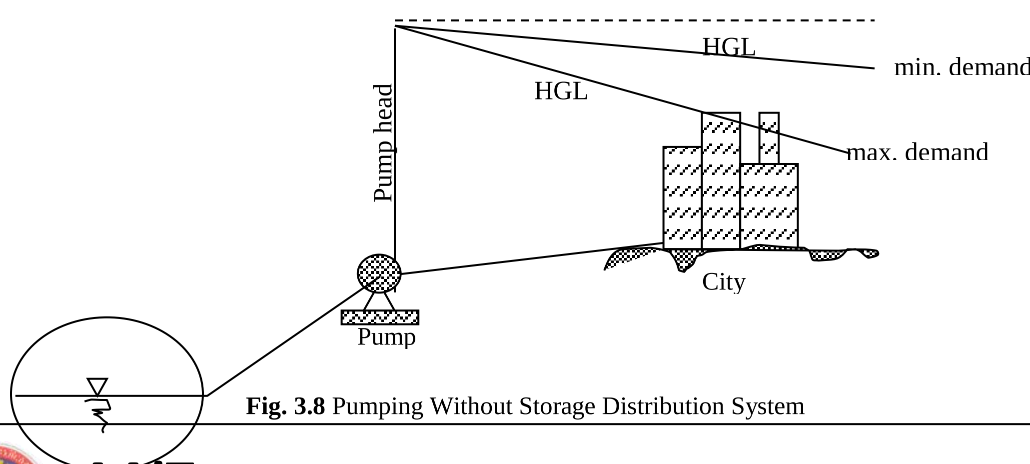



**Fig. 3.8** Pumping Without Storage Distribution System

***Pumping with storage***: In this system the treated water is pumped at a constant rate and stored into an elevated distribution reservoir from where it is distributed to the consumers by the action of gravity (**Fig.** 3.9). Sometimes the entire daily water demand is first pumped into the distribution reservoir and then distributed to the consumers. Many times it is pumped into the distribution mains and reservoirs simultaneously. The excess water during low demand period gets stored in the reservoir and supplied during high demand periods. The pumps work at a constant rate, which is adjusted in such a way that the excess quantity of water stored in the reservoir during low consumption nearly equals the extra demand during high consumption. This type of system is invariably and almost universally adopted because of its following advantages.

- The pumps work at uniform rate and can be operated at their rated capacities with high efficiency.
- The method is quite reliable because even during power outage, certain amount of water can be supplied from the storage facility.
- The method enables pumps to run for a short period of time in small towns.

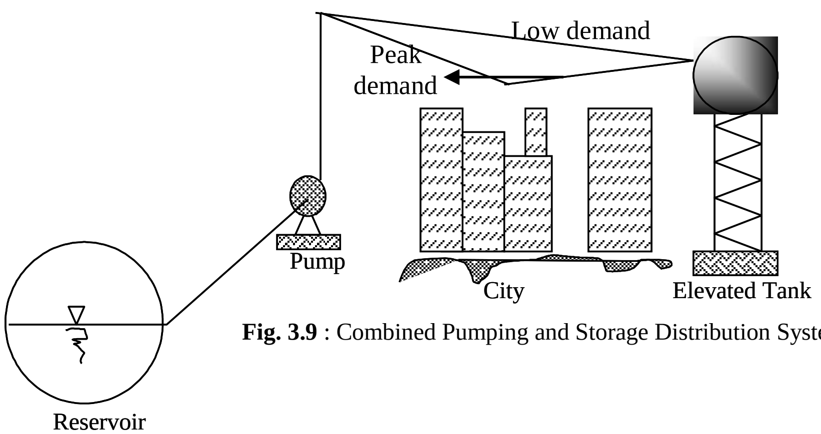



**Fig. 3.9** : Combined Pumping and Storage Distribution System

## 3.5 Layout of distribution systems

A water supply distribution system comprises networks of pipelines, storage facilities and other appurtenances. Its purpose is to transport treated water from the treatment facility to the consumer. It should have adequate capacity to meet the water requirements of a community under all demand conditions.

The pipe networks that make up the distribution system comprise the following:

- *Primary or arterial mains*
    - Constitute the basic structure of the system
    - Convey water from the pumping stations to and from storage facilities and to the various districts of the city.
    - Should be valved at intervals of not more than 1.5 km and all smaller lines connected to them should have valves.

    - Should be provided with blowoff valves at low points and air release and vacuum valves at high points.
- *Secondary lines or Sub-mains*: run from one primary main to another and should be located at spacings of 2-4 blocks.
- *Small distribution mains or branches*
    - Are connected to primary, secondary or other small mains and are valved
    - Supply water to every consumer and to the fire hydrants

The layout of distribution pipes generally follows the road pattern**.** Accordingly, there are four types of pipe network layouts - ***dead end system or branch system, gridiron system, ring system, and radial system.***

***Dead end system***: In the dead end system, also called branch system or tree system, there is one main supply pipe from which a number of sub-main pipes originate. Each sub-main then subdivides in to several branch pipes called laterals. From laterals, service connections are given to the consumers. It may be adopted for older towns and in areas where the settlement pattern is rather scattered.

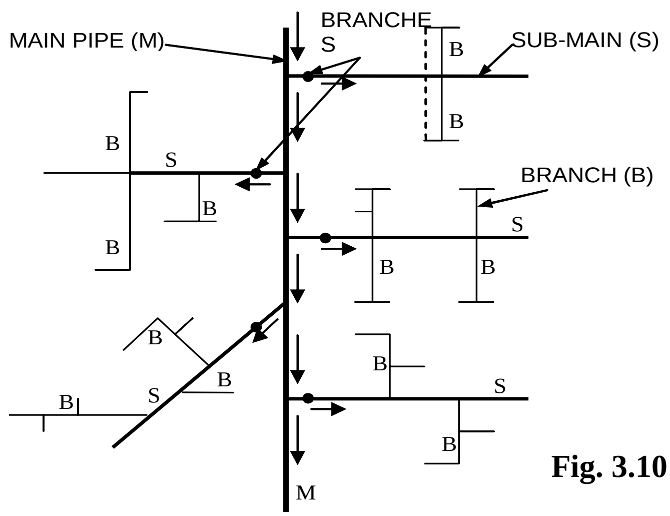



**Fig. 3.10**

Advantages:

- The distribution network can be solved easily, and it is possible to easily and accurately calculate the discharges and pressures at different points in the system.
- Lesser number of shut-off valves is required.
- Shorter pipe lengths are needed, and the laying of pipes is easier.
- It is cheap and simple and can be expanded easily

Disadvantages:

- If damage occurs to a main or a sub-main pipe, a considerable area may be without water.
- There are numerous dead ends in this system, which prevent the free circulation of water.
- It can give only limited supplies for fire fighting and may sometimes prove to be a serious handicap.

***Gridiron systems:*** In this system the mains, submains and branches are interconnected with each other. In a well-planed city or a town, the roads are generally developed in a gridiron pattern, and the pipelines in such places can follow them easily. Thus it is suitable for well-planned towns.

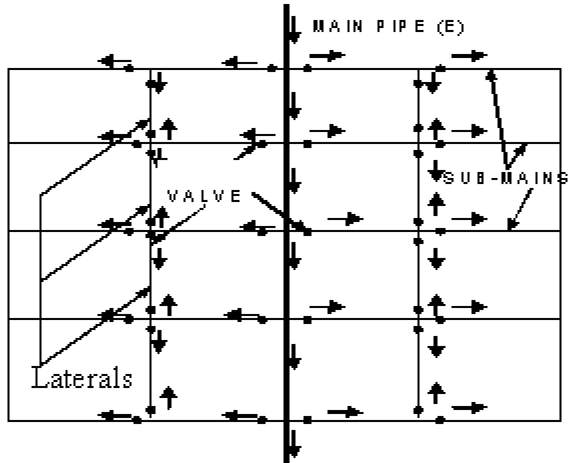



Fig. : Grid-Iron System

*Advantages:*

- The discharge to be carried by each pipe, the friction loss and the pipe sizes are reduced.
- In case of main damages and repairs only small area may be without supply.
- There are no dead ends and then there is continuous water circulation.
- During fire, more water can be diverted towards the affected point from various directions by closing and manipulating the various shut-off valves.

*Disadvantages:*

- It requires more pipelines, and a number of shut-off valves
- It has high cost of construction
- The design is difficult and expensive

***Ring systems:*** In this system, a closed ring, either circular or rectangular, is formed by laying feeder mains around the distribution area instead of through the area. The distribution area is divided into rectangular or circular blocks. This system is very suitable for well-planned towns and cities having well planned roads. The advantages as well as the disadvantages of this system are the same as gridiron systems. Sometimes, this system is used as a "looped feeder placed centrally around a high demand area" along with the gridiron system, and will improve the pressure at various points.

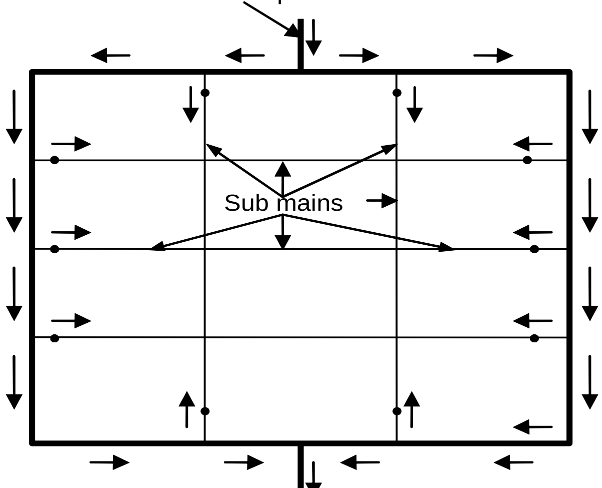



Fig. : Ring System

***Radial systems:*** If a city or a town is having a system of radial roads emerging from different centers, the pipelines can be best laid in a radial pattern by placing the distribution reservoirs at these centers. In this system, water is therefore taken from the water mains, and pumped into the distribution reservoirs placed at different centers and then to the service areas. This method ensures high pressure and efficient water distribution.

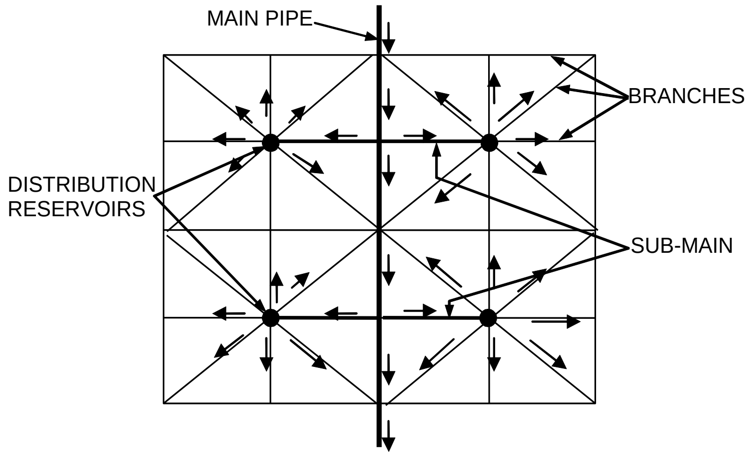



Fig. : Radial System

## 3.6 Distribution reservoirs

Water storage in the distribution system is provided for the following purposes.

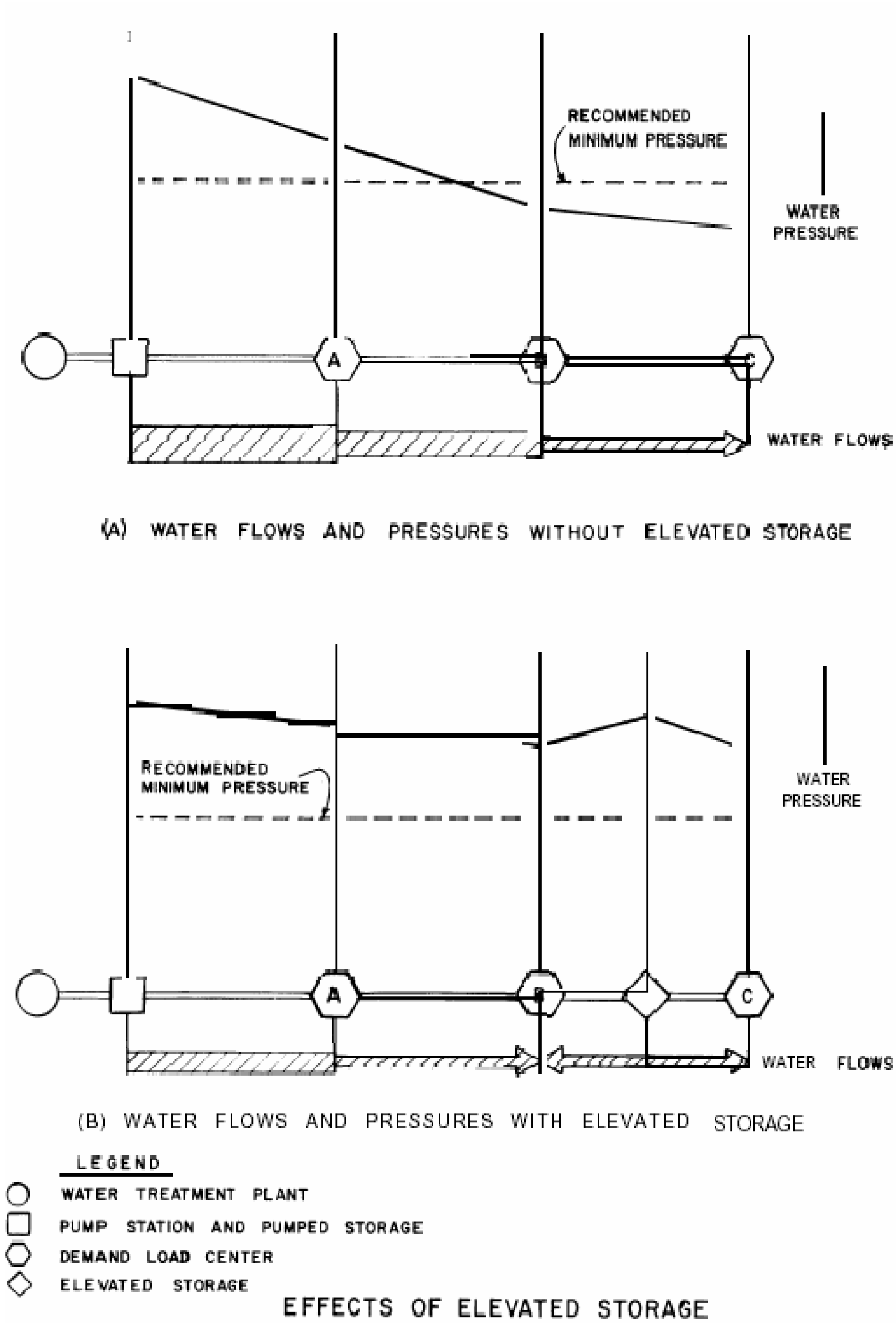
***Equalizing supply and demand:*** The demand for water normally changes throughout the day and night. Water stored in the reservoirs during low consumption will be released to equalize the demand during high consumption.

***Increasing operating convenience.*** In some situations it may be more practical and economical to build a larger plant and operate it only for 8 hours a day. In this situation, water treated during this period would be stored for use when the plant is not operating.

***Leveling out pumping requirements.*** With out storage, pumps need to match the changing demand by frequently turning on and off. This cycling of the pump causes increased wear on pump controls and motors, as well as increased electrical costs. Storage reservoir is required to overcome this situation.

***Providing water during source or pump failure.*** There are times when all pumps may not be available when needed, because of power failure, mechanical breakdown, or preventive maintenance. Sudden increase in demand can be caused by main breaks, broken hydrants, or similar problems. To meet these situations about 25% of the storage capacity must be reserved.

***Maintaining pressure levels within acceptable ranges:*** elevated storage facilities maintain pressure at required levels during peak demand periods. The following figure illustrates this.




***Providing water to meet fire demands*:** One of the major purposes for distribution system storage is meeting fire demands. Although fire demands may not occur very often or last very long, they can be much greater than consumer peak demands.
***Increase detention times*:** The added detention time provided by having water storage has two major advantages:

- Disinfection continues even at low chlorine levels

- Sand particles, flocs, or precipitated solids settle out before reaching the mains and customers.

***Blending water sources:*** Some water systems use water from different sources that can vary in quality. Blending these different sources together in a reservoir will often improve the quality of marginally acceptable water. It also provides a more uniform quality of water to the customers, rather than water that changes in taste and composition from day to day.

***Types of storage facilities***

Distribution storage facilities can be of three types- ground storage, underground reservoir and elevated storage (elevated tanks or standpipes). The choice between these storage types depends on topography, size of community, reliability of water supply, and economy. Ground storage facilities on hills high enough to provide adequate pressure are preferred; the economy and desirability of ground storage with booster pumping, as compared with elevated storage, must be determined in each individual area. In general, elevated tanks are most economical and are recommended for small water systems. Reservoirs and booster pumping facilities are often less expensive in large systems where adequate supervision can be provided.

***Important storage facility design considerations and details***

- Minimum capacity: Equalizing storage + Emergency reserve (about 25%) + Fire storage. The equalizing storage can be estimated by a mass curve method.
- Location: normally, it is more advantageous to provide several smaller storage units in different location than an equivalent capacity at a central site. Ground storage must be located near major transmission mains. If pumping is required, the ground storage facility should be located adjacent to the pumping station and its bottom should be higher than the pump centerline. The top of the reservoir should be set at an elevation close to that of the hydraulic gradient of the influent transmission mains. The location of elevated storages should be such that zones of high consumption lie between the pumping station and the tanks.
- Aesthetics: the style and color of the storage facilities should reduce visual impacts. The issue aesthetics is sensitive that engineers should leave to architects or community leaders.
- Ventilation: storage facilities must be vented to allow air to flow into and out of the reservoir as the water level rises and falls. The vent should have an insect proof screen and rain cover incorporated to protect water quality.
- Overflow: storage facilities may inadvertently become filled beyond their capacity. To protect the structural integrity of the facility, an overflow system that incorporate screens or flap valves to protect the water quality from insects and animal intrusion should provided. The overflow should not cause damage from ponding or flooding in adjacent areas.
- Security and safety: storage facilities should be located on a secured site and protected by relevant measures.

- Corrosion control: storage tanks constructed of steel must be protected from corrosion by epoxy painting systems designed for potable water service or cathodic protection system.

## 3.7 Design of distribution systems

***Design considerations***

- Design flow: *Peak hour demand* or *maximum day demand + Fire demand*, whichever is greater
- Minimum main sizes: generally, 150mm; high value districts, 200mm; major streets, 305mm; domestic flows only, 100m; small communities, 50-75 mm
- Velocity: typical values – minimum = 0.6-1 m/s; maximum = 2 m/s
- Pressure: should be within acceptable ranges; while exactly what constitutes a satisfactory pressure depends upon system-specific considerations, a typical minimum value is 140 kPa. Absolute maximum allowable pressures are dictated by the pressure ratings of the pipes and appurtenances used and regulatory requirements. Unnecessarily high pressures are wasteful in terms of the extra costs of the equipment and energy required to produce them, and the increased volume of water lost to leakage. For most small water systems there is no compelling need for the maximum pressure to exceed 410 kPa.

  In areas where the topography results in pressure level changes outside the acceptable ranges, it is advantageous to divide the supply network into pressure zones (see Fig. 3.12). Pipe mains are arranged in such a way that excessive pressures in the low-lying areas are avoided. Pressure relief valves and booster pumps are employed to obtain the desired pressure. Normally, the difference between pressure zones is between 24m and 37m.

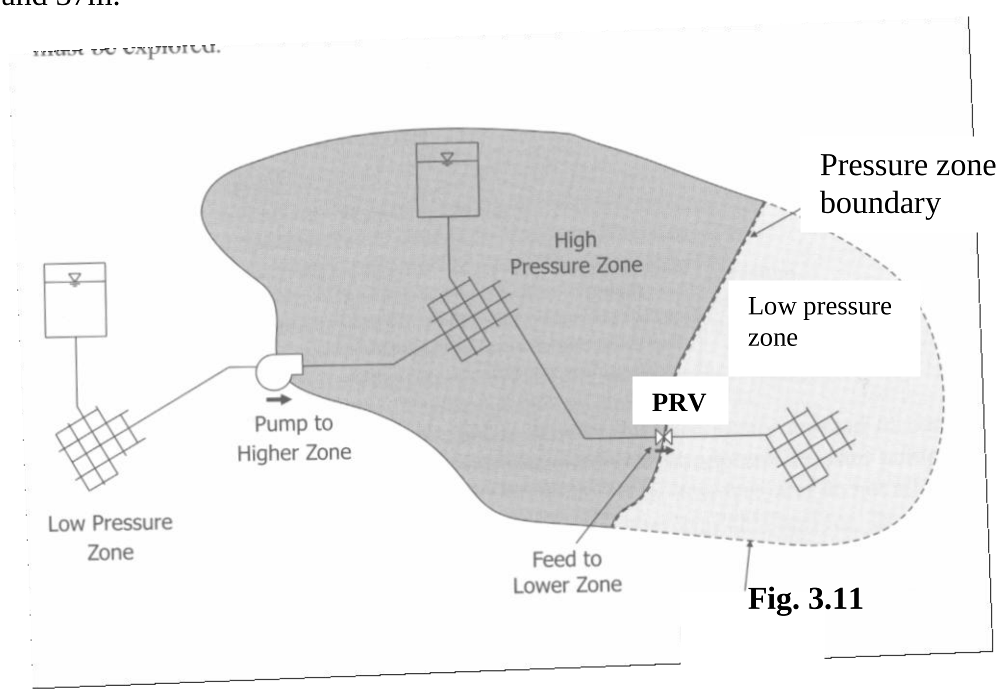



**Fig. 3.11**

***Hydraulic analysis***

Hydraulic analysis of a water supply distribution network is concerned with the determination of discharges and head losses in each pipeline, and pressure heads at critical points. Network analysis is not only important for designing new systems, but also for monitoring and upgrading existing systems. The following are the applications of network analysis.

- To assess the capacities of existing systems,
- To control pressure and reduce pumping cost,
- Design of new systems,
- Water quality monitoring, and
- Investigation of the effect of damage to main, storage tank locations, and other scenarios.

Commonly used hydraulic analysis methods include *Hardy cross method* and *Computer programs*. The Hazen-William equation is widely used to determine the head loss in a pipe.

$$Q = 0.278CD^{2.63}\left(\frac{h_f}{L}\right)^{0.54}$$

Where, Q = flow rate in $m^3/s$

C = coefficient of roughness

D = pipe diameter, m

$h_f$ = friction head loss, m

L = equivalent length of pipe, m

Some values of roughness coefficient for Hazen-William equation for different pipe materials is given in table 3-1 below.

**Table 3-1.** Values of Coefficient C for Hazen William formula

| **Pipe material** | **C** |
|---|---|
| Asbetos cement | 140 |
| Ductile iron | |
| Cement lined | 130 to 150 |
| New, unlined | 130 |
| 5-yer-old, unlined | 120 |
| 20-year-old, unlined | 100 |
| Concrete | 130 |
| Copper | 130 to 140 |
| Plastic | 140 to 150 |
| PPR | 130 |
| New welded steel | 120 |
| New riveted steel | 110 |

*Design procedures*

*Simple Distribution System*

Requirements: The sizes of the pipes should ensure availability of water at the end points (terminals) of the pipes, with the minimum allowable pressure at the time of maximum demand.

- Assign the required demand at each node or dead end
- Estimate the discharge flowing through the pipes
- Assume possible pipe diameters
- Calculate the head loss through that pipe
- Find the residual pressure at the end of the pipe.
- Compare this terminal pressure with the desired minimum and maximum pressures.
- If the required condition is not satisfied, then repeat steps (ii) through (vi) until the required conditions are met.

*Complex pipe Networks*

The Hardy Cross Method can be used to make hydraulic analysis of complex interconnected pipelines following the steps below.

- Assign the required demand at each node
- Assume the best distribution of flow that satisfies continuity by careful examination of the network. The flow entering a node must be equal to the flow leaving the same node
- Calculate the head loss, $h_f$, in each pipe. The algebraic sum of the heads around a closed loop must be zero. For a loop, take head loss in the clockwise flows as positive and in the anti-clockwise flows as negative
- Calculate the correction factor for each loop by

$$\Delta Q = -\frac{\sum rQ_o|Q_o|^{n-1}}{\sum rn|Q_o|^{n-1}} = -\frac{\sum h_f}{n\sum \frac{h_f}{Q_o}}$$

Where,

$\Delta Q$ = Correction discharge for the assumed discharge $Q_o$,

r = Constant depending on pipe,

$Q_o$ = assumed flow in a pipeline,

n = 1.85 to 2 normally, depending on equation used. n = 1.85 for Hazen-William eqn

- Apply the correction discharges to the assumed flows. The corrected discharge, Q, now becomes Q = $Q_o + \Delta Q$
- Repeat the above computations with the corrected flows until the corrections for each pipe are negligible.
- Velocities of flow and pressure levels must be within acceptable ranges.

***Computer programs***

The use of hydraulic analysis models has become common due to their important advantages over that of manual methods. The advantages include

- Models relieve engineers from tedious and iterative calculations and enable them focus on important aspects of the design
- Models better incorporate the complex real world system
- Models allow investigation of alternative designs over a wider range of conditions

There are a number of computer programs that can readily be used to perform complex pipe network analysis (e.g EPANET, WaterCAD). Models should be calibrated and verified before application. Important features of a typical hydraulic analysis model are briefly presented below.

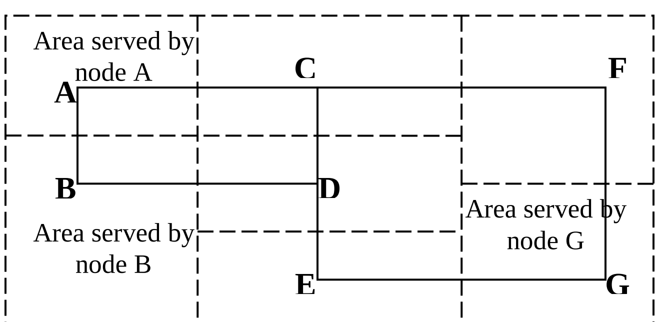
**Representation.** The various elements of a water distribution system are represented as network of *links or nodes* in the model.

| Element | Representation |
|---|---|
| Pipe | Link ◆———◆ |
| Reservoir, storage tanks, pumps, valves, controls, and<br>Junctions (intersection points, dead ends, water withdrawal and injection points) | Node ◆ |

**Skeletonization.** This refers to selecting and including those pipe network parts that have significant impacts in the behavior of the system. Criteria such as pipe diameter, nodal discharge, points with known condition (e.g. pressure head), type of element, etc. may be used to skeletonize the system.

**Demand allocation.** Water withdrawal rate at each node can be estimated manually or automated systems using GIS. One useful method follows:

- Using land use or zoning maps estimate the water demand for each type of land use
- Overlay the water distribution system map over the land use map and determine the applicable demand at each node
- Major water users should be considered separately and applied to the closest nodes




**System inputs.** Input requirements vary from system element to element as indicated in the table below.

| Element | Input |
|---|---|
| Reservoir | Hydraulic grade line and water quality |
| Storage tanks | Water levels (min, max, overflow, initial) |
| Junctions | Elevation |
| Pipes | Nominal diameter, length, coefficient |
| Pumps | Characteristic curve |

**Model outputs**. Outputs of a typical model run may include flow rate, head loss, velocity in each pipe, pressure at each node, residual chlorine, etc.