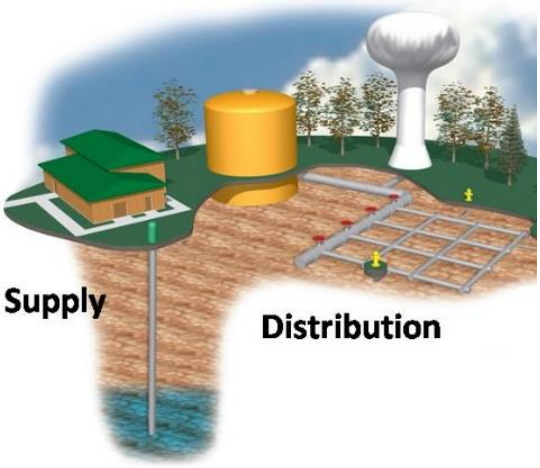


WATER DISTRIBUTION SYSTEMS

The United States (U.S.) water infrastructure has passed its peak, having been built over 50 years ago. According to the U.S. Environmental Protection Agency's (EPA) 2023 Drinking Water Infrastructure Needs Survey and Assessment, over 148,000 public water systems need an investment of $625 billion by 2041 to continue providing clean and safe drinking water. This includes the sub-systems called water distribution systems that move the water from suppliers to users.

Clearly, there is a significant need for plumbers who can restore the integrity and update these water systems across the country. Returning a water distribution system to effective, efficient, reliable, and cost-effective, operation will require plumbers to complete several types of maintenance, including emergency, regular, scheduled, preventative, and predictive. The combination of these types will also reduce the risk of contamination events that can change the quality of water to below EPA's primary water quality standards.

This lesson will explain the types of maintenance that need to be done for water distribution systems. It will also provide common system problems and ways to address them. Plus, it will provide you with information on the EPA's primary water quality standards.

1. Maintenance

A water distribution system will perform only as well as it is maintained. Therefore, it requires several types of maintenance to keep its integrity, provide reliable service, operate efficiently, and do it cost-effectively. If you elect to only perform regular maintenance, your system will be at higher risk of experiencing events like equipment failure, broken pipes, or device failures. Occurrences like these can lead to service interruptions, reductions, or loss and downtime.

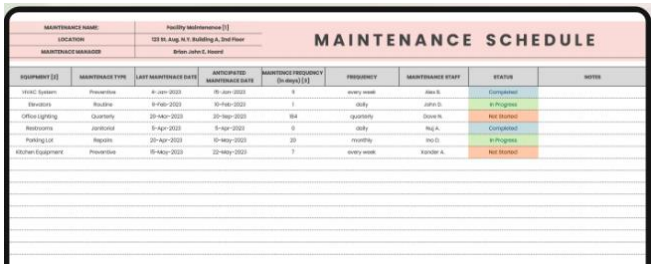
Types of Maintenance

- **Regular Maintenance**
  Regular Maintenance is not just a routine; it's a crucial part of maintaining smooth operations to ensure uninterrupted water service. The focus is on addressing small issues that can hinder, but not stop, system operation and water service. The actions may be done at intervals that accommodate the system, its equipment, devices, and level of use. Examples include:
  - **Check Fluid Levels**
    Fluid levels must be checked regularly in equipment like pumps and motors and refilled when necessary.
  - **Tighten Connections**
    Connections need to be checked regularly to ensure they stay tight to prevent leaks.
  - **Pump & Valve Cleaning**

Dirt, debris, sediment, corrosion, etc., that may collect and build up in pumps and valves need to be cleaned out frequently and consistently to ensure unhindered water flow.

- **Clear Drains**
  Drains need to be cleaned out regularly to prevent clogs and barriers that can slow or stop drainage.

Regular maintenance improves performance, provides cost savings by preventing issues, keeps maintenance costs down with fewer repairs needed, improves water quality, and prevents contamination.



- **Scheduled Maintenance**
  Scheduled Maintenance is planned and performed according to a predetermined schedule. It does not require forecasting and can be done based on time or usage intervals. It ensures that equipment and components receive regular upkeep according to the manufacturer's recommendations.

  Examples of actions that should be on your scheduled maintenance checklist include the following:

  - **System Updates**
    Upcoming system update releases need to be added to your maintenance schedule to ensure they are completed shortly after they become available.
  - **Flushing Sediment**
    Flushing sediments is crucial to distribution system operation and efficiency. Buildup can cause a system to work harder than necessary and wear it out more quickly. While flushing is often

done annually, you should do it more frequently to prevent reduced performance.

- **Manufacturer Recommendations**
  Equipment, like pumps or motors, has manufacturer-recommended maintenance. You need to add it to your maintenance schedule at designated intervals and complete it. You can often find the information on a manufacturer's website, in manuals, or specification sheets.

Scheduled maintenance contributes to keeping your water safe for public consumption, reducing the risk of leak contamination, increasing the lifespan of appliances, improving system reliability, and reducing the costs of maintaining your water distribution system.

- **Emergency Maintenance**
  Emergency Maintenance is unplanned maintenance that must be done for a water distribution system to remain or return to operation. Damage from natural disasters, infrastructure failures, and biological contamination can cause a need for emergency maintenance. For example, tornados or earthquakes can cause water main breaks that require immediate attention to restore water service.

  The benefit of emergency maintenance is it returns your distribution system to operation and enables you to once again provide service.

- **Preventative**

  Preventative Maintenance includes repairs and replacements done to prevent problems. It enables you to avoid unexpected breakdowns that can reduce, interrupt, or stop service. For example, by regularly testing system pressure, you can identify issues like small increases early and fix them before they become big problems threatening service or water quality.

  Planning, scheduling, and executing preventative maintenance will reduce system maintenance time and costs. It will also reduce your risk of interruptions or loss of water service.

  Actions you should complete include the following.

  - **Replace Parts**

    If a loss in performance is detected for a part, inspect it for damage and wear. Then repair or replace it promptly before it fails.
  - **Exercise Valves**

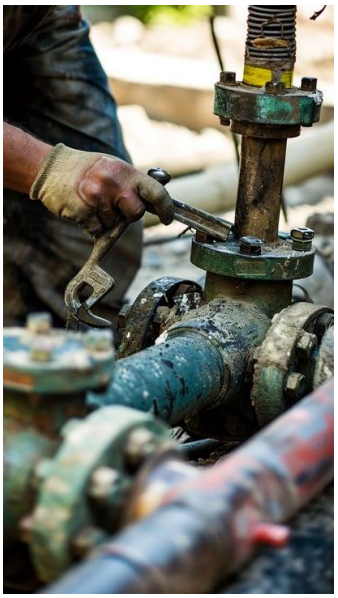
    Valves can lock up and stop the water flow. Therefore, you must prevent it by exercising valves regularly and consistently to ensure the full range of motion.
  - **Cleaning and Sanitization**

    Small amounts of water can remain in a system in places like joints, become stagnant, and affect water quality. Periodic cleaning and sanitation are necessary to prevent microbial growth.

- **Update Fixtures**
  As fixtures age, they can cease to operate properly, inhibit flow, or leak. Replace them with newer products before they become a problem.
- **Pipe Maintenance**
  Frequent inspection and maintenance of pipes are needed to identify and fix issues like blockages, cracks, or damage before they cause big problems, like flooded floors.

Preventative maintenance lowers repair and replacement costs, improves energy efficiency, increases efficiency, improves safety costs, and reduces the risk of failures that can threaten your system's ability to provide water service.

- **Predictive Maintenance**
  In Predictive Maintenance, you use data to predict when a water distribution system pipe or pipe will fail. This facilitates early detection and resolution before pipes turn into costly problems. For example, when a pipe breaks inside a building, large amounts of water can flow into the area where it occurred. This will cause damage and increase repair costs. It can also affect your ability to provide water service.



- **Corrective Maintenance**
  Corrective Maintenance corrects errors that affect system performance. Your intent is to restore a system to its full operating potential. For example, a backflow device may have been installed improperly and not functioning as it should, making a distribution system vulnerable to contamination. Therefore, you need to correct errors so that components, devices, and parts function as intended so that your system will operate as intended and efficiently.

- **Adaptive Maintenance**
  Adaptive Maintenance involves modifying a distribution system to adapt to changing conditions or requirements. Your focus is on adjustments that will enable the distribution system to operate and exhibit high performance regardless of different requirements.

  For example, standards and requirements may change how a backflow device must perform to prevent contamination. To comply, you may need to add pieces to the current device or alter its design or configuration. A second example is having to adapt a distribution system to accommodate changes in demand or usage patterns. Adaptive

maintenance aligns your distribution system with requirements, needs, and demands so it will operate cost-effectively.

Each type of maintenance plays a crucial role in the life of a water distribution system. By completing the combination of maintenance types, you can ensure your system will remain in service, operating at a high level of performance and efficiency, cost-effectively, and for an extended lifespan.

2. Potential System Problems

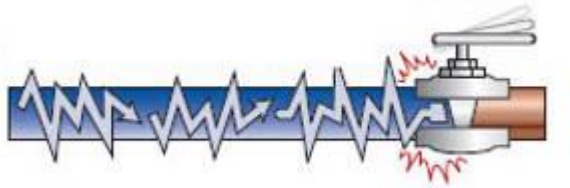
According to the University of Michigan, Center for Sustainable Systems, U.S. water systems have over 2.2 million miles of transmission and distribution mains. Nationwide, 250,000 to 300,000 water mains break every year, according to infrastructurereportcard.org. Pipe cracking, breaking, and failing are among several common problems that frequently occur in water distribution systems. Many are issues relating to aging infrastructure, pressure, failure, or contamination.

- **Common Pressure Issues**

  Pressure in a water distribution system is an essential factor for operation. At the same time, it can be one of the most frustrating things to manage. Your

target is maintaining 24/7 a uniform distribution of pressure across the entire system, which includes reducing any excessive pressure.

One frequently found pressure issue is pressure regulator failure. A properly functioning pressure regulator should maintain a water pressure of around 50 psi. If the device is not functioning properly, test and fix or replace the pressure regulator. Then, test the system pressure to ensure it is within acceptable levels.



Another common pressure problem is water hammer, which is also called hydraulic shock. It is often indicated by the sound of a construction hammer being used. Water hammer pressure is caused by shock waves that travel through a water system. When it occurs, pressure can loosen, crack, or rupture pipes, clog air chambers, wear out valves, and damage devices, parts, and equipment. It can be prevented by securing and wrapping loose pipes along with installing air-relief valves, air chambers, and water hammer arrestors.

High and low pressure also frequently need to be addressed and corrected in water distribution systems.

- **High Pressure**
  High pressure is a big problem in water distribution systems because it applies excessive pressure and stress to pipelines, valves, fittings, and other components. This stress can cause breaks, leaks, bursts, and failures. It can also cause premature wear, leading to costly repairs and service disruptions.

  Indicators:
  - Visible damage to pipes and/or leaks
  - Leaking faucets

- Continuously running toilets
- Abnormally high pressure readings
- Increased noise from pipes
- Rapid pressure fluctuations
- Components wearing out prematurely

Common causes:

- Pressure regulator failure
- Pipe corrosion or blockage
- Water hammers
- High pressure in municipal water supply
- Elevation differences between the building and water source
- Water heater thermal expansion
- Poorly installed plumbing
- Closed valves
- Excessive pressure buildup

Ways of correcting issues:

- Install a pressure reducing or pressure relief valve
- Install pressure regulators
- Cleaning debris out of pipes for unrestricted flow
- Check for leaks and make necessary replacements or repairs

– **Low Pressure**

Low pressure can also cause problems in a water distribution system. It can lead to inadequate water supply for daily activities, increased risk of contamination from backflow, potential damage to infrastructure due to pipe collapses, and reduced firefighting capabilities.

Indicators:

- Water flow and temperature from fixtures fluctuate
- Water flow from faucets is slower than usual
- Appliances or equipment are not functioning properly
- Pipes are corroded

Common causes:

- Clogged or corroded pipes
- Partially closed or blocked valves or meters
- Municipal water problems
- Malfunctioning pressure regulator
- Large increases in demand
- Debris buildup in water tanks

Ways of correcting issues:

- Replace failing equipment, devices, and parts
- Exercise valves and replace them if needed
- Flush pipes to remove materials, clogs, or debris
- Adjust the pressure regulator
- Install a water pressure booster pump

Managing pressure effectively can lower water demand, reduce the number of leak events, improve reliability, reduce energy costs, lower the risk of contamination, and lessen the number of pressure fluctuation events.

- **Leak Detection**

  For water distribution systems, it's common to find during inspections pipe issues such as leaks, cracks, breaks, or even failures. Connections can also loosen over time and cause gaps that can hold or leak water. These issues can cause a significant amount of water loss, reduce pressure, and provide a place for contaminant to enter into a system.

These issues can be prevented with several actions including the following.

- **Visual Inspections**
  Inspect and look at the system in person for drips, puddles, water stains, discoloration, mold, or musty odors around faucets, pipes, appliances, walls, ceilings, and floors.
- **Water Meter Checks**
  Turn off all faucets and see if the water meter stops. If it's still turning, there's a leak which needs to be fixed promptly.
- **Leak Detection Device**
  Install in your water distribution systems leak detectors to alert you through an alarm system when they occur.
- **Pressure Change Sensors**
  Changes in pressure can indicate a leak within a system. You should Install pressure sensors in several places throughout your water distribution system to detect leaks. Program the devices so they will frequently take and report pressure readings in real-time. Plus, set them to alert you if there is a large pressure increase.
- **Listen for Sounds**
  Bubbling, gurgling, or hissing noises coming from your walls or plumbing could indicate a leak. The sound of running water could also indicate leakage in a toilet or behind a closed wall. A leaking toilet can easily be fixed by adjusting the fill valve and flapper.

  If the leak is inside a wall, you will need to open it. Then, dry off the pipe and inspect it from top to bottom for the leak. Once you have found the leaking spot, you will need to fix or replace the pipe.

- **Common Contamination Problems**

  Components and parts used in water distribution systems are made of materials that change their composition over time and cause rather than prevent water contamination, such as corrosion.

  - **Corrosion**

    Corrosion is a frequent problem with distribution systems that have iron or steel pipes. Continued use over time that exposes these metals to water will cause corrosion that can integrate with water in the system and contaminate it. The corrosion will also make the pipe inter surface rougher which will create more friction and affect water's ability to flow. There are several ways to address this problem, including the following:

    - **Corrosion Inhibitors:** The use of corrosion inhibitor products can decrease the rate of attack by corrosion in certain environments on metal materials. Corrosion inhibitors are known for eliminating corrosion and helping lengthen equipment life.
    - **Coatings and Linings**: Coatings and linings inside pipe is another technique for preventing corrosion that inhibit it from forming.

- **Materials Selection:** You can also eliminate the risk of corrosion by selecting pipes made of materials that are at low risk.
- **Replacement:** The often more expensive and last option is replacing the corroded pipes.

Other ways of preventing the occurrence of corrosion are flushing pipes and keeping the water temperature low.

- **Backflow**

  Backflow is another way water can become contaminated and lose quality. When a backflow event occurs, contaminants are allowed to reverse their flow from a connected fixture, different pipeline, or equipment back into the drinking water that is in the water distribution system. Backflow creates a serious health risk if the event is not detected, and water is not tested before it is distributed into a public water system. A backflow event can also cause a drop in pressure, which can result in pressure within building interior pipes becoming greater than the water main pressure, which can damage.
  Backflow events can be prevented. The best method is to create an air gap that either eliminates a cross-connection or provides a barrier to backflow. You can also install backflow prevention devices for protection.

UPC Standards

The International Association of Plumbing and Mechanical Officials (IAPMO) Uniform Plumbing Code (UPC), which is the standard to follow in most U.S. states, requires backflow prevention devices be installed for prevention of nonpotable water from contaminating potable (drinking) water. Backflow prevention devices include double check valves, vacuum breakers, and combination vacuum breakers/backflow preventers. Air gaps are also required to prevent the reverse flow of contaminants into a water supply.

3. Distribution System Water Quality Issues

Public drinking water comes from public and private water supply companies and local governments. These companies are responsible for the process of producing and providing public drinking water—from collection to treatment, storage, and distribution. They are also responsible for bringing collected water, which is often groundwater, within the EPA's primary water quality standards and keeping it at that level of quality. When it flows to users, it must be safe for human consumption and use.

Keeping water at the public, also called potable or drinking, quality level, requires frequent testing for over 150 pollutants and 90 contaminants that are in the EPA’s water quality primary standards. For each, there are set limits for how much can be in public water when it is distributed to the public. In addition to these elements, there are other factors that can affect water quality and have the potential to make it unsafe for public distribution. Chemical, microbiological, and physical changes in a water distribution system can affect water quality. Examples include the thinning or loss of a system's Chlorine protective layer, fluctuations in pH levels, formation of Coliform Bacteria, introduction of pathogens, and increased water turbidity (high levels of suspended particles).

For example, if the contaminant of Sulfur Dioxide is allowed to enter a public water distribution system, it can strip away the necessary Chlorine residual layer that prevents the growth of bacteria, viruses, and other microorganisms inside a distribution system. Such an event will leave you with a system incapable of deterring these contaminants which can cause a downgrade of your water quality. When this type of event happens, it can make both the water and distribution system contaminated and force you to lower the quality levels making the water and distribution system unusable for public water applications.

Therefore, it is imperative that you become aware of frequently encountered issues, problems, and events that can affect water quality and how to prevent them. Examples of events that can lead to a loss in water quality from contamination include infrastructure conditions, cross-connections, pressure levels, backflow events, and stagnation.

- **Infrastructure Condition**

  The age and condition of your plumbing infrastructure can cause deficiencies in water distribution systems. Examples are a breach of physical pipe integrity, a breach of hydraulic pipe integrity, and a breach of water quality integrity. When these issues occur, the pipe can no longer maintain its integrity during operation. The pipe will often break or crack and leak water into the area where the failure has occurred.

  When a pipe breaks or cracks, it can create an opening for contaminants to enter the water distribution system. Elements in the environment of failure, such as air pollutants, bacteria, dirt, debris, untreated water, etc., may enter into the distribution system. When it happens, quality is usually compromised so the water becomes unsafe for public use or consumption.

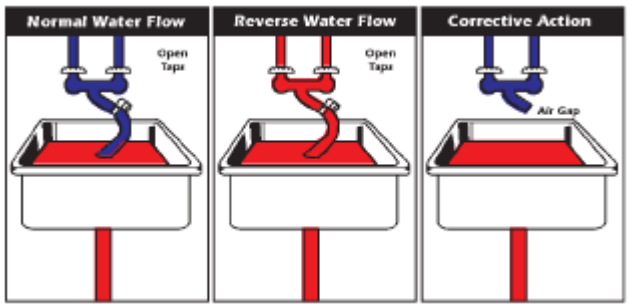
  To avoid such an event, complete frequent and consistent maintenance actions to maintain system integrity. Keep a log that is up to date with system equipment, devices, components, and parts listed for the distribution system. Also, log the date of installation, the manufacturer's projected lifespan, the material of construction, any maintenance that has been done, and when. This logged information will help you track and predict the best time for maintenance or replacements to avoid events like breaks and cracks. Plus, keep the distribution system operating efficiently.

- **Materials of Construction**

  Not all distribution system components are made of the same material of construction. Some materials are more durable than others. An example is PVC pipe that, unless damaged, can last for generations. This material makes them less likely pipe will lose its integrity, which can cause cracks, breaks, and failures. These occurrences create openings in a water distribution system that can allow pollutants to enter a system, that could contaminate the water and alter its quality.

  A pipe material's level of rust and corrosion resistance is also important to water quality. For example, cast iron pipes, which were once standard and are still in older homes, tend to corrode over time due to their lack of resistance. When this occurs, cast iron will often release toxins into the water that contaminate it and lower its quality.

  It is also important to consider how the pipe's material reacts to water and its environment over time. Lead pipes have been used for many years and are still used in some plumbing systems. However, over time, the lead breaks down and can emit toxins into the water traveling through it, contaminating it and changing its quality level.



- **Cross-Connections & Backflow**

  Cross-connections are connections between potable (drinking) water distribution systems' pipes and non-potable sources. You will often find them in agricultural irrigation systems, where cross-connections are used to physically connect an irrigation system with a potable water distribution system. These connections make it possible to transfer water into irrigation systems that are needed for growing crops.

  While this type of connection is necessary, it raises the risk that a distribution system and the water within it will become contaminated, which can change water quality. The cross-connection can become an inlet for the liquids in other connected systems to enter a water distribution system, which will change water quality.

  For example, if the pressure drops in a distribution system, it can create suction. That force can cause the contents of connected systems to flow backward and into the distribution system, polluting the water and reducing water quality. Such an event is often referred to as backflow or Backsiphonage and can leave you with unsafe and unusable water.

  The same outcome can occur when hoses are used as tools for distribution systems. For example, a hose may have been connected to a distribution system for draining water and left with one end connected to the system and the other in a bucket. When rising pressure causes backflow, the hose end in the bucket can pull its contents into the system. This, too, will cause contamination and threaten water quality.

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Therefore, it is critical to log and track both permanent and temporary connections to a water distribution system.

- **Water Age and Stagnation**

  Another issue that can affect quality is your water's age and level of circulation. Old water needs movement to prevent it from becoming stagnant or stale. If stagnation occurs, the water may be considered contaminated and of a quality no longer unusable for public applications. Prolonged water storage agung can also contribute to the formation of disinfection by-products, which may have health implications.

- **Pressure Variations**

  Common issues like temperature changes, clogs in pipes, and pressure regulator failures can all cause variations in pressure. These examples usually cause pressure to rise to levels beyond the limits of pipes, joints, connections, devices, etc. Such an occurrence can threaten system integrity. High pressure can cause breaks and failures, especially in pipes, that leave openings in a distribution system for a contamination event to occur. If an event occurs, water quality will be affected, and it may become unusable for the intended use like human use and consumption.

- **Seasonal Changes**

  Temperature fluctuations from changing seasons can impact water quality as well. For example, if there is heavy spring rainfall, it can cause runoff from agricultural lands that may wash pesticides and fertilizers into a river used as

a water source for drinking water. Such an occurrence will lead to increased contaminant levels in the treated water supply during that time.

Maintaining water quality requires awareness of potential threats, including those provided, and a comprehensive approach that includes regular monitoring, maintenance, and upgrades to infrastructure, as well as effective management of water treatment and distribution processes.