Drinking Water Plant
Operator Certification Training

WDC Volume I

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The Pennsylvania State Association of Township Supervisors (PSATS)
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Dering Consulting Group

Topical Outline

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I. EPA and DEP relationship

II. Operator Certification Act 11 and Chapter 302 Regulations
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   - C. Certified Operator and Owner Responsibilities

Unit 2 – Groundwater Source Development and Construction

I. Identify the considerations in new source development
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   - D. Testing

II. Identify well construction standards
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III. Describe well pumps, piping and appurtenances
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C. Determining number of days of supply based on customer demand (gal/hr)

D. Diluting a % strength solution for a day tank

E. Determining chlorine feed rate in gallons per day

F. Refilling a day tank based on a daily feed pump rate

Unit 4 – PA Act and Regulations

I. Identify key regulations.

II. Identify the maximum contaminant levels and monitoring and reporting requirements for selected regulated contaminants.

III. Identify one-hour reporting and public notification requirements.

Unit 1 – Federal and State Regulations

Learning Objectives

- State the roles of federal and state agencies regarding drinking water.
- Explain the requirements to becoming and maintaining operator certification

EPA is mandated by Congress through the Safe Drinking Water Act to establish drinking water regulations and periodically review these regulations to update them.

United States Environmental Protection Agency

EPA studies health issues related to water quality and develops regulations, standards, and guidance documents related to drinking water. The EPA legislates specific minimum requirements that the states must meet, though the states are generally permitted to enact more stringent requirements.

Pennsylvania Department of Environmental Protection

The Pennsylvania Department of Environmental Protection (Pa. DEP) has **primacy** , i.e., responsibility for enforcement of EPA drinking water regulations. Pa. DEP obtains primacy by meeting the minimum requirements mandated by EPA.

Operator Certification Act and Chapter 302 Regulations

The purpose of the operator certification (ACT 11) is to protect public health, safety and the environment. The act ensures that certified operators have appropriate skills, knowledge and abilities to make appropriate process control decisions during the operation of water systems and water distribution systems. To achieve this, the State Board of Certification of Water and Wastewater Systems Operators and the Pa. DEP set the training, experience and examination standards for operator certification. This was done in ACT 11 and in the Chapter 302 regulations. Chapter 302 Operators' Certification Program Regulations requires certified water operators to comply with all state and federal laws, rules and regulations.

ACT 11 and Chapter 302 Regulations

Every water system regulated under ACT 11 must have an **appropriately certified operator** and an appropriately certified operator must make all process control decisions of system operation.

What is an appropriately certified operator?
What is a process control decision?

An **appropriately certified operator** is an operator who holds a certificate of the same or higher class and with all the subclasses of the system at which they work or want to work.

A **process control decision** is any decision that changes or maintains water quantity or water quality of a water or wastewater system in a manner that may affect public health or the environment.

Act 11 does not require all operators that work at a water system to be certified; however only appropriately certified operators can make process control decisions. Uncertified and not appropriately certified operators can only make process control decisions when:

- Under direction of an appropriately certified operator or,
- Using Standard Operating Procedures (SOP) that were developed by an appropriately certified operator.

Additionally, an appropriately certified operator must be **available at all times** during system operations.

Available means that an appropriately certified operator is **on site or available to be contacted as needed** to make process control decisions for the system in a timely manner.

The requirements to becoming an appropriately certified operator include:

- **Education Requirement**
  - The applicant must be at least a high school graduate, possess a GED or have been an operator before February 21, 2002.
- **Examination**
- **Criminal History Check**
  - Completed not more than 90 days before the date the operator signs the application
- **Experience Requirement**
- Final **official approval by the Board** and awarded a certificate of a class and subclass(es) commensurate with your experience. Final approval will be granted after a thorough review of the applicant's information.

Certification Requirements

Experience Requirements

Classification	High School Diploma	CP	ASP	AS	BS/BA
A	4 years	2 years	1 year	3.5 years	2 years
B	3 years	1 year	6 months	2.5 years	1 year
C	2 years	6 Months	6 Months	1.5 year	6 Months
D	1 year	6 Months	6 Months	6 Months	6 Months
E	1 Year	6 Months	6 Months	6 Months	6 Months
Dn	6 Months	0	0	6 Months	0
Dc	6 months	0	0	6 Months	0

CP: A certificate program of a DEP-approved Certification Program in Water Treatment

ASP: An Associate Degree in a Water Treatment Program approved by DEP

AS: Associate Degree in environmental or physical sciences, engineering or engineering technology NOT approved by DEP

BS/BA: A bachelor's or graduate degree in Biology, Chemistry, Environmental Sciences, Physical Sciences, Sanitary or Environmental Engineering or Engineering Technology from a nationally-accredited college or university

Education/Experience Substitution (for High School Diploma ONLY)

Education/Experience	Total Experience Allowed
Successful completion of every 10 hours of post high school or post GED water or wastewater related training (as applicable) approved by DEP and determined by the State Board for Certification of Water and Wastewater Systems Operators (Board) to be applicable to the certification sought.	1 month experience per 10 hours of training.
Successful completion of a college course approved by DEP as being specifically applicable to the water or wastewater disciplines (Each semester college credit is equivalent to 15 hours.)	1.5 months experience for each semester college credit.

Experience can be demonstrated by participating in any of the following activities under the supervision of a certified operator or a certified operator of a higher classification than requested:

(1) Operation of mechanical equipment,

(2) Maintenance of mechanical equipment,

(3) Collection of samples,

(4) Analysis of chemical and biological samples,

(5) Performing calculations related to process control,

(6) Preparing or standardizing chemical and biological solutions,

(7) Compiling and completing monitoring data, determining appropriate process control measures

Examination Requirements

Types of Exams

Certification examinations measure the knowledge, skills and abilities necessary to successfully operate specific system sizes and technologies associated with the classification and subclassification of the water or wastewater system.

Examination for certification consists of a two (2)-part examination.

(i) **General Exam:** Measures the applicant's general knowledge, skills and abilities common to all water or wastewater systems regardless of size.

(ii) **Subclassification Exams:** Measures the applicant's specific knowledge, skills and abilities necessary to operate treatment technologies or system components related to the water and wastewater **subclassifications**.

Dc and Dn Classifications:

Separate and single water system examinations are prepared for both Class Dc and Class Dn water treatment plants.

Class E Distribution:

A separate and single examination for Class E water distribution systems and consecutive systems without treatment will be prepared for operator certification as well as a separate and single examination for wastewater collection systems.

Examination and experience requirements must be met before the Board can issue a certificate. On the next page are three tables that illustrate the water system classes, subclasses and requirements for the Dc and Dn certificates.

These three illustrations below identify the Water system classes and subclasses.

Water System Classes

A >5 MGD

B >1 MGD but ≤ 5 MGD

C >0.1 MGD but ≤ 1 MGD

D ≤ 0.1 MGD

E Distribution systems and consecutive water systems without treatment

Water System Subclasses

1. Conventional filtration
2. Direct filtration
3. Diatomaceous earth filtration
4. Slow sand filtration
5. Cartridge or bag filtration
6. Membrane filtration
7. Corrosion control and sequestering
8. Chemical addition
9. Inorganic removal
10. Organic removal
11. Gaseous chlorine disinfection
12. Non-gaseous chemical disinfection
13. Ultraviolet disinfection
14. Ozone disinfection

Small Water Systems

Dc systems

1. system serves less than 500 individuals or has no more than 150 connections, whichever is less;
2. the source of water for the system is exclusively groundwater,
3. requires only disinfection, and
4. meets other applicable requirements provided by the Act and is not in violation of the Act or other PADEP rules and regulations.

Dn system

Same criteria as Dc system except for condition #3. A Dn system is one where the water requires no treatment.

- **If you have treatment you cannot be classified as an E or Dn.**
- **If you have treatment other than disinfection you cannot be classified as a Dc.**
- **In order to have an appropriate license an operator must certified in both the class and sub-classes of the treatment plant they are operating.**
- **The advantage of being classified as either Dn or Dc is that the testing process is simplified. Both the Dn and Dc classes have stand-alone tests, and no sub-classification tests are required.**

Unit 1 Part 1 Exercise 1

Answer the next three questions.

1. What certificate is needed to become a water distribution operator?

How much experience would be needed for a person with only a high school diploma before the board would grant a certificate to make process control decisions at this plant?

2. What certificates would be needed to run a 50,000 gallon per day groundwater system that uses corrosion control and sodium hypochlorite disinfection?

How much experience would be needed for a person with a high school diploma before the board would grant a certificate to make process control decisions at this plant?

3. What certificate would be needed to run a groundwater system with 100 connections and 450 customers that uses sodium hypochlorite disinfection?

How much experience would be needed for a person with only a high school diploma before the board would grant a certificate to make process control decisions at this plant?

Note that the education must be approved by DEP.

Continuing Education Requirement

Certified operators are required to obtain continuing education depending on the operator class. The continuing education requirements are different for each operator class. Continuing education must be earned in their 3-year renewal cycle and the education must be approved by DEP.

Operator Class	Contact Hours First 3-Yr Cycle	Contact Hours Subsequent 3-Yr Cycles
A	15	30
B	15	30
C	15	30
D	8	15
E (Distribution)	8	15
Dc	4	9
Dn	3	6
Grandparented	8	15

Certified Operator and Owner Responsibility

Certificate holders are required to make sound judgment and must consider the health and welfare of their customers, community and the environment. If it is found that an operator has been negligent, committed fraud, falsified an application, falsified operating records, or failed to use reasonable care or judgment in performance of duties, the board may revoke suspend or modify a certificate.

Another important part of this responsibility is liability, with the new certification requirements liability of owners and operators comes to the forefront. Always use your best judgment or your system might find itself hit with a lawsuit.

Certified Operators must

- Meet all the requirements for recertification.
- Report to the system owner any know violation or system condition that may be or are causing violations of any department regulation or permit condition
- Report to the system owner any action to permit or eliminate a violation of applicable water system laws.
- Provide for the suitable O&M of a water system utilizing available resources to comply with all laws.
- Make or implement process control decisions, or direct actions related to process control decisions for specific water systems.

Owners must:

- Employ, identify and report to the department the names of available operators required by DEP.
- Require, supervise and direct certified operators to take such action so that the water system is in compliance with all laws.
- Provide a copy of permit conditions to the certified operator in responsible charge.

Owners, operators, non-certified operators and maintenance staff can be prosecuted for failing to comply with the **Drinking Water and Wastewater Systems Operators Certification Act.**

Unit 1 Part Exercise 2

Complete the following sentences by filling in the blanks.

1. Class B operators must obtain ____ hours of continuing education during their first renewal cycle and _______ hours during all subsequent renewal cycles.

2. Owners, _____________, non-certified operators and maintenance staff can be prosecuted for failing to comply with the Drinking Water and Wastewater Systems Operator Certification Act.

3. A _________________________ is a decision, which maintains or changes the quality or quantity of water or wastewater in a water system that may affect the public health or environment.

4. An ______________________ is defined as an operator having a certificate containing the class and subclass(es) matching the class and subclass(es) of the system that they operate.

5. If an owner directs a non-certified operator to make a process control decision, who may be in violation of the Operator's Certification Act?

   a) Owner
   b) Non-certified operator
   c) Both a and b
   d) Neither owner nor non-certified operator

Unit 1 Key Points

The Operator Certification Act ensures that certified operators have appropriate skills, knowledge and abilities to make appropriate process control decisions during the operation of water systems and water distribution systems.

- An **appropriately certified operator** is an operator who holds a certificate of the same or high class and with all the subclasses of the system at which they work or want to work.
- A **process control decision** is any decision that changes or maintains water quantity of water quality of a water or wastewater system in a manner that may affect public health or the environment.
- The Certification Board may revoke, suspend or modify a certified operator's certificate if that operator has been negligent, committed fraud, falsified an application, falsified operating records, or failed to use reasonable care or judgment in performing job duties.

Uncertified and not appropriately certified operators can only make process control decisions when:

- Under direction of an appropriately certified operator or,
- Using Standard Operating Procedures (SOP) that were developed by an appropriately certified operator.

Owners, operators, non-certified operators and maintenance staff can be prosecuted for failing to comply with the Drinking Water and Wastewater Systems Operators Certification Act 11 and Chapter 302 regulations.

Unit 2 – Source Development and Construction

Learning Objectives

- Identify the considerations in new source development
- Define safe yield and explain why it is important to groundwater supply sources.
- Explain the basic components of well construction and the importance of proper installation of the well casing.
- Define and explain wellhead protection

Prior to the development and construction of a water supply source there are many factors that need to be taken into consideration.

Water Supply Alternatives

When developing water supply sources, there are three alternatives.

1. Connect to an existing system.
2. Develop surface water resources.
3. Develop groundwater resources.

Facility Location

Considerations

No matter which of the three supply alternatives is used, the following considerations must be made.

- ☑ Anticipated adequacy and reliability of sources.
- ☑ Expected water quality.
- ☑ Monitoring and health requirements.
- ☑ Operation and maintenance costs.
- ☑ Cost of source development.

Sanitary Survey

The purpose of the Sanitary Survey is to discover, investigate, and evaluate conditions that may adversely affect the quantity or quality of the supply source.

Considerations

- ☑ Local geology, topography and size of recharge area, ground slope, and groundwater table.
- ☑ Local sources of pollution (landfills, sink holes, sewage systems, industrial discharges, etc.).
- ☑ Drainage area, population density, land use.
- ☑ Proximity to flood plains or impoundments.
- ☑ Proximity to other wells.

Wellhead Protection Area

Considerations

- ☑ Protect source by ownership, easements, deed restrictions, and zoning.
- ☑ 100 foot radius of source, minimum.

Wellhead protection is an important program in Pennsylvania. Under the program, water systems apply proper management techniques and various preventive measures to protect their ground water supplies. The underlying principle of the whole program is that it is much less expensive to protect ground water than it is to try to restore it once it becomes contaminated. In Pennsylvania, to meet the wellhead protection program, new community water system well permitting requirements, voluntary local wellhead protection programs, and a three-tiered approach to wellhead protection were enacted.

Based on the three-tiered approach, three WHP areas are delineated. All man-made sources that may impact human health are identified. Within these areas, management practices are implemented to manage the sources of contamination.

Testing

Overview

Testing is done for both the capacity (quantity) of water in the prospective well and for its water quality. The goal is to have a well that has a safe yield and a water quality that is potable, suitable for human consumption, or can be treated to a potable level.

Safe Yield – The amount of water that can be annually withdrawn from a groundwater basin without adverse impacts. This is the long term sustainable pumping rate.

General Well Hydraulics

☑ When water is pumped from a well, the water table in the vicinity of the well is lowered, creating a cone of depression.

☑ If cone of depression extends to surface water body, water will flow from the surface water body to the groundwater. This is known as induced recharge.

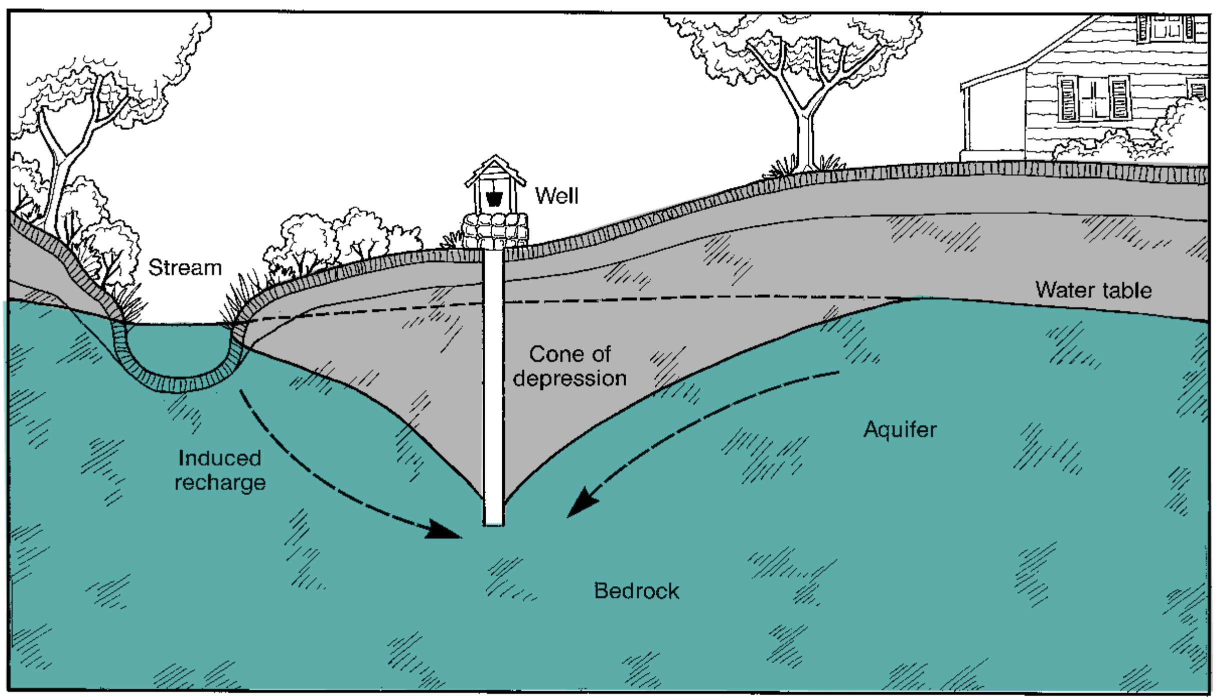


Figure 2.1 - Well Drawdown[1]

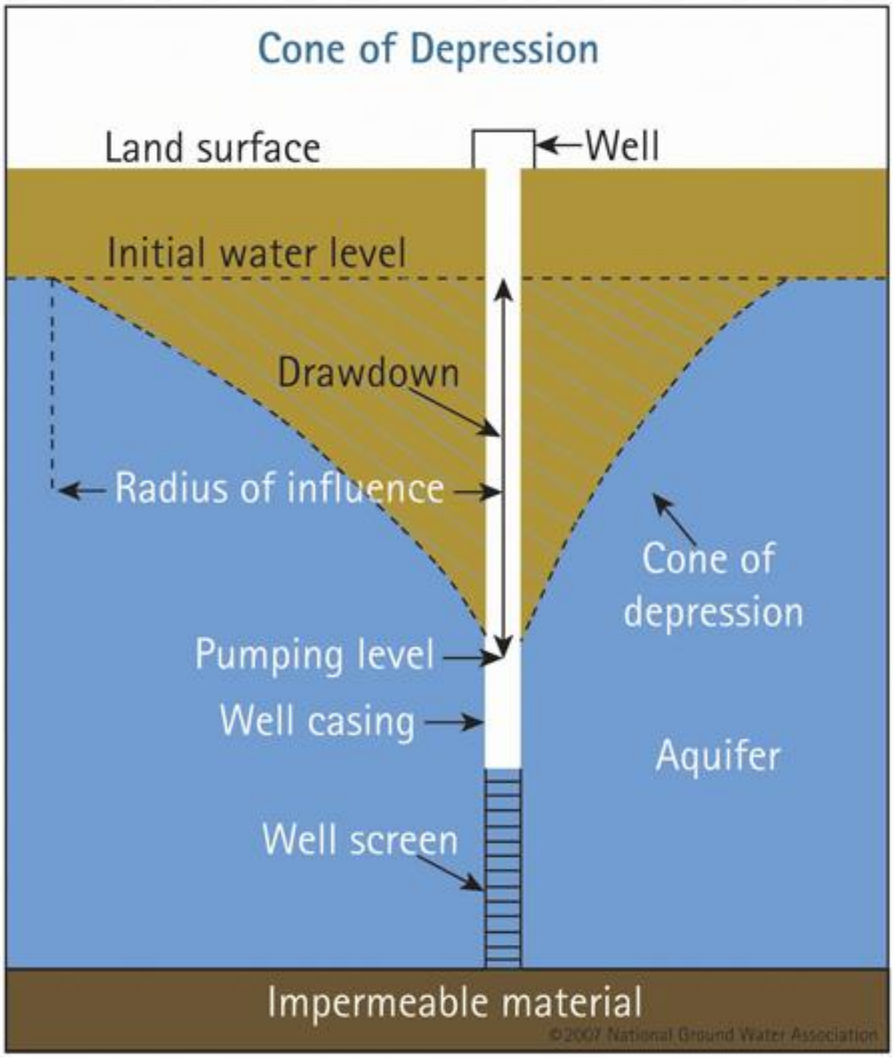


Figure 2.2 Well Pumping Definitions
(Reprinted with permission of the National Ground Water Association. Copyright 2007.)

Static water level (also known as initial water level)**:** The vertical distance in feet from the centerline of the pump discharge down to the surface level of the free pool while no water is being drawn from the pool or water table.

Drawdown: The drop in the water table or level of water in the ground when water is being pumped from a well. The difference in feet between the pumping water level and the static water level.

Pumping Water Level: The vertical distance in feet from the centerline of the pump discharge to the level of the free pool while water is being drawn from the pool.

Calculations using static water level, drawdown, and pumping water level:

Calculation #1: Calculating **drawdown** from static water level and pumping water level:

What is the drawdown in feet if the static water level is 150 feet and the pumping level is 180 feet?

Drawdown = Pumping water level – Static water level

Drawdown = 180 – 150 = 30 feet

Example #2: Calculating **static water level** from pump water level and drawdown

The water depth in the well when the pump is running (pumping level) is 250 feet with a drawdown of 50 feet. What is the static water level in the well when the pump is not operating?

Static Water Level = Pumping water level - drawdown

Static Water Level = 250 – 50 = 200 feet

Additional Definitions:

Radius of Influence: The radial distance from the center of a wellbore to the point where there is no lowering of the water table or potentiometric surface (the edge of its cone of depression).

Zone of Influence: The area surrounding a pumping well within which the water table or potentiometric surfaces have been changed due to groundwater withdrawal.

Cone of Depression – A depression in the groundwater table or potentiometric surface that has the shape of an inverted cone and develops around a well from which water is being withdrawn. It defines (in cross-section) the zone of influence of a well.

So, how do the three terms relate… The "zone of influence" is the **surface projection** of the cone of depression, where the "radius of influence" would be the distance from the center of the well to one edge of the "zone of influence".

Testing Protocol

☑ Drilling Log

- ► Complete DEP drilling report

☑ Plumbness and Alignment

- ► 40-foot long rigid dummy, ½ inch less than well diameter must move freely throughout length of well.
- ► Indicates that pump will not get stuck during installation or removal. A stuck pump could require abandonment of source.

Capacity Testing

The purpose for capacity testing is to determine if the well will be able to supply a safe yield.

☑ Step-Drawdown Test

- This test is used to predict the sustainable pumping rate. Although it is not required by regulatory agencies (DEP, SRBC), it is recommended.
- Well is pumped at several successively higher pumping rates and the drawdown for each rate (or step) is recorded.
- Usually conducted in a single day and requires 5 to 8 pumping rates, each lasting approximately 1 hour.

☑ Sustained Yield Test

- This test is used to evaluate aquifer and well capabilities and potential impacts to existing water supplies and the environment.
- Well is pumped continuously for a minimum of 48 hours. A greater length may be required. During this time several things must occur:
  - Static water level, pumping rate(s), drawdown, water recovery rate and level are measured and recorded;
  - Water Quality – measure and record pH, temperature and conductivity every 2 hours; and,
  - Collect water samples for quality determination at end of test period.

Water Quality Testing

☑ Wells

- Water samples are taken upon completion of the sustained yield pumping test, and the analysis is performed by a DEP certified laboratory.
- Testing Requirements—one set of samples required and tested for presence and amount of:
  - Volatile Organic Chemicals (VOCS) - Benzene, TCE, Toluene, etc.
  - Synthetic Organic Chemicals (SOCS) - PCBs, Alachlor, Lindane, Chlordane, etc.
  - Inorganic Chemicals (IOCS) - Arsenic, Chromium, Lead, Nitrates, Nitrites, Mercury, etc.
  - Microbiological Contaminants (Total Coliform) - 3 samples at 15 minute intervals
  - Radionuclides (Gross Alpha emissions and Gross Beta emissions) - the presence of radioactive material
  - Secondary Contaminants and Others - TDS, pH, iron, manganese, hardness, chloride, etc.
  - Turbidity – the clarity of the water sample

☑ Springs

- Water samples are collected minimally over a 6 month time period. At least 1 set is collected a minimum of 6 hours and a maximum of 24 hours after a significant rainfall event. The analysis is performed by a DEP certified laboratory.
- Testing requirements—the types of testing are the same as for wells; however, the number of samples required is different.
  - Volatile Organic Chemicals (VOCS) – 2 samples
  - Synthetic Organic Chemicals (SOCS) – 1 sample
  - Inorganic Chemicals (IOCS) – 2 samples
  - Microbiological Contaminants (Total Coliform) – 6 samples
  - Radionuclides (Gross Alpha and Gross Beta) – 1 sample
  - Turbidity – 6 samples

☑ Surface Water Identification Protocol (SWIP) Testing required by DEP

- This testing needs to be done on all ground water sources. Special monitoring is required of groundwater sources susceptible to direct surface water influence.
- Direct surface water influence possibilities include:
  - All springs, infiltration galleries, ranney wells, and crib intakes.
  - Wells if they meet one of the following four criteria:
    1. In carbonate aquifer with static water elevation ≤ 100 feet below ground level.
    2. In an unconfined aquifer with static water elevation ≤ 50 feet below ground level.
    3. In a confined aquifer located ≤ 50 feet below ground level.
    4. ≤ 200 feet from a surface water body (not applicable where static water elevation is > 100 feet below ground level).
- Special monitoring requirements
  - Daily sampling for turbidity, pH, specific conductance (or total dissolved solids), and temperature.
  - Daily measurements flow and/or source water level.
  - Weekly total and, if positive, fecal coliform samples.
  - Daily recording of precipitation and local surface water conditions.
  - Monitoring conducted for 6 months.
- If monitoring indicates a correlation between source water quality and precipitation or surface water conditions, DEP to conduct a Microscopic Particulate Analysis (MPA).
  - If results of MPA show presence of surface water organisms or organic debris, source will be considered **groundwater under the direct influence of surface water. (GUDI)**

Once the location of the water supply facility has been determined, how the well is constructed and the materials used is very important in helping to ensure we have the amount of water we need and that it is of potable quality. In this section, we will explore the components of well construction: 1) Casings, 2) Screens, 3) Upper Well Terminus, 4) Capping and Abandonment, 5) Well Pumps, 6) Discharge Piping, as well as 7) Special Construction Requirements.

Casings

Material

☑ New wrought iron or steel pipe

- ► Minimum weight and thickness to comply with American Water Works Association (AWWA) Standard A100, "Standard for Water Wells"
- ► Equipped with drive shoe when driven
- ► Welded or threaded joints

☑ Non-ferrous (PVC) pipe

- ► Comply with AWWA A100, "Standard for Water Wells"
- ► Shall not be driven

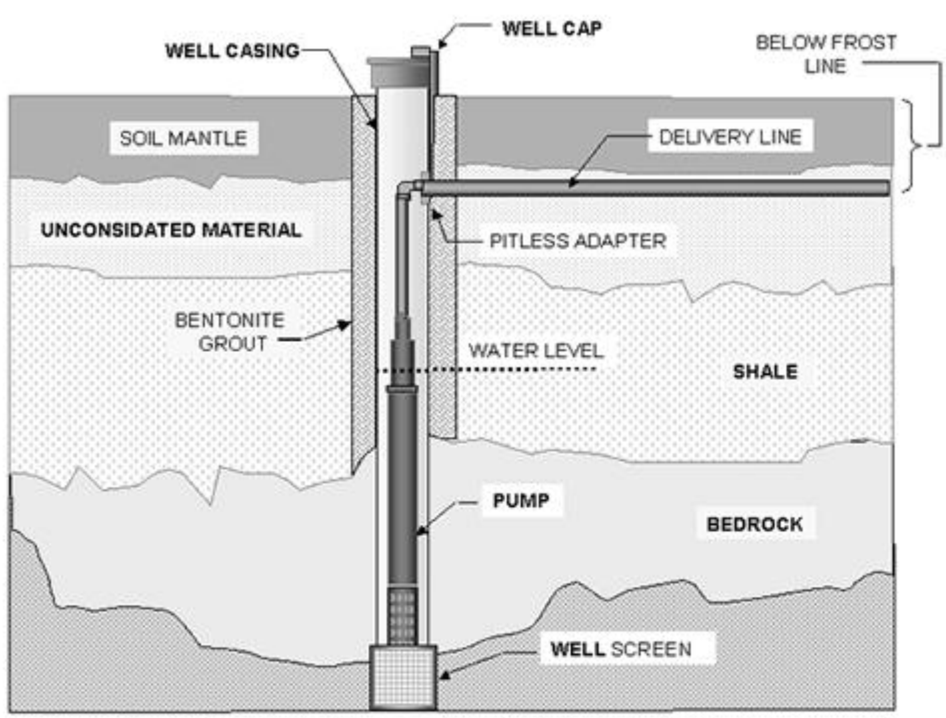


Figure 2.3 Well Components

Grouting

☑ All permanent well casings are to be surrounded by a minimum of 1.5 inches of grout. This is to be done to a minimum depth of 20 feet from the ground surface, or into the impervious subsurface formation which caps the aquifer - whichever is deeper.

- ► The purpose of grout is to seal out water of any unsatisfactory chemical or bacterial quality from surface or shallow subsurface waters and to stabilize soil formations which may cave.

☑ Specific grout mixtures can be found in DEP Public Water Supply Manual, Part II, Chapter 3, Section 3.3.5.7.

Annular space: A ring-shaped space between two circular shapes, such as the well casing and the well hole.

☑ Grout is to be added from the bottom of the annular space, in one continuous operation, until space is filled.

- ► When the annular space is less than four inches, the grout is to be installed under pressure with a grout pump.

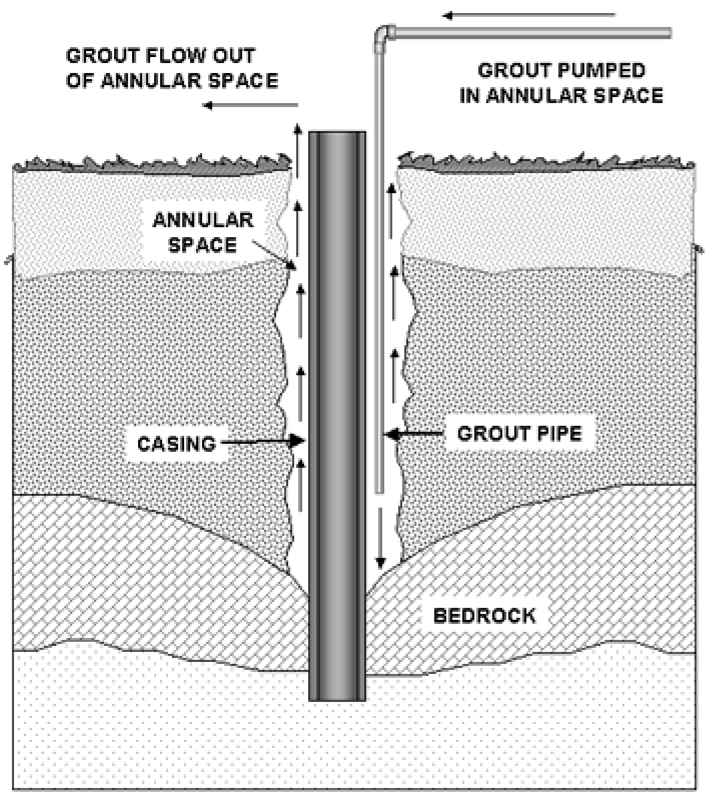


Figure 2.4 Grouting a well

Table 2.1 - Protective Casing Depths[2]

DEP Protective Casing Depths		
Water-Bearing Formation	Overlying Materials	Protective Casing Depth
Sand Or Gravel	Sand, or mixture of sand and gravel	The depth of casing will be governed by the pumping level (level of water during pumping). For pumping levels 30 feet or less, the casing shall extend 10 feet below pumping level. For pumping levels greater than 30 feet the casing shall extend five feet below pumping level.
	Clay or similar material containing layers of sand or gravel.	The casing shall extend five feet below the pumping level, but through the clay. The casing shall extend five feet below the pumping level, but through clay below any sand or gravel above the 30 –foot depth (See Section 3.3.6.2)
	Clay, or similar material only, to a depth of 35 feet or more.	The casing shall extend five feet below the pumping level. (See Section 3.3.6.2)
Limestone, Granite, or Quartzite	Mantle, to a depth greater than 50 feet for a radius of one mile.	The casing shall be firmly seated in the rock formation. (See Section 3.3.6.3)
	Mantle, to a depth less than 50 feet for a radius of one mile.	The casing shall extend 10 feet into uncreviced rock below 40 feet. (See Section 3.3.6.3)
Sandstone	Any material except limestone, to a depth of 35 feet or less.	The casing pipe shall extend 15 feet into firm sandstone or to the 40 foot depth.
	Any material except limestone, to a depth greater than 35 feet.	The casing pipe shall be effective seated into sandstone. Minimum cased depth shall be 40 feet.
	Limestone at variable depth.	The casing pipe shall be extended 15 feet into firm sandstone.

Two factors affect the Protective Casing Depth, the water bearing formation and the overlying materials.

☑ Unit 2 Part 1 Exercise

1. If the static water level is 40 feet and the pumping water level is 200 feet, what is the drawdown in feet? ________

2. If the pumping level is 280 feet and the drawdown is 100 feet, what is the static water level? __________

3. The space between the well casing and the well hole is known as the _________________________.

4. The distance from the center of the well to the outer edge of the cone of depression is:

a) Zone of influence
b) Drawdown
c) Radius of influence
d) Static water level

Screens

Purpose: The screen allows the free flow of water into the well; but prevents sand from entering too.

Requirements

If used, screens shall:

☑ Provide maximum open area while maintaining required structural strength.

☑ Have opening sizes based on a sieve analysis of the surrounding material.
- ► Sieve analysis: Method of determining particles size.

☑ Be constructed of materials resistant to damage from the chemical action of the groundwater or cleaning operations.

Upper Well Terminus

Requirements

☑ The permanent casing is to extend a minimum of 12 inches above the pump house floor or concrete apron, or at least 18 inches above final ground level.

☑ The well house floor is to be constructed a minimum of 6 inches above final ground level.

☑ The top of the casing is at least 3 feet above the highest known flood level.

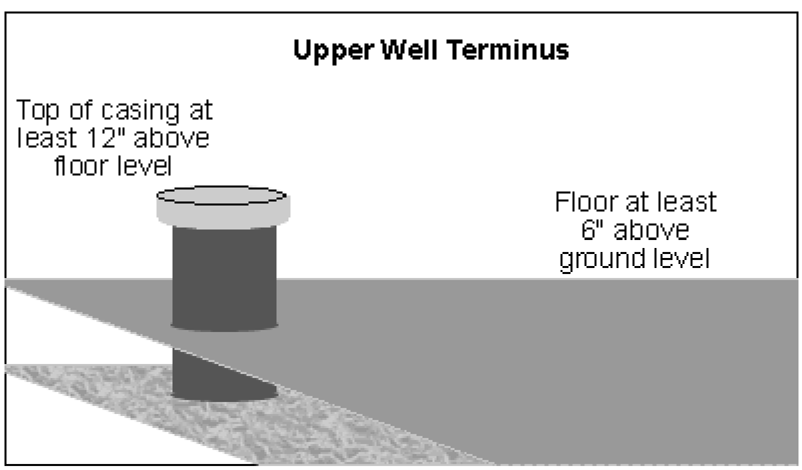


Figure 2.5 Upper Well Terminus

Capping and Abandonment

Capping

All new wells are to be capped until development as a water source or abandoned.

☑ A tight fitting wooden plug or welded metal plate is required.

Abandonment

Abandoned wells are to be sealed. This is required in order to restore the geologic conditions which existed prior to drilling.

☑ Sealing prevents the exchange of water from one aquifer to another.

☑ The preferred method is accomplished by filling the bore hole with neat cement grout or concrete slurry to the surface.

Well Pumps, Discharge Piping and Appurtenances

Pumps

☑ Line Shaft Pumps

- ► Drive motor located on surface, pumping assembly located in well.
- ► Pump sealed to casing to prevent entrance of surface water.

Figure 2.6 Line Shaft Pumps

☑ Submersible Pumps

- ► Pumping assembly and motor are submerged in the well.
- ► Top of casing is sealed against entrance of water.
- ► Electrical cable is attached to riser pipe.

Figure 2.7 Submersible Pump

Discharge Piping

☑ Check and shutoff valves

☑ Pressure gauge

☑ Flow measuring device

☑ Sample tap

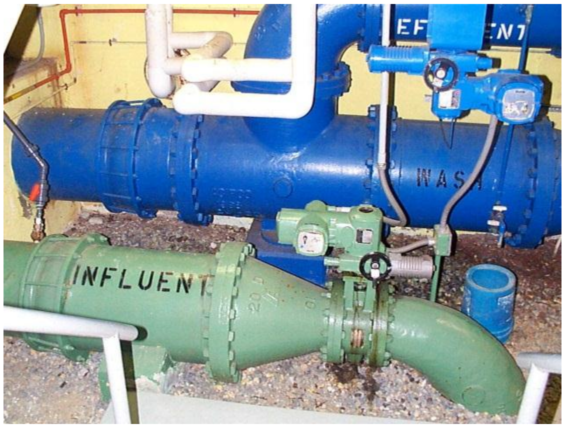


Figure 2.8 Piping

Appurtenances

☑ Pitless well units

- ► Shop fabricated
- ► Threaded or welded to casing pipe
- ► Watertight
- ► Contain facilities to measure water level in well

☑ Water level measurement

- ► Wells are to be equipped with means to measure water level such as an access port with a removable cap that allows a measuring device to be lowered into the well.

Types of Wells

Dug Wells

☑ May be considered only when acceptable drilled wells are not possible.

☑ Watertight cover required.

Gravel Pack Wells

☑ Require gravel packs to be placed in the well to stabilize the borehole. Gravel packs usually consist of a steel screen placed in the hole and the surrounding area is packed with gravel. This prevents the passage of sand into the well.

☑ Gravel pack is to be:

- ► Rounded, sandstone type material.
- ► Smooth, uniform, properly sized.
- ► Washed and disinfected immediately prior to placement.

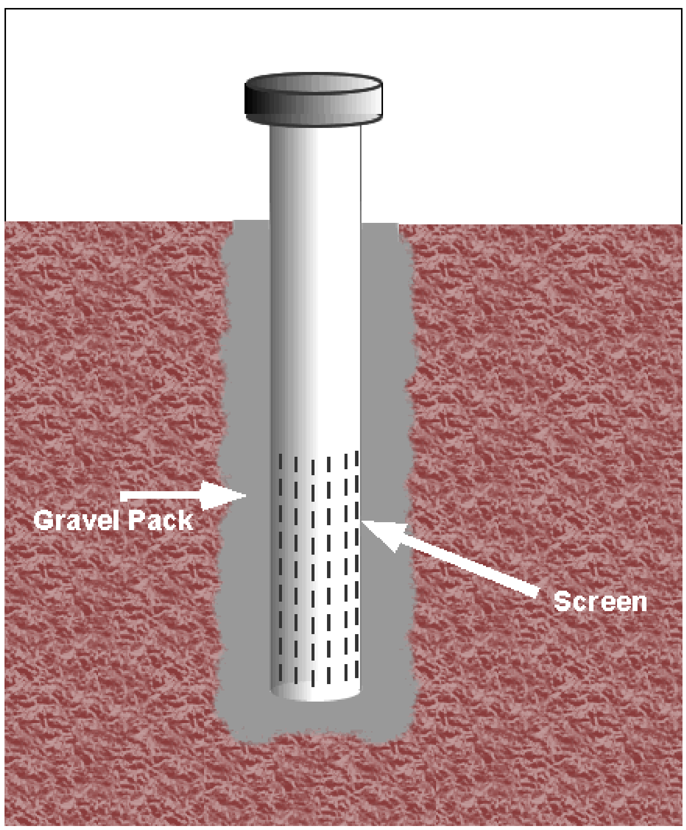


Figure 2.9 Gravel Pack

Sand or Gravel Wells

- ☑ Permanent casing to extend through clay or hardpan layers above the water bearing formation.
- ☑ If only permeable materials are above the aquifer, the casing is to extend a minimum of 20 feet below ground surface.
- ☑ If a temporary outer casing is used, it shall be withdrawn as grout is installed.

Limestone or Sandstone Wells

- ☑ Where depth of unconsolidated material above the aquifer is more than 50 feet, the casing is to be seated in unbroken rock (Figure 2.10a).
- ☑ Where depth of unconsolidated material is less than 50 feet, a minimum of 50 feet of casing is required (Figure 2.10b).

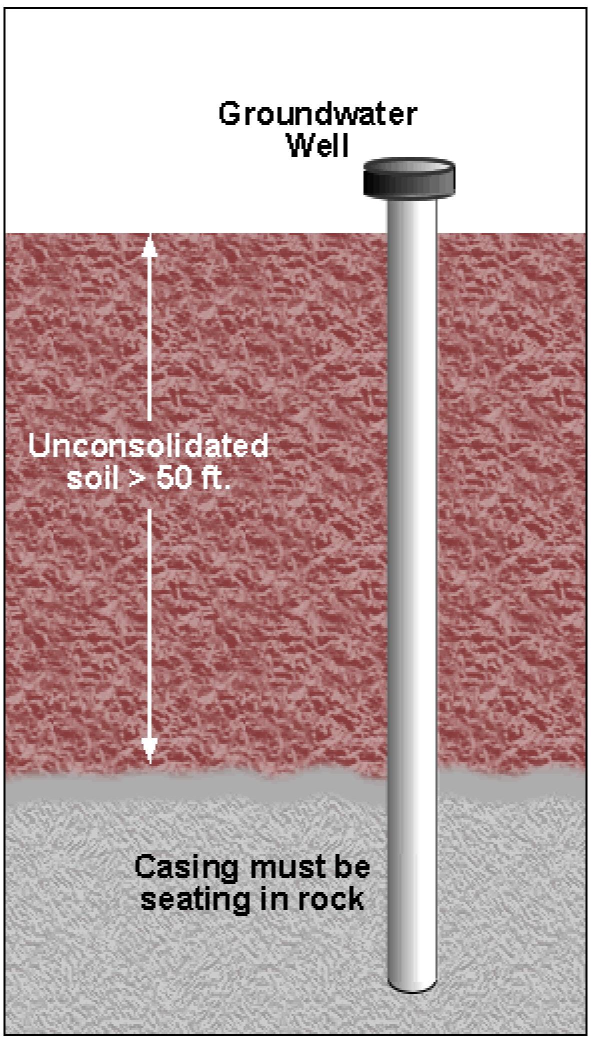


Figure 2.10a

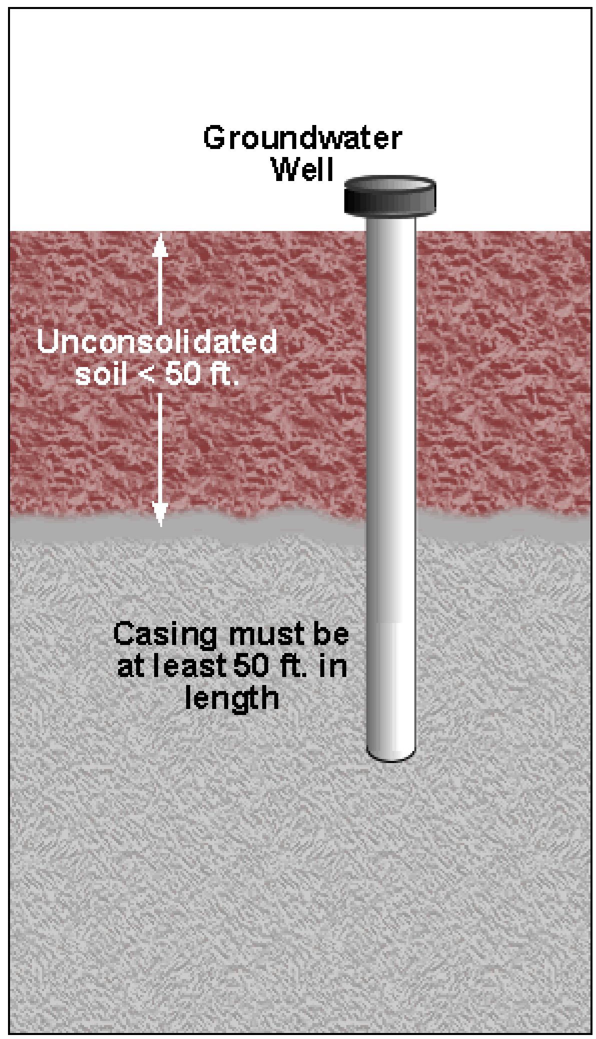


Figure 2.10b

Flowing Artesian Wells

☑ Flow is to be controlled.

☑ If confining layer erosion seems likely to occur, an inner casing is required.

Radial Water Collectors

☑ Radial collectors are to be essentially horizontal.

☑ Top of the caisson is to be covered with a watertight floor.

- ► All openings are to be curbed to prevent entrance of foreign material.

☑ Caisson walls are not to be penetrated by pump discharge piping.

Infiltration Galleries

☑ May be considered only when acceptable drilled wells are not possible.

☑ DEP to establish a minimum area that must be under the control of the source owner.

☑ Gravity flow in lines to collecting well.

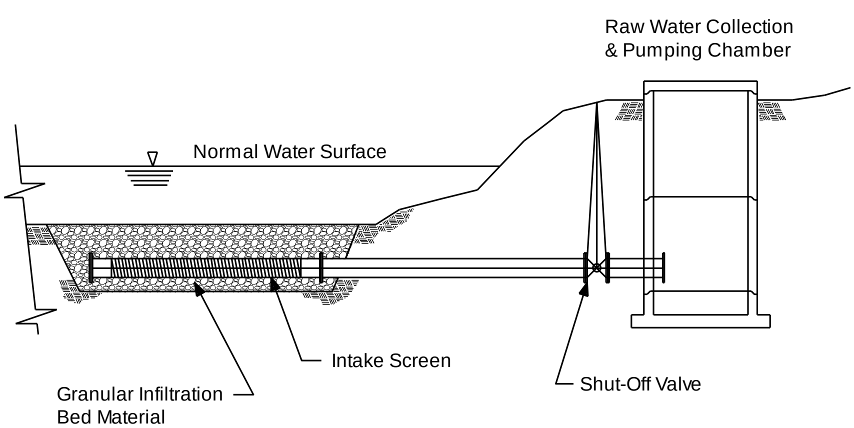


Figure 2.11 – Infiltration Gallery

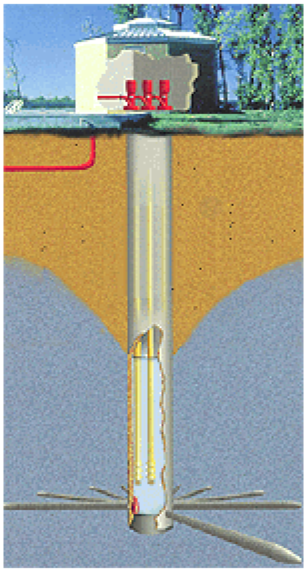


Figure 2.12 – Radial Collector[3]

Unit 2 Part 2 Exercise

1. The purpose of a well ___________________is to allow the free flow of water into the well; but prevents sand from entering too.

2. Filling the bore hole with neat cement grout or concrete slurry to the surface refers to:

a) Well rehabilitation
b) Well drilling
c) Well abandonment

3. Wells are to be equipped with means to measure water level such as an access port with a removable cap that allows a measuring device to be lowered into the well.

a) True
b) False

4. Well construction must conform to DEP guidelines for casing depth and grouting around the casing.

a) True
b) False

Key points for Unit 2 – Source Development and Construction

- Thorough planning and cost analysis are needed to determine a suitable site, initiate a sanitary survey, develop a wellhead protection plan if groundwater use is planned, and develop an adequate testing plan for ground water or surface water as needed.

- Testing requirements for a proposed well can be extensive and are recommended to include a determination of the safe yield which is the amount of water that can be withdrawn annually from a well without adverse impacts.

- The **static water level** is the vertical distance in feet from the pump discharge down to the surface level of the free pool while no water is being drawn from the pool or water table. The **drawdown** is the drop in the water table or level of water in the ground when water is being pumped from a well. The **pumping water level** is the vertical distance in feet from the pump discharge to the level of the free pool while water is being drawn from the pool.

    - Drawdown = Pumping water level – Static water level
    - Static Water Level = Pumping water level – drawdown

- Wells are to be equipped with means to measure water level such as an access port with a removable cap that allows a measuring device to be lowered into the well.

- DEP requires all ground water sources to undergo Surface Water Identification Protocol (SWIP) testing to determine if the groundwater is under the direct influence of surface water.

- Well construction must conform to DEP guidelines for casing depth and grouting around the casing.

- The top of the casing must be at least 3 feet above the highest known flood level.

- Abandoned wells must be properly sealed with grout to the surface to restore the geologic conditions which existed before drilling the well.

- New wells must be capped until developed as a water source or abandoned.

[1] "Illustration 7—Pumping from a well lowers the water table near the well creating a cone of depression" http"//pa.lwv.org/wren/(24 March 2003).

[2] "Table 2.1 Protective Casing Depths" http.//www.dep.state.pa.us/TechnicalGuidance/Draft_ technical_guidance.asp/383-2126-303 (05 May 2003).

[3] "Ranney Collector Wells" http://www.laynechristensen.com/ranney_collector_wells.html (05 May 2003).

Unit 3 – Math Principles and Process Control Calculations

Learning Objectives

- Describe math terms, principles and rules for solving equations.
- Review unit cancellation steps.
- Perform calculations for the following types of situations:
  - Determining chlorine demand
  - Determining how many minutes it takes to fill a storage tank
  - Determining number of days of supply based on customer demand (gal/hr)
  - Diluting a % strength solution for a day tank
  - Determining chlorine feed rate in gallons per day
  - Refilling a day tank based on a daily feed pump rate

Basic Math Principles for Solving Calculations

Here are some basic math terms and principles.

Fraction: A numerical expression containing a numerator and denominator that represents portions of a whole object. Fractions are used to represent ratios and represent division. For example, the fraction ¼ is used to represent the ratio 1:4 and 1 ÷ 4.

Parts of a Fraction

1. **Numerator:** The **top** number of a fraction that indicates how many parts are being considered.
2. **Division Line:** The line between the numerator and denominator that indicates that the numerator value is divided by the denominator value to convert a fraction into a decimal.
   Example: 1 ÷ 4 = 0.25 (as a decimal)
3. **Denominator:** The **bottom** number of a fraction that tells us how many equal parts into which the whole has been divided.

Fraction Written in Vertical Format:

Class Activity

Write the following fractions in **vertical** format:

1/8 = ________ (The numerator is: _______)

2/6 = ________ (The denominator is: ______)

$\frac{8}{10}$ means that ______ is divided by _________

Rules for Solving for an Unknown Variable (such as *X*)
When solving for the unknown variable (***X***), there are 2 basic objectives: 1. ***X*** must be in the numerator, **AND** 2. ***X*** must be by itself (on one side of the equation).
To accomplish these objectives, **only diagonal movement of terms across the equal sign is permissible in multiplication and division problems.** $\frac{(5)}{(3)} = \frac{(3)}{(5)}$

Explanation of diagonal movement and an example.

An equation is a mathematical statement in which the terms or calculation on one side = the terms or calculation on the other side. To keep both sides equal, any multiplication or division done to one side, must be done to the other. This keeps the equation balanced.

Example 1:

5X = 20

Question #1 regarding Example #1: Is the ***X*** in the numerator? ______

Question #2 regarding Example #1: Is the ***X*** alone on one side of the equation? _____

How do we use diagonal movement to place ***X*** alone on one side of the equation?

Answer:

- Divide both sides by "5" to get ***X*** alone and **treat both sides of the equation equally**.
  Notice that the 5 was moved from the top of the left side to the bottom of the right side of the equation – **a diagonal move.**

$\frac{\cancel{5}\mathbf{X}}{\cancel{5}} = \frac{20}{5}$

FINAL ANSWER: ________

Example 2:

$$2.5 = \frac{1{,}000}{X}$$

Question #1 regarding Example #2: Is the ***X*** in the numerator? ______
How do we move the ***X*** into the numerator?
Answer:

- Multiply both sides of the equation by ***X***. Or, you could think of it as simply moving the ***X*** diagonally from the denominator into the numerator.

$$X(2.5) = \frac{1{,}000\cancel{(X)}}{\cancel{X}} \qquad \textbf{OR} \qquad X(2.5) = \frac{1{,}000}{X}$$

Question #2 regarding Example #2: Is the ***X*** alone on one side of the equation? _____
How do we use diagonal movement to place ***X*** alone on one side of the equation?

Answer:

- Divide by 2.5 on each side of the equation so that the ***X*** is alone, but the equation keeps the same value.

$$\frac{X\cancel{(2.5)}}{\cancel{2.5}} = \frac{1{,}000}{2.5}$$

$$X = \frac{1{,}000}{2.5}$$

FINAL ANSWER: _________

Class Exercise Solving for *X*:

$$\frac{X}{200} = 2.4 \qquad\qquad 10 = \frac{3000}{X}$$

X = ________ ***X*** = ________

There are a few rules for doing the various mathematical functions like multiplication, division, addition and subtraction.

Order of Operation for Multiplication, Division, Addition and Subtraction
To solve for ***X*** when multiplication and division as well as addition and subtraction of terms is indicated, use the following steps: 1. Simplify as many terms as possible, using the order of operation: • If **brackets or parentheses** contain any arithmetic, **simplify within these groups first** by: ○ Completing the multiplication or division, **THEN** ○ Complete the addition or subtraction. • Complete all **multiplication and division** from left to right, **THEN** • Complete all **addition and subtraction** from left to right. 2. Verify that the ***X*** term is in the numerator. If it is not, move the ***X*** term to the numerator, using a diagonal move. 3. Verify that ***X*** is by itself, on one side of the equation.

Explanation of the Order of Operation and an example.

Example: $4\left(\frac{\mathbf{10}}{\mathbf{2}} + 3\right) + 6$

Step #1: Simplify terms **within parentheses** by **multiplying and dividing** from left to right.

= 4 (**5** +**3**) + 6

Step 1: $\frac{10}{2} = 5$

Step # 2: THEN simplify terms **within parentheses** by **adding and subtracting** from left to right.

= 4 (**8**) + 6

Step 2: (5 + 3) = 8

Step #3: Simplify terms **outside of parentheses** by **multiplying and dividing** from left to right.

= **32** + 6

Step 3: 4 X 8 = 32

Step #4: Simplify terms **outside of parentheses** by **adding and subtracting** from left to right.

= 38

Step 4: 32 + 6 = 38

Now let's discuss the concept of unit cancellation.

Problem Solving Using Unit Cancellation:

We give it that name because you cancel units until the problem is solved.

- Unit cancellation involves canceling units in the numerator and denominator of unit fractions to obtain the desired units of measurement.
- Unit cancellation can be used to make conversions or to solve problems.

There are three basic rules for using unit cancellation on the next page.

Basic rules for using unit cancellation:

Unit fractions should be written in a vertical format. A unit fraction has one unit in the numerator (above the line) and one unit in the denominator (below the line).

1. A fraction is structured like this: $\frac{\text{numerator}}{\text{denominator}}$

   For example, gallons per minute (GPM) should be written as $\frac{\text{gal}}{\text{min}}$

2. Any unit which appears in the numerator of one unit fraction and the denominator of another unit fraction is canceled.

   The following is an example of how units are canceled:

   $$20\ \frac{\text{gal}}{\cancel{\text{min}}} \times 60\ \frac{\cancel{\text{min}}}{\text{hr}} = 1200\ \frac{\text{gal}}{\text{hr}}$$

3. It may be necessary to invert data and the corresponding units.

   $$10\ \frac{\text{gal}}{\text{min}} \text{ is the same as } \frac{1\text{ min}}{10\text{ gal}}$$

Example Problem: An operator has determined it takes 30 lbs/day as a feed rate for a 12.5% hypochlorite solution. This solution provides 1.2 available lbs of chlorine/gallon of hypochlorite solution.
How many gal/day of 12.5% solution are needed to accomplish this feed rate?

Problem Set Up

List all known and unknown data.

Unknown: $? \frac{\text{gal}}{\text{day}}$ Known: $30 \frac{\text{lbs}}{\text{day}}$ $\frac{1.2 \text{ lbs of chlorine}}{1 \text{ gallon of 12.5\% solution}}$

Steps to solving problems using unit cancellation

Step 1: List unknown data including units in vertical format followed by an equal sign.

Example: Unknown data: $? \frac{\text{gal}}{\text{day}} =$

Step 2: Find data (known or a conversion) that has the same numerator unit as the unknown numerator. Place it to the right of the equal sign. Add a multiplication sign.

Positions your numerator unit

Example: $? \frac{\text{gal}}{\text{day}} = \frac{1 \text{ gal of 12.5\% solution}}{1.2 \text{ lb of chlorine}} \times$

Known data that was inverted

Steps 3 and 4: To cancel unwanted denominator unit, find data (known or a conversion) that has the same numerator unit. Place it to the right of data used in Step 2. Place a multiplication sign between each piece of data. Continue to place data (known or a conversion) into equation to systematically cancel all unwanted units until only the unknown denominator units remain.

Example: $? \frac{\text{gal}}{\text{day}} = \frac{1 \text{ gal of 12.5\% solution}}{1.2 \cancel{\text{lb of chlorine}}} \times \frac{30 \cancel{\text{lbs of chlorine}}}{\text{day}}$

Known data

Note 1: All units must cancel, leaving only the units you are solving for in the unknown data. If all units except the unknown units are not crossed out, check the list of known data to see if all relevant known data was used to solve the problem and all necessary conversions were made.

Note 2: If you need to invert the known data or conversion values and units to cancel, remember to move the appropriate units with the value.

Step 5: Multiply the values of all numerators and place this value in the numerator of the answer. Multiply the values of all denominators and place this value in the denominator of the answer. Divide to calculate the final answer.

Example: $? \frac{\text{gal}}{\text{day}} = \frac{30 \text{ gal of 12.5\% solution}}{1.2 \text{ day}} = 25 \frac{\text{gallons of 12.5\% solution}}{\text{day}}$

Important: Check the answer to verify that the value is reasonable.

Practice Problem:

In the previous example, we learned that it takes 25 gallons of 12.5% hypochlorite solution to achieve a 30 lbs/day feed rate. If the chemical feed pump is calibrated in mL/min, how many mL/min are in the 25 gal/day feed rate?

From this data, find units which need to be converted.

Volume units: gal to mL　　　　Time units: day to min

Find conversions from the conversion charts.

1 gal = 3,785 mL　　　　1 day = 1,440 min

Unknown Data: $?\frac{mL}{min}$　　　　Known Data: $25\ \frac{gal}{day}$

Directions: Using conversions and the known data, follow the unit cancellation steps to solve the problem.

Unit Cancellation Steps:

Step 1: List **unknown data including units** in vertical format followed by an equal sign.

Example: Unknown data: $?\ \frac{ml}{min} =$

Step 2: Find data (known or a conversion) that has the **same numerator unit as the unknown numerator**. Place it to the right of the equal sign. Add a multiplication sign. This positions your numerator.

$$?\frac{mL}{min} = \frac{3785\ mL}{1\ gal} \text{ X}$$

Positions your numerator unit

Step 3: To cancel unwanted denominator unit, find data (known or a conversion) that has the same numerator unit. Place it to the right of data used in Step 2. Place a multiplication sign between each piece of data.

$$?\frac{mL}{min} = \frac{3785\ mL}{1\ \cancel{gal}} \text{ X } \frac{25\ \cancel{gal}}{day} \text{ X}$$

Cancel unwanted units that match

Step 4: Continue to place data (known or a conversion) into equation to systematically cancel all unwanted units until only the unknown denominator units remain.

$$?\frac{mL}{min} = \frac{3785\ mL}{1\ \cancel{gal}} \text{ X } \frac{25\ \cancel{gal}}{\cancel{day}} \text{ X } \frac{1\ \cancel{day}}{1440\ min}$$

Unknown denominator unit matches final denominator unit

Step 5: Multiply the values of all numerators and place this value in the numerator of the answer. Multiply the values of all denominators and place this value in the denominator of the answer. Divide to calculate the final answer.

$$?\frac{mL}{min} = \frac{3785\ mL}{1\ \cancel{gal}} \times \frac{25\ \cancel{gal}}{\cancel{day}} \times \frac{1\ \cancel{day}}{1440\ min} = \frac{94625\ mL}{1440\ min} = 65.7\ \frac{mL}{min}$$

Unit Cancellation Steps

Step 1: List ? unknown data including units followed by an = sign

Step 2: Place data with same numerator unit to the right of the equal sign followed by a multiplication sign. This positions your numerator.

Step 3: To cancel unwanted denominator unit, next place data with same numerator unit.

Step 4: Continue to place data into equation to systemically cancel all unwanted units until only the unknown denominator units remain.

Step 5: Do the math (Multiply all numerator values, multiply all denominator values, then divide numerator by the denominator.)

Example:

The density of a liquid is 1 gm/mL in the Metric system. **What is the density in the English system (lbs/gal)?**

Notice that this conversion proves that the density of water = 8.34 lbs/gallon.

$$? \frac{\text{lbs}}{\text{gal}} = \frac{1\ \text{lb}}{454\ \cancel{\text{gm}}} \times \frac{1\ \cancel{\text{gm}}}{1\ \cancel{\text{mL}}} \times \frac{3785\ \cancel{\text{mL}}}{1\ \text{gal}} = 8.34\ \frac{\text{lbs}}{\text{gal}}$$

Helpful Hints:

$$\frac{\text{Numerator}}{\text{Denominator}}$$

Vertical format: 5 gal = $\frac{5\ \text{gal}}{1}$

1 gm = 1000 mg is written: $\frac{1\ \text{gm}}{1000\ \text{mg}}$ OR $\frac{1000\ \text{mg}}{1\ \text{gm}}$

“per” means divided by: Ex. 5 gpm = $\frac{5\ \text{gal}}{1\text{min}}$

Inverting: $\frac{5\ \text{gal}}{1\ \text{min}} = \frac{1\ \text{min}}{5\ \text{gal}}$

Process Control Calculations

There are several basic process control calculations:

1. Determining chlorine demand
2. Determining how many minutes it takes to fill a storage tank
3. Determining number of days of supply based on customer demand (gal/hr)
4. Diluting a % strength solution for a day tank
5. Determining chlorine feed rate in gallons per day
6. Refilling a day tank based on a daily feed pump rate

We'll start with the easiest calculation that operators need to make.

Chlorine Demand or Dose Calculation

- A sufficient amount of chlorine must be added so that the chlorine demand is met and the desired chlorine residual is provided.

  Chlorine Demand (mg/l) = Chlorine Dose (mg/l) – Chlorine Residual (mg/l)

  OR

  Chlorine Dose (mg/L) = Chlorine Demand (mg/L) + Chlorine Residual

Example #1: The chlorine demand of water is 2.1 mg/L. If a chlorine residual of 0.6 mg/L is desired, what is the required chlorine dosage in mg/L?

Chlorine Dose (mg/L) = Chlorine Demand (mg/L) + Chlorine Residual (mg/L)

? Dose = 2.1 + 0.6
= 2.7 mg/L

Example #2: The chlorine dosage is 2.9 mg/L. If the chlorine residual is 0.6 mg/L, what is the chlorine demand in mg/L?

Chlorine Demand (mg/L) = Chlorine Dose (mg/L) – Chlorine Residual (mg/L)

? Chlorine Demand = 2.9 – 0.6
= 2.3 mg/L

Practice Problem: Four mg/L of chlorine is used to disinfect a well that pumps at 25 gallons a minute. The chlorine residual is 0.3 mg/L after a 30-minute contact time. What is the chlorine demand of this well?

? Chlorine Demand = 4.0 – 0.3
= ______mg/L

Determining Length of Time to Fill a Storage Tank

Another process calculation that operators need to make involves how much time it takes to fill a storage tank based on a well pump capacity and a daily water demand.

We'll use unit cancellation steps to arrange the data in the proper position (numerator versus denominator).

Example: A well has the capacity to pump 250 gallons per minute. An operator has a daily water demand of 20,000 gallons a day. How many minutes is it necessary to operate the well pump to store a 1-day supply?

Step 1: Use unit cancellation step 1 to set up problem (? Unknown data with units)

$? \ \underline{\text{mins}} =$

Step 2: Use unit cancellation step 2 to place known data with **same numerator unit** to position numerator
NOTE: pump capacity data will need to be inverted

$? \ \underline{\text{mins}} = \dfrac{1 \text{ min}}{250 \text{ gal}}$

Positions the numerator unit

Step 3: To cancel unwanted **denominator unit**, next place known data with those same units in the numerator of the next data set to cancel unwanted units

$? \ \underline{\text{mins}} = \dfrac{1 \text{ min}}{250 \ \cancel{\text{gal}}} \times 20{,}0000 \ \cancel{\text{gal}}$

Cancel unwanted units that match

Step 4: Do the math (divide numerator by denominator)

$? \ \underline{\text{mins}} = \dfrac{20{,}0000}{250} = 80 \text{ mins}$

OR
One Step Calculation

$? \text{ mins} = \dfrac{\text{Daily Water Demand}}{\text{Pump capacity}}$

Practice Problem: A well has the capacity to pump 300 gallons per minute. An operator has a daily water demand of 25,000 gallons a day. How many minutes is it necessary to operate the well pump to store a 1-day supply?

Step 1: Use unit cancellation step 1 to set up problem (? Unknown data with units)

? $\underline{\text{mins}}$ =

Step 2: Place known data with **same numerator unit** to position numerator unit.

NOTE: pump capacity data will need to be inverted

$$? \ \underline{\text{mins}} = \frac{1 \text{ min}}{300 \text{ gal}} \longleftarrow \boxed{\text{Positions the numerator unit}}$$

Step 3: To cancel unwanted **denominator unit**, next place known data with those same units in the numerator of the next data set to cancel unwanted units

$$? \ \underline{\text{mins}} = \frac{1 \text{ min}}{300 \cancel{\text{gal}}} \times 25{,}0000 \cancel{\text{gal}} \longleftarrow \boxed{\text{Cancel unwanted units that match}}$$

Step 4: Do the math (divide numerator by denominator)

$$? \ \underline{\text{mins}} = \frac{25{,}0000}{300} = \underline{\qquad} \text{ mins}$$

OR One Step Calculation

$$? \text{ mins} = \frac{\text{Daily Water Demand}}{\text{Pump capacity}} = \underline{\qquad\quad}\text{mins}$$

Determining number of days of supply based on customer demand (gal/hr)

Another type of calculation an operator needs to perform involves determining the number of days of supply that are available based on customer demand in gal/hr.

Example: An operator loses power because of an ice storm. There are 10,000 gallons of water in the storage tank. The customer demand is 200 gallons per hour. Approximately how many days of supply are available?

Step 1: Use unit cancellation step 2 to place data with **same numerator unit** to position numerator

$$? \text{ days} = \frac{1 \text{ day}}{24 \text{ hrs}}$$

Positions the numerator unit

Step 2: To cancel unwanted **denominator unit**, next place known data with those same units in the numerator of the next data set to cancel unwanted units

NOTE: pump capacity data will need to be inverted

$$? \text{ days} = \frac{1 \text{ day}}{24 \cancel{\text{hrs}}} \times \frac{1 \cancel{\text{hr}}}{200 \text{ gal}}$$

Cancel unwanted units that match

Step 3: To cancel unwanted **denominator unit**, next place known data with those same units in the numerator of the next data set to cancel unwanted units

$$? \text{ days} = \frac{1 \text{ day}}{24 \cancel{\text{hrs}}} \times \frac{1 \cancel{\text{hr}}}{200 \cancel{\text{gal}}} \times 10{,}000 \cancel{\text{gallons}}$$

Cancel unwanted units that match

Step 4: Multiply the denominator values

$$? \text{ days} = \frac{10{,}000}{24 \times 200} = \frac{10{,}000 \text{ days}}{4{,}800}$$

Step 5: Do the math (divide numerator by denominator)

$$? \text{ days} = \frac{10{,}000}{4{,}800} = 2.08 \text{ days}$$

Simplified Calculation

$$? \text{ days} = \frac{\text{Storage Tank Volume}}{24 \text{ hrs} \times \text{Pump Capacity (gal/hr)}} = \_\_\_\_\_\_\_ \text{days}$$

Practice Problem: An operator loses power because of an ice storm. There are 9,000 gallons of water in the storage tank. The customer demand is 175 gallons per hour. Approximately how many days of supply are available?

Step 1: Use unit cancellation step 2 to place data with **same numerator unit** to position numerator

$$? \text{ days} = \frac{1 \text{ day}}{24 \text{ hrs}}$$

Positions the numerator unit

Step 2: To cancel unwanted **denominator unit**, next place known data with those same units in the numerator of the next data set to cancel unwanted units

NOTE: pump capacity data will need to be inverted

$$? \text{ days} = \frac{1 \text{ day}}{24 \cancel{\text{hrs}}} \times \frac{1 \cancel{\text{hr}}}{175 \text{ gal}}$$

Cancel unwanted units that match

Step 3: To cancel unwanted **denominator unit**, next place known data with those same units in the numerator of the next data set to cancel unwanted units (**HINT:** Insert known **volume** to cancel gallon units)

$$? \text{ days} = \frac{1 \text{ day}}{24 \cancel{\text{hrs}}} \times \frac{1 \cancel{\text{hr}}}{175 \cancel{\text{gal}}} \times \underline{\quad\quad} \cancel{\text{gallons}}$$

Cancel unwanted units that match

Step 4: Multiply the denominator values

$$? \text{ days} = \frac{9{,}000}{24 \times 175} = \frac{9{,}000 \text{ days}}{\underline{\quad\quad}}$$

Step 5: Do the math (divide numerator by denominator)

$$? \text{ days} = \frac{9{,}000}{4{,}200} = \underline{\quad\quad} \text{ days}$$

Simplified Calculation

$$? \text{ days} = \frac{\text{Storage Tank Volume}}{24 \text{ hrs} \times \text{Pump Capacity (gal/hr)}} = \underline{\quad\quad}\text{days}$$

Operators can also use unit cancellation to help them solve math calculations they need to perform to dilute hypochlorite solutions and calculate dosage feed rates.

Before we look at the calculations, we need to understand two important concepts about the **active strength** and the **"active ingredient" weight** of a solution.

When we are using chemicals that aren't 100% strength, we need to factor in the active strength of the chemical into our mixing and feed rate calculations.

Active Strength is the percentage of a chemical or substance in a mixture that can be used in a chemical reaction. (also referred to as % purity)

Sodium and calcium hypochlorite solutions are not 100 percent pure. For example, the sodium hypochlorite typically used is 12.5% pure. That means that out of every gallon of hypochlorite, only 12.5% is the chlorine component (% purity which provides the active ingredient), and the other material (87.5%) is not chlorine.

"**Active ingredient" weight** is the number of pounds of "active ingredient" per gallon of a % solution that cause a chemical reaction.

- This "active ingredient" weight value is used in 2 ways:
  1. It is used when determining how many gallons are needed to mix a diluted solution for a day tank.
  2. It is used to determine the "gal/day" feed rate.

To calculate the weight of the “active ingredient” within that solution, we need the specific gravity of the solution which is found on the SDS sheet.

Calculating the Weight of the “Active Ingredient” of a % Solution Chemical

EXAMPLE: How many pounds of chlorine are there in a gallon of sodium hypochlorite that is 15% pure that has a specific gravity of 1.3?

Step 1: Solve weight equation (lbs/gal) for 1 gallon of chemical

Weight of a solution, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

$$1.3 \times 8.34 \frac{\text{pounds}}{\text{gallon}} = 10.84 \frac{\text{pounds}}{\text{gallon}}$$

Step 2: Determine the “active ingredient” weight of the chlorine based on the % purity of solution

a) Convert % purity of solution into a decimal:

$$\frac{15\%}{100\%} = 0.15$$

b) Multiply the weight of a gallon (from step 1) by the % purity of the product (as a decimal).

$10.84 \frac{\text{pounds}}{\text{gallon}} \times 0.15 = 1.63$ pounds of available chlorine in a gallon of 15% sodium hypochlorite

This **“active ingredient”** weight provides the pounds of available chlorine that are found in each gallon of 15% sodium hypochlorite solution. Within the 10.84 pounds of 15% sodium hypochlorite, there are 1.63 pounds of available chlorine (e.g., active ingredient).

We purchase sodium hypo in 12%-15% strength, but we may have to dilute it to a lower percent strength. The only information we have is the "active ingredient" weight of the original solution.

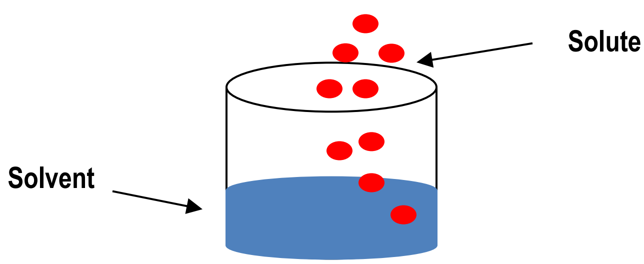
Using "active ingredient" weight value (lbs/gal) to dilute a solution for a day tank

Calculations for Mixing % Concentrations of a Chemical for a Day Tank

A day tank is used to store a limited supply of diluted chemical solution to be fed into the treatment system. The solution in a day tank can be diluted to a specific concentration (strength). The solution consists of two parts: the solute and the solvent.

1. Solute: The dry product that you are adding or the amount of dry product in a concentrated solution. (usually in pounds)

2. Solvent: The liquid which is dissolving the solute.



When you are adding a % solution to the solvent, you will have to convert the "lbs" of solute into "gals" of % solution.

The calculation to convert involves solving for "lbs" of solute and then converting those "lbs" into "gals" of % solution by using the "active ingredient" weight of the solution.

? lbs = Weight of water (e.g., density) $\frac{\text{lbs}}{\text{gal}}$ X Day tank volume (gallons) X %Diluted solution as a decimal

THEN use the "active ingredient" weight and unit cancellation to solve for gallons of % solution.

?gals = $\frac{1 \text{ gal}}{1.63 \cancel{\text{lbs}}}$ (inverted "active ingredient" weight) X ~~lbs~~ of solute

EXAMPLE: How many gallons of 15% sodium hypochlorite solution does it take to mix a 5% chlorine solution in a 100-gallon tank? There are 1.63 lbs of chlorine per gallon of 15% sodium hypochlorite solution. (e.g., "active ingredient" weight)

Step 1: Determine the # of pounds of chlorine that are needed for the diluted solution (5%) based on the volume of the day tank. (e.g., solute)

$$? \text{ lbs} = 8.34 \frac{\text{lbs}}{\cancel{\text{gal}}} \times 100 \ \cancel{\text{gal}} \text{ (day tank volume)} \times 0.05 \text{ (5\% as a decimal)} = 41.7 \text{ lbs}$$

Step 2: Use **"active ingredient**" weight with unit cancellation steps to convert **lbs**/gal to **gals**

Active Ingredient Weight of 15% hypo solution

Pounds of chlorine needed in diluted tank (Step 1)

$$?\text{gal} = \frac{1 \text{ gallon}}{1.63 \ \cancel{\text{lbs}}} \times 41.7 \ \cancel{\text{lbs}} = 25.6 \text{ gals of 15\% solution to create a 5\% solution}$$

OR

$$?\text{gal} = \frac{\text{lbs needed for diluted solution}}{\text{Active ingredient weight}}$$

Practice Problem: How many gallons of 15% sodium hypochlorite solution does it take to mix a 6% chlorine solution in a 100-gallon tank? There are 1.63 lbs of chlorine per gallon of 15% sodium hypochlorite solution. (e.g., "active ingredient" weight)

Step 1: Determine the # of pounds of chlorine that are needed for the diluted solution (6%) based on the volume of the day tank. (e.g., solute)

$$? \text{ lbs} = 8.34 \frac{\text{lbs}}{\cancel{\text{gal}}} \times 100\ \cancel{\text{gal}}\ \text{(day tank volume)} \times 0.06\ \text{(6\% as a decimal)} = \underline{\qquad}\ \text{lbs}$$

Step 2: Use "active ingredient" weight with unit cancellation steps to convert **lbs**/gal to **gals**

Active Ingredient Weight of 15% hypo solution

Pounds of chlorine needed in diluted tank (Step 1)

$$?\frac{\text{gal}}{1} = \frac{1 \text{ gallon}}{1.63\ \cancel{\text{lbs}}} \times \frac{50.04\ \cancel{\text{lbs}}}{} = \underline{\qquad}\text{gals}$$

OR

$$?\text{gal} = \frac{\text{lbs needed for diluted solution}}{\text{Active ingredient weight}}$$

The second way to use "active ingredient" weight is to use it to convert a "lbs/day" feed rate to a "gals/day" feed rate. This is necessary for liquid feed solutions.

Using "active ingredient" weight to determine the "gal/day" feed rate.

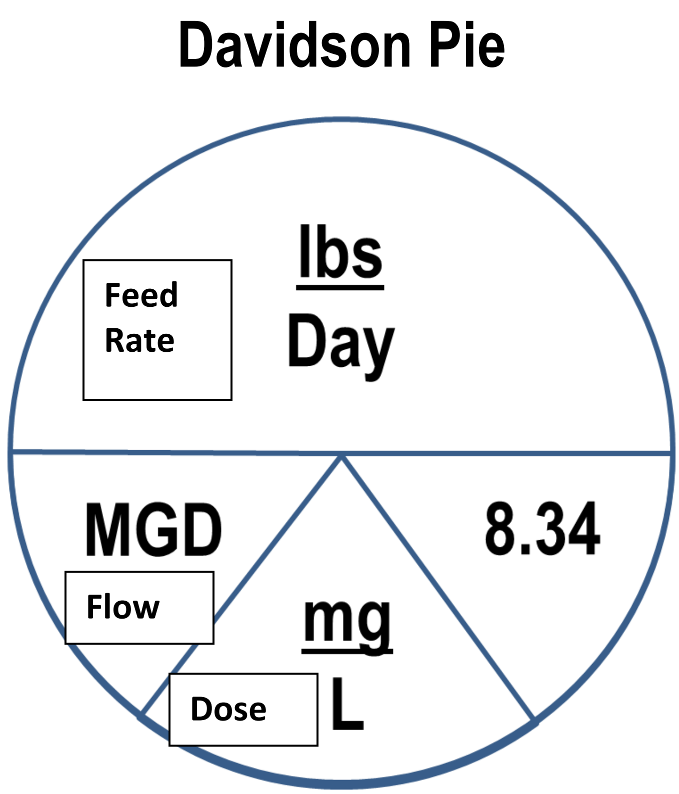
Let's begin with the basic "lbs/day" formula.

Chlorine Feed Rate Calculation

- To perform the calculation, you will need to know the amount of chlorine being added and the amount of water being treated.

Feed Rate, "lbs/day" = Flow (MGD) x Dosage (mg/L) x 8.34 lbs/gal

This formula is represented in the following diagram called the Davidson Pie which was created by Gerald Davidson, Manager, Clear Lake Oaks Water District, Clear Lake Oaks, CA.



Key Acronyms:

MG = million gallons
MGD = million gallons per day

Davidson Pie Diagram Interpretation and Formulas

This diagram can be used to solve for 3 different results: dosage, feed rate, and flow (or volume).

As long as you have 2 of those 3 variables, you can solve for the missing variable.

Davidson Pie Interpretation

Middle line = divided by (÷)
Bottom diagonal lines = multiply by (x)

In other words, here are the 3 equations that can be used with these variables:

1. **Feed Rate, lbs/day = Flow (MGD) or Volume (MG) x Dosage (mg/L) x 8.34** (which is the density of water)

2. Flow (MGD) = lbs/day ÷ (Dosage, mg/L x 8.34)

   Vertical Format: Flow(MGD) = $\dfrac{\textbf{Feed Rate (lbs/day)}}{\textbf{[Dosage (mg/L) x 8.34]}}$

3. Dosage (mg/L) = lbs/day ÷ (Flow, MGD x 8.34)

   Vertical Format: Dosage (mg/L) = $\dfrac{\textbf{Feed Rate (lbs/day)}}{\textbf{[Flow(MGD) x 8.34]}}$

We will only focus on the first equation that solves for feed rate in "lbs/day".

When you have a flow in gallons per minute (GPM) or gallons per day (GPD), you will need to convert those values into million gallons per day (MGD) before using the feed rate formula.

Converting from GPM to MGD before solving with the formula

Example: How many million gallons per day (MGD) are there in a 75 gallon per minute (gpm) flow rate?

Step 1: Convert gallons per minute into gallons per day using unit cancellation.

$$? \frac{\text{gal}}{\text{day}} = 75 \frac{\text{gal}}{\cancel{\text{minute}}} \times 60 \frac{\cancel{\text{minutes}}}{\cancel{\text{hour}}} \times \frac{24\ \cancel{\text{hours}}}{\text{day}} = 108{,}000 \frac{\text{gallons}}{\text{day}}$$

Step 2: Convert gallons per day into million gallons per day (MGD) using unit cancellation.

$$? \frac{\text{MG}}{\text{day}} = 1 \frac{\text{MG}}{1{,}000{,}000\ \cancel{\text{gallons}}} \times \frac{108{,}000\ \cancel{\text{gallons}}}{\text{day}} = 0.108\ \text{MGD}$$

Steps 1 and 2 can be combined like this:

Step 1: Convert gallons per minute into million gallons per day (MGD) using unit cancellation.

$$? \frac{\text{MG}}{\text{day}} = 1 \frac{\text{MG}}{1{,}000{,}000\ \cancel{\text{gallons}}} \times 75 \frac{\cancel{\text{gal}}}{\cancel{\text{minute}}} \times 60 \frac{\cancel{\text{minutes}}}{\cancel{\text{hour}}} \times \frac{24\ \cancel{\text{hours}}}{\text{day}} = 0.108 \frac{\text{MG}}{\text{day}}$$

You can also use the conversion of 1 day = 1440 mins (60 X 24) to remove 2 conversions (minutes/hour and hours/day)

Step 1: Convert gallons per minute into million gallons per day (MGD) using unit cancellation.

$$? \frac{\text{MG}}{\text{day}} = 1 \frac{\text{MG}}{1{,}000{,}000\ \cancel{\text{gallons}}} \times 75 \frac{\cancel{\text{gal}}}{\cancel{\text{minute}}} \times 1440 \frac{\cancel{\text{minutes}}}{\text{day}} = 0.108 \frac{\text{MG}}{\text{day}}$$

Converting from GPD to MGD before solving with the formula

Example: How many MGD are there in 150,000 gallons per day (GPD)?

Step 1: Convert gallons per day into million gallons per day (MGD) using unit cancellation.

$$?\frac{MG}{day} = \frac{1\ MG}{1{,}000{,}000\ \cancel{gallons}} \times \frac{150{,}000\ \cancel{gallons}}{day} = 0.15\ MGD$$

Now we are ready to insert the flow into the "lbs/day" feed rate formula and then use the "active ingredient" weight of the solution to determine how many gallons we need to feed.

Using "Active Ingredient" Weight to Convert Feed Rate from lbs/day to gals/day

Example: A water plant uses sodium hypochlorite (12%) to disinfect the water which provides 1.2 lbs/gal of available chlorine ("active ingredient" weight). The required dosage is 2.5 mg/L. They treat 118,000 gallons per day. How many **gallons** of sodium hypochlorite will need to be fed?

Step 1: Convert flow in gallons (per day) into MGD so that the feed rate (lbs/day) formula can be used.

$$?\ MGD = \frac{1\ MG}{1{,}000{,}000\ \cancel{gal}} \times \frac{118{,}000\ (\cancel{gal})}{1\ \ day} = 0.118\ MGD$$

Step 2: Solve for pounds per day (feed rate) for 100% pure chemical (no impurities).

Using the formula pounds per day = flow x dose x 8.34 = (0.118)(2.5)(8.34) = 2.46 pounds of chlorine is required.

Step 3: Use "active ingredient" weight with unit cancellation steps to convert lbs/day to **gals/day**

"Active Ingredient" Weight of 12% hypo solution

Feed Rate of 100% pure chlorine

$$?\frac{gal}{day} = \frac{1\ gallon}{1.2\ \cancel{lbs}} \times \frac{2.46\ \cancel{lbs}}{day} = \frac{2.05\ gals}{day}$$

Practice Problem: A water plant uses sodium hypochlorite (12%) to disinfect the water which provides 1.2 lbs/gal of available chlorine ("active ingredient" weight). The required dosage is 2.5 mg/L. They treat 35,000 gallons per day. How many **gallons** of sodium hypochlorite will need to be fed?

Step 1: Convert flow in gallons (per day) into MGD so that the feed rate (lbs/day) formula can be used.

$$? \text{ MGD} = \frac{1 \text{ MG}}{1{,}000{,}000\ \cancel{\text{gal}}} \times \frac{35{,}000\ (\cancel{\text{gal}})}{1 \text{ day}} = \underline{\hspace{2cm}} \text{MGD}$$

Step 2: Solve for pounds per day (feed rate) for 100% pure chemical (no impurities).

Using the formula pounds per day = flow x dose x 8.34 = (0.035)(2.5)(8.34) = ______ pounds of chlorine is required.

Step 3: Use "active ingredient" weight with unit cancellation steps to convert lbs/day to **gals/day**

Active Ingredient Weight of 12% hypo solution

Feed Rate of 100% pure chlorine

$$?\frac{\text{gal}}{\text{day}} = \frac{1 \text{ gallon}}{1.2\ \cancel{\text{lbs}}} \times \frac{\underline{\hspace{1.5cm}}\ \cancel{\text{lbs}}}{\text{day}} = \underline{\hspace{1cm}}\ \frac{\text{gals}}{\text{day}}$$

OR

$$?\text{gal} = \frac{\text{lbs of pure chlorine}}{\text{Active ingredient weight}} \text{ (Step 2)}$$

Summary of Steps for Solving Feed Formula Calculations in Gallons/Day for % Strength (i.e., % Purity) Solutions

Example: An operator wishes to achieve a dose 2.0 mg/L. How many gallons per day of 12% sodium hypochorite must be used to treat 45,000 gallons per day flow rate? The 12% hypo solution has an active strength of 1.2 lbs of chlorine/gallon of 12% hypochlorite solution.

Step 1: Convert flow in gallons (per day or per minute) into MGD so that the feed rate (lbs/day) formula can be used.

$$?MGD = \frac{1\ MG}{1{,}000{,}000\ \cancel{gal}} \times \frac{\text{volume of flow } (\cancel{gal})}{1\ day}$$ **OR**

$$?MGD = \frac{1\ MG}{1{,}000{,}000\ \cancel{gal}} \times \frac{\text{volume of flow } \cancel{(gal)}}{1\ \cancel{min}} \times \frac{1440\ \cancel{min}}{day}$$

Step 2: Solve for pounds (feed rate) for 100% pure chemical (no impurities).

$$?\ \frac{lbs}{day} = \text{Flow(MGD)} \times \text{dose(mg/L)} \times 8.34$$ = pounds of chlorine that are required.

$$= 0.045 \times 2 \times 8.34 = 0.75\ lbs/day$$

Step 3: Use "active ingredient" weight with unit cancellation steps to convert lbs/day to **gals/day**

"Active Ingredient" Weight of 12% hypo solution

Feed Rate of 100% pure chlorine

$$?\frac{gal}{day} = \frac{1\ gallon}{1.2\ \cancel{lbs}} \times \frac{0.75\ \cancel{lbs}}{day} = \frac{0.63\ gals}{day}$$

OR

$$?gal = \frac{\text{lbs of pure chlorine (Step 2)}}{\text{Active ingredient weight}}$$

Another calculation that operators need to make involves refilling a day tank based on a daily feed pump rate.

Refilling a Day Tank Based on a Daily Feed Pump Rate

Example: A water plant operator mixes 5 gallons of 15% hypochlorite solution in a 50-gallon day tank. If the feed pump uses 15 gallons of the solution in a 24-hour period, how many gallons of 15% solution must be added with water to refill the day tank to its 50-gallon capacity?

Step 1: Create the ratio of $\frac{\text{Original mixing volume (gals)}}{\text{Day Tank volume (gals)}} = \frac{\text{X(Unknown volume)}}{\text{Feed Pump Usage in a day}}$

$$\frac{5}{50} = \frac{X}{15}$$

Step 2: To get “X” alone, multiply 5 X 15 = 75 (in the numerator)

Step 3: Then divide numerator (75) by denominator (50) = 1.5 gal

$$\frac{75}{50} = 1.5 \text{ gal}$$

Practice Problem: A water plant operator mixes 4 gallons of 12.5% hypochlorite solution in a 30-gallon day tank. If the feed pump uses 10 gallons of the solution in a 24-hour period, how many gallons of 12.5% solution must be added with water to refill the day tank to its 30-gallon capacity?

Step 1: Create the ratio of $\frac{\text{Original mixing volume (gals)}}{\text{Day Tank volume (gals)}} = \frac{\text{X(Unknown volume)}}{\text{Feed Pump Usage in a day}}$

$$\frac{4}{30} = \frac{X}{10}$$

Step 2: To get "X" alone, multiply 4 X 10 = ______ (in the numerator)

Step 3: Then divide numerator (40) by denominator (30) = _________ gal

$\frac{40}{30}$ = ________gal

Key points for Process Control Calculations

- Remember to perform math calculations using the order of operation steps listed in this unit.
- You can use unit cancellation steps to solve for the units you are seeking. Be sure to begin with the numerator unit and cancel unwanted units until only the unknown denominator units remain.
- You can use the following equation to calculate chlorine dose, chlorine demand or chlorine residual.
    - Chlorine Dose (mg/L) = Chlorine Demand (mg/L) + Chlorine Residual (mg/L)
- To determine the number of minutes it takes to fill a storage tank, use the following equation:

$$\text{? mins} = \frac{\text{Daily Water Demand}}{\text{Pump capacity}}$$

- To determine the number of days of supply you have, use the following equation:

$$\text{? days} = \frac{\text{Storage Tank Volume}}{\text{24 hrs X Pump capacity (gal/hr)}}$$

- The Davidson Pie diagram can be used to solve for feed rate (lbs or lbs/day), flow (MGD) or dosage (mg/L) by using the following formulas:

1. Feed Rate, lbs/day = Flow (MGD) x Dosage (mg/L) x 8.34 (which is the density of water)

2. $$\text{Flow (MGD)} = \frac{\text{Feed Rate (lbs/day)}}{[\text{Dosage (mg/L)} \times 8.34]}$$

3. $$\text{Dosage (mg/L)} = \frac{\text{Feed Rate (lbs/day)}}{[\text{Flow(MGD)} \times 8.34]}$$

In order to use any of these formulas, all flows or volumes must be converted to either million gallons per day (MGD) or million gallons (MG).

- Specific gravity is used to calculate the **"active ingredient"** weight of a solution which provides you with the available lbs of chlorine/gallon of solution (e.g., "active ingredient" weight). The **"active ingredient"** weight is used when determining:
  - How many gallons are needed to mix a diluted solution for a day tank, using the following steps.

    Step 1: ? lbs = 8.34 $\frac{\text{lbs}}{\cancel{\text{gal}}}$ X Day tank volume X Diluted Solution % (as a decimal)

    Step 2: Convert **lbs**/gal to **gals** by dividing Step 1 "lbs" by active ingredient weight

    ?gal = $\frac{\text{lbs needed for diluted solution (Step 1)}}{\text{Active ingredient weight}}$

  - The feed rate in **gallons/day** for % solutions using the feed rate equation.

    Step 1: Solve for pounds (feed rate) for 100% pure chemical (no impurities).

    ? $\frac{\text{lbs}}{\text{day}}$ = Flow(MGD) x dose(mg/L) x 8.34 = pounds of chlorine that are required.

    Step 2: Convert lbs/day to **gals/day** by dividing Step 1 "lbs"/day by active ingredient weight

    ?gal = $\frac{\text{lbs of pure chlorine (Step \#1)}}{\text{Active ingredient weight}}$

- You can refill your day tank based on a daily feed pump rate by creating the following ratio:

  $\frac{\text{Original mixing volume (gals)}}{\text{Day Tank volume (gals)}} = \frac{\text{X(Unknown volume (gals)}}{\text{(Feed Pump Usage in a day)}}$

  - To get "X" alone, multiply original mixing volume X Feed Pump Usage in a day (numerator)
  - Then divide numerator by the denominator (day tank volume)

.

☑ Exercise for Unit 3 – Process Control Calculations

1. In order to use the Feed Rate formula which is lbs/day = Flow x Dosage x 8.34, name the units of measurement for the flow:

   a) MGD

   b) gpm

   c) gpd

   d) All of the above units can be used

2. If you have a flow in gpm, what calculation do you use to convert it to MGD?

   a) Multiply gpm X 24 and divide by 1,000,000

   b) Multiply gpm x 60 and divide by 1,000,000

   c) Multiply gpm x 1440 and divide by 1,000,000

   d) Divide flow in gpm by 1,000,000

3. If you have a flow in gal/day, what calculation do you use to convert it to MGD?

   a) Divide flow in gpd by 100

   b) Divide flow in gpd by 10,000

   c) Divide flow in gpd by 100,000

   d) Divide flow in gpd by 1,000,000

4. When using “active ingredient” weight to solve for “gallons”, what calculation do you use?

   a) ? gals = $1 \frac{\text{gal}}{1.63 \text{ lbs}}$ X “lbs” (either needed to dilute day tank solution or as a % solution feed rate)

   b) ? gals = $1.63 \frac{\text{lbs}}{\text{Gal}}$ X “lbs” (either needed to dilute day tank solution or as a % solution feed rate)

Refer to the ***“Summary of Variations of WDC Math Problems”*** table to see all the problems that we solved in Unit 3.

Unit 4 – PA Act and Regulations

Learning Objectives

- Identify key regulations that directly affect the water treatment plant operator.
- Identify the maximum contaminant levels, and monitoring and reporting requirements for selected regulated contaminants.

Safe Drinking Water Act

The **Safe Drinking Water Act** authorizes EPA to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water. These standards are divided into:

Primary Standards – National Primary Drinking Water Regulations (NPDWRs or primary standards) are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of specific contaminants in drinking water.

- Some contaminants are regulated by establishing a specific maximum concentration. These **maximum concentrations** are called **maximum contaminant levels** (MCLs) or **maximum residual disinfectant levels** (MRDLs). Some example MCLs and the only MRDL are listed below.

  The **maximum residual disinfectant level (MRDL)** is the maximum permissible level of a disinfectant added for water treatment that may not be exceeded at the consumer's tap without an unacceptable possibility of adverse health effects.

Contaminant	MCL or MRDL
Total Trihalomethanes (TTHMs), a DBP	0.080 mg/L
Haloacetic Acids (HAA5), a DBP	0.060 mg/ L
Bromate, a DBP	0.010 mg/ L
Chlorite, a DBP	1.0 mg/L
Benzene	0.005 mg/ L
Diquat	0.02 mg/ L
Chlorine (as Cl2)	4.0 mg/ L as maximum residual disinfectant level (MRDL)

- Other contaminants are regulated by requiring specific treatment techniques and performance requirements that will assure their removal.

Secondary Standards – National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

- Pa. DEP **does** require monitoring for secondary contaminants and is obligated to require public notification and treatment if the secondary MCLs are violated. Here are the secondary contaminants and their MCL values.

Contaminant	MCL
Aluminum	0.2 mg/L
Chloride	250 mg/L
Color	15 color units
Corrosivity	Non-corrosive
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 Threshold Odor Number (TON)
pH	6.5 – 8.5
Silver	0.1 mg/L
Sulfate	250 mg/ L
Total Dissolved Solids (TDS)	500 mg/L
Zinc	5 mg/L

Selected Federal and State Regulations

The Safe Drinking Water Act serves as the "springboard" for all Federal drinking water regulations. This section discusses some, but not all, of the more important rules and describes the major provisions of each.

Stage 1 Disinfectants and Disinfection Byproduct Rule: This rule became effective February 16, 1999. Pa. DEP has primacy for enforcement. This rule sets maximum contaminant levels (MCL's) for total trihalomethanes (TTHM's) and the total of five haloacetic acids (HAA5). It also sets maximum disinfectant residual concentrations for chlorine, chloramines, and chlorine dioxide. Some of the major provisions include:

- Applies to all public water systems that add a disinfectant during **any** part of the water treatment process.
- Sets MCL for TTHM's at 0.08 mg/L (80 parts per billion or ppb) and MCL for HAA5 at 0.06 mg/L (60 ppb).
    - For groundwater systems serving less than 500 people, the 2 required sampling points are located in the **distribution system.**
        - TTHM: 1 TTHM sample from highest TTHM location
        - HAA5: 1 HAA5 sample from highest HAA5 location
        - May be 1 **dual sample set** at the same location ***IF*** the highest TTHM concentration and highest HAA5 concentration occur at same location and during same month.
- Sets MCL for chlorite (a by-product of chlorine dioxide) at 1.0 mg/L and MCL for bromate (a by-product of ozone) at 0.01 mg/L (10 ppb).
- Sets maximum residual disinfectant levels (MRDL's) of 4.0 mg/L (as Cl_2) for chlorine, 4.0 mg/L (as Cl_2) for chloramines, and 0.8 mg/L for chlorine dioxide (as ClO_2).

Stage 2 is being phased in for all systems based on their population served and their source type (G or S)

Stage 2 Disinfectants and Disinfection Byproduct Rule: This rule became effective in PA in December 2009. Some of the major provisions include:

- Compliance is now determined as a **locational running annual average** (LRAA) at each TTHM and HAA5 monitoring site to better protect customers.

- Requires systems to submit a **monitoring plan** to identify locations and the sample collection schedule for TTHM/HAA5 samples.

Ground Water Rule: This rule became effective in PA in December 2009. Some of the major provisions include:

- Community groundwater systems are required to provide continuous disinfection and at least 4-log treatment of viruses (99.99% removal and/or inactivation). **NOTE:** Noncommunity water systems are not required to provide continuous disinfection if they are in compliance with the Total Coliform Rule. In other words, if they have never had a positive sample for total coliforms, fecal coliforms or *E. coli* they are not required to provide continuous disinfection.
- Community groundwater systems are required to maintain at each groundwater entry point a minimum residual disinfection concentration approved by DEP to provide 4-log treatment of viruses.
- DEP must conduct sanitary surveys that address the 8 components (source, treatment, distribution system, finished water storage, pumps/facilities/controls, monitoring, reporting and data verification, system management and operation, and operator compliance with state requirements) every 3 years. Community water systems must address any significant deficiencies DEP has described in a written notice no later than 30 days after DEP identifies the significant deficiency.

Total Coliform Rule: This rule became effective December 31, 1990. Pa. DEP has primacy for enforcement. This rule sets monitoring and compliance requirements for coliform bacteria.

Coliform bacteria make good indicator organisms because:

- They are always present when pathogens are present.
- The testing method for detection is easy and reliable.
- When they are absent, we can assume that pathogens are also absent.

Some of the major provisions include:

- All systems must have a written sample siting plan.

- For Community Water Systems, the number of samples is based on minimum population served.

- If any samples are positive for total coliforms, repeat samples (e.g., check samples) must be taken as follows:
  - Systems that collect more than one sample per month must collect at least three repeat samples within 24 hours for each sample that tested positive for total coliforms.
  - Systems that collect only one sample per month must collect at least four repeat samples within 24 hours for each sample that tested positive for total coliforms.
  - Systems must continue to collect repeat samples until all samples are negative or it is determined that the system has violated the MCL.
  - Systems that collect less than five samples per month must collect at least five routine samples during the month immediately following the positive sample.
  - Any sample that tests positive for total coliforms must be analyzed for *E. coli* or fecal coliforms.
- Water systems that collect fewer than five routine samples per month must undergo a sanitary survey every five years.

NOTE: Revisions to the Total Coliform Rule will become effective April 1, 2016. Contact your local DEP sanitarian for the revisions to this rule.

Sample Collection Techniques

Total and Fecal Coliform Bacteria and Heterotrophic Plate Count

Sampling Equipment:

Container:

- (3) 125 mL blue-capped bottles prefixed with sodium thiosulfate and sterilized.

Sample Collection Procedure:

1. Locate an appropriate sample tap. Select a clean, leak-free tap that provides enough clearance to fill the bottle. Remove aerator and screen.
2. Turn on cold water tap and allow system to flush until water temperature has stabilized (2-3 minutes). Reduce flow (to thickness of pencil).
3. Remove cap and hold in hand. Do not touch the inside of the cap or bottle. Fill each sample bottle to neck (leave airspace) and do not overflow.
4. Cap. Invert several times to mix.

Shipping/Handling:

- Fill out labels. Indicate initials of sample collector, sample ID#, date, time, sample location, requested parameters and preservative(s).
- Affix legal seal to bottle.
- Place 125 mL samples in ziploc baggie.
- Ice or refrigerate samples at 4°C from time of collection to analysis.

These procedures support the **"chain of custody"** which identifies the responsible parties for sample collection, storage, transfer, and lab analysis.

Arsenic Rule: This rule became effective March 23, 2001. Pa. DEP has primacy for enforcement. This rule reduces the MCL for arsenic in drinking water from its previous concentration of 0.05 mg/L (50 ppb) to 0.01 mg/L (10 ppb). This rule also examines the "best available technologies" (BAT's) for arsenic removal. Some of the BAT's discussed in this rule are summarized in the table below:

Table 4.1: Best Available Technologies For Arsenic Removal

Treatment Technology	Maximum Percent Removal
Ion Exchange	95
Activated Alumina	95
Reverse Osmosis	>95
Modified Coagulation and Filtration	95
Modified Lime Softening	90

- Groundwater systems typically sample once every 3 years for arsenic.
- When systems have 3 consecutive rounds of triennial (3 year) monitoring results for arsenic that is reliably and consistently below the MCL (e.g. 0.008 mg/L or less), they can submit a waiver application to DEP to request a 9 year monitoring frequency. If they meet the waiver application criteria, DEP will grant this reduced monitoring frequency.

Lead and Copper Rule: This rule became effective in 1991 with revisions that became effective April 11, 2000. Pa. DEP has primacy for enforcement. This rule deals mainly with lead and copper levels in water at the customers' tap. Major provisions of this rule include:

- Requires monitoring of lead and copper levels at customer taps. Monitoring requirements vary, depending upon the size of the system.
  - Monitoring requirements are broken down by systems serving more than 50,000 persons, systems serving 3,301 to 50,000 persons, and systems serving 3,300 or fewer persons.
  - Transient non-community water systems are excluded from this rule.
- Systems where lead and copper levels at the customer tap exceed action levels in the 90th percentile sample result (0.015 mg/L for lead and 1.3 mg/L for copper) must institute corrosion control practices. This usually involves additional chemical treatment at the water treatment plant to raise pH and make the water more stable and less corrosive.
- Follow-up monitoring is required to verify corrosion control practices are working.
- Water systems must provide educational information to their customers outlining the causes of elevated lead and copper levels, the health effects of lead and copper, and actions the customers can take on their own to reduce their risk of exposure.

Pennsylvania Water Supply Manual

Pa. DEP publishes a Pennsylvania Water Supply Manual that describes design and operation requirements under Pennsylvania regulations. The Manual is divided into parts:

- **Community System Design Standards** – covers design requirements for water treatment processes, facilities, and distribution for community systems.

- **Non- Community System Design Standards** - covers design requirements for water treatment processes and facilities for non-community systems.

- **Bottled Water, Bulk Water Hauling, Water Vending Machines, and Retail Water Facilities** – covers requirements for processing and handling bottled water and bulk water hauling equipment.

- **Operations and Maintenance** – provides guidance on system start-up, operation, maintenance, and monitoring and reporting requirements.

- **Emergency Response** – describes various types of hazards, accidents, and failures that can affect water treatment plant operations and provides guidance for developing appropriate response plans.

- **Cross-Connection Control/Backflow Prevention** - covers acceptable means and methods for preventing cross connections and backflow between non-potable and potable water systems.

Key Monitoring and Reporting Requirements

Microbiological (Coliform)

- Must be monitored monthly. The required number of samples is based on the population served.
- Samples are taken from the distribution system.
- A system is in violation if:
  - **Tier 1 Acute violation:** Any sample (routine or check) is fecal or *E. coli* coliform positive AND at least one check sample is total coliform positive.
  - **Tier 1 Acute violation:** If the fecal or *E. coli* test is not done as a follow-up analysis to the original total coliform positive sample, the check sample shall be considered fecal positive.

Here's a table that summarizes the acute TCR violations:

Table 4.2: Tier 1 Acute MCL violation if the following conditions exist:

	Total Coliform	Fecal or *E. coli*
Routine Sample	+	+
Associated Check Sample	+	

OR

	Total Coliform	Fecal or *E. coli*
Routine Sample	+	
Associated Check Sample	+	+

- **Tier 2 Monthly violation:** If two or more monthly samples (for systems collecting 1 to 39 samples per month) or more than 5% of all samples collected (for systems collecting 40 or more samples per month) are coliform positive.

Microbiological (source water *E. Coli*)

For groundwater systems that have not yet installed 4-log treatment of viruses, within 24 hours of notification of a total coliform positive routine sample, collect at least one raw sample from each groundwater source that is connected to the distribution system from which the total coliform positive sample was collected. Analyze raw sample for ***E. coli***.

Inorganic Chemicals

- For groundwater sources, one sample every three years is required or quarterly samples for at least 4 consecutive quarters if initial sample is over the MCL.
- Samples are taken from each point water enters the distribution system. (e.g., entry point)
- A system is in violation if average of routine and check samples exceeds the MCL for any regulated inorganic chemical contaminant.

Volatile Organic Chemicals and Synthetic Organic Chemicals

- One annual sample is required or quarterly samples for at least 4 consecutive quarters if initial sample is over the MCL.
- Samples are taken from each point water enters the distribution system. (e.g., entry point)
- A system has exceeded the MCL if average of routine and check samples exceeds the MCL.

For nitrate and nitrite samples, note that quarterly monitoring is triggered when a sample is over 50% of the MCL.

Nitrate/Nitrite

- One annual sample is required or quarterly samples for at least 4 consecutive quarters if initial sample is over 50% of the MCL.
- Samples are taken from each point water enters the distribution system. (e.g., entry point)
- A system has exceeded the MCL if average of routine and check samples exceeds the MCL.

Disinfection Byproducts

- Sampling requirements (frequency, number of samples, type of sample) for TTHM's and HAA5 vary according to source type and population served.
- Samples are taken from the locations within the **distribution system** that are or likely to cause high levels of TTHMs and HAA5s. (Stage 2)
    - For **surface water or GUDI systems serving less than 3, 300 people** and **groundwater systems serving less than 500 people:** TTHM and HAA5 samples are individual samples (not paired) and are collected at the highest TTHM site and the highest HAA5 even if those sites are at different locations. (Stage 2)
- A system has exceeded the MCL if the locational running annual average of **any site** exceeds the MCL. (Stage 2)

Radionuclides

- Level is based on one sample every four years (for groundwater systems).
- Samples are taken from the distribution system.

DPD – A commonly used method for measuring **chlorine residual** (total, free and combined) in water, using either burette titration or a color comparison to a standard. DPD is an abbreviation for N, N-**d**iethyl-***p***-phenylene-**d**iamine.

grab sample – is a single sample collected at a specific time and location.

Chlorine Residual Requirements

- **For groundwater systems:**
    - **Entry Point:** Minimum **free chlorine** entering the distribution system (i.e., **entry point**) no less than 0.40 mg/L or its equivalent as approved by DEP or other minimum residual approved by DEP to provide 4-log treatment of viruses.
        - A breakdown in disinfection treatment occurs when the **groundwater** system demonstrating at least 4-log treatment of viruses fails to meet, for greater than 4 continuous hours, the minimum DEP-approved residual disinfection residual requirements at the **entry point**.
        - Disinfectant residual must be monitored continuously **except** for groundwater systems serving 3,300 or fewer people. The lowest value recorded each day is reported.
            - Groundwater systems serving 3, 300 or fewer people shall take a **daily grab sample** at the entry point or other location approved by DEP **during the hour of peak flow.**
    - **Distribution:** A disinfectant residual acceptable to DEP shall be maintained through the **distribution system** of the community water system sufficient to assure compliance with the microbiological MCLs.
        - DEP will determine the acceptable residual of the disinfectant considering factors such as type and form of disinfectant, temperature and pH of the water, and other characteristics of the water system.
        - Chlorine residual samples are taken at the **same locations at representative points within the distribution system and at the same time as the total coliform samples.**

Lead and Copper

- Samples for lead and copper must be taken every six months, unless the system is below the action levels for lead and copper for two consecutive six month periods or has optimized corrosion control. In that case samples must be taken annually.

- Small or medium sized systems (less than 10,000 persons served) that are below the action levels for lead and copper for three consecutive years may reduce sampling to once every three years. Large systems that are below the action levels for lead and copper for three consecutive years may reduce the numbers of samples taken.

- Samples are taken at the point where water enters the distribution system and at a number of locations throughout the distribution system. The number of distribution samples that must be taken depends upon the number of persons served. A lead and copper sample is a **first-draw** (not flushed) **sample collected from a cold water tap** (usually a customer's faucet).

- A system must implement appropriate treatment techniques if the 90^{th} percentile value of the samples collected in any monitoring period exceeds the action levels for lead or copper.

- The action levels for lead and copper are 0.015 mg/L and 1.3 mg/L.

Secondary Contaminants

- The secondary contaminants most commonly monitored by the water treatment plant operator include: color, corrosivity, aluminum, chlorides, iron, manganese, odor, pH, and total dissolved solids.

The water treatment plant operator is responsible for recording, compiling, and reporting the results of water quality analysis to Pa. DEP.

One Hour Reporting Requirements:

Additionally, the water supplier has one hour reporting requirements for:

- All Tier 1 violations or situations
- Most Tier 2 violations or situations and
- Any sample that requires a check sample.

Tier 1 and Tier 2 Definitions:

- Tier 1 violations or situations are those that cause short-term, acute health effects. In the public notice, you are telling your customers to take specific actions like “boil your water for 1 minute” or “Don’t drink the water.” Drinking the water with an acute contaminant would make you sick **very quickly**. Water suppliers have 24 hours to issue a Tier 1 PN.
- A Tier 2 violation is a violation that has long-term chronic health effects. This means that it would take 70 years of drinking 2 liters of water each day to see the health effect. For this reason, water suppliers have 30 days to issue a Tier 2 PN. Also, the message within the PN does not require your customers to take any additional action.

The following violations or situations must be reported to the local Pa. DEP Regional Office within **one hour** of their occurrence:

Community Groundwater Systems Tier 1 Acute Violations or Situations under 25 Pa. Code § 109.408(a):

1. Violation of the maximum contaminant level (MCL) for total coliforms, when fecal coliforms or *E. coli* are present in the water distribution system, or when water supplier fails to test for fecal coliforms or *E. coli* when any check sample tests positive for total coliforms.
2. Violation of the MCL for nitrate, nitrite or total nitrate and nitrite or failure to take a confirmation sample within 24 hours of notification of an initial exceedance.
3. Violation of the maximum residual disinfectant level (MRDL) for chlorine dioxide when the water supplier does not take the required samples in the distribution system on the day following an entry point MRDL exceedance or when one or more samples taken in the distribution system exceeds the MRDL.
4. For groundwater systems, detection of *E. coli* in source water samples.
5. For groundwater systems, a breakdown in treatment that includes failing to maintain the minimum entry point disinfectant residual for more than four hours or failing to maintain adequate CTs (i.e. the calculated value of chlorine residual multiplied by the contact time) for more than four hours.

6. Occurrence of a waterborne disease outbreak or other emergency situation under 25 Pa. Code § 109.701(a)(3)(iii) that adversely affects the quality or quantity of the finished water and has a significant potential to have serious adverse effects on human health as a result of short-term exposure. Examples of emergency situations include:

- Failure or significant interruption in key water treatment processes involving disinfection, filtration or nitrate removal.
- Natural disaster that disrupts the water supply or distribution system.
- Chemical spill.
- An unexpected loading of possible pathogens into the source water that significantly increases the potential for drinking water contamination.
- An overfeed of a drinking water treatment chemical that exceeds a published maximum use value, such as National Sanitation Foundation's "Maximum Use Value," as applicable.
- A situation that causes a loss of positive water pressure in any portion of the distribution system where there is evidence of contamination or a water supplier suspects a high risk of contamination.
- A lack of resources that adversely affect operations, such as staff shortages, notification by the power utility of planned lengthy power outages or imminent depletion of treatment chemical inventories.

7. Other violations or situations with significant potential for serious adverse human health effects from short-term exposure.

Community Groundwater Systems Tier 2 Non-Acute Violations under 25 Pa. Code § 109.409(a):

1. Violation of the MCL for a chemical (including secondaries) or radiological contaminant.
2. Violation of the MCL for total coliforms occurs when total coliforms are present in the water distribution system in either routine or check samples. For systems taking less than 40 samples per month, more than one positive sample per month constitutes a violation.
3. Violation of the lead and copper rule treatment technique occurs when a system fails to install corrosion control treatment, maintain the range of values for the water quality parameter performance level requirements, or comply with the lead service line replacement requirements.
4. Failure to take corrective actions for a significant deficiency within required time frame or comply with a DEP-approved corrective action plan or schedule.

Check Samples Required under 25 Pa. Code § 109.301:

1. A sample result that requires the collection of check samples.

Public Notification Requirements

Tier 1 violations and situations require a Tier 1 PN
Tier 2 violations and situations require a Tier 2 PN
Tier 3 violations and situations require a Tier 3 PN

- The Tier 1 violations or situations pose **immediate** health effects and therefore require a public notice issued within 24 hours.
- Tier 2 violations pose **chronic** (long term) health effects and therefore require a public notice issued within 30 days.
- Tier 3 violations do not pose health effects

Table 4.3: Public Notification Delivery Deadlines

Tier	Deadlines for Notice	Deadlines to Contact DEP*
1	24 hours	1 Hour**
2	30 days	1 Hour for MCL, MRDL,TT Violations
3	1 year***	Not required

Notes:

***** For all Tiers, a copy of each notice issued must be sent to DEP within 10 days of the issuance, along with a certification that all PN requirements have been met.

****** For Tier 1, systems must also initiate consultation with DEP within 24 hours and issue a "Problem Corrected" notice within 24 hours of correcting the problem.

******* DEP recommends consolidating all Tier 3 violations/situations occurring within a given year into an annual notice.

Unit 4 Exercise

1. The barium level in your treated water has exceeded the MCL of 2 mg/L.

    a. Are you in violation? ______________

    b. Are you required to notify DEP within 1 hour? ___________

    c. Name the tier type of the public notice you must issue? _________ (Options: Tier 1, Tier 2, or Tier 3 PN)

    d. In what timeframe is this public notice required? ___________

2. Under the Lead and Copper Rule, where should the first-draw lead and copper tap sample be collected?
    a) Outside spigot
    b) Kitchen hot water tap
    c) Kitchen cold water tap
    d) Laundry sink

3. Indicate where the samples are collected (entry point or distribution) for the following contaminants:

    Total coliform samples ______________
    Nitrate samples ______________
    Arsenic samples ______________
    VOCs ______________
    SOCs ______________
    TTHM/HAA5 samples ______________

4. In a Tier 1 PN, how long should customers boil their water?

    a) 30 seconds
    b) 1 minute
    c) 2 minutes
    d) 5 minutes

5. When collecting a total coliform sample, the collector should leave air space at the top of the container.

   a) True
   b) False

Unit 4 Key Points

The United States Environmental Protection Agency (EPA) studies health issues related to water quality and develops regulations, standards, and guidance documents related to drinking water.

The Pennsylvania Department of Environmental Protection (Pa. DEP) has **primacy**, i.e. responsibility for enforcement of EPA drinking water regulations.

- DEP does require monitoring for secondary contaminants and is obligated to require public notification and treatment if the secondary MCLS are violated.

Community groundwater systems are required to provide continuous disinfection and at least 4-log treatment of viruses (99.99% removal and/or inactivation).

NOTE: Noncommunity water systems are not required to provide continuous disinfection if they are in compliance with the Total Coliform Rule.

There are many regulations that dictate the various duties of a water treatment operator. It is the operator's responsibility to maintain full knowledge of not only existing water treatment requirements, but also new requirements as they are developed.

- Water suppliers are required to notify DEP within one hour for the following types of violations or situations:
  1. Tier 1 violations or situations
  2. Tier 2 violations or situations
  3. A sample result that requires a check sample
- Water suppliers are required to issue a **Tier 1 public notice within 24 hours** experiencing a Tier 1 acute violation or situation.
- Water suppliers are required to issue a **Tier 2 public notice within 30 days** of experiencing a Tier 2 non-acute violation or situation.
- Water suppliers should post a copy of the Tier 1 violations or situations in an area of their plant so they can respond quickly and appropriately to these acute situations (see pages 4-15 and 4-15 for the Tier 1 descriptions).