Drinking Water Operator Exam Study Guide

WT3

Groundwater

Contents

General Regulatory

U.S. Environmental Protection Agency (U.S. EPA, USEPA, or EPA)

https://www.epa.gov/

- Mission: To protect human health and the environment.
- Federal agency that implements environmental laws written by Congress.
- Writes regulations and sets national standards for states and tribes to enforce through their own regulations.
- Indiana is in EPA Region 5, which includes Illinois, Michigan, Minnesota, Ohio, and Wisconsin.

Indiana Department of Environmental Management (IDEM)

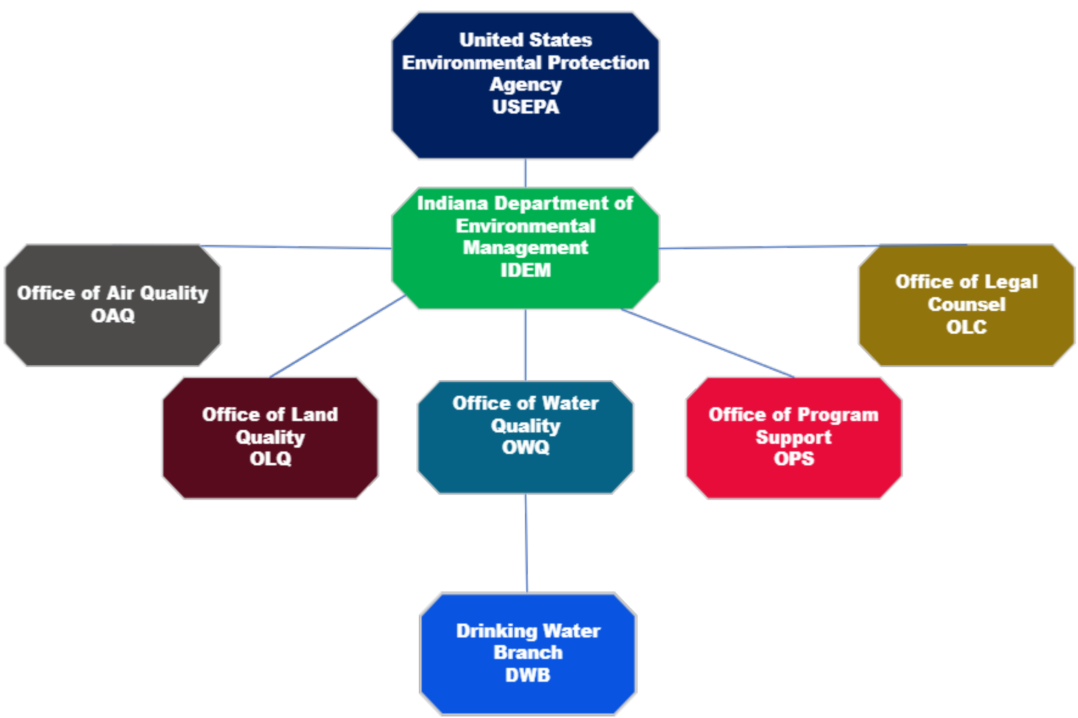
https://www.in.gov/idem/

- Mission - to implement federal and state regulations to protect human health and the environment while allowing the environmentally sound operations of industrial, agricultural, commercial, and governmental activities vital to a prosperous economy.
- Indiana has applied for and been granted **primacy** by the EPA.
- State agency that implements environmental regulations.
- IDEM is headed by the Commissioner, Chief of Staff, and General Counsel.
- Divided into five (5) Offices:
  - Office of Air Quality
  - Office of Land Quality
  - Office of Water Quality
  - Office of Program Support
  - Office of Legal Counsel

Office of Water Quality (OWQ) https://www.in.gov/idem/cleanwater/

- Office within the IDEM with a mission to monitor, protect, and improve Indiana's water quality to ensure its continued use as a drinking water source, habitat for wildlife, recreational resource, and economic asset.
- Achieves mission by developing rules, guidance, policies, and procedures in the following areas:
    - Surface and ground water quality assessment.
    - Regulation and monitoring of drinking water supplies and wastewater facilities.
    - Protecting watersheds and wetlands.
      Providing outreach and assistance to the regulated community and the public while supporting environmentally responsible economic development.
    - Indiana's Water Quality Standards as mandated by the Clean Water Act are the measure used for these activities.

Figure 1 - Federal and State Environmental Hierarchies



Drinking Water Branch (DWB) https://www.in.gov/idem/cleanwater/drinking-water/

- Branch of IDEMs Office of Water Quality that carries out the requirements of the federal **Safe Drinking Water Act (SDWA).**

- The Drinking Water Branch consists of six (6) sections:

  - Total Coliform & Compliance Support
  - Chemical & Surface Water Compliance
  - Field Inspections
  - Groundwater
  - Operator Certification and Capacity Development
  - Permits

Figure 2 - Drinking Water Branch Sections

Overview of Federal and State Regulations

Federal - Safe Drinking Water Act (SDWA) https://www.epa.gov/sdwa

- Established national drinking water standards to be administered and enforced by state agencies.
- Passed, or adopted, by Congress in 1974 to protect public health by regulating the nation's public drinking water supply.
- Applies to every public water system in the United States.
- Amended in 1986 and 1996 and requires many actions to protect drinking water and its sources.
- 1996 amendments greatly enhanced the existing law by recognizing the following as important component of safe drinking water.
    - Source water protection
    - Operator training
    - Providing funding for water system improvements
    - Public right-to-know
- SDWA requires the EPA to review its regulations every 6 years and strengthen them as science advances.

State - Indiana Administrative Code (IAC)

- Indiana regulations that govern how the federal regulations are enforced in the state of Indiana.
- DWB primarily utilizes IAC 327 Article 8.
- IAC establishes maximum contaminant levels (MCLs) for turbidity, microbiological contaminants, and radioactive contaminants.

- Public Notification: Violations of IDEM rules require notification to system consumers within a specific time frame.

  - Tier I Violation – 24 hours (immediate notification) acute health risk
  - Tier II Violation – 30 days
  - Tier III Violation – 12 months

  - When a system has complied with a public notification requirement, the system has ten (10) days to submit it to IDEM.

Operator Responsibility

- **The primary responsibility of a water treatment operator is to produce safe and pleasant drinking water.**
- Public Water System – At least 15 service connections or regularly serves 25 individuals daily at least 60 days per year.

Table 1 - Public Water Systems

Type of System	**Characteristics**	**Examples**
Community	Serves the same population year-round.	Municipal Utility
Non-transient non-community	Serves the same population for at least 6 months, but not the entire year.	Factories, Schools, Churches, Office buildings with their own water systems.
Transient non-community	Provides water to 25 or more people for at least 60 days/year, but not the same people on a regular basis.	Gas stations, Campgrounds, Rest Areas

WT3 operators can only operate WT3, WT2, and WT1 systems. **WT3 operators are the only ones who can operate a WT3 system.**

Class WT 3 includes systems that meet the following:

- Acquire water from one (1) or both of the following:
  - Ground water
  - Purchase
- (B) Utilize chemical feed

- (C) Have one (1) or more of the following:
  - Pressure or gravity filtration
  - Ion exchange processes if the population served is greater than three thousand three hundred (3,300)
  - Lime soda softening
  - Reverse osmosis
  - Inline filtration if the population served is greater than three thousand three hundred (3,300)

- IDEM requires all public water systems to have a designated operator who is the Certified Operator in Responsible Charge (CORC).
- The CORC is designated by the owner or governing body and is responsible for the operations of the treatment or distribution facility.
- They make decisions regarding daily operations which impact water supply and quality.
- A facility may have multiple operators, but there is only one CORC.

Table 2 – CORC Requirements

Operator Grade	CORC Requirements

All Grades	• The certified operator will be able to provide adequate supervision to all units involved.
	• Before undertaking multiple operator positions of responsible charge, a letter signed by the certified operator is submitted to the owner or governing body of each water treatment plant and water distribution system to be under the responsible charge of the certified operator providing the following information:
	  ○ The name and location of each water treatment plant and water distribution system to be under the responsible charge of the certified operator.
	  ○ The number of hours per week the certified operator shall work at each water treatment plant and water distribution system.

WT3	• Be monitored daily by a dependable person or automated system. • Have a certified operator on site for a minimum of five (5) daily visits every week.

Administration

- An operator is responsible for providing clean water with no foul tastes or odors from the treatment plant to the customers tap.
  - They are accountable to their chain of command, as well as their customers.
  - An operating plan should be in place, but the operator may need to modify the plan.
  -

- Monthly Report of Operations (MRO) – Report detailing things like routine maintenance, chemical feeds, and supply orders.

  - All community public water supplies that add chemicals to their water are required to make daily entries onto an MRO.

  - The certified operator-in-charge must sign the report and submit the MRO to IDEM within 10 days following the end of each month.

- Records need to be kept for as long as legally required:
    - Chemical analyses – 10 years
    - Bacteriological – 5 years
    - Sanitary Survey – 10 years

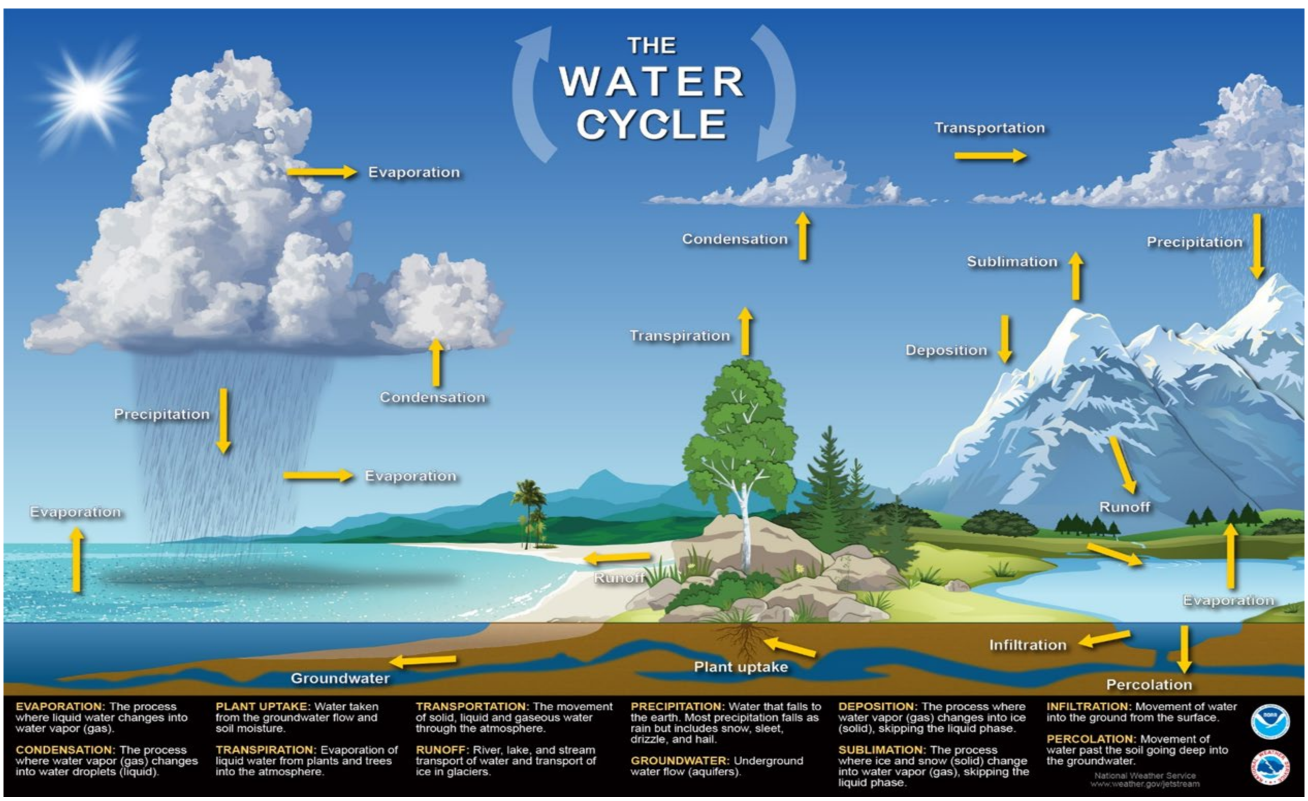
- Uniform Rate - A type of rate structure for charging customers to access the water
- To meet demand, it is important to know when consumption is at high levels.
  - Knowing demand ensures water supply will be available to meet demand.

- Average daily flow can help with forecasting demand for supply and help calculate future expenses.
- It allows operators to conserve water during low demand times to meet high demand later.
- Peak demand is usually in the evening.
- Low demand is usually very late at night or early in the morning.
    - Systems with irrigation systems may experience high demand in the early morning.

Source Water

Hydrological Cycle: The hydrological cycle covers the "continuous exchange" of water between the earth and the atmosphere

Figure 3 – The Water Cycle



Courtesy of The National Weather Service

- Condensation: The process of water vapor in the air turning into liquid water.
- Evaporation: The conversion of water from a liquid into a gas.
- Evapotranspiration: Evapotranspiration only covers water entering the atmosphere but does not include water moving from the atmosphere back to the earth.
- Precipitation: Water that falls to the earth. Most precipitation falls as rain, but includes snow, sleet, drizzle, and hail.
- Percolation: The slow seepage of water into and through the ground. The slow passage of water through a filter medium.
- Sublimation: The process where ice and snow (solid) change into water vapor (gas) skipping the liquid phase.
- Transpiration: The process of liquid water evaporating from plants and trees into the environment.
- Water expands roughly 9% between its liquid and solid forms (ice).

Groundwater

Aquifer: Saturated underground formation that will yield usable amounts of water to a well or spring.

- The formation could be sand, gravel, limestone or sandstone.
- The water in an aquifer is called groundwater.
- Confined aquifer: formation between low permeability layers that restrict movement of water vertically into or out of the saturated formation.
- Water is confined under pressure like water in a pipeline.
- In some areas confined aquifers produce water without pumps (flowing artesian well).
- Unconfined aquifer (water table aquifer) is the saturated formation in which the upper surface fluctuates with addition or subtraction of water.
- The upper surface of an unconfined aquifer is called the water table.

- Water in an unconfined aquifer is free to move laterally in response to differences in the water table elevations.

  - Anaerobic zone: bacteria use gases other than oxygen for metabolism.
  - Aerobic zone: bacteria use oxygen for metabolism.
  - Microbial growth occurs where these zones meet.

Figure 4 – Water Sources

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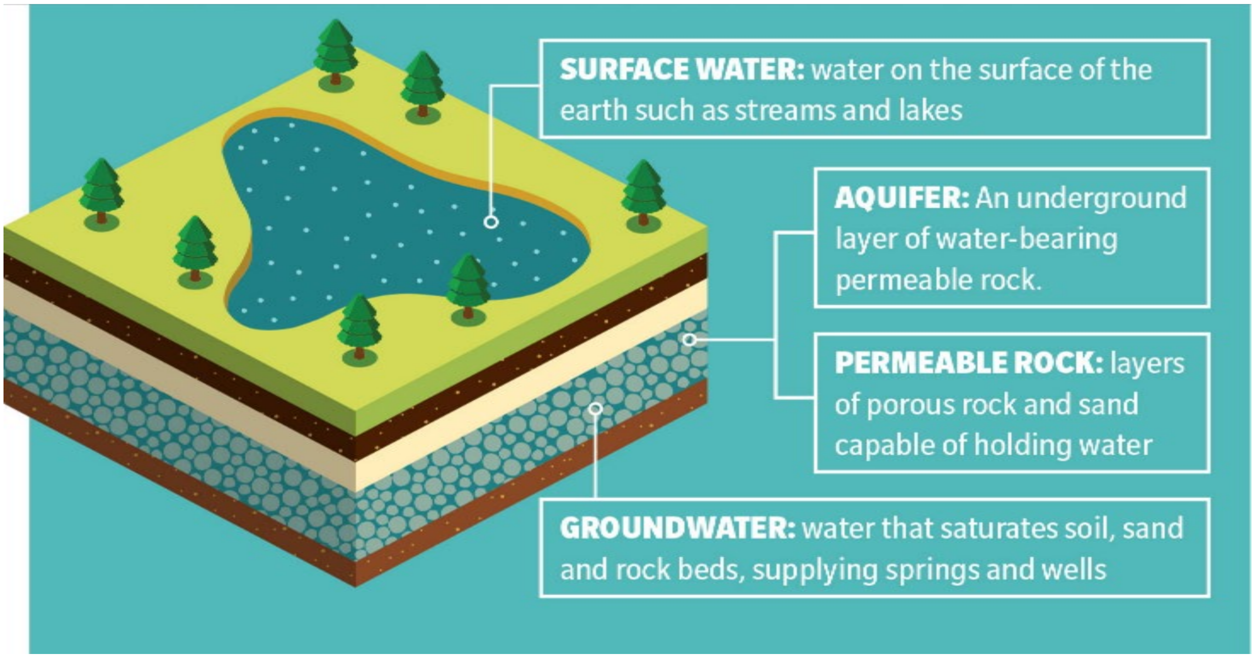

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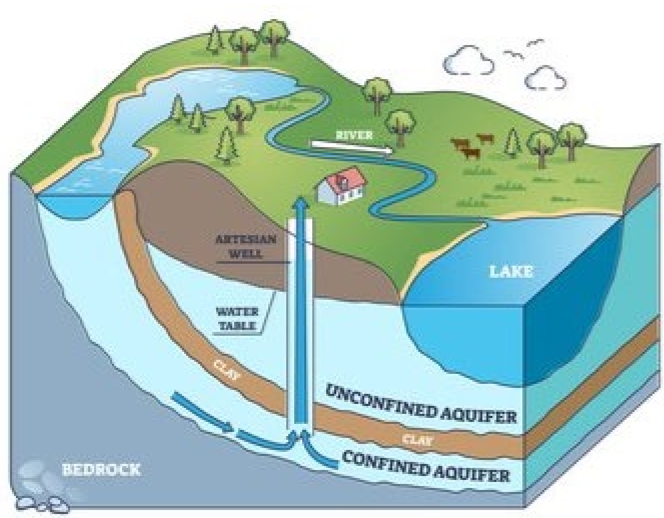
Figure 5 – Confined Aquifer



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Wells

A well is used to extract groundwater from an aquifer that can then be utilized for drinking water purposes.

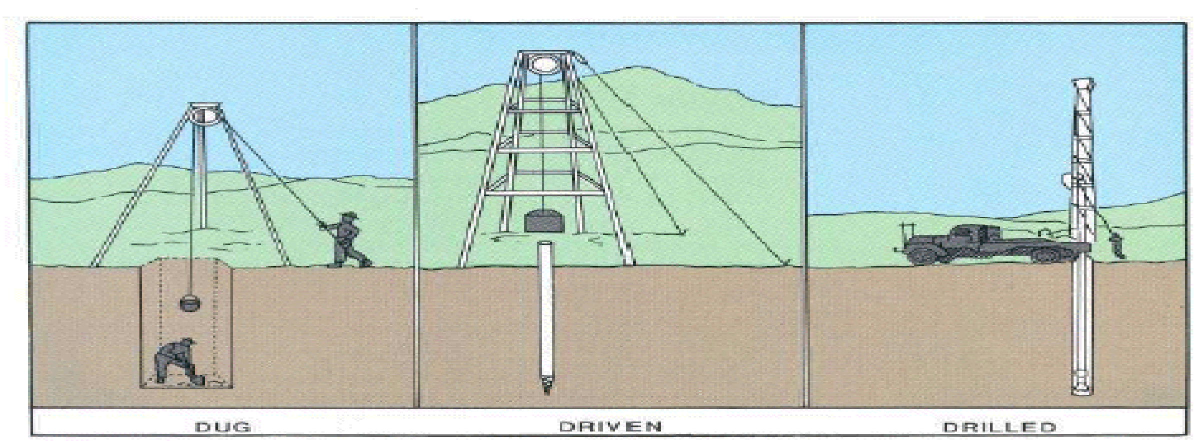
Types of Wells:

Table 3 – Types of Wells

Type	Characteristics	Depth
Dug	Excavated by hand shovel to just below water table	Shallow – just below water table (10-30 ft.)
Driven	Small-diameter pipe driven into soft earth, such as sand or gravel	Shallow – source of water is close to the surface (30-50 ft.)
Drilled	Large drill rigs that use bits to bore deep into the ground. Different bits can be used for rock or softer ground	Deep – a pump may be required to push water to the surface **Can be thousands of feet deep*

EPA.gov - *Learn About Private Wells*

Figure 6 – Types of Wells



USGS Publications Warehouse – USGS.gov

Well Components:

Table 4 – Well Components

Type	Description	Purpose
Well Casing	Tubular structure placed inside of a drilled well.	Maintains well opening and potentially keeps contaminated surface water from reaching the aquifer zone.
Well Caps	Cover on top of the well casing which protrudes from the ground.	Primary function is to keep contaminants out of the aquifer.
Well Screens	Screen attached to the bottom of the well casing.	Filters out large media in the aquifer from entering the well while allowing water to move through the well.
Pitless Adapter	Connector that allows the pipe carrying water to the surface to remain below the frost line.	It ensures that the sanitary and frost-proof seal is maintained.
Pump	Mechanical device using suction on pressure to raise, compress, or force liquids or gasses.	To draw the water from the aquifer.

wellowner.org, well system components

- Sanitary Seal - A seal around the wellhead that prevents contamination of the well.

- A sanitary seal is created by grouting a wellhead.

- Well-site surveys: A survey conducted when a well is proposed.

    - Performed to ensure the well can meet the demand, has the appropriate sanitary setback to avoid contamination, and can be dug and implemented safely.

    - Sanitary setback/ Isolation area - An area of at least 200 feet from a wellhead that does not contain any potential contamination sources.

        - Wellhead Protection Plan – tool for communities to protect their Community Public Water Systems. (https://www.in.gov/idem/cleanwater/information-about/groundwater-monitoring-and-source-water-protection/wellhead-protection-program/)

            - If the groundwater is treated, the sanitary setback can be reduced from 200 feet down to 100 feet.

        - Groundwater can contain high amounts of iron – this can be removed through oxidation and filtration.

        - When determining the presence of iron, sample as close to the groundwater source as possible – this will give an accurate representation of any iron levels.

- Drawdown – The lowering of the groundwater surface caused by withdrawal or pumping of water from a well.

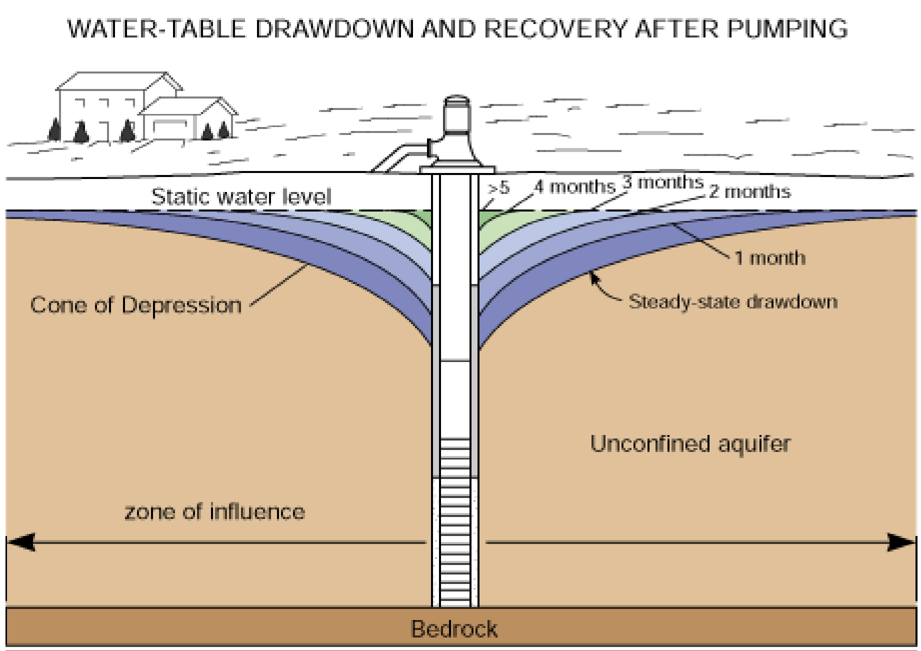
- It is the difference between the static water level and the pumping water level in a well pumped at a constant flow rate.

- A well with a high specific capacity will produce more than one with a lower specific capacity.

- Specific Capacity - A formula for determining if a well can adequately meet the demand of a proposed population or use.

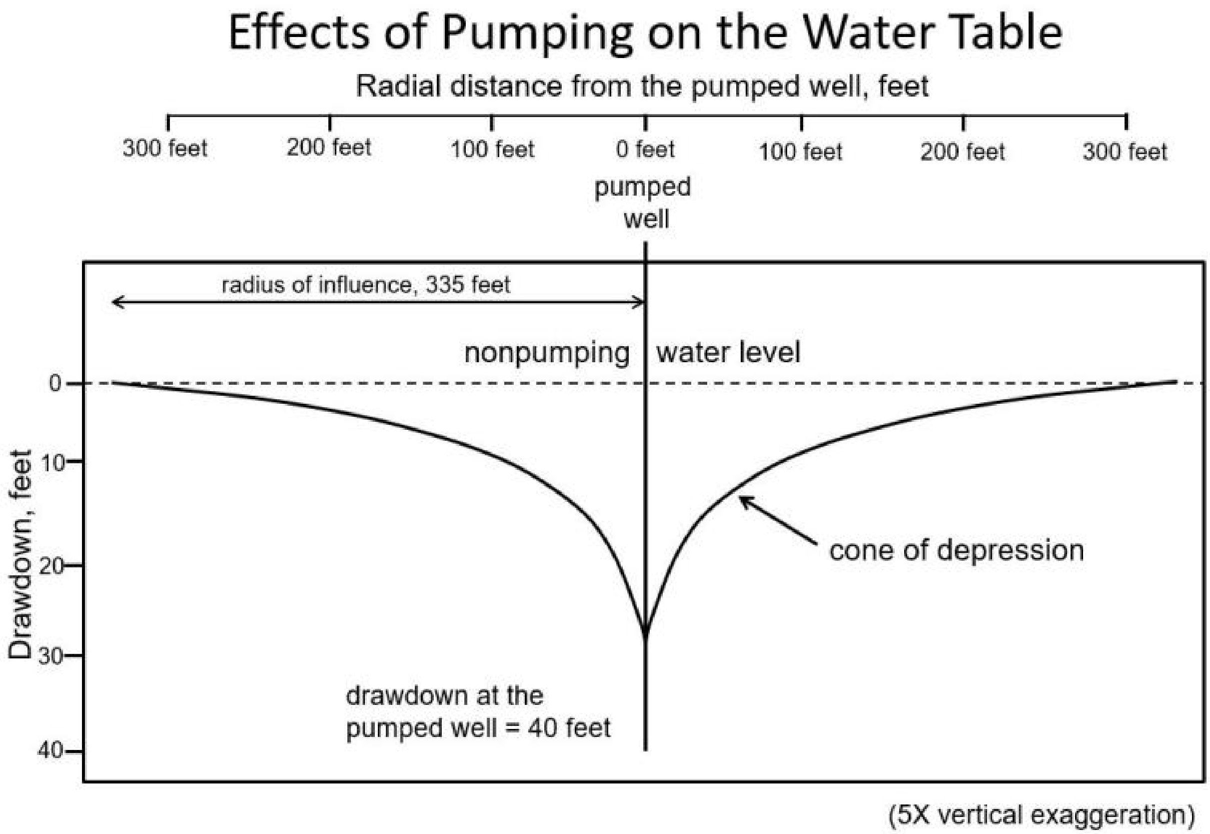
$$\frac{\text{Pump rate (Yield)}}{\text{Drawdown}}$$

Figure 7 – Water Table Drawdown



University of Kentucky

Figure 8 – Effects of Pumping on the Water Table



Courtesy of Missouri Department of Natural Resources

- Conservation - Water conservation allows for a reduced demand on water supply source
- Conserving measures may be necessary during drought conditions or population expansions

Well Maintenance

- Annual flow testing
- Visual inspection
- Checking pumps and valves for failing parts
- Electrical testing

GWUDI – Groundwater Under the Direct Influence of Surface Water

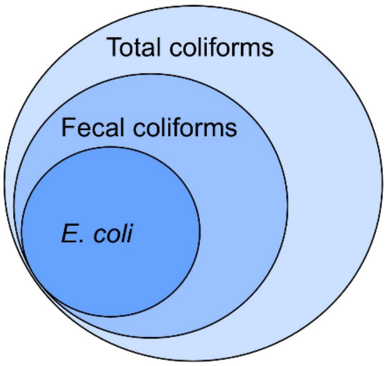
- Groundwater that has surface water characteristics.
- Groundwater with significant shifts in water quality, which are like nearby surface water sources such as:
  - Temperature
  - Turbidity
  - pH
  - Conductivity

- GWUDI is pumped from wells, then treated.

- GWUDI shows signs of a surface water system if the temperature of the water changes with the seasons.
- A true groundwater system will not change more than a degree or two year-round.
- Also referred to as an unconfined aquifer.
- GWUDI systems are subject to the rules of Surface Water Treatment and require a WT4 or WT5 Operator Certification.
  - Turbidity monitoring measurements must be less than or equal to 0.3 Nephelometric Turbidity Units (ntu) in 95% of samples.
  - Turbidity measurements must not exceed 1 ntu.

Revised Total Coliform Rule (RTCR)

Figure 9 - Total Coliforms



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- The Revised Total Coliform Rule (RTCR) requires testing for total coliforms and *E. coli*.

- If a sample has the presence of total coliform bacteria, then a test needs to be done to determine the presence of *Escherichia coli* (E. coli).
    - Total Coliforms are used as an indicator that other potentially harmful bacteria may be present.
    - *E. Coli* (*Escherichia Coli*) bacteria that come from the fecal waste of mammals (i.e. humans, cows, dogs), which can cause acute gastrointestinal illness such as diarrhea, vomiting, and cramps.

Sample Procedure:

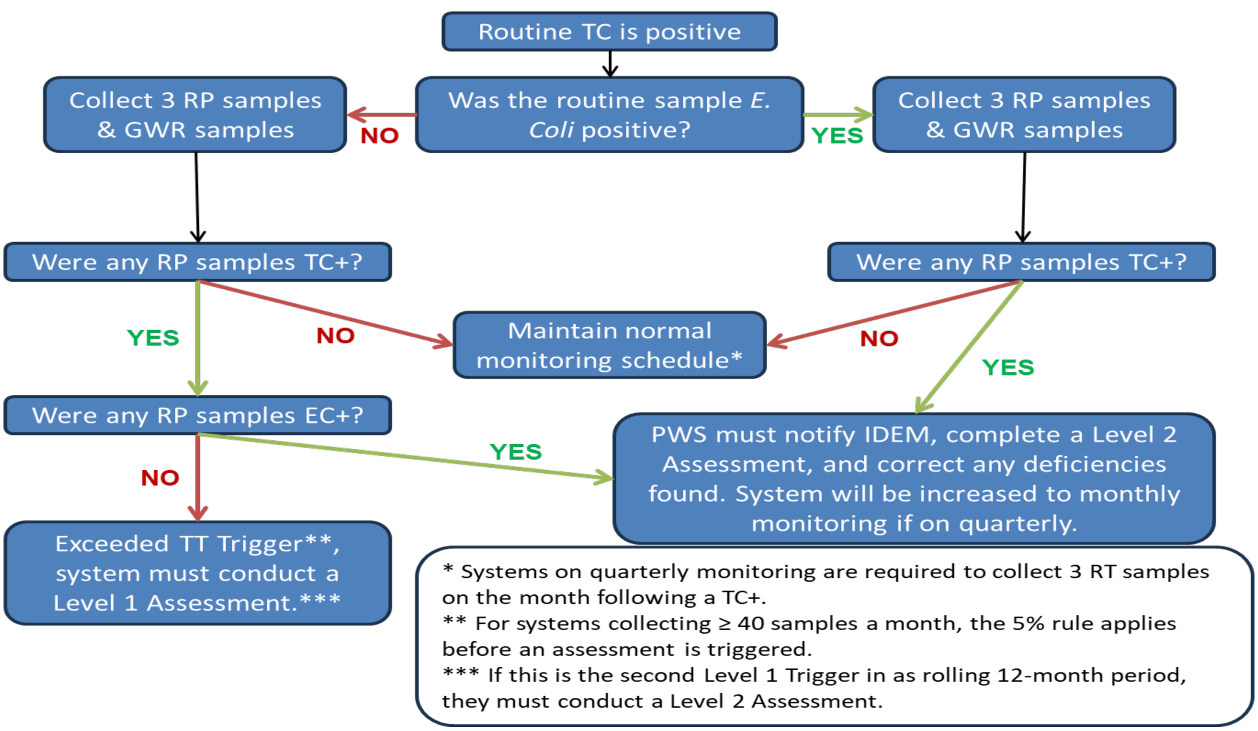
- When sampling, it is best to use a clean faucet that has a dedicated hot and cold tap.
- The sample should be pulled from the cold-water tap.

- Flush the system thoroughly, disinfect the faucet, flush again, then take the sample.

- Ensure the lid of the container is facing down, is not placed on a counter, and is not touched.
- Fill the container without splashing or rinsing.
- **Following the sample, a system has thirty (30) hours to get the sample to a lab.**
- **The sample should be kept between 4° and 10° Celsius.**
- The population served determines the number of coliform analysis samples required.
- If a routine sample tests positive for total coliforms, additional samples must be taken from the original tap, along with samples pulled from upstream and downstream.

If a sample tests positive for Coliform, IDEM must be notified within 24 hours!

Figure 10 – Positive Coliform Test Flowchart



Lead and Copper Rule (LCR)

- Dictates the monitoring requirements for lead and copper in systems.
- Lead and copper are based on “Action Levels” rather than “Maximum Contaminant Levels”.
- An action level represents a concentration above which they utility MUST reduce lead/copper levels
  - The action level for lead (Pb) is 0.015 mg/L.
  - The action level for copper (Cu) is 1.3 mg/L.

- If the lead or copper concentrations reach the action level, the water system must take steps to reduce the amount of lead or copper.

- A system must first take one sample per six-month monitoring period for two consecutive monitoring periods (one calendar year).

- Then the system may reduce to once per calendar year for three years, then reduce to once every three years.

- If a system’s lead and copper sample exceed action levels, the system must sample once per six-month monitoring period again.

- Lead and copper samples are collected from cold water taps at homes and businesses.

- The sample containers are 1000 mL rather than 100mL like Coliform samples.

- When monitoring for lead and copper, the system must use the first-draw or first-flush of the system after it has been unused for six hours.

- The Lead and Copper Rule does not include cast iron pipes with lead joints.

Sample Collection and Interpretation

- Samples are taken to assess water quality and ensure contaminant goals are met.
- The size and procedure of the sample will depend on what type of sample is taken.
- The person taking the sample is responsible for its preservation.

Table 5 - Sample Collection

Sample Type	Volume	Procedure	Notes
Coliform	100mL	See RCTR	Best performed on an unthreaded faucet. Sodium thiosulfate powder in sample container neutralizes chlorine residuals.
Lead and Copper	1L (1000mL)	See LCR	Fill sample container to the shoulder. Ensure that water has had time to stand in the pipes.
Grab Sample	N/A	Taken at a single time. Provides snapshot of water quality at that point.	Best used to test for dissolved gases, coliform, chlorine residuals, DBPs and pH
Composite Sample	N/A	Taken at intervals throughout the day. Shows changes over time.	Should be stored under 40° F (4° C), but above freezing temperature. Never appropriate for coliform sampling.
Continuous Sample	N/A	Continuously collected at desired points in the treatment system.	May be used to monitor raw source water or chemical residuals in the distribution system.

Lab Analysis

Lab analysis requires basic chemistry knowledge.

- Atom – basic unit of a chemical element
    - Made of a nucleus containing protons and neutrons that is surrounded by a cloud of electrons.
    - Electron clouds have rings, with the inner-most ring containing two electrons and each additional cloud containing up to eight electrons.
    - The outer most electron ring contains the valence electrons.
    - Valence electrons react with the valence electrons of other atoms to form chemical compounds.
    - Many metals have multiple valences.
    - The atomic number of an element indicates the number of electrons it contains.
- Ion – Charge carrying atom or molecule.
    - Anion – negative charge
    - Cation – positive charge
- Polarity – A molecule containing a positive charge at one end and a negative charge at the other
    - Water is polar, attracting both cations and anions.
    - Polarity makes water highly conductive.
        - TDS can impact water's conductivity.
- Water reaches maximum density at 4° C or 39.2° F.
    - Polarity causes water to form rings, which decrease density, as it freezes.
        - This is why ice floats in water.
- Organic refers to chemical compounds containing carbon.
- Inorganic refers to chemical compounds lacking carbon, or a carbon-carbon or carbon-hydrogen bond.
- pH – Potential of hydrogen – See Water Quality

Lab Equipment

Table 6 – Common Lab Equipment

Name	Use
Volumetric Flask	Accurately measures volume.
Burette	Dispensing solutions.
Pipette	Precisely measuring and transferring liquids.

Safety

Regulatory Agencies

- OSHA – Occupational Health and Safety Administration – Responsible for setting workplace safety standards. (https://www.osha.gov/)

- NIOSH – National Institute of Occupational Safety and Health regulates and approves Personal Protective Equipment (PPE) such as masks.

Confined Space

- A confined space is a space that is large enough for a person to enter and conduct work, however, has limited means for entry or exit.
- Has unfavorable natural ventilation.
- Not designed for continuous occupancy.
- Contains hazards that cause bodily injury or death.
- This can reduce the amount of breathable air in the environment, especially when working with hazardous or toxic substances.

    - Because of this, a confined space should **never** be entered unless you have the **appropriate training and permitting.**
    - **The safe range for oxygen levels in a confined space is between 19.5% and 23.5%.**
- Confined space permits require the entry supervisor to know the conditions of the confined space.
    - The entry supervisor is also responsible for terminating entries.

- A Self-contained Breathing Apparatus (SCBA) can be used in confined spaces.

    - These units are fitted with a low-air pressure alarm to alert the wearer when they need to leave the area.

Operations

- Operations describes the general running and maintenance of the plant.
- An operator is responsible for providing clean, safe drinking water to the population served.
- The primary concern if contamination is found is the health and safety of the public.
- Aside from disinfection and treatment, steps can be taken to secure your equipment and avoid contamination:
    - Gates, fences and cameras can be installed around storage tanks and buildings to deter entry.
    - Screens can be installed on vent openings, storage tanks, aerators and clear wells.
- Improper use of equipment can create problems in the distribution system.
- Shutting off a pump or closing valves too quickly can lead to water hammer.

    - Water hammer describes the oscillating pressure waves that move through a pipe when pressure in the system rapidly changes.
    - It can cause damage throughout the distribution system, leading to broken pipes, mains, or hydrants.
- Adjusting chemicals and their feed rates is the main way an operator controls the water treatment process.
- It is important to maintain chemical supplies and feeders.

Equipment

Meters

- A meter is a device used to measure the input or output of chemicals or water.

- Positive Displacement - Primarily used for lower flows (around .25 to 150 GPM); range from .5 inches to 2 inches.
    - An example would be a rotameter.
    - Used with chlorine/chemical feed.
    - Suction and discharge valves should be open when in use.
- Turbine - Primarily used for flows at or above 150 GPM
    - Sizes range from three inches to 20 inches.
- Demand meter – used to measure average power load during a specific period.

Valves

Table 7 - Valves

Valve type	Use	Notes
Gate valve	To allow or stop the flow of water.	Most common valve in the water supply system. Generates the least head loss when fully open.
Check valve	To keep water flowing in a single direction.	Not considered a backflow prevention device, can cause water hammer if closed too quickly.
Bypass valve	Used to divert water flow around a treatment device.	Used with a gate valve.
Globe valve	Used to control flow rate, or throttle, water in a pipeline.	A fully open globe valve will have higher head loss than any other valve.
Butterfly valve	Controls flow using multiple circular flaps in the middle of the device.	Low maintenance and appropriate for very large flows.
Needle valve	Controls flow rate using a tapered plunger on a spin handle.	Best for precision flow control.

Chemical Feed Equipment

Table 8 – Chemical Feed Equipment

Type	Use	Notes
Hypochlorinator	To feed liquid chlorine solution into the water supply.	Scale is most likely to form in the suction and discharge hoses.
Diffuser	Used to evenly disperse a chlorine solution into the main water flow.	
Injector	Creates a vacuum and enables a chlorinator to work.	

Vacuum regulator	Stops flow of chlorine gas in the event of a leak.	
Induction Mixer	To uniformly combine chemicals.	Can be used with gas or liquid.

SCADA

- Supervisory Control and Data Acquisition – used to control and monitor treatment process.
- Contains hardware and software components.
    - Remote terminal units (RTUs)
    - Communications
    - Master Station
- Human machine interface (HMI).

Pumps

Table 9 - Pumps

Type of Pump	Best Use	Drawbacks
Positive Displacement	Use mechanical force to repeatedly move a fixed volume of liquid through the system. Consistent flow rate. Reciprocating or rotary. Used for chemical feeds.	Pulsation can cause cavitation. Restricted flow. Can be difficult to maintain and clogs easily.

Deep Well Turbines (Vertical Centrifugal Pumps)	Best for high-capacity, deep water wells. Made to operate both in the well (bowl and turbine) and above-ground (motor) with a drive shaft connecting the two. The largest of pump types, this pump operates at high pressure and has high efficiency.	High maintenance costs.
Jet	A centrifugal pump that uses a venturi, or a restriction at the nozzle of the suction pipe, to increase effectiveness of the pump.	Low efficiency.
Submersible	Made to operate within the well casing. Multistage (multiple impellers) centrifugal pump with submersible electric motor.	This pump is small and sealed, making it difficult or impossible to do maintenance or repairs, but reduces the likelihood of losing its prime.
Centrifugal	Used to pump water from shallow wells (less than roughly 25 feet of head). and can operate against a closed valve.	Narrow optimum operating range and efficiency point. Not self-priming.

Table 10 – Pump Components

Component	Purpose	Troubleshooting
Suction pipe	Moves water from the source to the pump.	Avoid cavitation by listening for pinging noises. Keep line free of obstacles and clogs. Ensure valves are open.
Impeller	Moves the water, converting kinetic energy into pressure.	Ensure it is free from debris, primed, and turning in the correct direction. Check power supply, voltage, and frequency if it is running at the wrong speed.
Discharge pipe	Moves the water away from the pump.	Flow can be checked with a flowmeter. If flow is restricted, check the impeller.
Motor	Converts electrical energy to mechanical energy to move the pumps parts.	Check the temperature to avoid overheating. Ensure amp draw is within range of ratings on motor nameplate.
Shaft	Transfers torque from the motor to the impeller.	Check the bearings for wear. Open and close valves slowly to avoid water hammer. Ensure proper coupling and alignment.
Water screen	Made of a fine mesh material. Prevents debris from entering and damaging the pump.	Screen can get clogged and will require cleaning.

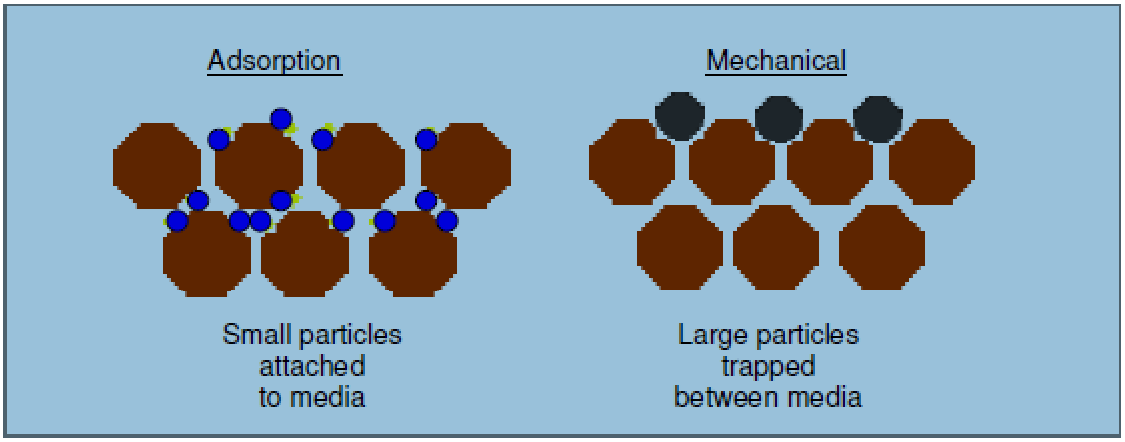
Pump Maintenance

- An operator should be able to recognize failures, troubleshoot, adjust equipment and make minor repairs.
- An operator should have a maintenance program.

- Regularly check all equipment.
  - Routine maintenance is the first level of maintenance.
- Change the oil in a new pump after the first month of operation.
- Cavitation - caused by unusually low pressure within the pump
  - Indicated by pinging sounds.
  - Avoid this by monitoring the speed of the variable-speed pump.
- Monitor the temperature to avoid overheating.
- Ensure that packing does not dry out.
  - Must be replaced when packing gland can't be tightened any further.
- Lubricate bearings on the shaft line with grease or oil – do not use animal oil.
- Overlubricating bearings may result in overheating.
- Follow the manufacturer's maintenance schedule.
- Ensure proper alignment between any shafts.
- Stagger rings of packing so that the joints are between 90 – 180 degrees apart.
- Taking equipment such as filters or pumps off-line may require additional maintenance tasks.

Filtration

Figure 11 – Adsorption vs. Mechanical Filtration



IDEM Drinking Water Branch – Operator Certification and Capacity Development Section

- Adsorption - particles suspended in the liquid **attach** to the filter media.
- Mechanical filtration - particles physically get trapped in the filter media

- Reverse osmosis is the smallest of membrane technologies with microfiltration being the largest.
    - Uses a permeable membrane for filtration.
    - The membrane is fragile but highly effective for removing arsenic.

- Filter Pore Size – Micro > Ultra > Nano > Reverse Osmosis (RO)

- Microorganism size – Virus < Bacterium < Protozoa

- Pressure filter capacity is 6-12 gpm/ft^2
- Gravity filter is 1-2 gpm/ft^2.

- Air binding - Caused by the release of dissolved gases in saturated cold water when pressure decreases in filter beds.

- Head loss - As the filter accumulates contaminants, the water level will rise due to the build-up of particles from adsorption and mechanical filtration.

    - Operating experience will determine the head loss point at which the filter should be backwashed (cleaned).

    - Iron (SMCL) - iron levels above 0.3 mg/L can cause red water.
        - High iron levels can also cause coffee to get very dark due to the reaction between iron and the tannic acid in coffee or tea.
        - Potassium Permanganate ($KMnO_4$) can be used to remove iron from water.
            - An overfeed of $KMnO_4$ will result in pink water
            - Will turn yellow once the reaction is complete

        - High iron can cause issues with ion-exchange water softening.
        - High iron can stain plumbing fixtures and clothes red.
        - Filtration when combined with oxidation is the most effective option for removing iron from groundwater.

Filter Maintenance

- Filters will become clogged with media after periods of use
- Backwash cycles clean mechanical filters to extend their lifespan.

    - Backwashing reverses the flow through filter to remove entrapped material.
    - Backwash rates should be ramped up slowly to avoid damage to the filter.
        - The goal is to remove impurities without losing filter media.

  - Pressure filters should be backwashed when head loss equals 8 psi, when turbidities rise, or at least once a week.
- Gravel on the surface of a sand filter can indicate a “blown” or upset filter.

- Mudballs - Clumps of filter media and other material.

  - Caused by an insufficient frequency of backwashing.

- Schmutzdecke - A mixture of fine sand and a sticky mat of suspended matter that forms on the surface of a sand filter.

- Manganese greensand - Optimum operating quality can be achieved by maintaining the greensand to ensure effluent stays at or below 0.05 mg/L.

  - After backwashing and stratifying, ensure 8-9% of the greensand is skimmed off.

- To increase the length of a filter run, add a layer of anthracite.

Backflow/Cross Connection

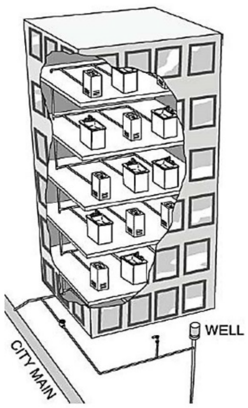
- Cross Connection Control (CCC) or Backflow Prevention - mechanism that prevents contaminated water from flowing backwards in a water system.

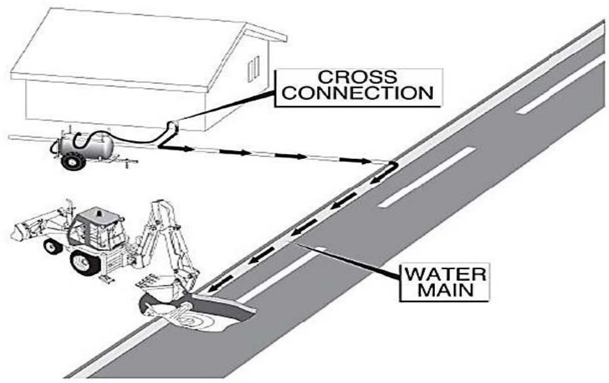
- Cross Connection – location in a system where a public water supply is directly or indirectly connected with another water supply system of unknow quality.
  - Creates potential for contamination.

- Backflow – condition where water from an outside system infiltrates the public water supply.
  - Back pressure - Resistant pressure exerted against the forward flow.
    - Think of this like blowing into liquid through a straw.

- Back siphonage - Backflow due to reduced pressure within a water system.
  - Think of this like sucking liquid through a straw.

Figure 12– Examples of Back pressure and back siphonage





EPA - How to Conduct a Sanitary Survey of Drinking Water Systems

Backflow prevention mechanisms:

Table 11 – Backflow Prevention

Mechanism	How it Works	Best Uses	Drawbacks
Air Gap	Creates vertical distance between the pipe or faucet and the rim of the receptacle.	Most common backflow prevention mechanism. A minimum 1-inch gap, or twice the diameter of the pipe is required.	Easy to bypass. Not reliable if the gap is too small.
Atmospheric Vacuum Breaker (AVB)	Contains an air inlet valve, check seat and air inlet port. When normal flow stops, the air inlet valve falls to block for back siphonage.	Simple, inexpensive way to prevent back siphonage.	Only protects against back siphonage. Not designed for continuous pressure for more than 12 hours. Cannot be tested.

Pressure Vacuum Breaker (PVB)	Contains an internally loaded check valve and internally loaded air inlet valve, which work independently with the air inlet valve downstream of the check valve.	Can be tested. Protects against back siphonage.	Will not protect against back pressure.
Double-Check Valve (DCV)	Two independent check valves located between two tightly closing shut-off valves that close in response to back pressure or back siphonage.	Low hazard cross-connection applications and internal protection in water management systems.	Not suitable for high hazard protection or chemigation.
Reduced Pressure Principle (RP)	A combination of independently working differential pressure valves, seat-check valves and shut-off valves that open and close based on pressure on the intake and effluent sides of the valves.	Appropriate for critical or hazardous environments.	Not recommended in confined spaces or pits.
Hose Bibb Vacuum Breaker	Designed to be mounted on a faucet to prevent back siphonage.	Suitable for indoor and outdoor faucets.	Can be subject to back pressure by having the hose outlet higher than the faucet.

Maintenance

The maintenance is different for each part of the treatment system.

Well Maintenance

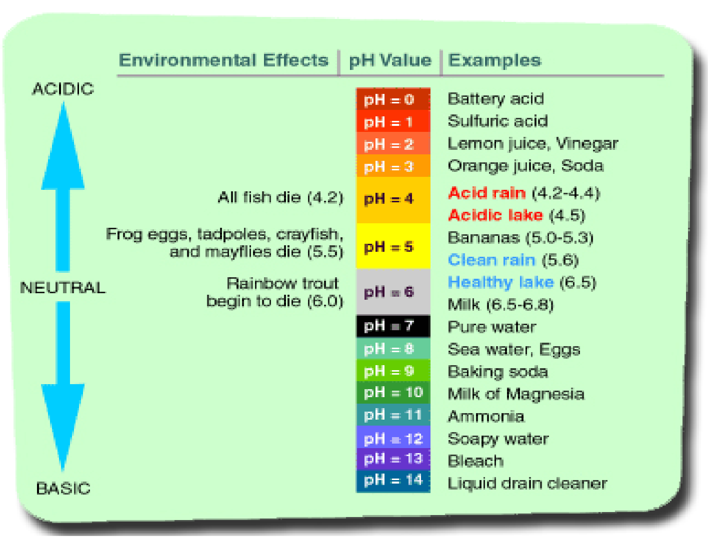
Pump Maintenance

Filter Maintenance

Water Quality

- Although many areas impact water quality, the most common are detailed below.
- pH – Potential of hydrogen – measures the concentration of hydrogen ions

Figure 13 – pH Scale



USGS -usgs.gov

- Corrosivity – Acidic, with potential to damage or destroy pipes, causing materials to leach into drinking water.

- Alkalinity – Basic, measures ability to neutralize acids.

- Dissolved gases – Radon, methane, hydrogen sulfide and carbon dioxide may be harmful to human health or indicate contamination.
- Total dissolved solids (TDS) – may impact odor, taste or chemical consumption.
    - High organic content/turbidity can impact pH, as well as taste and odor.
- Temperature – affects TDS, dissolved gases, and chemical consumption.
- High concentrations of iron or manganese may cause staining of clothing and plumbing fixtures.
- Activated Carbon is used to remove objectionable tastes and odors.
- Calcium and magnesium are responsible for hard water.

Disinfection & Treatment

Treatment Goals

- To provide clean, safe drinking water, without bad colors, odors or tastes.
- To remove or inactivate pathogens (protozoans, bacteria, viruses).
- To reduce natural and man-made chemical contamination to levels that meet regulatory guidelines and protect human health.
- To produce chemically stable water that will not corrode metal pipes and fixtures.

- **The following tables contain information on many common contaminants found in source water. A complete list of regulated contaminants can be found at** https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

Table 12 – Associated health hazards and removal techniques for regulated contaminants

Contaminant	Removal Techniques	Health Hazards
Giardia and Cryptosporidium	Reverse osmosis, absolute one-micron filters, UV Light, and filters certified for cyst removal	Acute Gastrointestinal problems, such as vomiting and diarrhea
Bacteria and Viruses	Chemical treatment, Reverse osmosis, UV light	Dependent on bacterium or virus
Arsenic	Adsorption	Skin damage, circulatory system problems, increased cancer risk
Disinfection byproducts	Point-of-entry adsorptive media systems, aeration, carbon filtration, and reverse osmosis	Increased cancer risk.
Lead	Reverse osmosis, and some carbon filters	Impaired mental and physical development in children.
Copper	Reverse osmosis or ion exchange	Short term - Gastrointestinal distress Long term – Liver and kidney damage. People with Wilson's disease are especially susceptible.
Nitrates	Reverse osmosis or ion exchange	Methemoglobinemia, a.k.a. blue baby syndrome.
Pesticides	Some carbon filters	Increased cancer risk.
Radium	Ion exchange or reverse osmosis	Increased cancer risk.
Radon	Granular Activated Carbon and aeration	Increased cancer risk.

Disinfection

- Disinfection is the process that inactivates pathogenic organisms.
    - Accomplishes this process by using chemical oxidants.
    - Systems that use chemical disinfection can reduce wellhead protection zone from 200 ft. to 100 ft.

Chlorine

- Used to kill bacteria and viruses.
- Measured as free chlorine or total chlorine.
- Free chlorine is the concentration of residual chlorine present as a dissolved gas.
- (DPD) Color comparator is the simplest way to measure free chlorine residuals.
- Breakpoint chlorination is reached when dosage is increased and a corresponding increase in the chlorine residual happens.
- Contact time is required – CT value = (Free Chlorine)(Contact time).
- Ineffective against Cryptosporidium and Giardia.
- Used to precipitate dissolved iron, manganese and sulfur.
- Comes in gas (Cl_2), solid (calcium hypochlorite) and liquid (sodium hypochlorite) forms
- Cl_2 gas is fed through a vacuum hose that connects the tank to an injector.
    - Dissolves in water to form hypochlorous acid (HClO or HOCl).
    - High and low vacuum conditions on the chlorinator indicate a problem with supply or the injector.
    - Cylinders are either 150lb or 1-ton.
    - A full 1-ton cylinder weighs 3,700lbs and will need transportation and lifts rated for that weight.
    - A 150 lb. cylinder has a max feed of 40-42 lbs./day.
    - A 1-ton cylinder has a max feed of 400 lbs./day.
    - The fusible plug on a 1-ton cylinder will melt at 160° F.

- Calcium Hypochlorite [$Ca(ClO)_2$] combined with water in a flash mixer to form a solution, then fed through an injector.
- Sodium Hypochlorite (NaOCl) is fed directly into the water being treated in its liquid form.
- Gas is the strongest disinfectant, followed by solid, then liquid.
    - Gas is the slowest to degrade and liquid is the fastest to degrade.
    - Chlorine gas is 2.5 times heavier than air.
    - Expansion ratio of liquid chlorine to gas is about 460:1
    - Gas requires more safety measures than liquid or solid.
    - Chlorine can generate harmful byproducts, THMs and HAAs.

- Clear wells - Water storage structures typically located at the end of a treatment train or well system.
    - Used for contact time when chemicals are added.

Safety Regulations for Cl

- **EPA**: A system with 2,500 pounds of chlorine for a single process must complete a risk management plan (RMP).

- **OSHA**: A system with 1500 pounds of chlorine for a single process must complete a site assessment under the process safety management (PSM) regulations.
    - The NIOSH concentration of Chlorine immediately dangerous to life and health (IDHL) is 10 ppm.
    - The OSHA permissible exposure limit (PEL) is 1 ppm.

Ozone

- Colorless, unstable gas made of three oxygen atoms (O_3)
- Effective in eliminating bacteria and viruses, iron, manganese, and hydrogen sulfide gas.
- Will deactivate Cryptosporidium and Giardia.
- Usually generated by passing dry air through a high voltage electric discharge, or UV generator.
- High equipment and operating costs.
- Does not leave a residual
- Requires special mixing techniques.
- Potential fire hazards and toxicity issues.

Aeration

- Aeration oxidizes water to remove gases and other elements in treatment.
- Oxygen precipitates metals like iron and manganese for removal.
- The exchange of gases from air to water for oxidation is called stripping.
  - This oxidation will precipitate metals like iron and manganese.
  - This process reduces or removes hydrogen sulfide, radon, CO_2, and VOCs from water.

- Diffused aeration – introduces air bubbles into the water in a contact chamber.
- Spray aeration – water sprayed through nozzles on a pipe grid, which breaks it into smaller drops.
- Multiple-tray aerators – Water trickles through a series of trays with slots or a wire mesh bottom.
  - Coarse media such coke, ceramic balls, or stone are placed at the bottom to increase surface area.
  - Air is supplied at the bottom of the enclosure and travels upward, counter to the flow of water.

- Cascade aerators – Water is allowed to flow downward over a series of steps, causing the water to fall in thin layers from one level to another.
- Packed tower aeration (Air Stripping) – Cylindrical tower is filled with randomly dumped packing material to provide more surface area for contact between water and air.
    - Henry's law – $C = kP$ – the amount of a dissolved gas is directly proportional to its partial pressure about the liquid.

Disinfection Byproducts (DBPs)

- Organic material in water reacts with chlorine compounds used for disinfection.
- Increase cancer risk and may cause nervous system and organ damage.
- Prevented by delaying chlorine application or using alternative disinfection techniques like ozone and UV treatment.
- Removed using Granular Activated Carbon (GAC), nanofiltration, or reverse osmosis.

Table 13 – Disinfection Byproducts and MCLs

DBP Type	**MCL**	**Types**
Haloacetic Acids (HAAs or HAA5)	0.06 mg/L	Monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, dibromoacetic acid.
Total Trihalomethanes (TTHM)	0.08 mg/L	Chloroform, bromodichloromethane, dibromochloromethane, bromoform.
Chlorite (ClO_2)	0.8 mg/L	N/A
Bromate (BrO)	0.01 mg/L	N/A

Volatile Organic Compounds (VOCs)

- Carbon based chemicals, often used in manufacturing.
- Can occur naturally.
- Increase risk of cancer and may cause organ and reproductive damage.
- Removed using Granular Activated Carbon (GAC), aeration, or RO.

Table 14 – Volatile Organic Compound Examples

VOC Type	MCL	Source
Benzene	0.005 mg/L	Gasoline, fuel and storage, Petrochemical drilling, processing and production, Landfill seepage
Toluene	1 mg/L	Gasoline additive; manufacturing and solvent operations, adhesives, glues
Carbon Tetrachloride	0.005 mg/L	Solvents and their degradation products, chemical plants, and industrial solvents / additives
Xylenes	10 mg/L	By-product of gasoline refining; paints, inks, detergents

Synthetic Organic Compounds (SOCs)

- Man-made organic chemicals.
- Used as pesticides, herbicides, and fuel additives.
- Removed using Granular Activated Carbon (GAC), aeration, or RO.

Table 15 – Synthetic Organic Compound Examples

SOC Type	MCL	Source
Glyphosate	0.7 mg/L	Runoff from herbicide use.
Alachlor	0.002 mg/L	Runoff from herbicide used on row crops.
Ethylene dibromide (EDB)	0.00005 mg/L	Discharge from petroleum refineries.
Polychlorinated biphenyls (PCBs)	0.0005 mg/L	Runoff from landfills; discharge of waste chemicals.

Inorganic Chemicals (IOCs)

- Made of two or more elements.
- Do not usually contain carbon.
- If carbon is present, lacks carbon-to-carbon or carbon-to-hydrogen bonds.
- Removed using adsorption/absorption, GAC, filtration and ion exchange.

Table 16 – Inorganic Chemical Examples

IOC Type	MCL	Source
Arsenic	0.01 mg/L	Erosion of natural deposits.
Chromium	0.1 mg/L	Natural deposits, mining, electroplating, pigments.
Cyanide	0.2 mg/L	Electroplating waste, steel, plastic and fertilizer production, mining.
Mercury	0.002 mg/L	Natural deposits, industrial waste, landfill seepage.
Asbestos	7 million fibers per liter. (MFL)	Old pipes, naturally occurring, landfill seepage.

Nitrates

- Forms of Nitrogen found in water, including Ammonia (NH_3), Nitrates (NO_3) and Nitrites (NO_2).

- Caused by runoff from fertilizer use, leaking septic tanks, sewage, and erosion of natural deposits.

- Methemoglobinemia “blue baby syndrome” - Caused by nitrite (when nitrate reacts with chlorine it creates nitrite).

- MCL for Nitrate is 10 mg/L.
- MCL for Nitrite is 1 mg/L.
- Treatment methods included ion exchange, reverse osmosis, and electrodialysis.

Fluoride

- Occurs naturally in Groundwater.
- Fluoride is often added during treatment to improve dental health of consumers.
- Optimal fluoridation set by DHHS is 0.7 mg/L.
- Chemicals used in fluoridation include: hydrofluosilicic acid (HFS), sodium fluoride, and sodium fluorosilicate.
- MCL is 4 mg/L.
- MCLG is 2 mg/L
- Health impacts from excessive fluoride include brown stains on teeth and bones.

Corrosion Control

- Corrosion is the destruction or damage of materials, especially metals, slowly through chemical action.
- Steps must be taken at the treatment to inhibit corrosion in the system.
- Corrosion can cause harmful metals like lead and copper to contaminate drinking water.

- Galvanic corrosion – dissimilar metals generate a current, which leads to a faster corrosion rate.
  - The further apart the metals are on the galvanic series, the faster the corrosion rate.
- Corrosion is controlled using several methods.
  - pH Adjustment
  - The pH of groundwater is usually between 6.0 to 8.5.
    - pH lower than 7 will cause corrosion in pipes.
    - A pH over 7 tends to deposit scale.
    - Raising the pH promotes precipitation of Calcium Carbonate (scale), which can offer protection against corrosion.
    - Potassium Permanganate used to soften water can lower the pH and cause corrosion.

- Cathodic Protection – sacrificial anodes, impressed current, or dissimilar metals are used to inhibit corrosion.

Softening

- Sawyer & Briggs, or Ficke classifications consider water with a calcium carbonate ($CaCO_3$) measure at or above 300mg/L very hard.

- Softening water is most effective for the removal of nitrite, iron, and arsenic.

- Overly soft water causes soap scum.

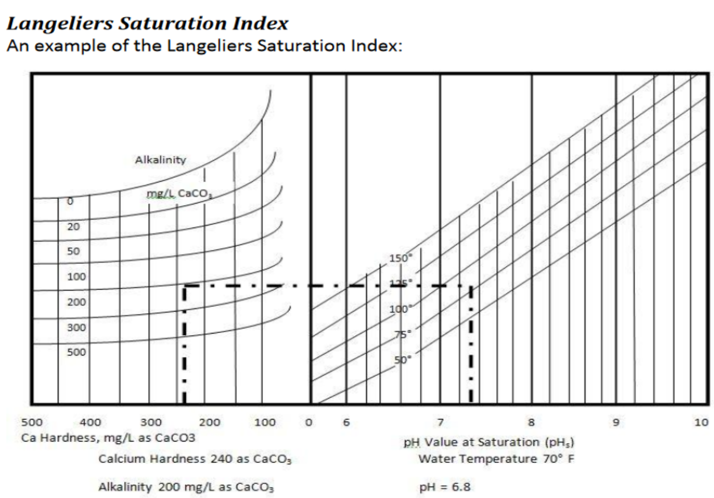
- Hard water consumes soap.
- Hardness is usually measured in milligrams per liter (mg/l) as $CaCO_3$ or grains per gallon (GPG).

Table 17 – Hardness measured on mg/L of Calcium Carbonate

Hardness Range	Classification
0 – 60 mg/L	Soft - Corrosive
61-120 mg/L	Moderately Hard
121 – 180 mg/L	Hard
181 +	Very Hard

- (1 GPG = 17.1 mg/l)
- Langeliers Saturation Index (LSI) calculates the calcium carbonate stability of water.
- LSI pH = pHA (actual) –pHS (saturation)
  - Negative numbers indicate the water is corrosive
  - Positive numbers indicate scale forming potential.
  - When the LSI/ LI is 0, water is said to be in equilibrium.

Figure 13 – Langeliers Saturation Index



AWWA Principles and Practices of Water Supply Operations: Basic Science Concepts and Applications

- Carbonate hardness or temporary hardness is from heating water, causing precipitation (dropping out of solution) of carbonate hardness.
    - Can be reduced with lime soda softening by adding slaked lime, $Ca(OH)_2$, to precipitate the hardness.
    - Precipitate is then filtered out.

- Potassium Permanganate is used to precipitate iron and manganese.

- Non-carbonate hardness is permanent and comes from sulfates and chlorides of calcium and magnesium in water.
    - Can be reduced by adding soda ash (Na_2CO_3) after lime soda softening.
    - A water treatment plant softening their water should analyze hardness daily.
    - Calcium and Magnesium are two minerals generally found to contribute to hardness.

Ion Exchange

- Exchanges the ions of sodium salts (NaCl) for calcium carbonate ($CaCO_3$)
- Sodium Chloride is used in zeolite softening.
    - High iron content hinders zeolite softening.
- Removes the hardness from the water and replaces it with salt.
- Uses a resin bed.
- Once the resin in the bed is spent it is "exhausted".
- Iron and manganese precipitate will foul cation exchange resin.

- To recharge the resin bed and extend its life, pass brine through the bed.
    - For individuals/areas on salt- or sodium-restricted diets, potassium chloride (KCl) can be used instead of sodium chloride.
    - Ion exchange should not be used when the concentration of iron (Fe), manganese (Mn) or the combination of the two exceeds 0.3 mg/l.
    - Ion exchange should not be used on raw or wash waters containing (high) dissolved oxygen (DO). Though water softeners will remove some soluble iron and manganese.

Calculations/Math Short and Long

- Calculations require proficiency in the following areas:
    - Calculating volume of pipes and tanks.
    - Calculating flow rate.
    - Calculating chemical dosage.
    - Converting units of measurement.
    - Calculating specific capacity.
    - Calculating drawdown.
    - Calculating chlorine residuals.
    - Calculating flow rate when pipes narrow or expand.
    - Calculating water pressure.
    - Calculating horsepower and water horsepower.

- A formula sheet will be provided for the exam. You can access it here: https://www.in.gov/idem/cleanwater/files/dw_ops_formula_conversion_tables.pdf

Acronyms

AVB	Atmospheric Vacuum Breaker
CCC	Cross Connection Control
DBP	Disinfection Byproducts
DC	Double Check Valve
DHHS	Department of Health and Human Services
DO	Dissolved Oxygen
EDB	Ethylene Dibromide
EPA, USEPA	Environmental Protection Agency
ft.	Feet
GAC	Granular Activated Carbon
GPG	Grains Per Gallon
GPM	Gallons per Minute
GWUDI	Groundwater under the direct influence of surface water
HAAs or HAA5	Haloacetic Acids
IAC	Indiana Administrative Code
IDEM	Indiana Department of Environmental Management
LCR	Lead and Copper Rule
LSI	Langeliers Saturation Index
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MFL	Million Fibers per Liter
MRO	Monthly Report of Operations
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Health and Safety Administration
OWQ	Office of Water Quality
pH	Potential of Hydrogen
PPE	Personal Protective Equipment
PSM	Process Safety Management
PVB	Pressure Vacuum Breaker
RMP	Risk Management Plan
RO	Reverse Osmosis
RP	Reduced Pressure
RTCR	Revised Total Coliform Rule
SCBA	Self-contained Breathing Apparatus
SDWA	Safe Drinking Water Act
SOC	Synthetic Organic Compounds
TDS	Total Dissolved Solids
THM	Trihalomethanes
UV	Ultraviolet
VOC	Volatile Organic Compounds

Glossary

Absorption	The process of one material being retained by another.
Adsorption	Adhesion of a substance to surface particles.
Aerobic	To metabolize using oxygen.
Anaerobic	To metabolize without using oxygen.
Anion	Negatively charged ion.
Aquifer	Saturated underground formation that will yield usable amounts of water to a well or spring.
Back pressure	Resistant pressure exerted against the forward flow.
Back siphonage	Backflow due to reduced pressure within a water system.
Backflow	Unwanted flow of water in the reverse direction.
Backwash	To clean a filter by reversing the flow of liquid though it.
Bacterium	Single celled organism that has a cell wall, but no organization within the cell or nucleus, some of which can cause disease.
Cation	Positively charged ion
Chemical	Substance used in, produced by, or concerned with chemistry.
Coliform	Bacteria always present in the digestive tracts of mammals and found in their waste.
Community Water System	Serves the same population year-round.
Condensation	The process of water vapor in the air turning into liquid water.
Confined aquifer	Formation between low permeability layers that restrict movement of water vertically into or out of the saturated formation.
Conservation	To prevent wasteful use of a resource.
Contaminant	Chemical or compound that does not belong in food or water, causing a negative impact on human health. SDWA defines a contaminant as any physical, chemical, biological or radiological substance or matter in water.
Cross connection	Any actual or potential connection between a drinking water system and a potential source of contamination.
Drawdown	The lowering of the groundwater surface caused by withdrawal or pumping of water from a well.
Evaporation	The conversion of water from a liquid into a gas.
Evapotranspiration	Water moving from the earth into the atmosphere by evaporation from soil and transpiration from plants.
Filtration	Removing solid particles from water by using a filter that allows liquid to pass while retaining the solid particles.
Gravity	Force that attracts and object toward the center of the earth.
Groundwater	Water that exists underground in saturated zones.
Head	Body of water kept at a certain height to supply necessary pressure, or the pressure exerted by a body of water kept at a certain height.
Ion Exchange	The exchange of ions of the same charge between an insoluble solid and a solution in contact with it.
Mechanical filtration	Suspended particles are physically trapped in the filter medium.

Meter	Device that measures the quantity or rate of something.
Non-transient non-community	Serves the same population for at least 6 months, but not the entire year.
Operator	Person who operates the facility.
Percolation	The slow seepage of water into and through the ground or the slow passage of water through a filter medium.
Pore	Small opening in a surface.
Precipitation	Water that falls to the earth.
Pressure	Continuous physical force used on or against an object.
Primacy	Preeminence, or ranking first in importance.
Protozoan	Microscopic single celled, motile organism that has organization within the cell wall and nucleus, which may cause illness in humans.
Responsibility	State of being accountable for something.
Reverse Osmosis	Separation technique where pressure is applied to a solution to force the solvent through a semi-permeable membrane.
Sanitary Seal	A seal around the wellhead that prevents contamination of the well.
Semipermeable	Allows some substances to pass through but not others.
Soluble	Able to be dissolved, especially in water.
Specific Capacity	A formula for determining if a well can adequately meet the demand of a proposed population or use.
Sublimation	The process where ice and snow (solid) change into water vapor (gas) skipping the liquid phase.
Transient non-community	Provides water to 25 or more people for at least 60 days/year, but not the same people on a regular basis.
Transpiration	The process of liquid water evaporating from plants and trees into the environment.
Turbidity	Cloudy, opaque or thick with suspended matter
Unconfined aquifer	The saturated formation in which the upper surface fluctuates with addition or subtraction of water.
Violation	Infraction, or rule breaking.
Virus	Submicroscopic infectious agent that replicates inside the cells of living organisms.
Water Table	The upper surface of an unconfined aquifer.
Well	A shaft sunk into the ground to obtain water, oil, or gas.
Wellhead	Above ground part of the well structure which controls pressure and connects to the production equipment below ground.