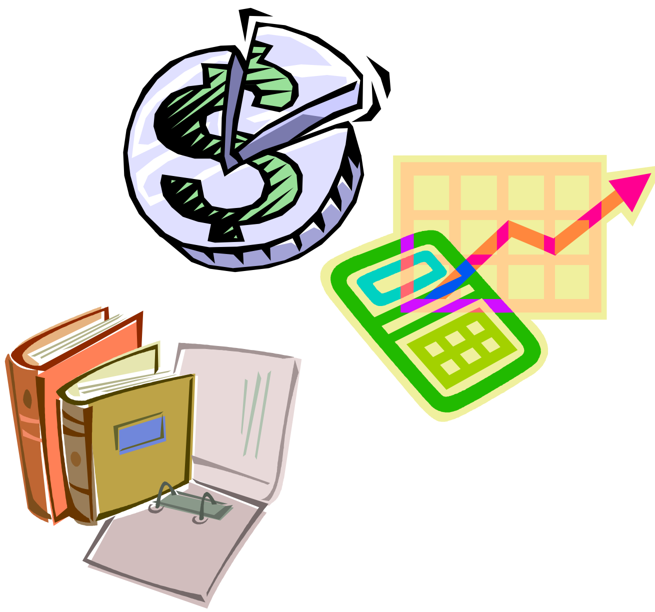
# Module 1
# WATER SUPPLY SYSTEM BASIC OPERATIONS

## Workbook



## Financial/Managerial Series

This course includes content developed by the Pennsylvania Department of Environmental Protection in cooperation with the following grantees:

RCAP Solutions, Inc.
Penn State Harrisburg Environmental Training Center

# Training Module 1
## *WATER SUPPLY SYSTEM BASIC OPERATIONS*

### Objectives:

By the end of the course, the learners should be able to:

- Identify the advantages and disadvantages of the two main water sources for municipal drinking water systems.
- Identify the basic components of a water treatment system.
- Identify the basic components of a water distribution system.
- Explain the function and necessity of each component.

## Table of Contents

## Introduction

#1

During this training module, we'll be describing:

- Advantages and disadvantages of the two main water sources for municipal drinking water systems;
- Basic components of a water treatment system;
- Basic components of a water distribution system; and
- Function and necessity of each component.

## Drinking Water Sources

#2

There are two main sources of drinking water, Surface Water and Groundwater.

Surface Water sources typically include Rivers, Streams, Lakes, Reservoirs. Groundwater under the direct influence of Surface Water (GWUDI), such as Springs, is another Surface Water source.

Groundwater sources include Aquifers and other sub-surface water, such as Wells.

#3

There are a number of advantages associated with using surface water as the source for your drinking water system.

Surface water is easily accessible and there can be large volumes of water available.

Additionally, since your treatment technology will be designed for surface water, you can utilize surface reservoirs for storage.

**#4**

Of course, there can be a number of disadvantages associated with using surface water as the source for your drinking water system. Surface water can be exposed to environmental pollutants such as agricultural runoff and disease-causing organisms.  Groundwater is less susceptible to these.  All water supplies have security issues; surface water can be more vulnerable than groundwater.

Additionally, since your treatment technology will be designed for surface water, it typically requires filtration equipment that may be more costly than groundwater treatment equipment.

**#5**

There are a number of advantages associated with using groundwater as the source for your drinking water system.

Groundwater usually requires less treatment than surface water.

Fairly consistent flow, quality, and temperature can make operation of treatment equipment easier.

Additionally, more sites are available for wells than surface water intakes for small, isolated communities.

#6

Of course, there can be a number of disadvantages associated with using groundwater as the source for your drinking water system.

Although not as susceptible as surface water, groundwater can still be subject to contamination by agricultural and domestic chemicals. Once contamination occurs, it may be long-lasting and difficult to remove.

It can also be subject to high levels of hardness and nitrates along with problems from iron and manganese content.

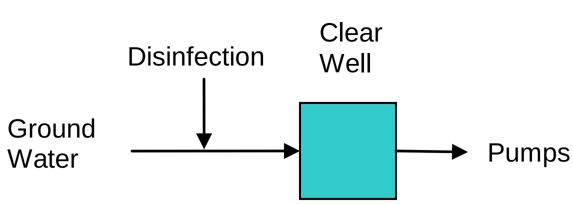
Additionally, multiple wells may be required to supply a community. Property issues such as condemnation, leasing, and location of wells are also concerns.

Wellhead protection zone maintenance can be problematic.

## Basic Water Treatment Processes

#7

The following graphic depicts the typical groundwater treatment processes you will encounter.

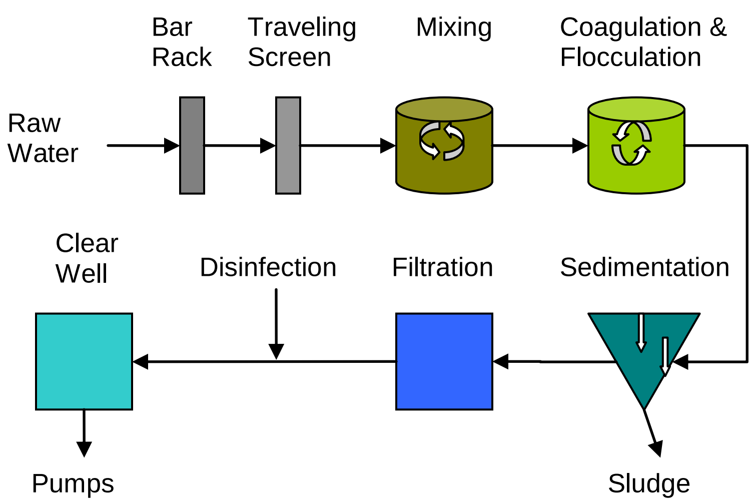


**#8**

Groundwater treatment is fairly straightforward. The disinfection of groundwater is similar to that of surface water. This will be covered later in the module.

**#9**

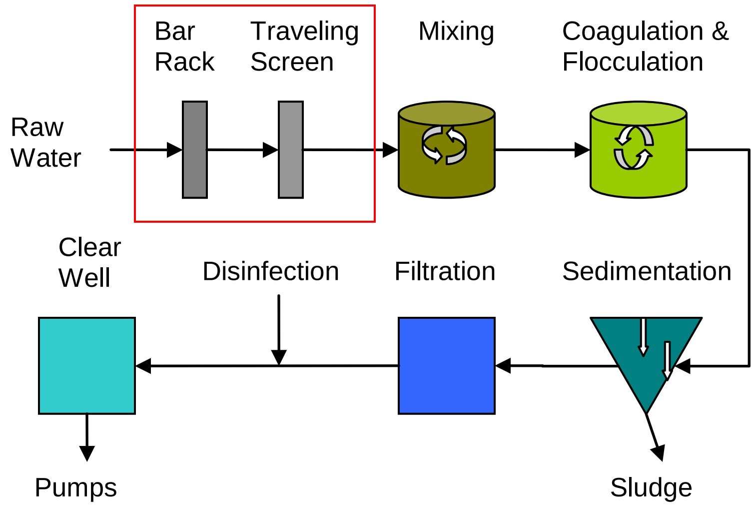
The following graphic depicts the conventional surface water treatment processes you will encounter.

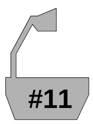



The following slides will describe each major process in greater detail.

**#10**

The following graphic highlights the racks and screens.

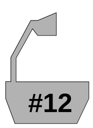


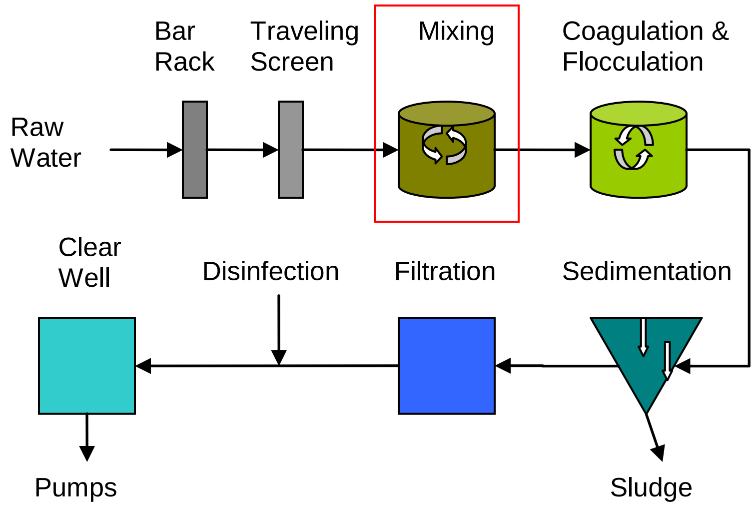

Racks and screens prevent algae, leaves, debris, and fish from entering the system.

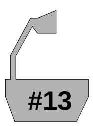
This includes pipes, and possibly pumps, to carry the water to the facility.

As an analogy, you may want to think about straining pasta in the kitchen.

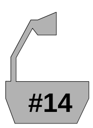



The following graphic highlights the mixing process.

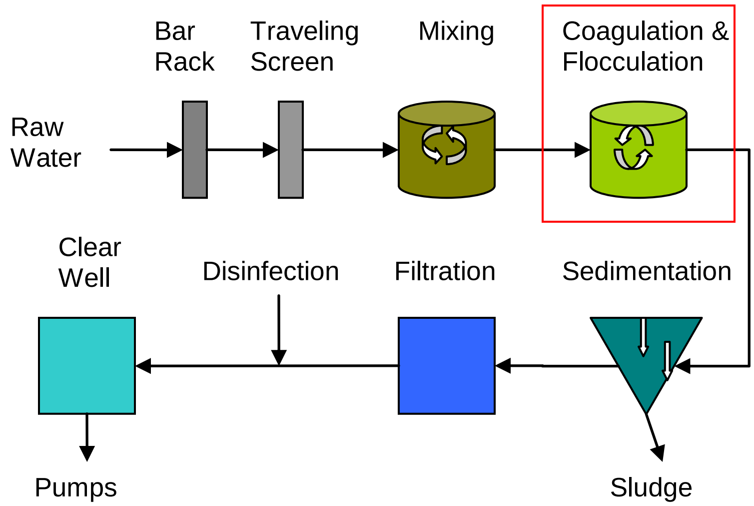


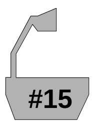




In the mixing process, chemical coagulant is mixed with source water to bring the suspended particles in contact with each other.




The following graphic highlights the coagulation and flocculation processes.

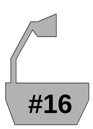


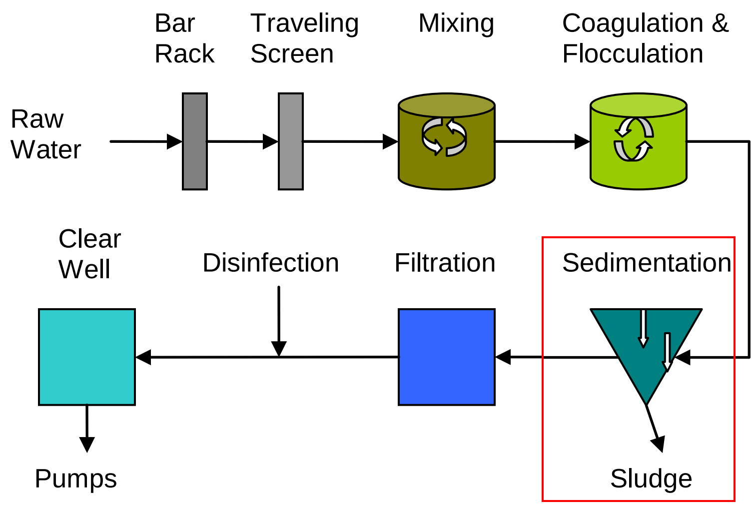

Coagulation and flocculation aid in filtration by increasing the size of the solids to be filtered and aid sedimentation by making the bound solids settle easier.

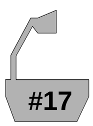
Removing solids makes the disinfection process more efficient since microorganisms can be trapped in the solids that are removed during coagulation and flocculation.

Making cheese by adding bacteria to form larger curds is a good analogy.




The following graphic highlights the sedimentation process.



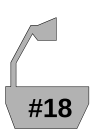

Sedimentation occurs in basins following coagulation and flocculation.

Sedimentation is the process of removing solids from the water. Basically, sedimentation is the same as settling solids out of the water.

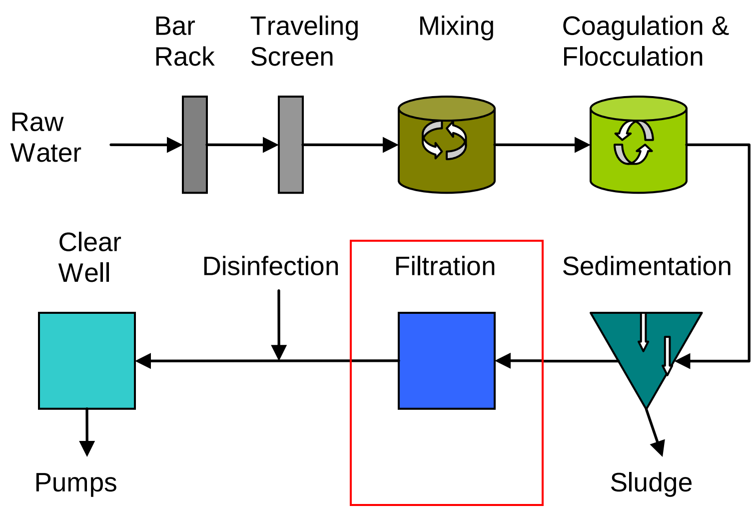
By settling solids from the water, the water treatment filters do not get blocked as quickly.

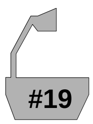
Periodically the settled solids must be removed from the sedimentation tanks.

An analogy to consider is Italian salad dressing with solids that settle over time.




The following graphic highlights the filtration process.




Filters remove solids suspended in the water. Types of solids include soil particles and microorganisms. Solids are removed by physical, chemical, and biological actions.

Physical action is similar to straining.

Chemical action includes adsorption (binds to) and absorption.

Biological action refers to “good” bacteria in the filter controlling unwanted harmful bacteria.

The following slides detail a few of the major filtration technologies. These include Slow Sand, Conventional, Direct, Diatomaceous Earth, Membrane, and Bag and Cartridge. Conventional filtration is the most common filtration technology in PA. Membrane filtration is becoming increasingly common.

#20

Slow Sand has the following characteristics:

- Low cost
- No coagulation and flocculation
- High land requirement
- Limited range of turbidity

Conventional Filtration has the following characteristics:

- Uses a filter bed with sand, anthracite coal, and mineral sands
- Activated carbon may be added to remove odors, improve taste, and adsorb organic compounds

#21

Direct Filtration has the following characteristics:

- Similar to conventional filtration but omits sedimentation and only applicable for high quality and seasonally consistent water supplies
- Requires advanced operator skills

Diatomaceous Earth has the following characteristics:

- Uses diatomaceous earth (chalk-like material) on a filter element in a pressurized vessel
- Most suitable for water with low turbidity and bacterial counts
- Chemical coagulation is not required

#22

Membrane Filtration has the following characteristics:

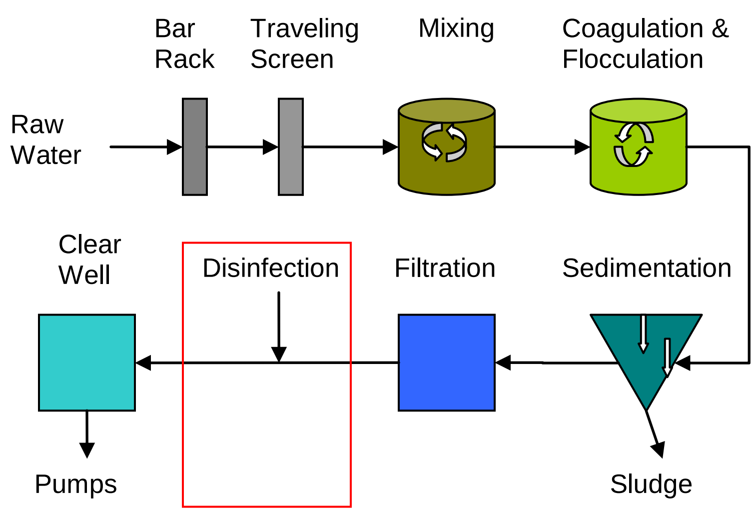
- Various types (micro-, ultra-, and nano-) all using porous membrane materials that remove contaminants under pressure
- High quality source water or pretreatment required
- Relatively expensive but capital costs are continuing to decline

Bag and Cartridge Filters have the following characteristics:

- Simple options for small systems, relying on physical removal, but issues of reliability remain
- High quality source water or pretreatment required

#23

The following graphic highlights the disinfection process.



**#24**

Disinfection is required because other treatment processes do not remove all disease-causing organisms.

The most common disinfection process involves the use of chlorine, an oxidizing chemical.

Other disinfection options include ozone and ultraviolet radiation.

The disinfection needs to be maintained in storage and distribution and can be boosted at other points in the system.

**#25**

Disinfection with chlorine can be performed with a variety of compounds.

Chlorine Gas:

- Adequate mixing and contact time must be provided after injection to ensure disinfection
- Can be dangerous and potentially lethal if handled improperly and released to the atmosphere
- This is a critical safety concern. Remember – Safety First!

Sodium Hypochlorite:

- Available as a solution of 5 – 15% chlorine
- Safer to handle but highly corrosive

**#26**

Calcium Hypochlorite:

- Solid white substance that dissolves easily in water (65% chlorine)
- Corrosive and can cause fire or explosion with organic materials

Chlorine may combine with organics to form trihalomethane (THM) compounds which are carcinogenic.  EPA will be requiring the removal of these compounds from certain systems.

**#27**

Disinfection with ultraviolet radiation (UV) penetrates cell walls of organisms and inhibits reproduction although it may not inactivate cryptosporidium or giardia cysts.

UV disinfection produces no toxic residuals.

UV disinfection has short contact times and is easy to operate.

UV is not commonly used since it does not leave a chemical residual in the water like chlorine.  In general, when chlorine is used and tasted at the tap, the entire pipe to your home has been disinfected.

It is unsuitable for water with high turbidity levels, color, or soluble organic matter, since the UV light cannot penetrate the water with solids in it.

#28

Disinfection with Ozone is another option.

A powerful oxidizing agent ($O_3$) is formed by passing dry air through a system of high voltage electrodes.

Ozone requires shorter contact time than chlorine.

Capital costs may be high.

Operation and maintenance are relatively complex.

#29

Other treatment processes you may encounter include Iron and Manganese Removal and Corrosion Control.

The need for these will depend on characteristics of the water source for the system.

#30

Iron and manganese can be removed by various oxidation and filtration techniques.  This mainly occurs in the treatment of groundwater.

This includes:

- Simple cascade aeration; requires no chemicals
- Sequestration with polyphosphates followed by chlorination or potassium permanganate (no solids or filtration needed)

- Ion exchange with manganese greensand filtration

**#31**

Corrosion control is important because corrosive water can cause metal pipes, etc., to disintegrate and also dissolve lead in old pipes and solder.

Corrosion can be reduced by adjusting pH and alkalinity, softening the water, and changing the level of dissolved oxygen.

**#32**

Let's see what you've learned so far.  Fill in the blank for the following statements.

1. There are two main sources of drinking water: __________ Water and ______________.
2. ____________ water is easily exposed to environmental pollutants such as chemicals and disease-causing organisms.
3. _________ and _________ prevent algae, leaves, debris, and fish from entering the system.
4. In the ___________ process, chemical coagulant is mixed with source water to bring the suspended particles in contact with each other.
5. ______________ and _____________ aid in disinfection by increasing the size of the solids to be filtered and aid sedimentation by making the bound solids settle easier.
6. ______________ will decrease solids loading on the filters.
7. Italian dressing is an analogy for _______________.
8. ______________ remove suspended solids and floc (silt, clay, bacteria, plankton, etc).

9. ______________ is required because other treatment processes do not remove all disease-causing organisms.

## Distribution System

#33

The main components of a Water Distribution System include:

- Pumps
- Storage facilities
- Transmission mains
- Valves and hydrants
- Meters

#34

Pumps provide lift to move water from the plant to elevated storage areas.

The majority of the line pressure is not provided by pumps but by storage elevation of the water which creates “head” that provides the pressure. However, many systems use booster pumps to provide additional pressure in areas that need it.

Pumps are a major portion of the O&M costs of the water system.

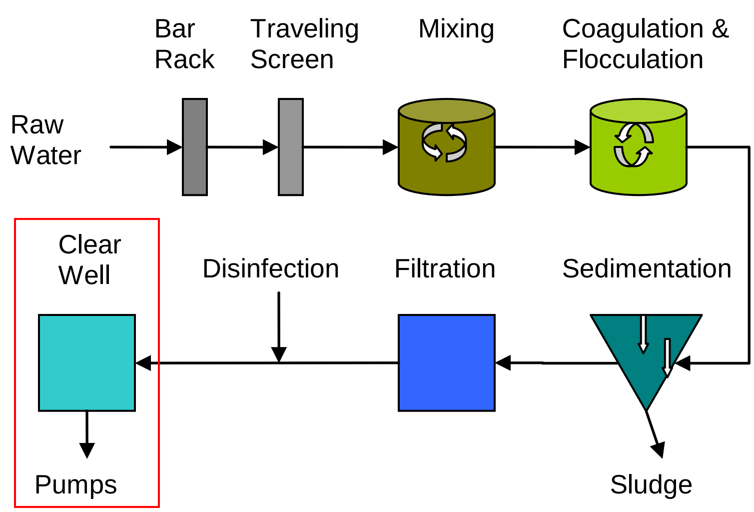
#35

Storage Facilities can consist of the following:

- Clear wells
- Stand pipes
- Elevated storage tanks

#36

The following graphic highlights the clear well.




#37

Clear wells are large concrete basins for storing treated water at the treatment facility or in the distribution system.

A clear well allows the treatment plant to operate at a constant rate, building up reserves during low-use hours and maintaining supply during peak-use hours.  It also can allow for additional contact time with disinfectants.

#38

Stand Pipes are tanks located on the ground, usually at higher elevations.

They require little maintenance and are ideal in situations where relatively low water pressure is required.

#39

Elevated Storage Tanks have supporting structures to elevate the tank to provide additional head (pressure).

They use gravity to pressurize water through the distribution system.

Storage tanks are typically filled in off-peak hours and monitored to maintain sufficient water pressure during high-use periods. An example of a high use period is early morning and mid-evening.

#40

There are different ways that transmission main systems can be designed.

Branching systems have dead-end lines that can cause taste and odor problems due to stale water in the ends of the lines.

Branching systems must be flushed out periodically. This is usually completed by releasing water in a systematic way from fire hydrants.

Loop or grid systems eliminate dead ends and provide more water in high-demand situations, such as fire fighting.

#41

There are different materials that can be used for transmission mains. The following are the most common:

Cast iron:

- Has great strength and high resistance to corrosion
- May last 100 years
- Most iron pipe now has a thin coating of cement mortar to prevent tuberculation (rusting) and reduce friction

Ductile iron:

- Stronger, more ductile (flexible) and lighter than cast iron
- Often coated with cement mortar to reduce internal corrosion

Plastic (polyvinylchloride or PVC):

- Low initial cost
- Lightweight
- Resistant to corrosion
- Low resistance to flow
- More susceptible to crushing
- Cannot be thawed electrically

#42

Valves are installed at intervals in the distribution system so that segments can be shut off for maintenance and repair.

They help to control the direction of flow and can control pressure by restricting flow from high to low-pressure areas.

Wet barrel hydrants are full of water at all times and can only be used where there is no danger of freezing.  Due to freezing, these are not generally used in PA.

Dry barrel hydrants have a valve located at the bottom of the barrel to control flow into the hydrant.  There is no water held within the hydrant.

**#43**

Meters are placed throughout the distribution system to measure the flow to main supply lines, pumping stations, connections to other utility systems and individual users.

They are used for billing purposes and to identify areas of water loss.

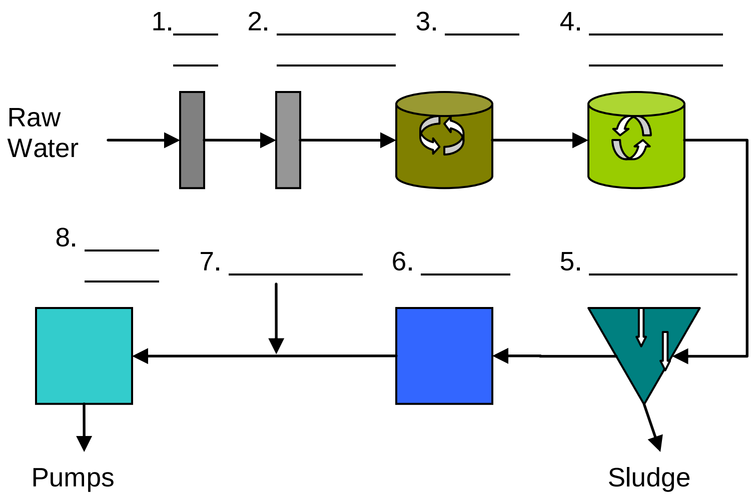
Metered billing will promote lower customer use and encourage conservation.

Old meters often under-record use; systems should have a standardized meter replacement program.

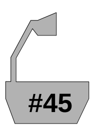
## Summary

**#44**

Before we review the key points of the module, let’s see what you’ve learned so far.  Take a few minutes to fill in the graphic in your workbooks and answer the questions beneath it.  You can look back through your workbooks if you need.




1. A clear well allows the treatment plant to operate at a ________ rate, building up reserves during low-use hours and maintaining supply during peak-use hours.
2. ___________ are installed at intervals in the distribution system so that segments can be shut off for maintenance and repair.
3. Pumps are a major portion of the _____________ costs of the water system.
4. ___________ are placed throughout the distribution system to measure the flow to main supply lines, pumping stations, connections to other utility systems and individual users.
5. ___________ provide lift to move water from the plant to elevated storage areas.




The key points of this module are:

- Water systems can differ in many areas but most have the basic components in treatment and distribution.
- Knowledge of the basic components of the water treatment system can help you make better decisions relating to the system.

- Knowledge of the basic components of the water distribution system can help you make better decisions relating to the system.

- There are advantages and disadvantages to each type of water source.

## Resources and References

#46

The following are references and resources you can use for additional information:

PA Department of Environmental Protection, Technical Assistance and Outreach, (717) 772-4058, Dennis Lee

RCAP Solutions, Inc., (814) 861-6093
Don Schwartz, PA/NJ Program Manager

Penn State Harrisburg Environmental Training Center

National Drinking Water Clearinghouse (West Virginia University) Tech Briefs for Small Water Systems – "Treatment technologies for Small Drinking Water Systems"

Drinking Water Handbook for Public Officials (December 1992; EPA-810-B92-016)

Drinking Water and Wastewater Handbook for Local Officials (October 2000; Maryland Center for Environmental Training under EPA Contract)

The complete list of training modules includes:
- Module 1, Water Supply System Basic Operations

- Module 2, Responsibilities of Governing Boards
- Module 3, The Safe Drinking Water Act
- Module 4, Dealing with Consultants, Technical Assistance Providers, Regulators, and Funding Agencies
- Module 5, The Basics of Accounting and Finance for Small Water Systems
- Module 6, Business Planning for Small Water Systems
- Module 7, Budgeting and Capital Improvements Planning Overview for Small Water Systems
- Module 8, Rate Design Overview for Small Water Systems
- Module 9, Bidding, Purchasing, and Leasing
- Module 10, Project Management Overview for Small Water Systems