# Distribution 101: How does water get from the source to your tap?

# From the web site

# http://www.nesc.wvu.edu/ndwc/articles/ot/sp01/distribution_101.html

by **Kathy Jesperson**
*On Tap* Asociate Editor
*kjespers@wvu.edu*
*with technical assistance from* **Vipin Bhardwaj**, Technical Assistance Specialist

Most people don't give a second thought to how their drinking water gets to their homes. It just does. But those of us who work in the drinking water industry know that the process is a bit more complicated.

Most customers think distribution systems are the network of pipes beneath roads and streets that transport water from treatment plants to individual households, businesses, and other customers. And while this is true, distribution systems also include pumps, storage tanks, fire hydrants, service connections, meters, and other equipment.

**There's More Than One Type**
Distribution systems may be classified as grid or branching systems, or a combination of the two. (See figure Types of Water Distribution System.)

Generally, engineers prefer a grid system to a branching system because it can supply water to any point from at least two directions. It also permits any broken pipe sections to be isolated for repair without disrupting service to large areas of the community.

A branching system has numerous terminals or "dead ends" that prevent water from being circulated throughout the system. Further, water tends to stagnate in dead-end patterns, making them more susceptible to taste and odor problems. This kind of pattern requires frequent flushing, so hydrants should be placed at the extreme end of these lines.

A combination system is the type most commonly used. It can incorporate loop feeders, which distribute the flow to an area from several directions. Street patterns, topography, development, and treatment and storage facilities dictate a distribution system's design.

Typically, distribution systems are designed to satisfy domestic, commercial, and industrial water needs. The system must have enough pressure to deliver water to customers, as well as enough to meet fire-fighting purposes. At the same time, pressure should not be so excessive that serious problems occur.

As pressure increases, so do leaks and breaks. Communities then spend money to transport a product that never makes it to its destination and is, therefore, wasted. Because more than half the cost of a municipal water supply system is for the distribution network, it is important that the system's design maintains a reasonably uniform pressure. (See the *Tech Brief* insert about leak detection.)

In hilly or mountainous terrain, the distribution system is usually divided into two or more service areas or zones. These areas are typically interconnected, and workers may close interconnections using valves during normal operation hours. This prevents the system from having to maintain extremely high pressure in low-lying areas to ensure reasonable pressures at higher elevations. In addition, water pressure can remain relatively constant when pressure-regulating valves are installed.

**The Pressure Is On**

If you've been around the water industry for any period of time, you've probably heard talk of "head." Loosely defined, head is a measurement of water's potential to flow. The distribution system needs head, which is the difference between a source of water supply and the point at which the water is drawn. This head difference is what drives the flow of water. Water will flow from a point of higher head to a point of lower head.

Head difference is maintained in a distribution system either by gravity or by pressure (pumping). Often, public water supply systems use some combination of both. In gravity systems, tanks store water at strategic locations sufficiently elevated to create the working pressure water requires to move the water to demand points. Water always flows in the direction of gravity, which means downhill. Further, water will always try to equalize its level.

However, water that is at the same level does not have a head difference. So, pressure must be applied to force water through the pipe. Hence, when elevated storage is impractical, pumps provide the required working pressure within the system. In these pressure systems, the pumps are normally located at the treatment plant and perhaps within the distribution system.

In combined systems, water storage facilities are used along with provision for pumping. This system type stores water during times of low demand, while assuring that a sufficient quantity is available to meet the peak demand. Typically, water is pumped directly into the distribution system. The quantity of water exceeding the demand automatically feeds into a storage facility or reservoir. Engineers may also design a system that pumps supply water to a storage facility, which in turn, might flow into the distribution system by gravity.

**Where's the pipe?**
The pipeline network consists of arterial water mains also called "primary feeders" or "trunk lines." These lines carry water from the treatment plant to areas where it's needed in the community.

Water mains must be placed three to six feet below the ground surface to protect against traffic loads, prevent freezing, and protect against accidental damage from digging or construction activities. Because the water in a distribution system is under pressure, pipelines can follow the shape of the land, uphill as well as down.


**Photo Caption**-Safety is of utmost importance when installing or repairing distribution lines. The trench box laying here on its side is about to be placed inside a recently excavated trench. The box shields workers from cave-ins by shoring up exposed soil walls that might fall in otherwise. Photo by Jamie Knotts.

Smaller-diameter pipelines called "secondary feeders" or "branch lines" tie into the mains. Usually not less than six inches in diameter, these pipe-lines are placed within the public right-of-way so workers can install service connections for all potential water users.

Pipelines must be installed with proper bedding and backfill. Soil compaction under the pipe (bedding) as well as above the pipe (backfill) is necessary to provide proper support. A water main should never be installed in the same trench with a sewer line. Where the two must cross, the water main should be placed above the sewer line to prevent possible cross connection issues.

Pipes must be able to resist internal and external forces as well as corrosion. Water pressure inside the pipes, the weight of the overlying soil, and vehicles passing over them place stress on pipelines. In addition, metal pipes may rust internally if the water supply is corrosive or externally because of corrosive soil conditions.

Pipelines also may have to withstand what are known as "water-hammer" forces. Water hammers occur when valves are closed too rapidly, causing pressure surges through the system. To avoid water hammers, try not to open or close hydrants or valves too quickly.

Maintaining pipelines is critical to operating a system. Proper maintenance means flushing mains; checking valve operation, residual disinfection, and hydraulic operation; adding back flow devices; and controlling corrosion.

**Pipes Are Made of Different Materials**
Distribution pipes are made of asbestos cement, cast iron, ductile iron, plastic, reinforced concrete, or steel. Pipe sections are easily joined with a coupling sleeve and rubber-ring gasket. Cast iron has an excellent record of service, with many installations still functioning after 100 years.

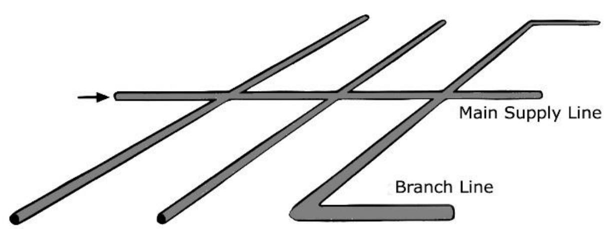
Ductile iron, a stronger and more elastic type of cast iron, is used in newer installations. Iron pipes are made in diameters up to 48 inches and are usually coated to prevent corrosion. Underground sections are connected with bell-and-spigot joints; the spigot end of one pipe section is pushed into the bell end of an adjacent section. A rubber-ring gasket in the bell end is compressed when the two sections are joined, creating a watertight, flexible connection. Flanged and bolted joints are used for above-ground installations.

The use of plastic pipes or PVC (polyvinyl chloride) is steadily increasing. Available in diameters up to 24 inches, they are lightweight and easily installed. These pipes are also corrosion-resistant, and their smoothness provides good hydraulic characteristics. Threaded screw couplings or bell-and-spigot compression-type joints are used to join plastic pipes. (See the Tech Trend insert for more information about plastic pipes.)

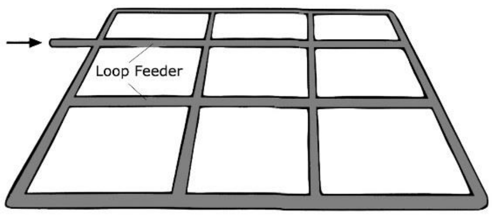
Pre-cast reinforced concrete pipe sections up to 12 feet in diameter are used for arterial mains. Reinforced concrete pipes are strong and durable. They are joined using a bell-and-spigot-type connection that is sealed with cement mortar. Steel pipe is sometimes used for arterial mains in above ground installations. It is very strong and lighter than concrete pipe; however, the interior must be lined and the exterior must be painted and wrapped to protect against corrosion. Sections of steel pipe are welded together or joined with mechanical coupling devices.

The interior of metal pipes often has a plastic or other type of lining to prevent any rusting that may lead to water quality deterioration. The exteriors of metal pipes also are coated with an asphalt product and wrapped with special tape to reduce corrosion due to contact with certain soils.

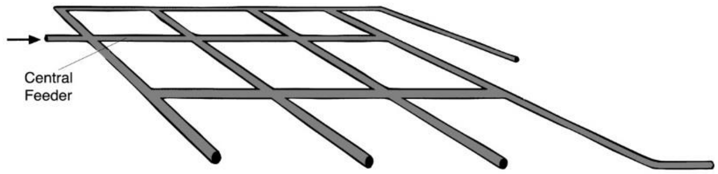
### Types of Water Distribution System




**Branching System**




**Grid System**




**Combination System**

**Pumps Are an Integral Part of the System**
Many kinds of pumps are used in distribution systems. Pumps that lift surface water and move it to a nearby treatment plant are called low-lift pumps. These pumps move large volumes of water at relatively low discharge pressures. Pumps that discharge treated water into arterial mains are called high-lift pumps. These operate under higher pressures. Pumps that increase the pressure within the distribution system or raise water into an elevated storage tank are called booster pumps. Well pumps lift water from underground and discharge it directly into a distribution system.

Centrifugal pumps are the most common type used in distribution systems. With these pumps, a rapidly rotating impeller adds energy to the water and raises the pressure inside the pump casing. The flow rate through a centrifugal pump depends on the pressure against which it operates. The higher the pressure, the lower the flow or discharge. Another kind of pump is the positive-displacement type. This pump delivers a fixed quantity of water with each piston cycle or rotor. Water is literally pushed or displaced from the pump casing. A positive-displacement pump’s flow capacity is unaffected by the pressure of the system in which it operates.

**What are valves?**
To function properly, a water distribution system requires several types of fittings, including hydrants and shut-off valves. The hydrant’s main purpose is to provide water for fire-fighting. However, they also are used for flushing water mains, pressure testing, water sampling, and washing debris off public streets.

Many types of valves are used to control the quantity and direction of water flow. Gate valves are usually installed throughout the pipe network. They allow sections to be shut off and isolated while repairing broken mains, pumps, or hydrants. A type of valve commonly used for throttling and controlling the rate of flow is called a “butterfly valve."

Safety valves or pressure relief valves are important in long pipelines for surge control. Air relief valves are desirable at high points in pressure lines where other relief is not available. Blow-off valves are used at low system elevations and dead-end lines to permit emptying or flushing when necessary. Vacuum relief valves are used to prevent complications caused by negative pressures.

**Why are storage tanks and reservoirs necessary?**
Distribution storage tanks, familiar sights in many communities, serve three basic purposes: they must meet the water needs of residential and commercial customers, accommodate fire-fighting and emergency purposes, and equalize operating pressures.

Distribution storage tanks are built at ground level or on hilltops higher than the service area. In areas with flat topography, the tanks may be elevated above ground on towers to provide adequate water pressures, or ground-level storage tanks with booster pumping may be used.

Reservoirs are classified as underground, ground level, elevated, or standpipe. An underground reservoir or basin—either open or covered—may be at or below grade level and formed either by excavation or embankment.

An elevated reservoir is a tank supported above ground by a structural framework. Steel and wood have been used in constructing stand-pipes and elevated tanks, which are normally enclosed. Most systems prefer to use covered reservoirs for treated water because water in open reservoirs is subject to falling dust, soot, and dust-borne microorganisms; to contamination by animals, including birds and human beings; and to algae growth. Utilities may need to control algae and microbial slime growths in open distribution reservoirs by adding copper sulfate or chlorine (or both) to the water.

Surface reservoirs are usually lined with concrete, Gunite, asphalt, or an asphalt membrane. While these reservoirs may be covered or uncovered, many systems cover them to prevent animals or humans from contaminating the water and to prevent algae from forming in the water.

Standpipes or elevated tanks are usually needed when a surface reservoir does not produce sufficient head. A standpipe is a tall, cylindrical tank that provides useful storage (the upper portion that is above the discharge pipe) and supporting storage, which acts to support the useful storage and provide the required head.

Furthermore, to ensure adequate disinfection, operators should maintain a sufficient chlorine residual throughout the distribution system. In a large distribution system, rechlorinating water may be required. This is often done at the distribution reservoirs.

The amount of storage needed should be about equal to the average daily demand and should take into consideration the volume of water needed to satisfy the community's peak hourly demands. During the late night and early morning hours when water demand is very low, high-lift pumps are used to fill storage tanks. During the day when the water demand is high, water flows out of the tank, helping satisfy hourly peak water needs. This allows for a uniform flow rate at the treatment plant and pumping station.

Emergency storage should sustain the community during periods when the inflow to the reservoir is shut off, such as when lines are shut down for service, repair, or when a pumping equipment failure occurs. Emergency storage should be sufficient to last several days.

**Fire-Fighting Capacity Is Critical**
A distribution system's ability to deliver an adequate quantity of water to meet demands of the domestic, commercial, and industrial users and to provide the necessary flow for fire protection depends upon the carrying capacity of the system's network of pipes. In all but the largest systems, the flow necessary to fight a major fire is usually the major factor determining the amount of water to be stored, the size of the system's mains, and the pressure needed.

Fire flow standards require a minimum residual water pressure of 20 pounds per square inch gauge (psig) during flow. It is common to maintain pressures of 60 to 75 psig in industrial and commercial areas and 30 to 50 psig in residential areas. Engineers should design distribution system mains and pipes to withstand these pressures.

Requirements for fire-fighting purposes should be sufficient to provide water for 10 to 12 hours in large communities and two hours in smaller ones. Fire-fighting reserves can be calculated by figuring how much water is needed per minute times the duration it's needed. For example, if 2,750 gallons per minute are needed for 10 hours, total fire-fighting storage would be 1.65 million gallons.

**It All Makes the System**

All of these elements must be incorporated into the a distribution system's design because when customers want fresh drinking water, all they want to do is turn on the tap. Without pipelines, pumps, valves, pressure, and storage, that wouldn't be possible.