How to Conduct a Sanitary Survey of Drinking Water Systems

A Learner's Guide

DESIGNED TO ASSIST IN THE DELIVERY OF A
SANITARY SURVEY TRAINING COURSE

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Disclaimer

The Drinking Water Protection Division of the U.S. Environmental Protection Agency (EPA) Office of Ground Water and Drinking Water has reviewed and approved this document for publication. This document provides guidance to personnel conducting sanitary surveys and contains several recommended questions. This guide uses the terms “sanitary survey” and “surveyor” exclusively to avoid any confusion due to multiple definitions of other terms. The term “state” where used in this document includes EPA where EPA is the Safe Drinking Water Act (SDWA) primacy authority and where applicable.

The statutory provisions and EPA regulations described in this document contain legally binding requirements. This document is not a regulation itself, nor does it change or substitute for those provisions and regulations. Thus, it does not impose legally binding requirements on EPA, states, or the regulated community. This document does not confer legal rights or impose legal obligations upon any member of the public.

This document is not intended to be comprehensive and other approaches may be appropriate for conducting sanitary surveys and satisfying the requirements of the National Primary Drinking Water Regulations (NPDWR) for sanitary surveys. While EPA has made every effort to ensure the accuracy of the discussion in this document, the obligations of the regulated community are determined by statutes, regulations or other legally binding requirements. In the event of a conflict between the discussion in this document and any statute or regulation, this document would not be controlling.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

ANSI	American National Standards Institute
APU	Auxiliary Power Unit
APWA	American Public Works Association
ASCE	American Society of Civil Engineers
AVB	Atmospheric vacuum breaker
AWWA	American Water Works Association
BAT	Best Available Technology
$CaCO_3$	Calcium carbonate
CFR	Code of Federal Regulations
Cl_2	Chlorine
ClO_2	Chlorine dioxide
CR	Continuous regeneration
CT	Residual disinfectant concentration (mg/L) X Contact time (minutes)
CWS	Community water system
DBP	Disinfection Byproducts
DBPRs	Disinfectants and Disinfection Byproducts Rules (Stage 1 and Stage 2)
DE	Diatomaceous Earth
DPD	N,N Diethyl-1,4 phenylenediamine sulfate
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GAC	Granular activated carbon
GPCD	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
GWR	Ground Water Rule
GWUDI	Ground Water under Direct Influence of Surface Water
HAA5s	Haloacetic acids
HDPE	High-density polyethylene
HOCl	Hypochlorous acid
IESWTR	Interim Enhanced Surface Water Treatment Rule
IR	Intermittent regeneration process
$KmnO_4$	Potassium permanganate
LCR	Lead and Copper Rule
LRAA	Locational Running Annual Average
LT1ESWTR	Long Term 1 Enhanced Surface Water Treatment Rule
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
mA	Milliamp
MCL	Maximum Contaminant Level
MF	Microfiltration
mg/L	Milligrams per liter

mm	Millimeters
MRDL	Maximum Residual Disinfectant Level
$NaClO_2$	Sodium chlorite
NF	Nanofiltration
NPDWR	National Primary Drinking Water Regulations
NSDWR	National Secondary Drinking Water Regulations
NSF	NSF International
NTNCWS	Non-Transient Non-Community water system
NTU	Nephelometric Turbidity Unit
Ocl	Hypochlorite ion
O&M	Operation and maintenance
OEL	Operational Evaluation Level
OSHA	Occupational Safety and Health Administration
PAC	Powdered activated carbon
pH	Hydrogen ion concentration
PHS	U.S. Public Health Service
PLC	Programmable Logic Controller
PM	Preventive maintenance
PPE	Personal protective equipment
ppm	Parts per million
PRV	Pressure reducing valve
psi	Pounds per square inch
PSOCs	Potential sources of contamination
PVB	Pressure Vacuum Breaker
PVC	Polyvinyl chloride
PWS	Public Water system
QCRV	Quality Control Release Valve
RADs	Radionuclides
RO	Reverse osmosis
RPP	Reduced Pressure Principle Backflow Preventer
RPZ	Reduced Pressure Zone
RTCR	Revised Total Coliform Rule
SCADA	Supervisory Control and Data Acquisition
SDS	Safety Data Sheets (formerly MSDS: Material Safety Data Sheets)
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
SOCs	Synthetic organic chemicals
SOP	Standard operating procedure
SWAP	Source water assessment program
SWTP	Surface water treatment plant
SWTR	Surface Water Treatment Rule
TDS	Total dissolved solids

TNCWS	Transient Non-Community water system
TT	Treatment technique
TTHMs	Total trihalomethanes
UF	Ultrafiltration
µm	Micrometer
UV	Ultraviolet (light)
VOCs	Volatile Organic Contaminants
WHPP	Wellhead Protection Program

Introduction

A sound sanitary survey program is an essential element of an effective primary enforcement (primacy) agency Public Water System Supervision program. A sanitary survey provides a snapshot of the operating status of a public water system (PWS). Utilizing this information, staff can evaluate the status of a system. Well-executed and documented sanitary surveys are a proactive and protective public health measure and are fundamental to helping the PWSS program ensure that a water system is providing safe drinking water and protecting public health.

Every primacy agency is required to have a sanitary survey program that meets the requirements of the Safe Drinking Water Act (SDWA). Title 40 of the Code of Federal Regulations (CFR) Part 142.16 describes specific requirements for the sanitary survey program and its authorities. Every primacy agency must create a standard measurement system for evaluating each of the eight essential elements to ensure consistency when conducting sanitary surveys.

The intent of this guide is to provide sanitary survey students with an additional resource they can reference in conjunction with their field guide, for use during field and classroom training, and during subsequent mentor-led sanitary surveys.

This learner's guide references the voluntary consensus standards for PWSs by the Water Supply Committee of the Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, "Recommended Standards for Water Works, 2018 Edition" commonly referred to as the "Ten States Standards." This guide also references industry standards of the American National Standards Institute (ANSI) and NSF International (NSF) and the American Water Works Association (AWWA). These references are provided for information only. Any state regulations, standards, policies and recommendations would be applicable to PWSs in those states.

Disclaimer: *Terminology may vary from agency to agency. This guide uses the terms "sanitary survey" and "surveyor" exclusively to avoid any confusion due to multiple definitions of other terms. A "surveyor" in the context of this guide refers to someone conducting a sanitary survey.*

Learning Objectives

By the end of this chapter, students should be able to:

- Define "sanitary survey," identify the eight elements of a sanitary survey, describe sanitary and significant deficiencies, and explain the purpose of a sanitary survey of a PWS.
- Explain the "multiple barrier" approach and understand how a breach of one or more barriers indicates conditions or deficiencies that may cause public health risks in a typical PWS.
- Understand the focus of the training is the identification of conditions or deficiencies that may cause public health risks in a typical PWS.
- Understand the components of sanitary survey training, and the layout of the Learner's Guide and Field Guide.
- Identify knowledge gaps that will require additional training.

What is a Sanitary Survey?

Definition: A sanitary survey includes but is not limited to, an onsite review of the water source, treatment, pumping and storage facilities, equipment, operation, maintenance and monitoring compliance of a PWS to evaluate the adequacy of the system's capability for producing and distributing safe drinking water (see 40 CFR 141.2 and 40 CFR 141.401(b) for regulatory definitions).

The elements evaluated in a sanitary survey provide multiple barriers for the protection of public water supplies. A sanitary survey serves as an important and proactive public health measure, identifying areas that are in need of additional attention and resources or improved performance by the PWS to ensure continuing compliance with the National Primary Drinking Water Regulations (NPDWR) as well as State regulations and requirements. The on-site sanitary survey also serves to maintain continuing communication between the PWS and the state and provides an opportunity to inform water system personnel of new regulations or requirements, training opportunities and other available resources and, if appropriate, provide technical assistance.

A sanitary survey must include the following eight essential elements (40 CFR 142.16):

1. Water source (protection, physical components, and condition)
2. Water treatment
3. Distribution system
4. Finished water storage
5. Pumps, pumping facilities, and controls
6. Monitoring, reporting, and data verification
7. Water system management and operation
8. Operator compliance with state requirements

The Multiple Barrier Approach

The elements of the sanitary survey address multiple barriers that work together to prevent drinking water contamination. If one of these barriers were to fail, as long as other barriers are still in place, the public water supply and public health remain protected. Understanding this concept is vital as a water system can be producing safe drinking water and still have one or more deficiencies that need to be corrected. It is important, however, for water systems to strive to have multiple barriers reliably in place to keep contaminants from reaching the public. The best practices of sanitary integrity to protect public health are discussed in the appropriate chapters of this guide.

Identifying Deficiencies in a Sanitary Survey

A sanitary survey will determine if deficiencies are present in a PWS and verify the PWS's compliance with SDWA regulations. This information serves as a benchmark by which to gauge the effectiveness of a PWS and is valuable in addressing the PWS's present and future needs.

Sanitary deficiencies are actual or potential defects in a water system's infrastructure, design, operation, maintenance, or management that cause, or may cause interruptions to the "multiple barrier" protection system and adversely affect the PWS's ability to produce safe and reliable drinking water in adequate quantities. These defects could be a physical gap or an operating condition or practice that allows contamination to occur.

Significant deficiencies are serious sanitary deficiencies identified in water systems which include, but are not limited to, defects in design, operation, maintenance, or a failure or malfunction of the sources, treatment, storage, or distribution system that the primacy agency determines to be causing, or has potential to cause, the introduction of contamination into the water delivered to consumers. Though primacy agencies usually have a list of significant deficiencies available, with at least one for each of the eight elements, these lists should not be limiting; any surveyor conducting a sanitary survey should have the ability and authority to make significant deficiency determinations based on observations on-site. Water systems must correct significant deficiencies in accordance with timeframes established in the NPDWR (see details in Chapter 2).

While a sanitary survey is intended to identify deficiencies before they present a public health risk, there are occasions during sanitary surveys when an existing serious public health threat may be observed. The surveyor conducting the sanitary survey should be able to identify such situations and understand how to react so that the appropriate action is taken to eliminate the public health risk as quickly as possible.

Sanitary surveys can also be a valuable tool for primacy agencies to go beyond what is required and educate a water system on topics such as upcoming regulations, proper sampling techniques, capacity development opportunities, strategies for extreme weather events and conditions, and other technical assistance needs (see Chapter 15 – Other Considerations).

For sanitary surveys performed by EPA, PWSs must respond in writing to significant deficiencies identified in sanitary survey reports no later than 45 days after receipt of the report, indicating how and on what schedule the PWS will address significant deficiencies noted in the survey. PWSs must correct significant deficiencies identified in sanitary survey reports according to the schedule approved by EPA, or if there is no approved schedule, according to the schedule provided by the PWS if such deficiencies are within the control of the PWS.

Frequency of Sanitary Surveys

Sanitary surveys must be conducted no less than once every three years for community water systems (CWSs) and no less than once every five years for non-community water systems (40 CFR 142.16). Primacy agencies may choose to conduct sanitary surveys more frequently than the minimum requirements. Surveyors may conduct sanitary surveys in a phased approach, evaluating specific elements over multiple visits; however, surveyors must evaluate all elements within the required period. Students can find details on reducing sanitary survey frequency in Chapter 2: Drinking Water Regulations.

Who Conducts Sanitary Surveys?

Sanitary surveys should be conducted by competent personnel who have experience and knowledge of the design, operation, maintenance, and management of PWSs. These individuals should be qualified to assess problems and make sound decisions using hydrological, hydraulic, mechanical, and other basic engineering and management knowledge.

Course Description

Purpose of the Training

The U.S. Environmental Protection Agency (EPA) has designed this training course for personnel who inspect and evaluate PWSs. Its purpose is to apply basic scientific information and a working knowledge of the operation, maintenance, management, and technology of a PWS in order to complete the evaluation of PWSs and identify sanitary deficiencies, including significant deficiencies that may be present This course addresses each of the eight essential elements of a sanitary survey, presents the activities of a sanitary survey, and identifies questions to ask as well as conditions to look for while conducting a sanitary survey. This training also presents the process for conducting a sanitary survey, familiarizes the student with security concerns, reviews applicable federal drinking water regulations, and explains the relationship between federal and state regulations.

Student's Guide on How to Conduct a Sanitary Survey

EPA has also designed this guide to complement classroom training. As much as possible, chapters follow the same order as a sanitary survey; from organizing the sanitary survey to moving through the water system starting at the source and ending at the "tap" (distribution). Most chapters follow the format described below.

- Provide a general introduction and learning objectives.
- Discuss data collection.
- Provide technical information on a topic and present potential questions to ask during the sanitary survey for that specific topic.
- Present additional technical information and questions if necessary.
- Provide some examples of possible significant deficiencies. All significant deficiencies listed in this Learner's Guide are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed in each chapter.

Many chapters provide references where students can find additional information on a specific topic. In order to facilitate the reader's ability to locate those materials, a comprehensive list of reference material (publications, videos, CDs, DVDs, etc.) appears in Appendix A.

The following are the components of this guide and the activities the student will be able to perform after working through them.

- **Organizing the Sanitary Survey** – Prepare for, conduct, and perform follow-up activities for a sanitary survey.
- **Drinking Water Regulations** – Explain the applicability of federal regulations that apply to water systems during a sanitary survey and their relationship to state regulations.
- **Water Sources** – Evaluate water supply sources and intake structures to determine proper source protection and sufficiency.

- **Pumps and Pumping Facilities** – Identify proper operation and maintenance (O&M) of water system pumps and pumping facilities.
- **Treatment Processes** – Evaluate treatment processes, facilities, components, and techniques and related chemical addition and handling.
- **Storage Facilities** – Evaluate the adequacy, reliability, and safety of finished water storage.
- **Distribution System** – Evaluate the adequacy, reliability, and safety of the PWS for distributing water to consumers.
- **Cross-Connections** – Identify cross-connections and evaluate the cross-connection control program.
- **Process Control Monitoring, Laboratory Procedures, and Data Integrity** – Review monitoring data for source and finished water quality for bacteriological, physical, chemical and radiological properties and, as required, perform and evaluate results of field analyses.
- **Management** – Evaluate the effect of management practices on the reliability of the PWS and review the qualifications of PWS personnel.
- **Other Considerations** – While the eight essential elements must be included in a sanitary survey, it may be helpful to the PWS to discuss other considerations (e.g., sustainability, water system security, extreme weather) during the sanitary survey. This guide briefly discusses these additional considerations, with references for additional related resources.

Field Reference

A field guide is also provided during training – *Sanitary Survey Field Reference: For Use When Conducting a Sanitary Survey of a Small Water System*. This reference is compact in design so a surveyor can easily use it in the field. It lists questions contained in this Learner's Guide to help review key survey points during the survey. Some graphics are also included.

1 Organizing and Completing the Sanitary Survey

Organization and planning are essential in order to conduct an effective and efficient sanitary survey. Planning begins even before the first phone call to arrange the on-site survey, and does not end until the sustainable correction of all sanitary deficiencies. The sanitary survey process has three stages.

- Preparation, including background research
- On-site survey
- Follow-up activities to ensure PWSs correct sanitary deficiencies

Though the NPDWR require sanitary surveys to be conducted, the sanitary survey process should be a cooperative partnership between the primacy agency and the water purveyor since each share the common goal of providing safe drinking water to the public.

1.1 Learning Objectives

By the end of this chapter, students should be able to:

- Determine how, and with whom, to communicate before, during and after an on-site survey;
- Explain the activities that the surveyor needs to accomplish during the preparation phase and the importance of each activity;
- Know the sequence of activities that are required during the on-site survey, and how to properly document findings during the sanitary survey; and
- Explain the follow-up activities, which are required after the surveyor completes the on-site sanitary survey, including finalizing deficiencies and writing the sanitary survey report.

1.2 Estimating Time Needed

Time management is an essential element in completing a sanitary survey in an efficient manner. The estimation of time should include all activities prior to, during, and after the on-site survey. Although the time needed to complete a sanitary survey will vary with the complexity of the water system and the experience of the surveyor, a general rule of thumb is that it will take two hours in the office for every hour spent in the field.

1.2.1 Research

1.2.1.1 Review Files

Prior to each sanitary survey, the surveyor should review available information on the water system. This review helps the surveyor become familiar with the PWS's history and condition and understand remarks made during the survey regarding previous letters or conversations that otherwise may be taken out of context or misunderstood.

It is important to gather as much of the following water system information as possible. This information should be available from the primacy agency's electronic databases and hard-copy files, or the surveyor may acquire it during the survey. Knowledge of the PWS's history conveys to water system personnel the surveyor's professionalism and concern for the PWS. Some sources of available information include:

Ground water systems must provide the State, at the State's request, any existing information that will enable the State to conduct a sanitary survey (40 CFR 141.401(a)).

- Prior sanitary survey reports and follow-up documentation on all deficiencies identified.
- Correspondence with the primacy agency.
- Compliance monitoring results.
- The PWS's consumer confidence reports.
- Records of enforcement actions or warnings of potential actions.
- Plans and schematics on file. For example:
    - Source protection plans.
    - Treatment plant schematics including chemical feed points and treatment processes.
    - Monitoring, emergency or contingency plans.
    - Cross-connection control plans.
    - Capital improvement plans.

1.2.1.2 Regulations and Standards to Consider

The surveyor should also review and consider the following materials prior to the survey (See Chapter 2 for details on regulations):

- 40 CFR Part 141 - National Primary Drinking Water Regulations, as adopted by the primacy agency, including, but not limited to, the following subparts:
    - Subpart H, Filtration and Disinfection.
    - Subpart I, Control of Lead and Copper.
    - Subpart L, Disinfectant Residuals, Disinfection Byproducts, and Disinfection Byproduct Precursors.
    - Subpart P, and Subpart T, Enhanced Filtration and Disinfection.
    - Subpart S, Ground Water Rule.
    - Subpart V, Stage 2 Disinfection Byproducts Requirements.
    - Subpart W, Enhanced Treatment for *Cryptosporidium*.
    - Subpart Y, Revised Total Coliform Rule.
- 40 CFR Part 142 National Primary Drinking Water Regulations Implementation, as implemented by the primacy agency. This includes 40 CFR 142.16 that describes the sanitary survey program, among other things, and 40 CFR 142.34 that describes entry of establishments, facilities, or other property.

- Additional state regulations.
- State engineering and construction standards.
- Minimum operator certification requirements.

1.2.2 Contacts

The surveyor should contact the water system owner in order to:

- Explain the purpose of the sanitary survey.
- Schedule a meeting location, date, and time when key personnel will be available.
- Discuss any preparations the water system staff will need to make for the sanitary survey.

Note: In cases where EPA is conducting a survey, the surveyor must give written notice to the water system and the state primacy agency prior to conducting the sanitary survey (see 40 CFR Part 142.34).

The surveyor should verbally contact the water system, followed by a short-written notification summarizing the phone call. Primacy agencies take different approaches to notification (e.g., hard copy versus email), so the surveyor should find out the appropriate approach of the agency for the particular water system being surveyed. In addition to reiterating the content of the phone conversation, written notification should also provide instructions for requesting changes to the schedule. This is also a good opportunity to inform water system personnel of specific information they should have available during the sanitary survey. Notification should occur within a time frame that will give PWS personnel sufficient time to respond.

The surveyor should contact the person directly responsible for the overall management of the PWS (e.g., chief executive officer (CEO), mayor, water commissioner, PWS manager) in order to obtain cooperation, gather information, coordinate with other departments or agencies, and transmit the results of the survey. Prior to the on-site survey, the surveyor should contact the people identified in the table below.

Table 1-1: Essential Contacts

Contact	Purpose
Water System Owner and Operator	
	Obtain cooperation.
	Establish sanitary survey dates.
	Explain purpose of sanitary survey.
	Request that necessary information be available.
	Coordinate gaining entry to site.
	Ensure presence of all necessary operational personnel during sanitary survey.
Other Regulatory Agencies	
	Ensure cooperation and coordination.
	Obtain information pertinent to the PWS.

1.2.3 Schedule Changes

The surveyor should make any needed schedule changes as early as possible. A surveyor should never postpone or cancel a sanitary survey without prior notification to the water system's representatives.

1.3 Organizing Field Equipment

Having the necessary field equipment is critical to conducting a successful sanitary survey. The surveyor needs to bring multiple types of equipment for testing, support, and safety. The surveyor should verify all equipment is in good working condition before leaving for the on-site survey. Equipment that is broken, dirty, in disrepair, out of calibration, or otherwise improperly maintained does not provide accurate, dependable, or reproducible data needed to support potential violations, nor does it provide adequate protection.

Note: Always bring extra batteries into the field and fully charge all equipment before leaving the office.

The following sections provide information on the various types of equipment and their uses as well as provide a list of recommended equipment. The surveyor should bring equipment based on the type of PWS surveyed.

1.3.1 Field Testing Equipment

Properly calibrated testing equipment is necessary to ensure the water system is providing accurate data and is a good way to verify the water system's equipment is in proper working condition. Many surveyors have the operator take simultaneous measurements using their own equipment as a way to spot check calibrations. Prior to the on-site survey, it is important for the surveyor to calibrate all testing instruments, check expiration dates of reagents and control solutions, and understand current standard testing methods.

1.3.1.1 Recommended Field Testing Equipment List

Recommended types of field testing equipment include, but are not limited to, the following:

- **Portable pH meter (digital, not analog):** Used at both surface water and ground water systems. Surveyors use the pH results to assist with disinfection CT calculations (residual disinfectant concentration in milligrams per liter (mg/L) multiplied by contact time in minutes) and to ensure PWSs are using the right chemical treatment for their water (e.g., disinfection, coagulation, corrosion control).

- **Pressure gauge:** Used at all types of PWSs to check water pressure in the distribution system. The surveyor should know the required minimum pressure and check levels in multiple locations within the distribution system, including the high points and the points furthest from the plant/wells.

- **Residual chlorine test kit (hand held colorimeter or portable spectrophotometer):** Used at all types of PWSs to measure the chlorine (free and/or total) residual throughout the PWS. For PWSs that provide chloramines as a distribution disinfectant, the surveyor should measure total and free chlorine, and for PWSs that use chlorine for secondary distribution disinfection, the surveyor should measure free chlorine. Because there is no direct chemical method for measuring chloramine residual, the surveyor can approximate the monochloramine residual by subtracting the measured free chlorine residual from the measured total chlorine residual.

- **Survey support equipment:** Survey support equipment is needed to aid the surveyor in all aspects of the sanitary survey including getting to the location, photo documentation, making observations, performing calculations, and transporting samples (if necessary).

1.3.1.2 Recommended Survey Support Equipment List

Recommended types of sanitary survey support equipment include, but are not limited to, the following:

- **Locational equipment (GPS units, maps, smart phones):** Used to locate the desired destination. GPS units and smart phones can also provide latitude/longitude information for critical facilities.
- **Camera:** Provides photographic evidence of any deficiencies found during the sanitary survey.
- **Calculator:** Used to calculate the appropriate CT requirements, average daily demand, sufficient capacity, appropriate hydraulic detention time, surface overflow rate, or hydraulic loading rates.
- **Tape measure:** Used to measure distances from a well or storage tank to potential sources of contamination (PSOCs). A measuring wheel is another helpful tool for measuring setback distances. The calculator and tape measure may be needed to determine the size of different basins, calculate hydraulic detention times, surface overflow rates, or hydraulic loading rates.
- **Watch with second hand or stopwatch function:** Used to determine flow rates for calculating CT values or calibrating chemical feed pumps.
- **Binoculars:** Used to observe tank hatches, vents, and overflow pipes that are located at the top of standpipes or elevated storage tanks.
- **Mirror:** Used to look under vents on tanks, wells and air release valves as well as provide natural lighting by reflecting sunlight into dark areas such as vaults, valve pits, or other dark areas in a water system. Most cell phones with a built-in light and reversible camera can also serve this purpose.
- **Flashlight:** Provide lighting in dark areas such as vaults, valve pits, or other areas in a water system. Most cell phones with a built-in light can also serve this purpose.
- **Clipboard:** Provide support to fill out the sanitary survey forms. Storage clipboards allow a surveyor to store completed forms, especially on windy days.
- **Small rag:** Useful for wiping base plates, cleaning faces on gauges and wiping hands.
- **Ice chest (if taking samples):** May be needed to preserve and ship any samples that may have to be taken during the sanitary survey. Some samples, such as, bacteriological samples may also require ice to keep them at an appropriate temperature during transportation.

1.3.2 Safety Equipment and Safety Precautions

A critical aspect of the sanitary survey is safety. This is a concern for the field surveyor as well as staff who operate the PWS. Surveyors should create a site-specific safety plan before the survey that includes a map, verified emergency phone numbers, and directions to the nearest medical facility.

Safety hazards vary based on geographic locations and type/complexity of PWSs. Surveyors should be aware of the potential hazards on-site and take the appropriate steps to mitigate such hazards. Some examples of safety hazards typically found at water systems include, but are not limited to:

- Electrical shock.
- Exposure to chemicals.
- Entering confined spaces.
- High-intensity noise.
- Slips, trips, and falls.
- Falls from elevated sites.
- Active construction sites.
- Traffic by vaults near roadways.
- Environmental exposures (animals, rodent droppings, weather, plants, etc.).
- Drowning.

1.3.2.1 Recommended Safety Equipment List

Prior to the on-site survey, the surveyor should ensure that personal protective equipment (PPE) is available. We acknowledge that many agencies do not provide this equipment; however, the surveyor may wish to provide some of the equipment and ensure that items such as respirators are available at the site. The following is a list of the most frequently used equipment:

- **Safety hats (hard hats):** Provide protection from falling objects and overhead obstructions in pipe galleries. They also may provide a means of identification.
- **Safety glasses with side shields:** Provide eye protection from chemicals and flying objects. Supplement the safety glasses with a full-face shield when working around some chemicals.
- **Safety harness (fall protection)**: Protects the wearer from falls while climbing tanks (if allowed).
- **Gloves:** Provide protection against injuries from chemicals and equipment. Rubberized materials are preferred over leather or cloth gloves.

Note: Oxygen-deficient atmosphere areas should be labeled as a "permit required confined space" and would require the surveyor to be trained and permitted to enter. Most agencies do not allow surveyors to enter confined spaces. Agencies should also train surveyors to recognize confined spaces and to avoid them.

- **Steel-toed safety boots:** Provide protection from falling objects.
- **Earplugs or muffs:** Provide hearing protection around pumps or other machinery.

1.4 General Recommendations for On-Site Surveys

1.4.1 Keep Purpose in Mind

In conducting the on-site survey, it is important for the surveyor to remember the purpose of the sanitary survey. The surveyor is to perform an on-site review of the elements of the PWS utilized for the production and distribution of safe drinking water, including water source, facilities, equipment, operation, maintenance, and management. The surveyor should not let the sanitary survey be solely an exercise in filling in the blanks on a particular form. A surveyor needs to consider the water system thoughtfully, concentrate on identifying potential or existing public health risks, and identify related deficiencies.

Caution: Surveyors should be cautious in instructing water system officials on how to "fix something." Giving advice on how to correct or fix a problem could lead to enforcement and credibility issues if the system personnel listen to the surveyor and "the fix" does not work.

1.4.2 Be Punctual – Work with the Water System Staff

The first step in performing a successful on-site survey is to be punctual. A successful sanitary survey needs representatives of the water system to participate in the sanitary survey process; tardiness is unprofessional and reflects poorly on the surveyor's abilities. Individuals in charge of management, operation, and maintenance should all be involved during the on-site survey. This provides the surveyor with critical information about the PWS and allows the surveyor and staff members to interact and develop a mutual understanding of the purpose of the sanitary survey as well as confidence in each other's abilities. Once the surveyor has established this trust, the staff may be willing to be more open about PWS operations and problems.

1.4.3 Use Forms and Field Notes

Field notes, diagrams, and completed survey forms are critical to the sanitary survey process. A properly designed form, whether paper or electronic, can facilitate and simplify the surveyor's evaluation. A field survey form is a data management tool. It can serve as a systematic guide during the sanitary survey and ensure completeness so the surveyor does not overlook critical data or other information. A good form anticipates questions and affords the surveyor the opportunity to focus on answers and responses as well as record observations without the distraction of planning the next question.

In most cases, the best practice involves the surveyor using a standard form to help cover all points of the PWS, while remembering that filling out a form is not the primary function of the sanitary survey. The surveyor should understand the purpose of each question. The judicious use of a standard form provides uniformity of surveys, ensures completeness, facilitates recordkeeping, documents observations, and provides a benchmark for future surveys.

1.4.4 Communications During the On-Site Survey

1.4.4.1 Contacts During the Survey

During the survey, the surveyor should work with the owner of the water system and the operational personnel.

When meeting with the PWS owner, the surveyor should:

- Obtain information pertinent to the PWS.
- Explain required and recommended follow-up actions by the PWS.
- Explain what action will result from the sanitary survey.
- Describe timing and content of the sanitary survey report.

When communicating with the operational personnel, the surveyor should:

- Obtain information pertinent to the PWS and how it is operated.
- Explain required and recommended actions.

1.4.4.2 Relationship with Operator

Establishing a good relationship with the operational personnel is important to the success of the sanitary survey. The operator of the water system occupies a unique position in the water supply industry. In many cases, the operator is responsible for all aspects of the PWS from operation of the plant to budgeting for equipment. In small water systems especially, the operator may also be responsible for other services in the community (e.g., wastewater treatment, road repair). Consequently, the operator may have a basic working knowledge of his or her water system and processes, but not necessarily knowledge of the regulatory requirements. A surveyor can foster a positive relationship with the operator by answering any questions the operator may have, providing helpful information about upcoming trainings and regulations, and explaining why defects or deficiencies found during the survey are a concern.

1.5 Sequence of Activities

The surveyor should conduct the on-site sanitary survey in a systematic fashion. The sequence should include the following steps (details of these steps follow):

- Initial briefing and introductions.
- Background review.
- Management assessment.
- Facility walk-through.
- Surveyor's assimilation of findings.
- Debriefing.

1.5.1 Initial Briefing and Introductions

After introductions, the surveyor should describe the sequence of activities to complete during the on-site survey. This is also an opportunity for the surveyor and water system personnel to discuss concerns not directly related to the survey (e.g., proposed regulations or activities of the primacy agency). The water system should have management, operations, and maintenance staff represented at this briefing.

1.5.2 Background Review

During this part of the sanitary survey, the surveyor should review previous sanitary survey reports and discuss actions taken by the water system on any sanitary deficiencies identified or cited in that report. In addition, basic information should be obtained or verified, including (but not limited to):

- Number and classification of connections and the population served.
- A schematic of the PWS layout (or a map).
- A description of the major facilities and plans for future improvement (e.g., capital improvement plans).

1.5.3 Management Assessment

Although the owners and managers are the primary focus, the operations and maintenance personnel should also participate. During this phase, the surveyor will assess the adequacy of programs and procedures including:

- SDWA compliance sampling and site plans.
- Source protection.
- Cross-connection control.
- Contingency and emergency plans.
- Corrosion control.
- Safety.
- Training.
- Finished water storage tank cleaning and inspection records.
- Distribution maintenance programs (e.g., PWS flushing, pressure testing, valve inspection and repairs, hydrant inspection and repairs, water main replacement, and rehabilitation).
- Financial management.
- Capital improvement.
- Recordkeeping.
- Preventive maintenance (PM) and standard operating procedures (SOPs).

The surveyor will also assess how the PWS responds to customer complaints and whether staffing is adequate. Does the PWS have an updated map? Do they have locational information for customer complaints, line breaks, locations with low disinfectant residuals, pressure readings, positive coliform samples, and other problem areas?

Finally, the surveyor should review the operational records from in-house monitoring, records required for compliance reporting, and records the water system is not required to submit to the primacy agency in preparation for the next phase of the on-site survey.

1.5.4 Facility Walk-Through

Note: The surveyor should not attempt to adjust or operate any of the plant equipment.

It is beneficial to the successful outcome of a sanitary survey that the individuals responsible for O&M participate in this phase. The surveyor should begin at the water source and follow the "water stream" to work through the entire PWS including the water distribution system and the pumping and storage facilities. At each step in the process, the surveyor should conduct visual observations and ask the O&M staff specific questions about the process, equipment, and strategies employed. The manner in which the surveyor poses questions to the operators should not be suggestive in nature. For example, an accurate answer is more likely to be obtained when asking, "How do you determine when to backwash a filter?" rather than, "You always backwash the filter prior to an increase in filtered water turbidity, right?" Another rule of thumb is never to assume anything. Even if the surveyor believes they know the answer to a particular question, the surveyor should ask the question anyway. The answer will build on the surveyor's assessment of the operator's knowledge and may lead to an additional series of questions regarding the PWS.

1.5.5 Surveyor's Assimilation of Findings

At this stage, the surveyor should work alone to complete the sanitary survey form and to identify and prioritize the sanitary deficiencies found during the sanitary survey. Top priority should be given to the sanitary deficiencies that are determined to pose an imminent threat to public health, significant deficiencies, then other deficiencies, and finally to recommendations. The primacy agency should provide and maintain all current definitions and policies for making determinations of significant deficiencies. The surveyor, however, should be free to act on deficiencies he or she sees that fall outside the specific definitions of anticipated significant deficiencies. The surveyor should be able to identify new types of significant deficiencies on-site if necessary. This is the time when the surveyor should, if necessary, seek advice from peers or supervisors in the primacy agency office regarding the findings and required actions. The surveyor should also use this time to prepare for the debriefing.

1.5.6 Debriefing

STATED PREVIOUSLY, determining deficiencies is an important task of the surveyor. If there is any doubt while on-site, the surveyor may be better off to return to the office and discuss findings before making specific deficiency determinations or setting deficiency priority (e.g., significant).

Prior to leaving the site, the surveyor should meet again with the individuals who attended the initial meeting and brief them on the sanitary deficiencies identified in order of priority. The surveyor should explain what action will result from the sanitary survey and when, and advise the water system representatives that the primacy agency will provide them with a sanitary survey report of findings, required action, and recommendations. If possible, the surveyor should provide the PWS with a preliminary list of significant deficiencies and lead a discussion of the resolution of those deficiencies. The sanitary survey report will include an official list of significant deficiencies that will require PWS follow-up. The surveyor should discuss all-important issues in the debriefing so there are no surprises in the final written report.

1.5.7 Follow-up

Follow-up activities include:

- Finalizing documentation and prioritization of all sanitary deficiencies and recommendations identified during the on-site survey.
- Completing the formal sanitary survey report. The surveyor should include corrective action requirements for any significant deficiencies identified, as well as timelines for completion. Also, identify any differences between the findings in the written report, the oral debriefing, or any preliminary deficiency list provided to the water system.
- Notifying appropriate organizations of the results.
- Following up on questions asked by water system personnel.

1.6 The Sanitary Survey Report

1.6.1 Importance of the Report

The sanitary survey report is a critical component of the sanitary survey for use in tracking current compliance with water statutes and regulations as well as for evaluating a PWS's compliance ability. Perhaps more importantly, it provides a record that supports enforcement actions if deficiencies are not addressed and to allow future surveyors to track progress. It also provides information needed during emergencies and when technical assistance providers are on-site. It is the surveyor's responsibility to the water system and to the public to provide an accurate and detailed description of improper operation or other PWS deficiencies in a sanitary survey report.

1.6.2 Official Notification

In most cases, the sanitary survey report constitutes the official written notification of the survey and any significant deficiencies that were found. Receipt of the report starts the clock for correcting significant deficiencies. Some primacy agencies use the preliminary deficiency list (if written and left with the water system staff) discussed during the on-site debriefing as official written notification of significant deficiencies. Undocumented verbal communication is not reliable and should not be considered sufficient. The surveyor should document important information, such as violations and deficiency determinations, in the sanitary survey report. The completed report should reiterate the information presented to PWS personnel by the surveyor at the end of the on-site survey. If the written report is different from the oral debriefing, the surveyor should inform the water system manager in advance and explain clearly how the findings have changed.

The report itself can be as brief as a letter, if the surveyor found few deficiencies, but it should be as detailed as necessary to convey to the water system what deficiencies exist. However, by just listing the deficiencies, the surveyor may not accomplish the objective of informing the PWS of a problem and seeking its correction. Primacy agencies sometimes incorrectly assume all managers or operators can understand the surveyor's comments and technical references. Even if the water system personnel understand what the surveyor has identified, they may not be able to complete corrective actions effectively if they do not understand the reason for those actions. The report should describe the deficiencies in basic terms and explain the reasons for corrective action. An explanation of how a problem adversely affects the PWS and public health is more likely to motivate the water system operator to correct it. Some primacy agencies send reports via certified mail with a "return receipt requested" to document receipt by the PWS; others send the report by regular mail.

1.6.3 Report Content

Elements of the report include:

- The date the sanitary survey was conducted and by whom.
- The names of those present during the sanitary survey, besides the surveyor.
- A schematic of the PWS and, when possible, photographs of key components and all deficiencies.
- A schematic of any treatment facilities showing locations of chemical injection, clearly documenting the order in which chemicals are added.
- The sanitary survey findings and a discussion of any differences in the findings presented in the debriefing and the final report.
- The surveyor's findings regarding current compliance monitoring plans including sampling frequency, number of samples, sample locations and collection dates, if required, as applicable for the Revised Total Coliform Rule (RTCR), Lead and Copper Rule (LCR), Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR), and Ground Water Rule (GWR).
- A list of all significant deficiencies with corrective action requirements and deadlines for completion.
- The surveyor's signature, and in some cases the water system official's signature.
- A listing of all other sanitary deficiencies and recommendations, in order of priority.

1.6.4 Importance of Documentation

No matter how professional the sanitary survey was, how involved or detailed the field aspects of the sanitary survey were, or how many deficiencies were pointed out verbally during the survey, it is important for the primacy agency to document all findings in writing so the PWS's owners and managers are made aware of deficiencies that require correction.

In addition, if the surveyor does not properly document all details, the primacy agency will find the use of any of the sanitary survey findings for enforcement purposes very difficult. Remember, when the primacy agency finds and cites significant deficiencies or other violations, a compliance schedule, consent agreement, administrative order, or litigation may be necessary to ensure prompt and proper correction.

1.7 Corrective Action

1.7.1 Correcting Significant Deficiencies

Corrective action is required for any PWS with a significant deficiency identified by the primacy agency (GWR and 40 CFR Part 142 National Primary Drinking Water Regulations Implementation of the Interim Enhanced Surface Water Treatment Rule (IESWTR)). The period for completion depends on the PWS type.

1.7.2 Correcting Sanitary Defects

If the primacy agency conducted a sanitary survey that also satisfied the requirement for a level 2 assessment triggered under the RTCR, the surveyor will need to identify any sanitary defects in addition to identifying significant deficiencies. Once notified, the water system has a very short (30-day) timeframe in which to address these sanitary defects or have an approved schedule for correction under the RTCR. Requirements related to RTCR Level 2 assessments and sanitary defects are described in more detail in Section 2.

1.7.3 Technical Assistance and Training

Water systems can address many of the items identified as sanitary deficiencies in-house. However, some deficiencies may be complex and require outside assistance. While water systems strive to be in compliance, many water systems with compliance issues may need some assistance in determining the cause of their performance problems and in the planning of corrective actions needed to achieve compliance. This assistance often takes the form of training and on-site hands on, system-specific technical assistance. The integration of training and technical assistance into the overall enforcement strategy has, in many states, proven to be the most effective method for achieving and maintaining compliance while promoting a partnership between the water system, the regulatory staff, and the training and technical assistance providers.

Technical assistance and training resources vary from state to state, can take many forms, and involve a variety of approaches. Many states have developed a means to provide assistance to a water system, either at the request of the water system or through a referral from a sanitary surveyor. In most states, the primacy agency provides some form of technical assistance, either directly or through an agency grantee (a technical assistance provider). Often, surveyors provide resource listings, referrals, and other forms of general technical assistance. Many states have an environmental training center or other organization that can provide more specific technical assistance to explain and demonstrate exactly what to do to resolve problems. Private-sector consulting services are also available in most states.

1.7.4 Limitations

Surveyors should temper any advice with a realistic assessment of their personal experience and knowledge of the problem. If the surveyor provides erroneous information, money, time, and credibility could be lost, while the sanitary deficiency continues. Surveyors who have limited experience should refer problems to more experienced personnel. Incorrect technical assistance that does not correct the problem can have ramifications ranging from loss of credibility to challenges to authority regarding corrective action.

1.8 State Recordkeeping

Sanitary survey reports must be kept on file by the state for at least twelve years (40 CFR 142.14(d)(1)). States are also required to maintain the following additional records related to sanitary surveys:

Significant deficiencies – Records of written notices of significant deficiencies; records of corrective action plans, schedule approvals, and State-specified interim measures; and records confirming that a significant deficiency has been corrected (40 CFR 142.14(d)(17)(i–iii).

Treatment changes – Any change in treatment requirements for filtered systems due to a watershed assessment conducted during a sanitary survey or an equivalent source water assessment that determined significant changes occurred in the PWS's watershed that could lead to increased contamination of the source water by *Cryptosporidium* (40 CFR 142.14(a)(9)(iii)).

2 Drinking Water Regulations

In addition to specifying Maximum Contaminant Levels (MCLs), the federal drinking water regulations address sampling location, frequency, recordkeeping, and other requirements that should be subject to compliance determinations during a sanitary survey. The surveyor should also review variances, exemptions and any enforcement orders. There are many requirements for each drinking water regulation; in this chapter, we only focus on the aspects of regulations the surveyor should address during the sanitary survey.

The regulations provide protection at each of the barriers within the multiple barrier approach. The suite of Surface Water Treatment Rules (SWTRs) and GWR cover the *source* barrier. The Chemical Contaminant Rules (e.g., Phase I, II and V, arsenic), along with the SWTRs, address the *treatment* barrier. The Stage 1 and Stage 2 DBPRs and the RTCR address the *distribution* barrier. The rules mentioned above are not a comprehensive accounting for all three barriers so the surveyor must understand all applicable regulations and how they relate to the multiple barrier approach to protecting public health with respect to PWSs, in order to make on-site compliance determinations.

2.1 Learning Objectives

By the end of this chapter, students should be able to:

- Explain the importance of making an accurate determination of population served by the PWS and number of service connections.
- Determine if a water system is a PWS subject to EPA regulations, as adopted by the state.
- Properly classify a PWS as community, non-transient non-community, or transient non-community.
- Explain the importance of and determine whether the PWS has made modifications to its sources, treatment, or distribution system without state approval.
- Describe the on-site compliance determinations that should be made for various provisions of the NPDWRs adopted by the state, including: siting; total coliform monitoring; triggered source monitoring; surface water treatment; lead and copper; organic, inorganic and radiological contaminants; disinfectants and disinfection byproducts (DBPs); reporting; recordkeeping; and public notification.
- Determine whether the PWS is operating in accordance with the National Secondary Drinking Water Regulations (NSDWRs) as adopted by the state.
- Determine compliance with ANSI and NSF standards for direct and indirect additives if these are part of state regulations or policies.
- Determine if the PWS is complying with conditions set forth in variances, exemptions, or compliance orders.

2.2 Data Collection

When determining a PWS's compliance with regulatory requirements, the surveyor must rely on information available in the primacy agency office as well as information gathered in the field. Various reports, correspondence, engineering studies, and monitoring data are important sources of information for determining a PWS's compliance. This information is typically available in the office for review and evaluation. Prior to a survey, the surveyor should review the following:

- Any violations of MCLs, treatment technique (TT), monitoring, or reporting.
- Current information on population served and number of service connections.
- State-approved coliform sample siting plan.
- State-approved DBP sample siting plan.
- State-approved lead and copper sample siting plan.
- State-approved determination of 4-log treatment of viruses, (using inactivation, removal, or a primacy agency-approved combination of 4-log inactivation and removal) before or at the first customer for all ground water sources, if the PWS is claiming 4-log credit for any of its ground water sources for GWR compliance.
- Consistency with NSDWR.
- Variances or exemptions that apply to the PWS.
- Compliance orders that apply to the PWS.
- Documentation of state approval for the installation of new facilities or changes to the PWS.

Upon arrival at the PWS, the surveyor should ensure the information evaluated prior to the survey is still valid and consistent with the records held at the primacy agency. The surveyor should also review as appropriate:

- Monthly operating reports (MORs).
- Daily logs appropriate to the treatment in use.
- Calibration logs for instruments in use.

2.3 Regulations and Standards to Consider

The surveyor should review the following regulations and standards prior to the survey:

- EPA or state primary and secondary drinking water regulations.
- State design standards or guidelines.
- ANSI/NSF standards.

2.4 Drinking Water Regulations

2.4.1 Safe Drinking Water Act of 1974 and Amendments

In recognition of potential public health risks associated with the nation's drinking water, Congress enacted the SDWA in 1974. Congress intended for the Act to ensure the delivery of safe drinking water by PWSs and to protect underground water sources from contamination. In 1986, Congress greatly expanded the number and type of contaminants to be regulated and strengthened EPA's enforcement authority by amending SDWA. In 1996, Congress amended SDWA once again to include provisions for state revolving loan funds to improve water systems. Because of these amendments, EPA was also required to base regulations on cost/benefit and risk assessment considerations, identify best available treatment technologies, and establish guidelines for operator certification and for providing monitoring relief to small water systems.

2.4.2 Code of Federal Regulations

EPA publishes (promulgates) final regulations in the *Federal Register,* and annually, EPA regulations are published in Title 40 of the Code of Federal Regulations (CFR). The agency has incorporated, or codified, all NPDWRs under 40 CFR Part 141, which is divided into subparts and sections for specific regulatory provisions. For example, Section 858 of Part 141 (40 CFR 141.858) codifies the repeat *E. coli* monitoring requirements for the RTCR. The CFR is available from the Government Printing Office in Washington, D.C., and can be accessed electronically from the internet (see www.eCFR.gov).

2.4.3 National Primary Drinking Water Regulations

SDWA requires EPA to establish regulations for contaminants in drinking water that may have an adverse effect on public health. These NPDWRs (40 CFR Part 141) include MCLs or TT for more than 100 contaminants. The regulations also specify monitoring and testing procedures.

2.4.4 NPDWRs Implementation

The SDWA requires EPA to define the requirements for allowing state primary enforcement ("primacy") agencies to implement and enforce state regulations. EPA codified these primacy requirements in 40 CFR Part 142, National Primary Drinking Water Regulations Implementation. For this delegation of authority, states must promulgate regulations at least as stringent as the federal regulations. When EPA promulgates new regulations, the states must submit primacy revision packages either containing the new state regulations for EPA review and approval, or adopt federal regulations by reference in order to maintain primacy. In primacy states (every state but Wyoming and the District of Columbia), state personnel derive their authority from state or federal drinking water regulations. Therefore, the surveyor needs to apply the equivalent state regulations to any federal regulations cited in this guide, if appropriate.

2.4.5 National Secondary Drinking Water Regulations

EPA also sets National Secondary Drinking Water Regulations (NSDWR), codified in 40 CFR Part 143. These regulations address drinking water contaminants that primarily affect the taste, odor, or color of drinking water. Such aesthetic considerations are a concern because where a PWS provides water that is unappealing to the senses, its users may seek alternative supplies, some of which may be unsanitary. Although not federally enforceable, EPA intended for these regulations to be guidelines for states and PWSs. Individual states may choose to adopt and enforce these secondary regulations.

2.4.6 Public Water Systems

2.4.6.1 Definition

A public water system (PWS) is a system for providing water for human consumption through pipes or other constructed conveyances, which has at least 15 service connections or regularly serves at least 25 people at least 60 days a year. A PWS includes any collection, treatment, storage, and distribution facilities under control of the PWS operator and used primarily in connection with its operation and any collection or treatment facilities not under such control that are used primarily in connection with such a PWS (40 CFR 141.2).

The surveyor will determine if the water system continues to meet the definition of a PWS by verifying answers to the following questions during the sanitary survey:

- How many people does the water system serve?
- How many service connections does the water system have?
- Does the water system provide service at least 60 days (not necessarily 60 consecutive days) a year?

This information determines whether a water system meets the definition of a PWS in SDWA and whether it is subject to NPDWRs.

2.4.6.2 Types of Systems

Although NPDWRs apply to all PWSs, the regulations make a distinction between community and non-community water systems. The regulations also make a distinction between TNCWS and NTNCWS.

2.4.6.2.1 Community water systems

Community water systems (CWS) serve residential populations of at least 25 people or 15 service connections year-round. Users of CWSs may be exposed to any contaminants in the water supply over an extended period (e.g., years) which would subject them to both acute and chronic health effects.

2.4.6.2.2 Non-Community water systems

Non-community water systems do not serve permanent residential populations. Non-community water systems are either non-transient or transient water systems.

- Non-transient non-community water systems (NTNCWS) serve on a regular basis at least 25 of the same persons at least 6 months per year. Like CWSs, these water systems can expose users to drinking water contaminants over an extended period (subjecting users to risks of both acute and chronic health effects). Schools, churches and factories that have their own water systems usually fall under this definition.

- Transient non-community water systems (TNCWS) serve short-term users. As a result, user-exposure to any contaminants would only be brief (i.e., no chronic exposure), but users would still be subject to experiencing acute health effects. Examples of TNCWS are restaurants, hotels, campgrounds or gas stations that have their own water systems.

These distinctions, and others such as service population and water source, are important because the primacy agency regulates these water systems differently. Population served determines sampling frequency in a number of regulations such as the RTCR, LCR, inorganic chemicals, and the suites of rules covering disinfectants, DBPs, and surface water treatment.

Most water system operators know precisely how many individual service connections their water system has, but not necessarily the population served by the water system. Some states use a factor (i.e., estimated persons per connection) multiplied by the number of service connections to estimate population. During the sanitary survey, the surveyor should determine if the state records on population and number of service connections are up-to-date. The state will have to evaluate how changes in the population affect the water system's status relative to any SDWA requirement.

A surveyor must evaluate a water system's characteristics for proper classification and application of regulations.

2.4.7 Sanitary Surveys and the Regulations

2.4.7.1 Sanitary Survey Definition and Frequency

2.4.7.1.1 Definition

Sanitary survey means an on-site review of the water source, facilities, equipment, O&M of a PWS for evaluating the adequacy of such source, facilities, equipment, O&M for producing and distributing safe drinking water.

2.4.7.1.2 Sanitary Survey Frequency

The primacy agency must conduct sanitary surveys no less than once every three years for CWSs and no less than once every five years for NTNCWSs and TNCWSs to meet the requirements under Section 40 of CFR Part 142.16(o) (2) for ground water systems and under 40 CFR 142.16(b) for subpart H water systems. Subpart H water systems are those whose sources include surface water or Ground Water under the Direct Influence of Surface Water (GWUDI) or both.

Primacy agencies may choose to conduct sanitary surveys more frequently than the minimum requirements. The state may also conduct sanitary surveys in a phased approach, evaluating specific elements over multiple visits; however, the state must evaluate all eight elements within the required sanitary survey frequency. Primacy agencies may reduce the frequency of sanitary surveys of community ground water systems to once every 5 years if the PWS meets either of the following requirements: (1) the water system provides at least 4-log treatment of viruses (using inactivation, removal, or a primacy agency-approved combination of 4-log inactivation and removal) before or at the first customer for all its ground water sources; or (2) the water system has an outstanding performance record (as determined by the primacy agency and documented in previous sanitary surveys) and has no history of total coliform MCL or monitoring violations since the last sanitary survey. In addition, primacy agencies may allow sanitary surveys of community surface water systems to be conducted no less than every five years if the primacy agency has determined the water system has had outstanding performance based on prior sanitary surveys.

2.4.7.2 Deficiencies, Defects, and Significant Deficiencies

Sanitary deficiencies are defects in a water system's infrastructure, design, operation, maintenance, or management that cause, or may cause interruptions to the "multiple barrier" protection system and adversely affect the PWS's ability to produce safe and reliable drinking water in adequate quantities.

> A sanitary defect, as defined in 40 CFR 141.2, is "*a defect that could provide a pathway of entry for microbial contamination into the distribution system or that is indicative of a failure or imminent failure in a barrier that is already in place.*"

The GWR introduced the definition for significant deficiencies for PWSs using ground water under 40 CFR 142.16(o)(2)(iv):

> *Significant deficiencies are serious sanitary deficiencies identified in water systems which include, but are not limited to, defects in design, operation, maintenance, or a failure or malfunction of the sources, treatment, storage, or distribution system that the primacy agency determines to be causing, or has potential to cause, the introduction of contamination into the water delivered to consumers.*

The GWR also requires primacy agencies to define at least one significant deficiency for each of the 8 essential elements of a sanitary survey.

For subpart H water systems, the regulations are not as prescriptive. Under 40 CFR 142.16(b)(1)(ii):

> *The State must describe how it will decide whether a deficiency identified during a sanitary survey is significant for the purposes of paragraph (b)(1)(ii) of this section.*

Paragraph (b)(1)(ii) requires:

> *States must … assure that PWSs respond in writing to significant deficiencies outlined in sanitary survey reports … no later than 45 days after receipt of the report, indicating how and on what schedule the PWS will address significant deficiencies noted in the survey.*

2.4.7.3 Correcting Significant Deficiencies

Corrective action is required for any PWS with a significant deficiency identified by the primacy agency (SWTR, GWR, and 40 CFR Part 142 National Primary Drinking Water Regulation Implementation). Surveyors should refer to their primacy agency's requirements for water systems that are notified of a significant deficiency. Schedules for responding to and taking corrective action for significant deficiencies varies among primacy agencies.

2.4.7.3.1 Ground Water Systems

Per the federal GWR, if the state identifies a significant deficiency at a ground water system, the PWS must implement one or more of the following corrective action options:

- Correct all significant deficiencies.
- Eliminate the source of contamination.
- Provide an alternate source of water.
- Provide treatment, which reliably achieves 99.99 percent (4-log) inactivation or removal of viruses.

Once the PWS receives written notification from the state, with findings of one or more significant deficiencies, the PWS has 30 days from receipt of that written notification to consult with the primacy agency regarding any required corrective actions. In many cases, the primacy agency tells the PWS what actions they need to take and gives the PWS a deadline in the original written notification, constituting the consulting requirement. The PWS then has 120 days (or earlier if directed by the primacy agency) from receipt of the original written notification to complete the required corrective action or be on a plan and schedule approved by the primacy agency.

2.4.7.3.2 Surface Water Systems

If the primacy agency identifies a significant deficiency at a surface water system, the primacy agency has the authority to require the PWS to respond to the primacy agency in writing, within 45 days of receipt of written notification of the significant deficiency, concerning a corrective action plan to address the significant deficiencies. The primacy agency can be more stringent than this and ultimately determines the schedule for completion.

Note: In order to maintain consistency within the sanitary survey program, many primacy agencies use the same corrective action requirements regardless of the type of system. As long as the primacy agency program is as stringent as the federal regulations, the state can use the same requirements for both system types.

2.4.7.4 Siting Requirements: Advanced Notification

Section 40 of CFR 141.5 requires water systems to notify the primacy agency before a new water system is constructed. The regulation also specifies that the PWS should avoid, to the extent possible, siting in areas subject to earthquakes, floods, and fires.

The surveyor should be alert to any changes made by the PWS without the primacy agency's approval. The surveyor should evaluate all facilities, particularly wells, subject to flooding and recommend protection, if lacking, for those facilities located in flood plains. EPA's *Flood Resilience: A Basic Guide for Water and Wastewater Utilities* (USEPA, 2014) will prepare a surveyor for this task.

2.4.8 Revised Total Coliform Rule Requirements

2.4.8.1 Sample Siting Plan

The RTCR (40 CFR 141.802) requires a water system to have a written sample siting plan that is subject to state approval. The surveyor must verify that the PWS has an approved plan and is using it. The surveyor must also evaluate the plan to determine if it meets the requirements of the RTCR. The rule requires collecting samples "which are representative of water throughout the distribution system." The rule also contains a table that shows the minimum number of samples required based on population served.

In reviewing the sample-siting plan, the surveyor should note that more samples than the minimum might be required in order to be "representative." Some issues to be concerned with include failing to meet inactivation (CT) requirements at or before the first customer, dead ends, long residence time in the PWS, multiple sources, storage tanks, areas of low pressure, biofilm, and cross-connections.

Furthermore, the surveyor should review and document in the sanitary survey report the findings from the RTCR special monitoring evaluation, which the surveyor is required to conduct during sanitary surveys of small ground water systems [40 CFR 141.854(c)(2) and 40 CFR 141.855(c)(2)].

2.4.8.2 Reduced Monitoring

Special monitoring evaluations conducted during sanitary surveys can be used as one condition for allowing the RTCR monitoring frequency for certain CWSs serving fewer than 1,000 persons and using only ground water to be reduced to no less than one coliform sample per quarter [40 CFR 141.855(c)(2)].

2.4.8.3 Special Monitoring Evaluation

During each sanitary survey, the surveyor must conduct a special monitoring evaluation for all ground water systems serving 1,000 or fewer people. The special monitoring evaluation is a RTCR requirement where the surveyor must assess the appropriateness of the sampling frequency, number of samples, sample locations and collection dates based on new data from the sanitary survey, and then determine whether the PWS needs to update the sampling plan.

The surveyor should determine how effective the source, treatment and distribution barriers are regarding protection from contamination, and then modify the sampling plan as needed for public health protection. In addition, the surveyor may need to change the sampling sites and frequency for any of the following reasons as determined during the sanitary survey:

- Increase in population.
- New distribution system areas served.
- New storage tanks.
- Deterioration of water system infrastructure.

2.4.8.4 Sanitary Survey Instead of a Level 1 or Level 2 Evaluation

When monitoring results trigger a level 1 or level 2 assessment under the RTCR, PWSs may have a sanitary survey performed within 30 days of the assessment trigger. When a sanitary survey also satisfies a level 1 or level 2 RTCR assessment requirement, special care must be made by the primacy agency to annotate sanitary defects under the RTCR.

> A sanitary defect is defined as *"…a defect that could provide a pathway of entry for microbial contamination into the distribution system or that is indicative of a failure or imminent failure in a barrier that is already in place"* (40 CFR 141.2).

Additionally, the PWS must correct any sanitary defect or have an approved schedule of corrective actions within 30 days after triggering the assessment. In situations where a surveyor identifies a sanitary defect under the RTCR that is also a significant deficiency, the PWS must adhere to the RTCR's requirements for addressing a sanitary defect.

2.4.9 Ground Water Rule

Under 40 CFR 141.400 and 142, the Ground Water Rule (GWR) addresses risks posed to drinking water from microbiological contaminants in ground water sources through a risk-targeting approach that relies on four major components:

1. Periodic sanitary surveys of ground water systems that require the evaluation of the eight essential elements and the identification of significant deficiencies (e.g., a well located near a leaking septic system).
2. Source water monitoring to test for the presence of *E. coli*, *enterococci*, or coliphage in raw source water samples. The primacy agency determines which of these fecal indicators must be monitored. There are two monitoring provisions:
    - **Triggered monitoring:** For PWSs that do not already provide treatment that achieves at least 99.99 percent, (4-log) inactivation or removal of viruses and that have a total coliform-positive routine sample under RTCR sampling in the distribution system.
    - **Assessment monitoring:** As a complement to triggered monitoring, a primacy agency has the option to require PWSs, at any time, to conduct source water assessment monitoring to help identify high-risk PWSs.
3. Corrective actions required for any PWS with a significant deficiency or source water fecal contamination. The PWS must implement one or more of the following corrective action options:
    - Correct all significant deficiencies.
    - Eliminate the source of contamination.
    - Provide an alternate source of water.
    - Provide treatment, which reliably achieves 99.99 percent (4-log) inactivation or removal of viruses.
4. Compliance monitoring to ensure that treatment technology installed to treat drinking water reliably achieves at least 99.99 percent (4-log) inactivation or removal of viruses at or before the first customer of each ground water source.

During the survey and in addition to the check of source waters and components at ground water systems, the surveyor should examine the sanitary conditions around the source water monitoring points. The surveyor should determine whether the PWS has addressed past significant deficiencies or source water fecal indicator positives using at least one of the four required corrective actions listed above.

For any PWSs approved for compliance (4-log) monitoring, the surveyor should check the sanitary conditions at the compliance monitoring point(s). The surveyor should also review the monthly operating report to make sure the PWS is monitoring disinfectant residuals as required. In addition, the surveyor should determine if any changes have occurred that would require a re-evaluation of the minimum residual required to achieve 4-log before the first customer for each ground water source (e.g., additional wells, changes to disinfection, additional distribution line, new booster pumps, etc.).

2.4.10 Surface Water Treatment Rule

2.4.10.1 General Requirements

Subpart H of 40 CFR Part 141 (Filtration and Disinfection) contains requirements for the filtration and disinfection of surface water supplies and ground water supplies under the direct influence of surface water (defined as "subpart H water systems"). The TT requirements consist of installing and properly operating water treatment processes that achieve 99.9 percent removal and/or inactivation of *Giardia lamblia* (*G. lamblia*) and 99.99 percent removal and/or inactivation of viruses. Water systems have two ways of complying with SWTR requirements. They can meet all the filtration avoidance criteria in 40 CFR 141.71 and provide 99.9 percent *G. lamblia* and 99.99 percent virus inactivation by disinfection, or they can provide both filtration and disinfection that, in combination, meet the removal/ inactivation requirements for *G. lamblia* and viruses.

2.4.10.2 Ground Water Under the Direct Influence of Surface Water

As noted above, PWSs that use ground water sources under the direct influence of surface water are subject to the SWTR and, therefore, are included in the definition of subpart H water systems. The state may base its determination for direct influence on site-specific measurements of water quality (such as the occurrence of insects, algae, or pathogens such as *G. lamblia* or *Cryptosporidium*) or documentation of well-construction characteristics and geology with field evaluations. A source subject to flooding, or the alteration of a stream course bringing it closer to a well, might result in a change in water quality. During the sanitary survey, the surveyor should evaluate any conditions that might cause the state to alter its determination whether surface water is directly influencing a ground water source.

2.4.10.3 No Recontamination

Water cannot be subject to recontamination by surface water after treatment, for example, by using open, uncovered finished water storage or transmission lines subject to runoff. During a sanitary survey, the surveyor should verify that treated water is not subject to recontamination by surface water.

2.4.10.4 First Customer

The PWS must meet the removal and/or inactivation requirements at or before the first customer. The surveyor should identify the first customer and ensure the PWS is meeting the requirements for removal and/or inactivation at that point.

2.4.10.5 Entry Point Disinfectant Residual

The disinfectant residual entering the PWS cannot be less than 0.2 mg/L (as free chlorine) for more than 4 hours and the PWS must provide continuous monitoring. The only exception is for PWSs that do not provide filtration and serve fewer than 3,300 persons; such PWSs may take grab samples at specified frequencies in lieu of continuous monitoring [40 CFR 141.74(b)(5)].

Table 2-1: Grab Samples Frequency by Population

Water System Size by Population	Grab Samples per Day
<500	1
501 - 1,000	2
1,001 - 2,500	3
2,051 - 3,300	4

2.4.10.6 Disinfectant Residual in the Distribution System

A disinfectant residual cannot be undetectable in more than 5% of the samples collected in the distribution system each month for any two consecutive months Samples must be taken at the same time and place as coliform samples. PWSs may also use a heterotrophic plate count to determine disinfectant residual compliance. During the sanitary survey, the surveyor should verify the PWS meets all conditions for disinfection. The surveyor should also determine whether the PWS measures residuals at the proper locations throughout the distribution system as well as at times required by specific regulations (e.g., RTCR). Testing techniques should also conform to the rule.

2.4.10.7 Qualified Personnel

The SWTR requires that qualified personnel operate each subpart H water system. Compliance with the state's operator certification program meets this requirement, and the surveyor should verify operator licenses during the sanitary survey.

2.4.10.8 Unfiltered System Requirements

To avoid filtration, a subpart H water system must meet stringent source water quality and site-specific conditions designed to ensure safe drinking water.

- Source quality conditions: Unfiltered water systems must monitor raw source water immediately before the first point of disinfection and have a fecal coliform concentration of less than or equal to 20/100 mL, or a total coliform concentration of less than or equal to 100/100 mL in at least 90 percent of all measurements over the previous 6 months. In addition, the turbidity of the source water cannot exceed 5 Nephelometric Turbidity Units (NTU) at the same sampling point (with some exceptions).
- Site-specific conditions: In addition to the source water quality conditions, PWSs meeting the filtration avoidance criteria must comply with disinfection requirements that:
    - Ensure 3-log *G. lamblia* and 4-log virus inactivation. The regulations specify CT values that the water system must meet at or before the first customer.
    - Ensure either 2-log or 3-log inactivation of *Cryptosporidium*, based on source water concentrations.

  - Provide redundancy of components or automatic shut-off when the residual is < 0.2 mg/L.
  - Ensure a residual of 0.2 mg/L entering the distribution system.
  - Provide a detectable residual in the distribution system when measured at the same time and place where coliform samples are collected.
  - Maintain a watershed control program that minimizes the potential for contamination by *G. lamblia,* viruses, *Cryptosporidium*, and other pathogens.
- Be subject to an annual on-site inspection. On-site inspections for PWSs subject to the filtration avoidance criteria are similar to sanitary surveys, and the state may accomplish this during sanitary surveys. Items to be reviewed include:
  - Effectiveness of watershed control.
  - Condition of intake.
  - Disinfection facilities and their O&M.
  - Operating records.
  - Effectiveness of disinfection.
  - Needed improvements.
  - Waterborne disease outbreaks.
  - Maintain compliance with the RTCR and the DBPRs.

During the sanitary survey, the surveyor should review the PWS's data on raw water quality and its source water protection program. The surveyor also should check the available CT for compliance.

2.4.10.9 Filtered System Requirements

PWSs providing filtration must meet the requirements described below.

2.4.10.9.1 Pathogen Filtration Performance Requirements

PWSs that are unable to comply with all criteria to avoid filtration must meet the 3-log *G. lamblia* and 4-log virus inactivation and/or removal requirements and 2-log *Cryptosporidium* removal requirements by using both an appropriate filtration technology and disinfection. PWSs must measure compliance with the TT requirements of the SWTR against turbidity performance criteria that are specific to the type of filtration in use (subject to primacy agency approval) and adequate CT to inactivate the remaining *G. lamblia* and viruses.

2.4.10.9.2 Turbidity Requirements

The regulations for surface water treatment establish minimum turbidity performance criteria for the various filtration methods. The turbidity performance criteria differ depending on the type of filtration that is being used. Turbidity performance criteria for each filtration method are provided below.

2.4.10.9.3 Conventional and Direct Filtration

Filtered water turbidity must be less than or equal to 0.3 NTU in 95 percent of the measurements taken every month. The turbidity level of representative samples of a PWS's filtered water must not exceed 1 NTU at any time.

2.4.10.9.4 Slow Sand Filtration

Filtered water turbidity must be less than or equal to 1 NTU in 95 percent of the measurements taken every month. A primacy agency may allow a higher level of turbidity if it determines that there is no significant interference with disinfection at the higher turbidity level. The turbidity of slow sand filter effluent must never exceed 5 NTU. The surveyor should verify the PWS meets these conditions if the primacy agency allows the PWS to exceed 1 NTU.

2.4.10.9.5 Diatomaceous Earth Filtration

Filtered water turbidity must be less than or equal to 1 NTU in 95 percent of the measurements taken every month. The turbidity level of representative samples must not exceed 5 NTU at any time.

2.4.10.9.6 Other Filtration Technologies

Alternative filtration technologies must be capable of consistently achieving 99.9 percent and 99.99 percent removal and/or inactivation of *G. lamblia* cysts and viruses, respectively. The original SWTR requires PWSs using alternative filtration technologies to comply with the turbidity performance criteria for slow sand filtration (40 CFR Section 141.73(b) and (d)). With the promulgation of the Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) in January 2002, subpart H water systems, regardless of population, must demonstrate to the primacy agency that alternative technologies are capable of 99 percent *Cryptosporidium*, 99.9 percent *G. lamblia*, and 99.99 percent virus removal and/or inactivation. For PWSs that can make this demonstration, the primacy agency establishes turbidity performance criteria at a level that ensures adequate pathogen removal.

2.4.10.9.7 Turbidity Measurements

The surveyor should verify that the water system is taking the required turbidity measurements, that the results are accurate and reliable, that sampling frequency, locations, and analytical procedures are appropriate, and that the turbidity readings comply with the SWTR requirements. The surveyor should check for compliance with CT requirements and ensure the PWS operator is properly completing the daily calculations.

2.4.10.9.8 Operation and Maintenance

The surveyor should verify the water system has in place all required filtration and disinfection facilities and is properly operating and maintaining those facilities.

2.4.11 Interim Enhanced Surface Water Treatment Rule

Title 40 CFR Part 141, Subpart P, Enhanced Filtration and Disinfection (40 CFR 141.170-.175), includes additional requirements for subpart H water systems that serve 10,000 or more persons. These requirements took effect January 1, 2001, and primarily address public health risks from *Cryptosporidium*. They include:

- Turbidity limits that are more stringent for combined filter effluent from conventional and direct filtration plants.
- Continuous monitoring of individual filter effluent in conventional and direct filtration plants.
- Follow-up actions for exceeding “trigger” turbidity levels in two consecutive measurements taken 15 minutes apart at an individual filter for conventional and direct filtration plants.
- Requirements for all filtered water systems to remove 99 percent (2-log) *Cryptosporidium* cysts.
- Disinfection profiling and benchmarking.
- Measures to control *Cryptosporidium* in the watersheds of unfiltered water systems meeting the criteria for avoiding filtration.

Surveyors should check to see if PWSs that are required to prepare disinfection profiles have actually done so. Water systems must retain disinfection profile data in a graphical format acceptable to the state for review during the sanitary survey regarding any significant changes to disinfection practices, planned or otherwise. As part of IESWTR, the surveyor must also designate in the sanitary survey report any sanitary deficiencies deemed by the state to be “significant” deficiencies. Surveyor follow-up is then necessary to ensure the PWS responds in writing and addresses the significant deficiencies.

2.4.12 Long Term 1 Enhanced Surface Water Treatment Rule

The LT1ESWTR applies requirements similar to those of the IESWTR to PWSs that use surface water or ground water under the direct influence of surface water and serve fewer than 10,000 persons.

2.4.13 Long Term 2 Enhanced Surface Water Treatment Rule

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) requires monitoring of raw source water to determine if levels of *Cryptosporidium* exist in quantities high enough to warrant additional treatment. Depending on the calculated average, PWSs could be required to provide additional treatment that achieves an additional one, two, or 2.5 log removal/inactivation of *Cryptosporidium*. PWSs serving less than 10,000 people have the option to monitor each source for *E. coli* as a surrogate and would only monitor for *Cryptosporidium* at sources with an average result of all 52 biweekly samples exceeding the appropriate trigger level.

2.4.14 Filter Backwash Recycling Rule

The surveyor should determine whether direct and conventional filtration plants recycle spent filter backwash water, sludge thickener supernatant, or liquids from dewatering processes. Plants that recycle regulated flows must bring them back to the head of the plant (after June 1, 2003) or to an alternative location approved by the primacy agency. The primacy agency also determines if treatment or equalization of the recycle stream is necessary. The surveyor should also make sure the plant complies with the rule’s monitoring and reporting requirements.

2.4.15 Lead and Copper Rule

Under 40 CFR 141.80 to 91, CWSs and NTNCWSs must collect first-draw samples from strategically located service connections and have them analyzed for lead and copper. If the levels of lead or copper exceed action levels (0.015 mg/L for lead and 1.3 mg/L for copper) in more than 10 percent of the required samples, the PWS must take corrective action.

The surveyor should verify that the PWS has taken the required first-draw samples at sites from its monitoring plan, that the PWS has appropriately prioritized sampling from the highest tier sites in the distribution system, and that the monitoring plan is up to date. It is particularly important with small water systems to make sure they are sampling at appropriate locations and times. Small schools, for example, often sample at the beginning of the school year usually from taps not used for weeks or months; they then exceed action levels because of the excessive time water was in the line. Lead and copper tap samples must be collected from taps used for drinking and not utility sinks or hose bibs.

When monitoring results exceed either of the action levels, the surveyor must ensure that the PWS has taken appropriate follow-up corrective actions, including optimal corrosion control studies and treatment when necessary.

2.4.16 Stage 1 and 2 Disinfectants and Disinfection Byproducts Rules

CWSs and NTNCWSs that chemically disinfect their water must meet the requirements of 40 CFR Part 141, subparts L (Stage 1 DBPR) and V (Stage 2 DBPR), collectively referred to as the DBPRs. Portions of the DBPRs also apply to TNCWSs that use chlorine dioxide. Components of the DBPRs that surveyors should be aware of include:

- MCLs for DBPs including bromate and chlorite as well as MCLs based on locational running annual averages (LRAAs) for total trihalomethanes (TTHMs) and haloacetic acids (HAA5s).
- Maximum residual disinfectant levels (MRDLs) for chlorine, chloramines, and chlorine dioxide.
- Monitoring plan requirements.
- Enhanced coagulation and enhanced softening requirements to address DBP precursors for subpart H water systems that have conventional or softening plants.
- Operational Evaluation Level (OEL) requirements: An OEL report is required if the OEL is exceeded. See 40 CFR 141.626 for the OEL definitions for TTHM and HAA5.

Each PWS affected by this rule must develop and implement a monitoring plan that the water system must have available for the primacy agency's review. The PWS must then maintain the monitoring plan and make it available for survey by the primacy agency and customers (PWSs serving more than 3,300 persons must submit their plans to the primacy agency). The surveyor should review the monitoring plan while on-site to ensure that monitoring is in accordance with the rule.

2.4.17 Inorganic and Organic Chemicals

CWSs and NTNCWSs are required to monitor for inorganic and organic chemicals as found in 40 CFR 141.23 and 40 CFR 141.24, respectively. For both groups of contaminants, samples are required at the entry points to the distribution system. Surveyors should verify that the PWS appropriately monitors all sources (including emergency sources) at their entry points. It is important to note that TNCWSs are required to monitor for nitrate and nitrite.

2.4.17.1 Waivers

Under certain conditions, states may grant waivers to water systems from monitoring requirements (including reduced or no monitoring) for volatile, synthetic and inorganic chemicals. The primacy agency may grant "use" waivers based on knowledge of previous use of a contaminant including application, manufacture, transport, storage or disposal. Additionally, the primacy agency may grant a waiver based on resistance to sources of contamination and wellhead or watershed protection. The surveyor should review any waivers during preparation for the sanitary survey and evaluate these factors during the survey. If conditions have changed, the primacy agency may have cause to reconsider a waiver previously granted or to grant a new waiver. The following waiver considerations should be reviewed during a sanitary survey.

- The PWS must monitor for asbestos, unless the state has issued a waiver, at a tap served by asbestos cement pipe. The surveyor should verify this information.
- A primacy agency may grant a waiver for organics that results in reduced monitoring based on the following factor(s):
  - Knowledge of previous use (including transport, storage, or disposal) of the contaminant within the watershed or zone of influence of the PWS.
  - If previous use of the contaminant is unknown or it has been used previously, then the following factors shall be used to determine whether a waiver is granted.
  - Previous analytical results.
  - Proximity of the PWS to a potential point or non-point source of contamination (e.g., spills and leaks of chemicals at or near a water treatment facility or at manufacturing, distribution, or storage facilities, or from hazardous and municipal waste landfills and other waste handling or treatment facilities).
  - The environmental persistence and transport of the contaminants.
  - The number of people served by the PWS and the proximity of a smaller water system to a larger water system.
  - How well the water source is protected against contamination, such as whether it is a surface or ground water system. Ground water systems must consider factors such as depth of the well, the type of soil, and wellhead protection. Surface water systems must consider watershed protection.

2.4.18 Radiological Contaminants

CWSs are required to sample for radiological contaminants. Samples are required at the entry points to the distribution system. Surveyors should verify that PWSs are appropriately monitoring all sources (including emergency sources) at their entry points. The surveyor should review compliance with radiological monitoring requirements while on-site or when reviewing the PWS's files, prior to the sanitary survey.

2.4.19 Unregulated Contaminants

During a sanitary survey, the surveyor must be alert to contaminants other than those regulated under national primary or secondary regulations. The SDWA provides the authority for EPA to publish health advisories for contaminants not subject to any NPDWR. Health advisories provide information on contaminants that can cause human health effects and are known or anticipated to occur in drinking water. EPA's health advisories are non-enforceable and non-regulatory and provide technical information to states agencies and other public health officials on health effects, analytical methodologies, and treatment technologies associated with drinking water contamination. Drinking water contaminants for which EPA has issued a health advisory are often evaluated for future regulation in accordance with the process required by the SDWA. To regulate a contaminant under SDWA, EPA must find that it:

1. May have adverse health effects;
2. Occurs frequently (or there is a substantial likelihood that it occurs frequently) at levels of public health concern; and
3. There is a meaningful opportunity for health risk reduction for people served by PWSs.

Aside from contaminants with an EPA health advisory, of particular concern are contaminants the PWS may introduce to the water during the processes of collecting, treating, storing, or distributing.

2.4.20 Direct and Indirect Additives

2.4.20.1 Treatment, Chemicals, and Coatings

Water systems are responsible for assuring treatments, chemicals, and coatings in contact with drinking water meet certain industry consensus standards for water contact or treatment. Agencies or other non-governmental organizations acceptable to the primacy agency can provide certification standards for products intended for contact with potable water.

2.4.20.2 40 CFR 141.111

EPA regulations place limits on two contaminants that may be contained in organic polymers used in coagulation and filtration. The water system must annually certify to the primacy agency in writing that the dose and monomer level do not exceed the following:

- Acrylamide, 0.05 percent dosed at 1 part per million (ppm).
- Epichlorohydrin, 0.01 percent dosed at 20 ppm.

During a sanitary survey, the surveyor should determine that the PWS is complying with these requirements.

2.4.20.3 NSF Standard 60

NSF International (NSF) is the organization responsible for developing Standard 60, which covers direct additives to drinking water. Examples of direct additives include water treatment chemicals such as chlorine, polymers, coagulants and aids, fluoride compounds, copper sulfate, and corrosion control chemicals.

2.4.20.4 NSF Standard 61

NSF Standard 61 covers indirect additives. This category of additives includes products that come into contact with drinking water or into contact with treatment chemicals, such as filter media, coatings, liners, solvents, gaskets, welding materials, pipes, fittings, valves, chlorinators, and separation membranes. PWSs can identify NSF Standard 60 or 61 certified products by markings directly on the product or on their packaging. Lists of certified products are available from the certifying agencies.

2.4.20.5 State Requirements

Although there are no federal regulations requiring that additives used must meet NSF Standards 60 and 61, many states have such requirements. In any event, the surveyor should determine if the PWS uses additives specifically designated for use with potable water and is aware of the certification program for those additives.

2.4.21 Operator Certification

EPA guidelines specify minimum standards for the certification and recertification of operators of CWSs and NTNCWSs. All states have requirements that meet the EPA guidelines. The surveyor should always check to ensure each PWS complies with the state requirements.

2.4.22 Recordkeeping

There are a number of general recordkeeping requirements specified in 40 CFR 141.33. In addition, the SWTR (40 CFR 141.75), LCR (40 CFR 141.91), and NPDWRs have specific requirements. The surveyor should verify and evaluate the availability of these records for each applicable rule at the water system during a sanitary survey.

2.4.22.1 Other Records

In addition to records required by federal regulation, the water system should maintain a variety of other records to ensure the continual proper O&M of the PWS. These include monitoring plans for disinfectants and DBPs; disinfection profiles; maps of the PWS; as-built plans; and water quality data from source, treatment, and distribution. The surveyor should evaluate the availability and security of these records during the sanitary survey.

Table 2-2: Records and Retention Schedule

Records to Keep	Retention Period
Bacteriological analyses	5 years
Chemical analyses	10 years
Actions to correct violations	3 years
Sanitary survey reports	10 years
Variance or exemption	5 years
Turbidity results	5 years
All lead/copper data	12 years
Monitoring plans for RTCR, LCR & DBPRs	As long as subject to the rule(s)

2.4.22.2 Data Integrity

SDWA and its regulations require self-monitoring and self-reporting by water systems to show compliance with the regulations. The consequences of non-compliance can be severe (e.g., compliance orders and penalties). Errors in information reported to the state can result from ignorance of proper testing procedures and instruments that are out of calibration. Data falsification is rare, but serious. During a sanitary survey, the surveyor should be alert to intentional or unintentional errors in data. Chapter 13 provides more information on data integrity.

2.4.23 Variances, Exemptions, and Orders

Variances, exemptions, and federal or state enforcement actions or orders contain provisions that require the PWS to comply with certain conditions. (For example, a compliance order will normally include a schedule.) The state can use a sanitary survey to determine a PWS's progress in complying with these conditions. The primacy agency can also use sanitary surveys to determine, case by case, the need for, and the possible conditions that may be set forth in, a variance, exemption, or order.

2.5 Sanitary Deficiency Questions and Considerations - Regulations

- **Is the information in the primacy agency files on population served and number of service connections accurate?**

  Prior to the sanitary survey, the surveyor should check population served and other background information available in the primacy agency's database. The surveyor should compare information in the database with water system records and the operator's answers to related questions during the survey to make sure they are consistent. During the survey, the surveyor should consider any developments (e.g., subdivisions, schools, factories, office parks) that have either opened or closed since the last survey, and how any change impacts the water system's population served. The population served figure is important because it is used for several regulatory requirements including the number of routine compliance samples collected each month for RTCR.

- **Is the information on the status of the PWS correct (i.e., is it large enough to be a PWS, and is its classification as CWS, TNCWS, or NTNCWS correct)?**

  The surveyor should compare the population served with the definition of a PWS and various types of PWSs to confirm that the water system is classified correctly.

- **Is the PWS in compliance with various provisions of the NPDWRs, including siting of facilities, coliform monitoring, filtration and disinfection, lead and copper corrosion control, organic and inorganic contaminants, and direct and indirect additives?**

  The surveyor should review each regulatory requirement with the operator to check that all regulatory monitoring is being conducted, water quality monitoring results meet regulatory limits, and all other requirements are being met.

- **Has the PWS modified its source, treatment process, chemicals used, or distribution system without primacy agency approval?**

  The surveyor should review the last sanitary survey report and note any changes in source, treatment, chemicals, or distribution system facilities. No major changes should be made without primacy agency approval.

- **Is the PWS using chemicals and coatings approved by ANSI/NSF or another third party?**

  NSF is the organization responsible for developing Standard 60, which covers direct additives to drinking water. Examples of direct additives include water treatment chemicals such as chlorine, polymers, coagulants and aids, fluoride compounds, copper sulfate, and corrosion control chemicals. NSF Standard 61 covers indirect additives. This category of additives includes products that come into contact with drinking water or into contact with treatment chemicals, such as filter media, coatings, liners, solvents, gaskets, welding materials, pipes, fittings, valves, chlorinators, and separation membranes. PWSs can identify NSF Standard 60 or 61 certified products by markings directly on the product or on their packaging. Lists of certified products are available from the certifying agencies.

- **Does a qualified operator staff the PWS?**

  In preparation for the sanitary survey, the surveyor should review primacy agency requirements for operator certification and determine which types of operators are required for the water system being inspected. Operator certification requirements are determined by the primacy agency and are often based on population served, source type, and complexity of the water treatment process. The surveyor should ask if enough certified operators are available to cover all shifts. Current records should be reviewed to ensure the operators' contact information is correct and the operator-in-responsible-charge is correctly identified. Surveyors should also review the most recent operator certifications to ensure that they have not expired.

- **Does the PWS maintain all appropriate records?**

  Each SDWA regulation has recordkeeping requirements. Bacteriological records must be kept for 5 years. Chemical records and sanitary survey records must be kept for 10 years.

- **Does the PWS comply with conditions set forth in any waivers, variances, exemptions, or orders?**

  The surveyor should check the primacy agency database to identify whether the water system has any current violations, enforcement actions, or administrative orders. The surveyor should also ask the operator if there are any current waivers, variances, or exemptions to regulatory requirements.

- **Does the PWS have a written monitoring plan for disinfectants and DBPs?**

  The surveyor should ask for copies of written plans for conducting regulatory monitoring for the RTCR and the DBPRs. The surveyor should confirm that the sampling locations currently used are the sites identified in the plans.

- **Was the PWS required to prepare a disinfection profile? If so, is it available for review?**

  The surveyor should check to see if the water system has made any significant changes to disinfection practices that triggered the requirement to prepare a disinfection profile and benchmark. If yes, the surveyor should check that the water system has prepared the disinfection profile and accurately identified the benchmark. The water system should retain disinfection profile data in a graphical format acceptable to the primacy agency for review during the sanitary survey.

2.6 Significant Deficiency Examples

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The primacy agency determines both significant deficiencies, and the corresponding corrective actions.

- No or inadequate site maps for collecting regulatory samples:
  - LCR.
  - DBPRs.
  - Chemical monitoring.
- Inadequate or incorrect sample point(s).
- Not using NSF-approved materials or additives.
- Not abiding by the records retention policy.
- Recycled water not flowing back to head of plant.
- Insufficient or no qualified operators.
- Incorrect CT calculation

3 Ground Water Sources

Surveyors should determine the safety and reliability of any ground water source during the sanitary survey. Ground water sources, such as wells and springs that are determined to be ground water, are the first safety barrier in the multiple-barrier approach including the prevention of waterborne diseases.

3.1 Learning Objectives

By the end of this chapter, students should be able to:

- Evaluate the safety, adequacy, and reliability in terms of quantity and quality of ground water sources.
- Evaluate the adequacy of well head protection.
- Review the key components of wells.
- Identify the key data required to determine sanitary deficiencies.
- Recognize sanitary deficiencies associated with facilities, operations, maintenance, management, and contingency planning.
- Identify improper well construction and equipment installation.
- Determine compliance with federal, state, and local regulations.
- Recognize risks associated with extreme weather events (i.e., drought, flood)

3.2 Data Collection

Generally, the surveyor should collect enough data needed to evaluate the safety, adequacy, and reliability of all water sources used by the PWS, including emergency sources. For example, raw water quality data can help evaluate the safety of the source. Information about aquifer yield and design flow rate is important to determine the capability to meet water demands. The following narrative and sanitary survey questions discuss the types of data the surveyor should collect.

3.3 Regulations and Standards to Consider

Most of a PWS's regulatory requirements focus on the quality of water entering the distribution system. However, source water quality is a major part of the SDWA, including the GWR.

3.4 Basic Ground Water Source Information

Ground water systems are generally simpler PWS types to operate and maintain. They do not usually require extensive levels of treatment or training for operator certification, unless special treatment is required (e.g., iron, manganese, arsenic, radionuclides or other regulated contaminants found in the aquifer). Operators must still have the skills necessary to operate and maintain the PWS as well as provide continuous disinfection, if required by the primacy agency.

Very small ground water systems usually do not have much management structure. The operator is often the owner, meter reader, maintenance crew, bill collector and financier for the entire PWS. The operator may also have other duties, including a full-time job. This means that all the technical, managerial and financial responsibilities for the PWS's sustainability could very well fall on the shoulders of one person who only operates the PWS on a part-time basis.

As a result, these very small water systems could have difficulty maintaining compliance with NPDWRs and state requirements and difficulty with maintaining the physical components of the water system.

3.5 Quantity

A range of factors affect water availability including, but not limited to, water loss, conservation, extreme weather (drought, flooding, etc.), and security over a long-term planning horizon, such as 15 to 20 years. The water system should demonstrate water availability in its capital improvement program and planning documents.

The surveyor should evaluate the capability of the PWS to meet the demands placed on each of its applicable components. Demands exceeding available treatment capacity can cause inadequately treated water to enter the distribution system. Similarly, inadequate pressure in the PWS may exist when well pumping and source capacities cannot maintain sufficient water levels (as well as the capacity of transmission lines, pumps, distribution system piping, storage facilities, etc.).

Inadequate pressure affects consumers' use of the water supply, hinders firefighting capabilities, and creates opportunities for contaminants to enter the PWS through cross-connections. Interruptions in water service represent a public health hazard. A general rule of thumb for minimum water pressure is about 30 pounds per square inch (psi); however, primacy agencies set their own standard.

3.5.1 Estimating Demand[1]

Water demand is the volume of water required by users to satisfy their needs. Water demand varies from location to location and from day to day within a location. Demand also depends on the time of day, the day of the week, the season of the year, prevailing weather conditions and unusual events such as fires or main breaks.

The water system operator should be recording the daily water demand, or total daily water usage, and should be able to produce and understand the average daily water demand (the average amount of water used in a day), the maximum daily water demand (the maximum amount of water used in a day), and seasonal variations in usage. Additionally, the operator should understand any consequences from peak instantaneous usage and their impacts on the capacity of system components. Considering peak usage is important in order to ensure the water system can always maintain sufficient pressure throughout its distribution system.

Alternatively, most primacy agencies have *community water demand factors* (expressed as gallons per capita per day (GPCD) for estimating the average daily water demand. Many primacy agencies also have equations to estimate maximum daily demand as well as the peak instantaneous usage for various water systems. Water demand (excluding firefighting) for most regions ranges from 120 to 300 GPCD

[1] See Appendix A for references on this topic.

(depending on allowances for frequent lawn watering, swimming pool maintenance, industrial and commercial process water, cooling water, etc.). Rural communities, however, tend to use water primarily for residential purposes so the water demand can be as low as 100 GPCD.

The surveyor should recognize the importance of the relationship between source water quantity and storage. Storage facilities maintain system pressures and provide water for fluctuating demands while the source water quantity is typically a more consistent flow that is designed to gradually fill a storage tank. Alternatively, hydropneumatic systems use compressed air in a pressure vessel to maintain distribution system pressure, and rely more closely on pump capacity to meet short-term system demands. Hydropneumatic tanks are more frequently used on very small water systems. The surveyor should be prepared to make reasonably accurate estimates of probable water demand for a wide variety of types and sizes of PWSs.

3.5.2 Emergency Demand

Many states require alternate sources of water in case of emergencies. For ground water systems, these emergencies include well failures, catastrophic events (i.e., tornados, hurricanes, etc.), flooding in well locations, aquifer depletion and contamination incidents around the wellhead or in the aquifer itself.

PWS managers are responsible for planning, identifying and securing alternate sources of water supply, and how the PWS would deliver water to the PWS's customers. In fact, their water system may serve as an alternate supply for another water system. Alternate sources might include an interconnection to another PWS, use of inactive or backup wells, drilling a new well, water tanker delivery, bottled water delivered to customers on an interim period, or other means of safe water supply.

3.5.3 Sanitary Deficiency Questions and Considerations – Quantity

- **Is the safe yield sufficient to meet current and future demands?**

  Capital improvements may be necessary if source production is insufficient to meet PWS needs, if storage is insufficient based upon state requirements, or if PWS components are undersized to convey or maintain sufficient pressures under peak demands.

- **Is the quantity of the source sustainable?**

  Given that a water system's source is one of the first areas evaluated using the multiple barrier approach, the key to ensuring the sustainability of the water system is for the surveyor to evaluate several factors that could affect the long-term viability of the source. These factors may include PWS type, size, extreme weather conditions, storage facilities used, and customer type.

  Decreasing trends in quantity (i.e., aquifer depletion) are also important to note. Records of measured water levels should provide this information, but the surveyor should be prepared to make reasonable estimates when records are not available.

  The following questions will help the surveyor assess the adequacy of source capacity.

- **Does the PWS have plans or procedures to respond to variations in their source water supplies?**

  The surveyor should ask if the water system has written practices for emergency operations such as operating during drought conditions.

- **Does the PWS track or have data regarding aquifer levels, recharge areas and related information for its sources?**

  The surveyor should ask whether the recharge area for each well has been mapped, and if data are collected on depth to water table (i.e., the elevation of the ground water). If the water system is monitoring and recording well water level, does the water level ever drop to an elevation that puts the well pump's effectiveness at risk? The surveyor should also ask what operational changes the water system is making based on well water level readings.

- **Has the PWS had to increase pumping depths in their wells or drill deeper wells? Have any wells gone dry?**

  During periods of drought or high usage, the water table may be reduced to a lower elevation. If the water table is below the elevation of the well pump, the pump will not be able to deliver water to the PWS. In this case, the water system may have to drill a new well or install a pump in an existing well at a lower elevation.

- **Does the operator monitor and maintain alternate/emergency supplies (e.g., intakes, valves, pumps, consecutive connections) to assure good operational conditions?**

  Many primacy agencies require that water systems identify, monitor, and maintain alternate sources of water in case of emergencies. For ground water systems, these emergencies include well failures, catastrophic events (e.g., tornados, hurricanes), flooding in well locations, aquifer depletion, and contamination incidents around the wellhead or in the aquifer itself.

- **Are there constraints or limits on reserve or alternate sources (e.g., permits, water rights, hydraulic limitations, costs)?**

  If the water system uses any reserve or alternate sources, the surveyor should document any permits obtained and operational limits specified by these permits. If the water system relies on an interconnection with another PWS for emergency purposes or to augment their supply when demand is high, the surveyor should consider the regulatory status of the interconnected PWS and identify any potential issues related to water quality or quantity that may arise when that auxiliary water is being used. For example, there may be controls in place that limit flow rates, or the PWS's pressure may change when an emergency source is being employed (i.e., when the water system is either providing water or accepting water). In addition, using backup sources sometimes requires additional or different treatment; the surveyor should ask the operator about any additional conditions that must be met when using the auxiliary sources.

- **Does the capacity/flow of the ground water source vary? If so, how does the PWS meet demand during those periods?**

  The surveyor should ask the operator if the pumping rate from each ground water source has remained constant over the long-term. If a pump test is available for the well, the surveyor should discuss with the operator how the current pumping rate compares with the pump test conditions. If less water is available during drought periods, the surveyor should ask what operational changes are made during these periods.

- **Are consecutive water systems subject to reductions in supply due to wholesale supply variations? If so, does the consecutive water system have alternatives or contingencies to meet demands?**

  A consecutive water system is a PWS that buys or otherwise receives some or all of its finished water from one or more wholesale water systems. Delivery may be through a direct connection or through the distribution system of one or more consecutive water systems.(40 CFR 141.2). The surveyor should ask the water system manager if there are any restrictions on supply from the wholesale provider, and if so, what contingency plans are in place.

- **Does the PWS have an operational master meter?**

  Without an operational and calibrated master meter, it is difficult for the PWS to monitor production accurately. Some PWSs meter the hours their pumps run. With this information, and inlet and outlet pressures of the pump, the surveyor can use the appropriate pump curves to estimate production.

- **How many service connections are there? Does the PWS meter all service connections?**

  This number of residential and other service connections gives the surveyor an idea of the size of the PWS in terms of number of homes and businesses served by the PWS. Meters allow the PWS to calculate a water balance that may aide the PWS in determining water loss, as well as determine demand estimates. There is also a correlation between metered service connections and water conservation (i.e., the cost of water as a function of the amount used).

  If the primacy agency estimates population served on the number of connections multiplied by a factor for average household occupants, the state should only include connections billed by the PWS (e.g., exclude connections at vacant lots).

- **Does the PWS have interconnections with neighboring PWSs or a contingency plan for water outages?**

  It is important for PWSs to have plans to correct causes of water outages without interruption of service and to minimize pressure drops in the distribution system and other potential adverse effects throughout the PWS. This is especially important in arid or drought-stricken areas. These plans should include contact information and locations of the valves that interconnect the PWS with their emergency source. An operator also needs maps of valve locations to isolate sections of pipe if a line break is the source of the outage. Understanding the locations of valves is important for promptly isolating the effects of main breaks and minimizing water loss. The surveyor should ensure interconnections are only to sources approved by the state.

- **Does the water system have redundant sources?**

  Many states require CWSs supplied by ground water to have at least two supply wells that individually meet demands, or an emergency connection to another water system in case the primary source fails.

3.6 Quality

3.6.1 Source Contamination

The likelihood of contamination (depending on the well's vulnerability and geology of the area) increases as the proximity to PSOCs to the source increases. Examples of PSOCs include septic tanks, construction projects, chemically treated agricultural land, concentrated animal feeding operations, chemical storage areas, and industrial discharge. Other sources of contamination include proximity to a lake or a stream, sewers, runoff from a flooding event, iron, manganese, or other chemicals (e.g., arsenic, selenium, fluoride, radionuclides, etc.) in soil and rock formations.

3.6.2 Sources of Impurities

The impurities in natural waters depend largely on the circumstances of the source and its history. Water destined to become ground water may pick up impurities, including possible contaminants, as it seeps through soil and rock. As a preliminary step for determining the contamination risk, the surveyor should refer to the PWS's source water assessment, which should have an inventory of potential contaminant sources and a determination of the well's vulnerability.

Uptake of minerals by water is common. The natural straining of water as it moves through soil and aquifer material can remove some particulates, and combined with a relatively long retention period in the ground, often aids in removing and reducing active microorganisms. However, a long retention time can also create problems. Purging contaminated ground water typically requires time and money.

3.6.3 Sanitary Deficiency Questions and Considerations – Quality

- **Does the PWS have a smooth-nozzle raw water tap and treated water tap for each well?**

  Under the GWR, a total coliform positive sample in routine distribution sampling triggers raw water sampling for a fecal indicator at the wells if the ground water system is conducting triggered source water sampling. Have any raw water samples (compliance or non-compliance) indicated a problem?

- **Are there any abandoned wells and have they been properly closed?**

  Surface supplies or improperly abandoned wells physically connected to a water system may pose a public health threat by introducing contamination via a cross connection. For example, any feed lines used to treat raw water can create a cross-connection if the treatment inlet to the raw water does not have a sufficient air-gap to prevent siphoning of raw water to finished water in the event of a pump or power failure. This is a public health risk (i.e., a cross-connection). The PWS should physically disconnect raw water transmission lines from abandoned sources.

- **Are there unused or auxiliary wells connected to the distribution system?**

  The PWS also should properly plug unused or abandoned wells in a manner prescribed by state regulations to prevent contamination of the aquifer.

3.7 Wells

3.7.1 Utilities - Main Source

Ground water is a primary water source for many PWSs. It is readily available in most areas of the country in sufficient quantities to meet the needs of small water systems. Ground water generally has better microbiological quality than surface water. However, a number of ground water systems have contamination issues due to erosion of natural deposits, improper underground chemical storage tanks, agricultural chemical application, etc. Ground water often requires little treatment prior to use, while surface water usually needs extensive treatment to remove or inactivate bacteria, *G. lamblia*, *Cryptosporidium,* and viruses as well as remove organic material.

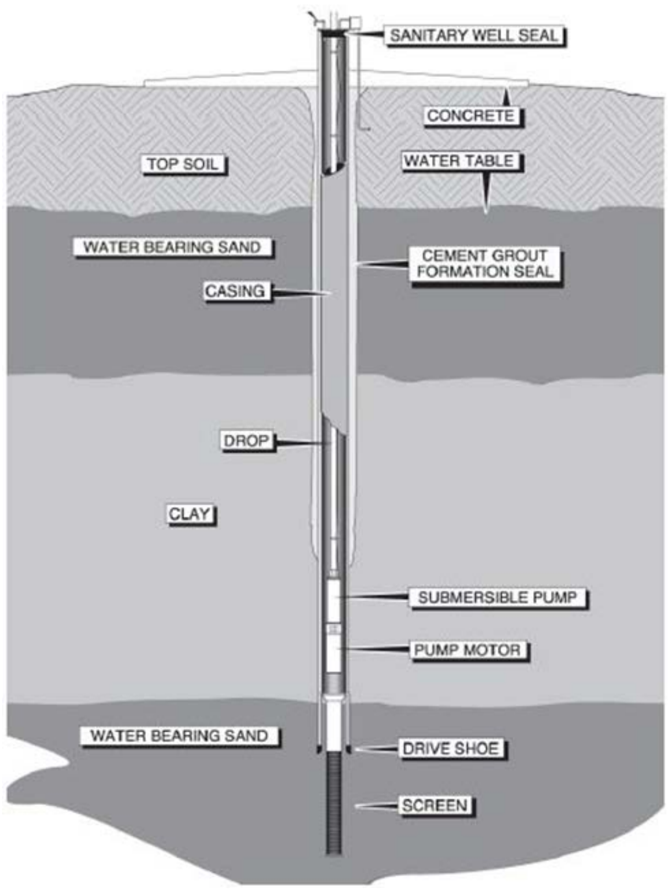

Figure 3-1: Components of a drinking water well with submersible pump

3.7.2 Well Components

Surveyors will not be able to evaluate many well components because they are underground. The following narrative describes some of the more important components.

3.7.2.1 Casing

A well casing prevents the collapse of the bore hole, keeps surface and subsurface pollutants from entering the water source, provides a column of stored water for positive well pump suction head, and houses the pump and its discharge pipe.

3.7.2.2 Grout

During construction, well drillers frequently fill the open annular space left around the outside of the well casing with concrete or bentonite clay grout. This grout prevents surface water and shallow ground water from entering and potentially contaminating the well, and it prevents water from moving between aquifers. PWS wells should have a grout seal that meets the primacy agency's requirements.

3.7.2.3 Screens

Screens installed at a well's intake point hold back unstable aquifer material and permit the free flow of water into the well. The well screen should be of good quality (e.g., good structural properties, corrosion resistant, and hydraulically efficient). Where formation conditions are suitable, many small water systems use perforated or slotted casings in lieu of screens.

3.7.2.4 Sanitary Seal

Wellhead covers or seals at the top of the casing or pipe sleeve connections prevent contaminated water and other material from entering the well. Several types of covers and seals are available to meet the variety of conditions encountered, but the principles and objectives of allowing free movement of air while excluding contamination are the same.

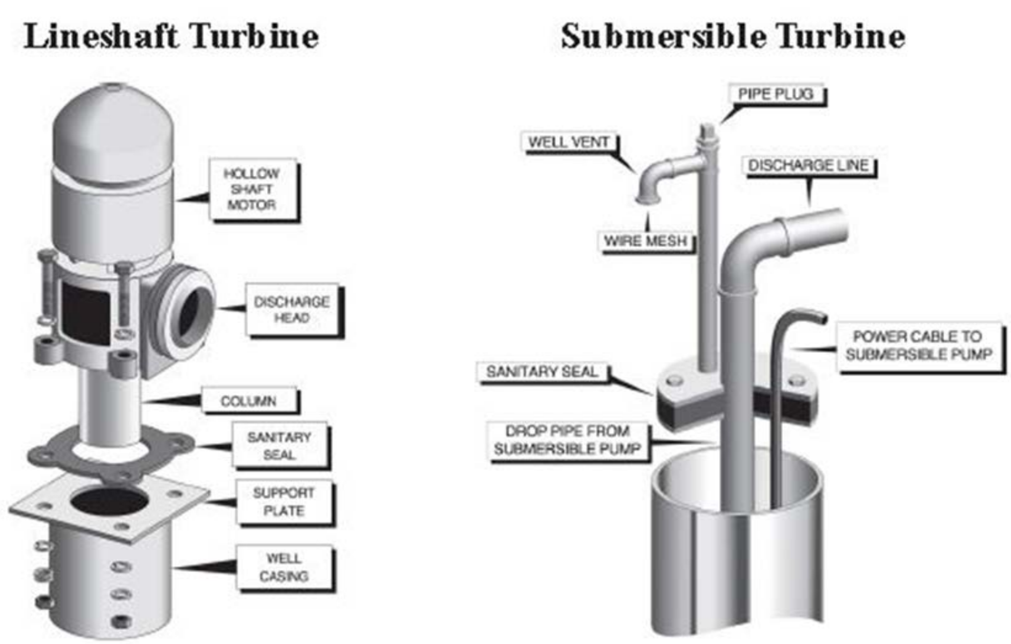

Figure 3-2: Lineshaft turbine and submersible turbine upper well construction

3.7.2.5 Pitless Units

Pitless units and pitless adapters eliminate the need for a well pit. Design standards do not recommend a well pit to house the pumping equipment or to allow access to the top of the well casing because the pits can flood, introduce pollution hazards, and present confined space entry risks. Some states prohibit the use of pits. A pitless adapter generally includes a special fitting that can be inserted through a hole in the well casing. The well discharge piping is attached to the fitting in a manner that should provide a tight seal. A pitless unit completely replaces the well casing between the frost line and the ground surface. Both pitless systems allow water to be discharged from the well below frost depth and, at the same time, provide good accessibility to the well pump and drop pipe for repairs without excavation. An illustration of the components of a pitless adapter is provided in Figure 3-9.

3.7.3 Aquifer Classification

Confined (artesian) and unconfined (water table) define the two classifications of aquifers. The distinction between the two is important in terms of the vulnerability of the aquifer to man-made contamination. In a confined aquifer, the water is sandwiched between an upper and a lower layer of impermeable material called an aquiclude. Clay, the most frequently encountered aquiclude, forms a natural barrier to the upward or downward migration of ground water. This barrier restricts the downward movement of contaminants from the surface into the confined aquifer, protecting the wells and springs that draw water from it. Aquicludes also restrict migration of contaminants from other aquifers above or below the confined aquifer. Because of the protection provided to confined aquifers, their water is relatively invulnerable to contamination.

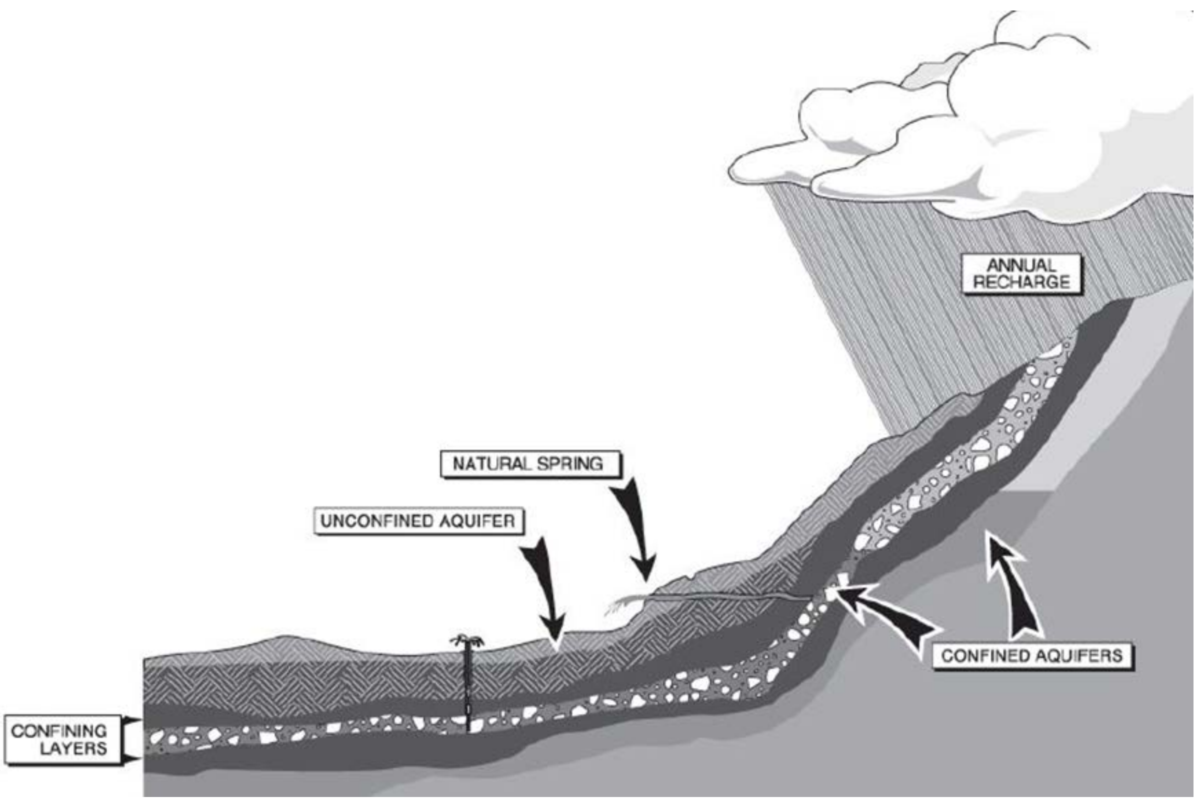

Figure 3-3: Aquifer types

3.7.4 Unconfined Aquifer Contamination

An unconfined aquifer rests on an aquiclude and has no confining layer above it. As a result, percolation of precipitation and infiltration of surface water from streams, lakes, and reservoirs carries water and contaminants from the surface into the aquifer. Therefore, water in unconfined aquifers is comparatively vulnerable to contamination.

During the sanitary survey, the surveyor should determine the adequacy of the PWS's source water protection program that may include an evaluation of resources devoted to the effort. The surveyor may also have to consider: Does the PWS have an actual program? Is the program active? Is the program able to control sources of contamination identified in the source water assessments? Has the PWS discontinued the program because the PWS was unable to implement important tasks such as identifying or controlling sources of contamination?

3.7.5 Wellhead Protection Program

The Wellhead Protection Program (WHPP) is a pollution prevention and management program used to protect underground sources of drinking water. Section 1428 of the 1986 SDWA amendments established the national WHPP. The law required states to incorporate certain program activities, such as delineation, contaminant source inventory, contingency planning, and source management into their WHPPs. The law required EPA approval of the plans prior to implementation, and all states have EPA-approved WHPPs. Although section 1428 applies only to states, a number of tribes are implementing the program as well.

WHPPs provided the foundation for many of the state source water assessment programs (SWAP) under the 1996 SDWA amendments (as referenced in Chapter 4 under Source Water Protection). Most states also use the WHPP as a foundation for assessing and protecting ground water systems. State WHPPs vary greatly. For example, some states require CWSs to develop management plans, while others rely on education and technical assistance to encourage voluntary action. Other states have mandatory requirements for wellhead protection at the local level.

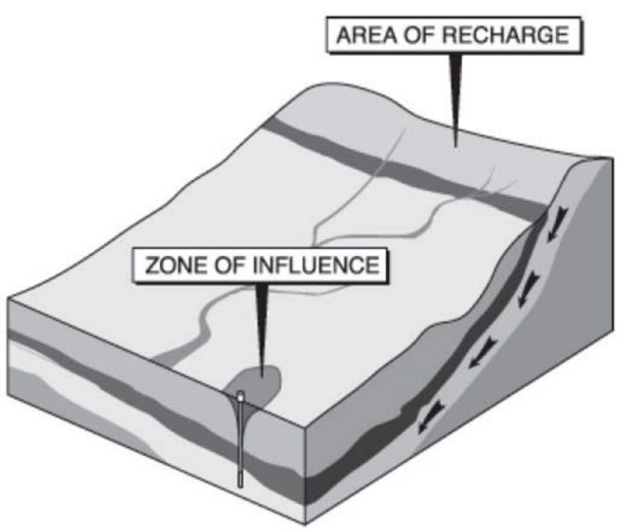

Figure 3-4: Recharge and zones of influence

3.7.6 Sanitary Deficiency Questions and Considerations - Wells

- **Is the well in a confined or unconfined aquifer?**

  The surveyor needs to know the class of aquifer to evaluate properly the source's vulnerability to contamination. Ask the operator or manager at the water system for the name of the aquifer and its type or obtain them from well drilling records. Well logs made during well drilling can indicate whether there are one or more confining layers above the well screen. Confining layers may impede the flow of ground water or contaminants downward into the aquifer. The surveyor may already know this information from preparation work done prior to the sanitary survey but should ask anyway to evaluate the operator's knowledge of the source.

- **Is the well site subject to flooding?**

  The PWS should maintain the area around a well such that the grading directs any surface water runoff away from the well site. Any openings in the well casing should be located above the primacy agency's criteria related to well siting and flood elevation.

  The Federal Emergency Management Agency (FEMA) can provide Flood Insurance Rate Maps (FIRMs) through its National Flood Insurance Program. FIRMs show the base flood elevation in a given area. The surveyor may obtain information on flooding and site drainage from the operator or through visual inspection, and flood-stage records.

  The surveyor should also be familiar with EPA's *Flood Resilience: A Basic Guide for Water and Wastewater Utilities* (USEPA, 2014), which outlines a simple, 4-step assessment process to help and water utilities know their flooding threat and identify practical mitigation options to protect critical assets.

- **Is the well located near any immediate or PSOCs?**

  The appropriate state regulatory agency should be consulted for its policy concerning well location, particularly the minimum protective distances between the well and sources of existing or potential contamination.

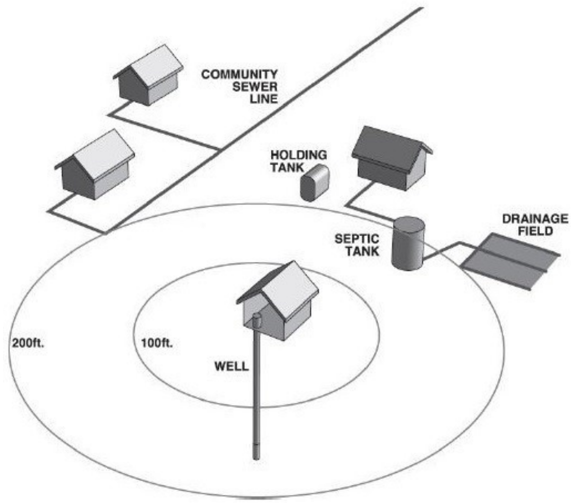

Figure 3-5: Sample minimum distances from well to pollution sources

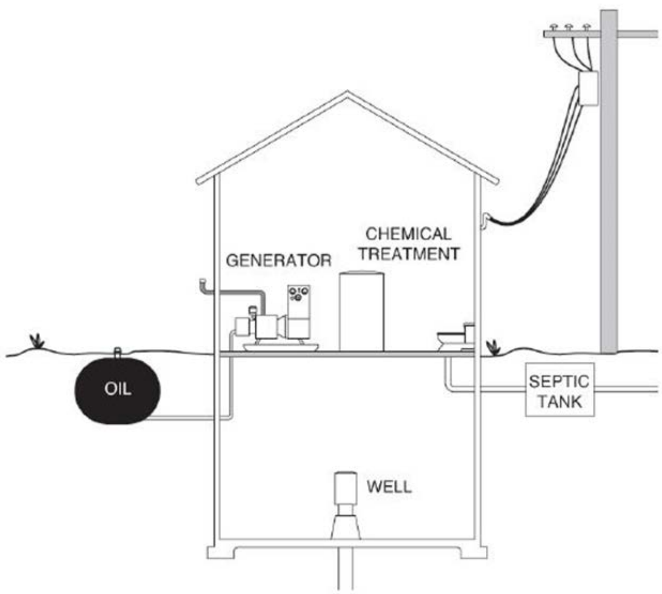

Figure 3-6: Potential contamination sources

- **Look for other contamination sources.**

  During the sanitary survey, surveyors should also be alert for PSOCs, other than those listed above. Fuel and chemical storage facilities and transmission lines are important sources to evaluate. Pollution from these sources can travel much farther than pollution from the sources in the illustration above. The surveyor should evaluate on-site water treatment chemical storage and fuel tanks as well as off-site sources. Spills and highway runoff that contain petroleum products or deicing salt can contaminate shallower wells nearby. The application of fertilizers and other chemicals in rural areas, and the proximity of sources to cultivated fields and golf courses are additional considerations.

- **Is there a WHPP in place?**

  The water system may have developed a WHPP as defined by the primacy agency (see Section 3.7.5 for more details on requirements). During the sanitary survey, the surveyor should ask if this program exists, and if there is a written plan that can be reviewed.

- **Is there a driller's log available?**

  The driller's log or well log summarizes information collected and observations made as the well was drilled. This information may include the types of soil, the depth at which each type of soil is found (i.e., thickness of each subsurface formation), the depth to bedrock, and the elevation of the water table. The well log may also provide the name and contact information for the company that drilled the well, and the date the well was drilled. The surveyor should ask for a copy of the driller's log.

- **How deep is the well?**

  The greater the depth of the aquifer being used, the less chance there is that surface contamination will degrade water quality. Deeper aquifers generally have a more consistent quality of water. If a driller's log is available, it will include the well depth.

- **How often is drawdown measured?**

  Drawdown is the difference between static water level and pumping water level. Measuring drawdown is important because changes in static water level or drawdown can indicate problems in the aquifer (declining water level) or pump. Such changes also can indicate well encrustation. The operator should be regularly measuring drawdown and recording the results.

- **What is the depth of the casing?**

  The well casing must be strong enough to resist the pressures exerted by the surrounding formation and corrosion by soil and water environments. The casing and grout seal must be in adequate condition to prevent untreated water from contaminating the well. How old is the casing and has it been inspected? If a driller's log is available, it will include the date that the casing was installed. During the sanitary survey, the surveyor should ask when the casing was last inspected and if a survey report is available.

- **What is the depth of the grout seal and does it meet primacy agency standards?**

  Specific grouting requirements for a well depend on surface conditions, especially the location of pollution sources, and subsurface geologic and hydrologic conditions. To achieve the desired protection against contamination, ask the operator if the annular space is sealed to whatever depth is required by the primacy agency's standards.

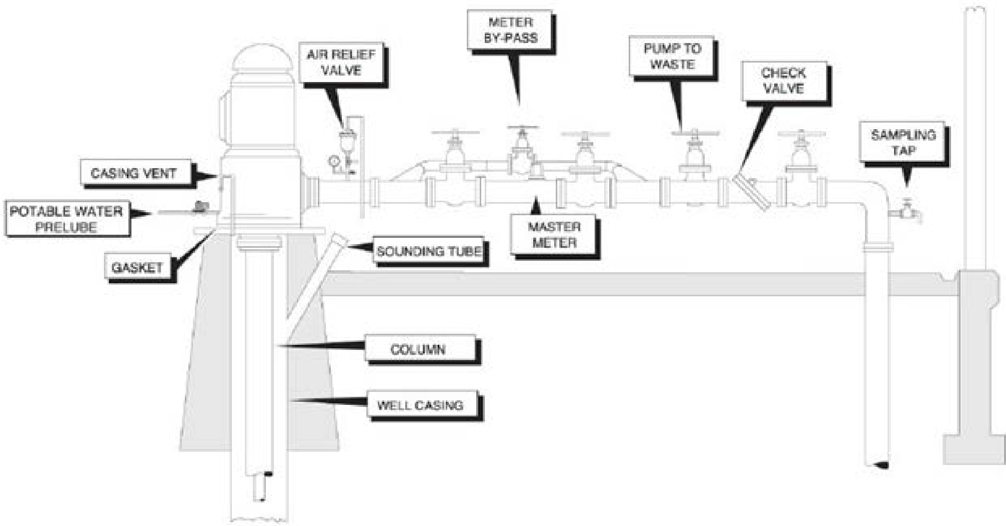

Figure 3-7: Turbine installation detail

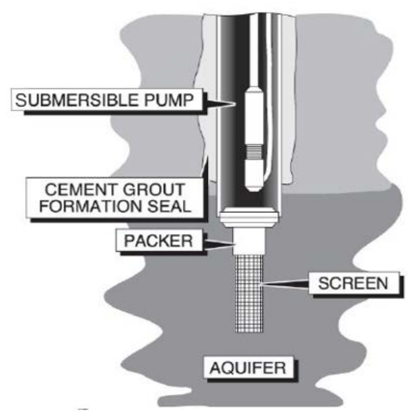

Figure 3-8: Lower well construction with submersible turbine pump

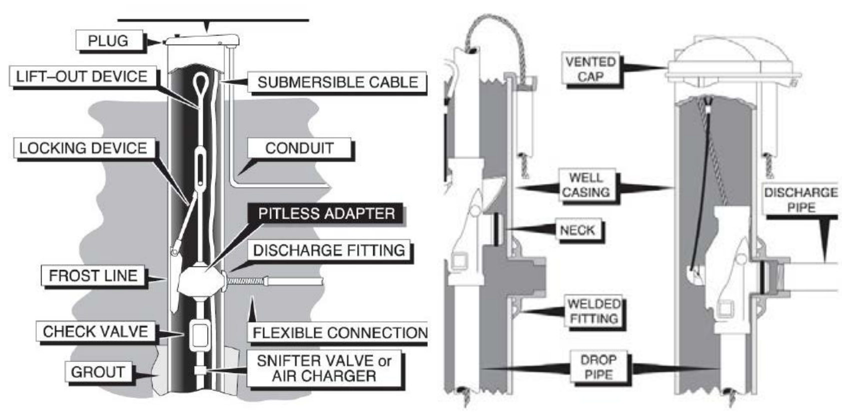

Figure 3-9: Pitless adapter detail

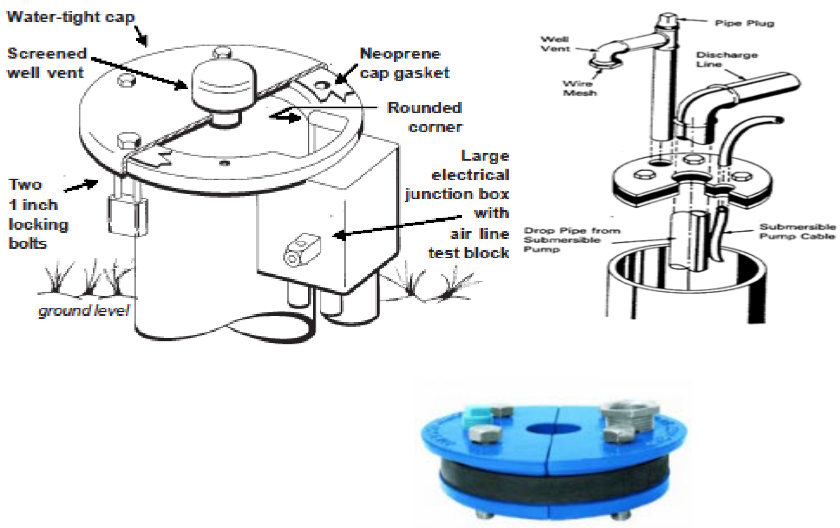

Figure 3-10: Split top well cap

Figure 3-11: Well cap without sanitary seal (left) and well cap with sanitary seal (right)

- **Does the sanitary seal meet primacy agency standards?**

  Wellhead covers or sanitary seals at the top of the casing or pipe sleeve connections prevent contaminated water and other material from entering the well. Well covers and pump platforms should be elevated above the adjacent finished ground level and sloped to drain away from the well casing. During the sanitary survey, the surveyor should check the well cap to confirm that it is equipped with a sanitary seal. If the sanitary seal or gasket is visible around the edge of the well cap, the surveyor should check that it is in good condition. The surveyor should also check the type of well cap to confirm that it meets primacy agency requirements.

- **Does the casing extend above the floor or ground and meet primacy agency well construction standards?**

  The Ten States standards specify that the casing should extend at least 18 inches above the final ground surface and at least 12 inches above the pump house floor. This provides protection against surface runoff or drainage problems. Primacy agency design and construction standards typically recommend 18 inches above the ground when there is no potential for flooding; the surveyor should refer to the primacy agency standards. The casing should extend above potential levels of flooding and be protected from floodwater contamination and damage.

- **Does the well casing vent meet primacy agency well construction standards?**

  The Ten States standards specify that the vent terminate no less than 12 inches above the ground or floor, or 3 feet above maximum flood level with return bend facing downward and screened with a 24 mesh corrosion resistant screen. The surveyor should refer to the applicable primacy agency standards to check whether the vent height and characteristics meet requirements. The vent opening should be covered with a non-corrodible screen to keep dust, insects, and rodents from entering the well.

- **If the well is in a pit, is it subject to flooding or runoff from impervious surfaces?**

  The surveyor should evaluate the well pit from the ground level because it is usually a confined space and proper training and equipment is required. Using a flashlight, the surveyor can look for water marks on the walls of the pit to determine if flooding has occurred. The surveyor can view the area adjacent to the well pit and in particular, the slope of the ground relative to the pit location, to assess the likelihood of flooding or runoff from impervious surfaces entering the well pit. The surveyor should ask the operator how often flooding occurs in the area or if they recall any times when the well pit was flooded.

- **Is the well pit checked and cleaned as part of regular maintenance?**

  The surveyor should ask the water system operator how often the well pit is checked and cleaned, and whether there is a defined maintenance program. Also, the surveyor should ask how maintenance work is scheduled and documented.

- **Does the well have a suitable smooth-nozzle raw-water sampling tap?**

  This is important for collecting raw water samples. While not all primacy agencies prohibit their use, threaded taps can introduce contaminants through the attachment of a hose, creating a cross-connection.

- **Do check valves, blow-off valves, and water meters function properly and does the PWS maintain them?**

  The operator should maintain, operate and regularly exercise valves to prevent contaminants from entering the well and to assure all valves open and fully close when needed.

- **Has the PWS properly protected the upper termination of the well?**

  The water system should protect the upper termination of the well with either a small building (well house) or a security fence to protect it from vandalism and vehicle damage. The area should be sloped away from the well to prevent surface water from draining toward the casing.

- **Does the PWS provide lightning protection?**

  Lightning surges can develop in power lines during thunderstorms. Such surges can damage pump motors, resulting in loss of water supply and costly repairs. To protect against this, the PWS can install lightning arresters where electrical service lines connect to service entrance cables, or at the motor control box.

- **Is the pump intake located below maximum drawdown?**

  Locating the pump intake sufficiently below maximum drawdown prevents the pump from running dry.

- **Are check valves accessible for cleaning?**

  As with aboveground valves, the operator should maintain these valves and keep them operational to prevent the backflow of distribution system water into the well. Not all check valves, however, are accessible for cleaning. Many submersible pumping systems rely on sufficient velocities to keep valves clean from sediment.

- **Has there been any decline in water quality or quantity over time?**

  Some water quality changes that may present themselves over time include changes in iron and manganese levels, increased salinity as a result of salt water intrusion or impacts of road salt use, and increased nitrate levels due to agricultural activities or poorly operated septic systems. Operators may need to adjust their treatment and operations in response. Challenges due to reduced quantities of available water should also be evaluated.

- **Have the well casing and screens been inspected?**

  Surveyors should visit and consider each well being used by the water system including inactive wells, wells recently abandoned and wells used as emergency supplies. At each well, the casing and visible grout should be inspected to ensure there are no cracks, holes or other opportunities for surface contamination to enter the wells. Surveyors should also confirm that vent screens are secure and in place. Vent screens can be inspected using a small mirror or a cell phone in reverse camera mode.

3.8 Springs

3.8.1 Safe Capture

To properly develop a spring as a source of supply, the PWS must capture the natural flow of ground water below the ground surface in a way that does not contaminate the water. Springs are subject to contamination by wastewater disposal systems, animal wastes, and surface drainage. If not mitigated, the state may classify these springs as a "Subpart H" surface water source subject to requirements of the SWTRs.

3.8.2 Spring Types

Springs may be gravity or artesian. Gravity springs occur where a water-bearing stratum overlays an impermeable stratum and outcrops to the surface. The water permeates at the point where the impermeable stratum outcrops. They also occur where the ground surface intersects the water table. This type of spring is particularly sensitive to seasonal fluctuations in ground water storage and frequently dwindles or disappears during dry periods. Gravity springs are characteristically low-yielding sources, but when properly developed they may be satisfactory for small water systems.

Artesian springs discharge from openings in the confining layers of artesian aquifers. They may occur where a fault ruptures the confining formation over the artesian aquifer. Artesian springs are usually more dependable than gravity springs, but they are particularly sensitive to the pumping of wells developed in the same aquifer. Consequently, pumping of nearby wells, as well as seasonal flow variations, may reduce or eliminate flow to artesian springs.

3.8.3 Criteria for Selection

Important criteria for spring sources include selection of a source with acceptable water quality, development to provide the required quantity of water, and sanitary protection of the spring collection system. Water systems must develop springs based on prevailing geological conditions.

3.8.4 Spring Source Collection System

3.8.4.1 Perforated Pipe

A system of perforated pipes, driven into the water-bearing stratum or laid in gravel-packed trenches, intercepts spring flow. This collection of pipes then directs the flow into a collection box or tank. As an alternative, a watertight concrete collection chamber, constructed with openings in the bottom, a sidewall, or both, intercepts the flow. This chamber may also serve as a storage tank.

Where possible, the walls of the collection chamber should extend to bedrock or into an impervious stratum. The watertight walls should extend high enough above the finished ground level to prevent surface water from entering. An overlapping (shoebox) cover prevents the entrance of debris.

3.8.4.2 Spring Box

Usually constructed in place out of reinforced concrete, the spring box is designed to intercept as much of the spring as possible. When a spring is located on a hillside, the downhill wall and sides extend downward to bedrock or impervious soil to ensure that the structure holds back water to maintain the desired level in the chamber. PWSs may use supplementary cutoff walls of concrete or impermeable clay to assist in controlling the water table near the tank. The lower portion of the uphill wall of the tank must have an open construction to allow water to move in freely while holding back aquifer material. Back filling with graded gravel helps restrict the movement of aquifer material.

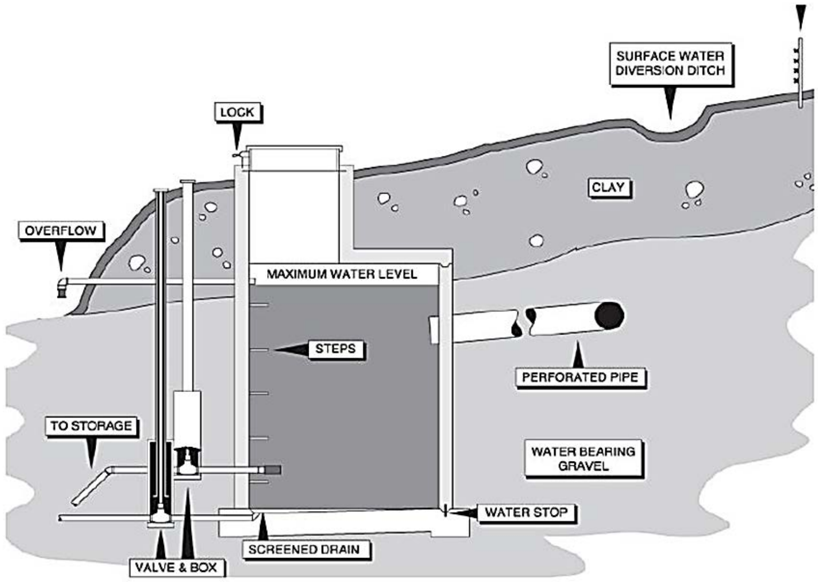

Figure 3-12: Example of a spring collection system. While this illustration shows water leaving the spring collection system and traveling to storage, some water systems do not have storage after their spring collection systems.

At the completion of construction, the PWS should maintain an area around the spring box, covered with an impermeable material (clay or membrane). This area should be sloped away to prevent surface water from entering the collection system.

3.8.4.3 Spring Box Cover

The tank's manhole should have a cover framed above the roof surface that ensures a good fit. The opening should be fitted with a hinged, lockable, watertight cover that extends down the frame. The inside of the cover usually has a rubber gasket to provide a tight seal and should be pliable. When the spring box is covered, the manhole should be elevated above the covering sod according to primacy agency standards.

3.8.4.4 Drain Pipe

A pipe passing through a wall of the spring box at the floor level with an exterior valve allows draining when the interior of the tank needs cleaning or an inspection. The end of the pipe should extend far enough to direct water away from the spring box and should freely discharge onto a drain apron to prevent erosion. The valve works to exclude small animals and insects, so there may or may not be a screen depending on state requirements.

3.8.4.5 Overflow

The tank should have an overflow pipe placed slightly below its maximum water level elevation that discharges any overflow away from the spring box onto a drain apron to prevent erosion. The overflow pipe outlet should be covered with a non-corrodible screen to prevent rodents, birds, and insects from entering the spring box. The screen should meet primacy agency specifications. A flapper valve alone may not be adequate protection for the overflow pipe outlet as debris, ice, or snow can prevent the valve from completely closing.

3.8.4.6 Intake to System

Water flows through a screened intake line located above the floor of the collection box to provide water to the distribution system. The surveyor should examine the area between the intake pipe and the concrete structure for signs of leakage.

3.8.5 Sanitary Deficiency Questions and Considerations – Springs

- **Has the PWS protected the recharge area?**

  Activities in the recharge area and the degree to which they are controlled can affect the quality of the water source.

- **What activities and land uses take place in the recharge area?**

  Is it industrial, agricultural, forested, or residential? Different types of activities potentially subject the spring to pollutants from land uses, spills, and runoff. The surveyor should ask the operator if the recharge area for the spring has been mapped.

- **What conditions cause changes to the quality of the water?**

  Springs are subject to contamination by wastewater disposal systems, animal wastes, and surface drainage. The surveyor should note the presence of any such contamination sources at the spring site, and any physical gaps in the spring box that could allow contaminants to enter the water source. The surveyor should ask the operator if the recharge area is inspected for changes in land use, flooding, fire, or other changes in soil conditions that could affect water quality. Identify the conditions that potentially affect water quality and the corrective measures that the PWS has implemented.

- **Has the spring source been sampled and evaluated for surface water influence?**

  A good indicator that surface water is reaching the spring is a marked increase in turbidity or flow after a rainstorm. The surveyor should ask the operator if turbidity or flow monitoring was conducted after a rainstorm, or if any other testing has been completed to determine if the spring is a ground water under the direct influence of surface water (GWUDI) PWS subject to the SWTRs.

  During the sanitary survey, the surveyor should document the setback distance of the spring box from any nearby surface water source. The surveyor should ask the operator how this setback distance changes during spring runoff and after a heavy rainfall.

- **Is the site subject to flooding?**

  Does the grade direct surface water and runoff away from the spring? The PWS should maintain a proper grade to avoid introducing surface water into a spring.

- **Is the spring's intake adequately constructed and protected?**

  Is the supply intake properly located, and is the tank-side of the intake screened? The screen and location of the intake reduce the withdrawal of sludge or debris that may build up in the chamber. If there is cause for this to be a concern (e.g. the tank has never been cleaned, there have been customer complaints), the surveyor could observe water discharged from the chamber through a blow-off valve, if available, to see if sludge or otherwise discolored water is visible. This would indicate whether or not the tank needs cleaning. If larger debris particles are present, the screen on the tank side of the intake is either damaged or missing.

- **Does the PWS provide adequate site protection?**

  The following precautionary measures help ensure spring water of consistently high quality:

  - Locate a surface drainage ditch uphill from the source to intercept surface water runoff and carry it away from the source. Springs close to agriculturally developed land treated by pesticides and herbicides may be particularly susceptible to contamination.
  - Provide security fencing, locked covers, and warning signs for protection from stray livestock and from tampering.

- **Is the spring box properly constructed?**

  The spring box should be watertight to prevent the inflow of undesirable water. The spring box cover should be overlapping, impervious, and lockable. Are drain and overflow pipes properly constructed? Do they discharge onto a concrete apron or other suitable material that prevents erosion and directs water away from the spring box? The drain valve provides protection from small animals and insects so the water system should have it screened according to primacy agency requirements. The PWS may have a flapper valve on the end of the overflow to exclude small animals and insects, and there may also be a screen inside of the flapper valve depending on state requirements. The screen provides additional protection in case debris, ice or snow props open the flap. The screen should meet primacy agency standards.

3.9 Well(s) Survey: Sanitary Survey Findings and Revised Total Coliform Rule

During each sanitary survey, the surveyor must conduct a special monitoring evaluation for all ground water systems serving 1,000 or fewer people. The special monitoring evaluation is a RTCR requirement where the surveyor must assess the appropriateness of the coliform sampling frequency, number of samples, sample locations and collection dates based on new data from the sanitary survey.

The surveyor should determine how effective the source, treatment and distribution barriers are regarding protection from contamination, and then modify the sampling as needed for public health protection. In addition, the surveyor may need to change the sampling sites and frequency for any of the following reasons as determined during the sanitary survey.

- Increase in population
- New distribution system areas served
- New storage tanks

- Deterioration of water system infrastructure

The surveyor should coordinate with the appropriate state staff to re-evaluate the RTCR monitoring frequency for any PWS (not monitoring monthly) when sanitary survey findings show*:

- Failure to meet approved well construction standards
- Deficiencies in source water protection
- Significant deficiencies and/or sanitary defects at well source(s)

**See 40 CFR 141.854(g)(1), 40 CFR 141.854(e)(2), 40 CFR 141.855(d)(1)(ii)*

3.10 Possible Significant Deficiencies for Ground Water Sources

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The state (primacy agency) determines both significant deficiencies and the corresponding corrective actions.

- No or inadequate access buffer (restricted area) around well.
- No emergency or secondary well.
- Openings, holes, pitting, corrosion on well casing subjecting the well to surface water contamination.
- Inadequate sanitary seal.
- Bad seal around electrical conduit to submersible pump.
- No air venting of the well to prevent creating a vacuum within the well, which could draw in water of questionable quality from upper strata.
- No or cracked well pad, erosion under/around the pad, pad not sloped away from casing, or pad too small.
- Improperly constructed spring boxes, including cracks, holes, or lack of seal around electrical conduit; no means of locking access hatch.
- Spring supply is intermittent or inadequate to meet demand.
- Continuing decline in water quality or capacity.
- Spring supply is subject to surface water influence.

4 Surface Water Sources

A PWSs' source water is the first area of protection in the multiple-barrier approach to achieve safe drinking water. Surveyors should determine the quality, adequacy and reliability of the source during a sanitary survey.

4.1 Learning Objectives

By the end of this chapter, students should be able to:

- Evaluate the surface water source adequacy and reliability in terms of quantity and quality, especially considering impacts from extreme weather events such as flooding and drought.
- Understand the Source Water Assessment Program (SWAP) for relevant information.
- Identify surface water source sanitary deficiencies.
- Evaluate surface water intake adequacy.
- Evaluate roof catchment sanitary deficiencies.
- Determine compliance with federal, state, and local regulations.

4.2 Data Collection

Generally, the surveyor should collect enough data needed to evaluate the safety, adequacy, and reliability of all water sources used by the PWS, including emergency sources. For example, raw water quality data help evaluate the safety of the source. High raw water turbidity or coliform indicates problems with source quality and may assist in regulatory compliance determinations. Information on surface water treatment plant (SWTP) design flow rate (or capacity) is important to determine adequacy to meet specific water demands. The following narrative and sanitary survey questions discuss the types of data the surveyor should evaluate.

4.3 Regulations and Standards to Consider

Most of the regulatory requirements focus on the quality of water entering the distribution system. However, surface water quality is a major part of the following regulations:

- Surface Water Treatment Rule (SWTR)
- Interim Enhanced Surface Water Treatment Rule (IESWTR)
- Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR)
- Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)
- Stage 1 and Stage 2 Disinfectants and Disinfection Byproducts Rules (DBPRs)

See Chapter 2 of this Guide for more information on these and other applicable rules.

4.4 Basic Surface Water Source Information

Surface sources used by water systems require consideration of additional factors not usually associated with ground water sources. When water systems use rivers, streams, open ponds, lakes, or open reservoirs as sources of water, the risk of contamination and spread of microbial disease generally increases.

The physical, chemical, and bacteriological contamination of surface water make it necessary to regard such sources as unsafe for domestic potable use unless surface water treatment, including filtration and disinfection, is provided. However, some states allow water systems to avoid filtration so long as the PWS meets all avoidance criteria defined in the SWTR. A PWS that uses surface water or Ground Water under Direct Influence of Surface Water (GWUDI) must disinfect.

The treatment of surface water to ensure a constant, safe supply requires diligent attention to O&M by the PWS's owner and operator. Principal surface water sources that may be developed or controlled include catchments, ponds or lakes, surface streams, and irrigation canals. Except for irrigation canals, where flows depend on irrigation activity, these sources derive water from direct precipitation over the drainage area.

4.5 Quantity

The value of a reservoir (pond or lake) as a source includes its ability to store water during wet periods for use during times of little or no precipitation. According to "*Recommended Practices for Water Works*" (i.e., 10-State Standards), the quantity of water at the source shall:

- Be adequate to meet the maximum projected water demand of the service area as shown by calculations based on a one in fifty-year drought or the extreme drought of record, and should include consideration of multiple year droughts. Requirements for flows downstream of the intake shall comply with requirements of the appropriate reviewing authority.
- Provide a reasonable surplus for anticipated growth.
- Be adequate to compensate for all losses such as silting, evaporation, seepage, etc.
- Be adequate to provide ample water for other legal users of the source.

A range of factors affect water availability including, but not limited to, water loss, conservation, extreme weather events, and security over a long-term planning horizon, such as 15 to 20 years. The water system should demonstrate water availability in its capital improvement program and planning documents.

For multiple reservoirs located on a river, water systems and primacy agencies must be cognizant of drought conditions at upstream reservoirs that may limit discharge from those reservoirs, ultimately affecting flow into downstream reservoirs.

The surveyor should evaluate the capability of the PWS to meet the demands placed on each of its applicable components. Demands exceeding available treatment capacity can cause inadequately treated water to enter the distribution system. Similarly, inadequate pressure in the PWS exists when demand exceeds the source capacity (as well as the capacity of transmission lines, pumps, distribution system piping, storage facilities, etc.).

Inadequate pressure affects the consumers' use of the water supply, hinders firefighting capabilities, and creates opportunities for contaminants to enter the PWS through cross-connections. Prolonged interruptions in water service represent a public health hazard. A general rule of thumb for minimum water pressure is about 30 psi; however, primacy agencies set their own standard.

4.5.1 Estimating Water Demand

Water demand is the volume of water required by users to satisfy their needs. Water demand varies from water system to water system and from day to day within a water system. Demand also depends on the time of day, the day of the week, the season of the year, prevailing weather conditions, and unusual events such as fires or main breaks.

The water system operator should be recording the daily water demand, or total daily water usage, and should be able to produce and understand the average daily water demand (the average amount of water used in a day), the maximum daily water demand (the maximum amount of water used in a day), and seasonal variations in usage. Additionally, the operator should understand any consequences from peak instantaneous usage and their impacts on the capacity of system components. Considering peak usage is important in order to ensure the water system can always maintain sufficient pressure throughout its distribution system.

Alternatively, most primacy agencies have *community water demand factors* (expressed as gallons per capita per day (GPCD) for estimating the average daily water demand. Many primacy agencies also have equations to estimate maximum daily demand as well as the peak instantaneous usage for various water systems. Water demand (excluding firefighting) for most regions ranges from 120 to 300 GPCD (depending on allowances for frequent lawn watering, swimming pool maintenance, industrial and commercial process water, cooling water, etc.). Rural communities, however, tend to use water primarily for residential purposes so the water demand can be as low as 100 GPCD.

The surveyor should recognize the importance of the relationship between source water quantity and storage. Storage facilities maintain system pressures and provide water for fluctuating demands while the source water quantity is typically a more consistent flow that is designed to gradually fill a storage tank. Alternatively, hydropneumatic systems use compressed air in a pressure vessel to maintain distribution system pressure, and rely more closely on pump capacity to meet short-term system demands. Hydropneumatic tanks are more frequently used on very small water systems. The surveyor should be prepared to make reasonably accurate estimates of probable water demand for a wide variety of types and sizes of PWSs.

4.5.2 Emergency Water Demand

In case of the depletion of source water such as during extreme drought, substantial ground water subsidence, or water conservation district allocation limits, the water system should identify an alternate source of water supply and explain how the PWS would deliver water to the PWS's customers. Alternate sources might include a second reservoir, an interconnection to another PWS, use of inactive wells, digging a new well (major time factor issue), water tanker delivery, bottled water delivered to customers on an interim period, or other means of safe water supply.

4.5.3 Sanitary Deficiency Questions and Considerations – Water Quantity

- **What is the total design production capacity?**

  Comparing this figure with metered or estimated demand figures allows the surveyor to determine if the source quantity is adequate.

- **What is the present average daily production?**

  Comparing this figure with values for other, similar PWSs on a per capita basis may point out problems within the PWS. For example, if consumption is at a relatively high rate, or if production trends are increasing without an accompanying population or metered-use increase, the PWS may be experiencing excessive water loss (i.e., leakage). Alternatively, high per capita consumption may indicate an opportunity to conserve water during an extreme drought via water use restrictions.

  Water loss: A direct method to determine water loss is to compare master meter production with the corresponding accounted-for demand using the equation:

  Production – Consumption = Water Loss (estimate)

  Consumption would include metered water from customers (such as homes and industry) as well as accounted-for water flushed or used by the municipality (e.g., Fire Department, irrigation of public areas, etc.).

- **What is the maximum daily production?**

  The surveyor should compare the maximum daily production to the design capacity of the various major PWS components. Review the operating records from the maximum demand day to determine the performance of the source, treatment, storage, and distribution system under stressful conditions.

- **Is the safe yield sufficient to meet current and future demands?**

  The water system should have a plan for capital improvements once average daily production approaches or exceeds a certain percentage of the design capacity of major PWS components (e.g., the safe yields of the sources of supply or the raw water pumping and transmission, treatment, finished water pumping, storage, and additional sources). Many states have regulations that define the percentage of design capacity where PWSs have to begin planning for expansion.

- **Is the quantity of the source adequate?**

  Given that a water system's source is one of the first areas evaluated using the multiple barrier approach, the key to ensuring the sustainability of the water system is for the surveyor to evaluate several factors that could affect the long-term viability of the source, which also gives the surveyor a better understanding of future potential deficiencies. These factors may include PWS type, size, extreme weather conditions, storage facilities used, and customer type.

Decreasing trends in quantity are also important to note. Operating records should provide this information, but the surveyor must be prepared to make reasonable estimates when operating records are not available.

The following questions help the surveyor assess the adequacy of source capacity.

- **Does the supply vary by season? During which period is water most abundant?**

  The surveyor should ask the operator how the water supply is affected by seasonal changes and seasonal demand. Some surface water supplies are impacted by runoff from snowmelt while others are more affected by drought conditions or seasonal activities in the watershed.

- **Does the PWS have plans or procedures to respond to variations in their source water supplies?**

  The surveyor should ask the operator how operational practices are affected by seasonal variations in source water quality or quantity, and review how the water system adjusts operations to prevent seasonal changes from causing any public health concerns.

- **Does the PWS track or have access to flows, levels, and related information for its sources?**

  During the sanitary survey, the surveyor should ask to review source water records such as reservoir level, flow rate, safe yield calculations, and related information.

- **If a lake or reservoir is a source, are multiple intake depths/locations available for variations in water levels?**

  Reservoirs are often designed with intakes at different levels and/or locations because the water quality can vary. The lowest level intake may be susceptible to disturbances in the reservoir sediment and taste, odor, and color problems due to iron, manganese, or sulfides in the water. The highest-level intake may at times be impacted by algal blooms, related taste and odor problems, DBP precursors, and possibly cyanotoxins. Having multiple intakes gives the water system flexibility in reservoir operations. More information is provided in Section 4.8.

- **What is the capacity of raw water/off stream storage? Is it adequate to meet existing or expected seasonal variations?**

  The surveyor should ask whether the water system has additional storage for raw water what storage capacity is available. Raw water reservoirs that are used by water systems with river sources often allow high turbidities in the river water to settle before the water enters the treatment plant. For PWSs with arrangements like this, the surveyor should ask if the water system dredges the holding reservoir periodically. If it does not, the surveyor should ask if turbidity levels entering the treatment plant have increased over recent years; such an increase may be due to a shorter hydraulic residence time in the raw water reservoir due to sediment buildup.

- **Does the operator monitor and maintain alternate/emergency supplies (e.g., intakes, valves, pumps, consecutive connections) to assure good operational conditions?**

  The water system may have written agreements and physical connections to adjacent water systems so that water can be purchased and delivered in case of an emergency. The surveyor should ask whether any such agreements are in place, and whether the physical connection is maintained in an operating condition. If the water system owns an emergency supply and related components, what monitoring and maintenance are conducted to keep this source of supply available?

- **Are there constraints or limits on reserve or alternate sources (e.g., permits, water rights, hydraulic limitations)?**

  If the water system uses any reserve or alternate sources, the surveyor should discuss with the operator any permits and operational limits specified by those permits.

- **Are consecutive water systems subject to reductions in supply due to wholesale supply variations? If so, does the consecutive water system have alternatives or contingencies to meet demands?**

  The surveyor should ask the water system manager if there are any restrictions on supply from the wholesale provider, and if so, what contingency plans are in place.

- **If permits are required, is the facility operating within the limits? Are permits available?**

  Some states require PWSs to have operating permits. PWSs that discharge waste streams to ground or surface water may be required to have discharge permits (e.g., National Pollutant Discharge Elimination System permits).

- **Does the PWS have an operational master meter?**

  Without an operational and calibrated master meter, it is difficult for the PWS to monitor production accurately. Some PWSs meter the hours their pumps run. With this information, and inlet and outlet pressures of the pump, the surveyor can use the appropriate pump curves to estimate production.

- **Does the PWS have interconnections with neighboring PWSs or a contingency plan for water outages?**

  PWS plans to quickly correct causes of water outages are important to minimize pressure drops in the distribution system and other potential adverse effects throughout the PWS, especially in arid or drought-stricken areas. These plans should include locations of the valves that interconnect the PWS with their emergency source. These plans also need locations of valves to isolate sections of pipe if a line break is the source of the outage. The surveyor should ensure interconnections are only to sources approved by the state.

4.6 Quality

4.6.1 Source Contamination

The likelihood of contamination increases as the proximity to PSOCs to the source increases. Examples of PSOCs include septic tanks, construction projects, chemically treated agricultural land, concentrated animal feeding operations, chemical storage areas, and industrial discharge. The surveyor should review the water system’s source water protection plan for potential pollutant sources.

Additional health-based contamination (and treatment cost) issues are algae blooms that can increase DBP precursors (algal-derived carbon), create cyanotoxins, as well as generate taste and odor issues. Cyanotoxins are toxins produced by bacteria called cyanobacteria (also known as blue-green algae). To assist PWSs in managing risks from cyanotoxins, see *Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water* (USEPA, 2015).

4.6.2 Contaminant Classifications

Typical classifications of substances that alter the quality of source water include 1) organic, 2) inorganic, 3) biological, or 4) radiological, as listed below. Students may find further information on regulated contaminants in the NPDWRs (40 CFR part 141), online at http://www.ecfr.gov.

Organic chemicals contain the element carbon. The NPDWRs currently regulate over 50 organic chemical contaminants. Different organic chemicals derive their names from their differing carbon structures. Organic water pollutants include:

- Detergents.
- DBPs, such as chloroform, found in chemically disinfected drinking water.
- Food processing waste, which can include oxygen-demanding substances, fats and grease.
- Insecticides and herbicides (a wide range of organohalides and other chemical compounds).
- Petroleum hydrocarbons.
- Decomposing vegetative matter.
- Volatile organic contaminants (VOCs), such as industrial solvents.
- Chlorinated solvents, which are dense non-aqueous phase liquids (DNAPLs), may fall to the bottom of reservoirs, since they do not mix well with water and are denser.
- Polychlorinated biphenyl (PCBs).
- Trichloroethylene.
- Perchlorate.
- Various chemical compounds found in personal hygiene and cosmetic products.
- Drug pollution involving pharmaceutical drugs and their metabolites.
- Toxins from harmful algal blooms.

Inorganic contaminants, including organometallic compounds, cover all chemical compounds except the organic compounds. Some of the regulated inorganic chemicals (IOCs) include nitrate, cyanide, and toxic metals (arsenic, fluoride, etc.). Inorganic water pollutants include:

- Acidity caused by industrial discharges.
- Ammonia from food processing waste.

- Chemical waste as industrial byproducts.
- Fertilizers containing nutrients - nitrates and phosphates.
- Heavy metals from motor vehicles and acid mine drainage.
- Silt (sediment) in runoff from construction sites, logging, slash and burn practices or land clearing sites.

Biological contaminants are pathogenic microorganisms. Inadequately treated water may contain disease-causing organisms, or pathogens. Pathogens include various types of bacteria, viruses, protozoan parasites, and other organisms. Regulated biological pathogens, indicators, and TT are shown below:

- *Cryptosporidium*.
- *Giardia lamblia (G. lamblia)*.
- *Legionella*.
- Enteric viruses.

Pathogen indicators that the EPA regulates:

- Turbidity.
- Fecal coliform or *Escherichia coli* (*E. coli*).
- Fecal indicators (*Enterococci* or coliphage).
- Total coliforms (revised to a TT under the RTCR).

Radionuclides (RADs) are an unstable form of a nuclide. A nuclide is a general term applicable to all atomic forms of an element. The number of protons and neutrons in the nucleus characterize nuclides, as does the amount of energy contained within the atom. Nuclides may occur naturally or be artificially produced. There are four RADs currently regulated by the NPDWR. Usually RADs come from natural deposits (except beta particles that are usually man-made). The regulated RADs are listed below:

- Combined radium-226/-228.
- (Adjusted) Gross alpha.
- Beta particle and photon radioactivity.
- Uranium.
- Tritium.
- Strontium.

4.6.3 Treatment

Because surface water is subject to contamination by humans and natural processes, and because its quality can vary considerably over time, a relatively high degree of treatment is required to ensure surface water's safety on a continuous basis. Surface water treatment is generally more sophisticated than ground water treatment, requires more diligent O&M, and usually results in higher costs.

4.6.4 Sanitary Deficiency Questions and Considerations – Water Quality

- **Does the PWS monitor raw water quality? Has raw water monitoring of the source(s) indicated the presence of *E. coli, G. lamblia,* or *Cryptosporidium*?**

  A review of monitoring data required under the LT2ESWTR will indicate if the source has elevated levels of *E. coli* or *Cryptosporidium*. If the level of *Cryptosporidium* is high enough, the water system will have been required to provide additional treatment to remove or inactivate the oocysts. If there are multiple sources, was each source monitored as required under LT2ESWTR or at least monitored after a common blending location before the PWS applied any treatment? Did the PWS conduct monitoring after all raw water was no longer subject to additional runoff?

  Most drinking water regulatory monitoring requirements relate to treated water, which is water in the treatment process, at the entry point to the distribution system, or in the distribution system. Water systems should have an appropriate raw water monitoring program to track changes in quality that includes attention to periods of high runoff, drought, and other stressful situations, such as potential or actual contaminant sources.

- **Does the PWS track changes in raw water quality?**

  The surveyor should ask what type of database is used to manage raw water quality data and how does the water system use historical data to track water quality trends.

- **What conditions cause fluctuations in water quality?**

  Weather, water system operations, and activities in the watershed can affect water quality. Conditions such as stratification within the reservoir, algal blooms, ice formation, drought and low water level, winds, flooding, changing currents, and time of day may adversely change water quality. Identify the conditions creating such problems along with the measures the PWS is taking to mitigate them.

- **Are there changes that could affect treatment?**

  Changes in source water pH, alkalinity, temperature, turbidity, and color can affect water treatment operations. For example, several chemical reactions proceed at a slower rate when the water is colder; longer holding times or higher chemical doses may be needed for different treatment steps under such cold water conditions. As another example, when the source water has higher turbidity, sediment will accumulate in the sedimentation basin at a faster rate, and the filters may need to be backwashed more frequently.

- **Are there any abandoned, unused, or auxiliary sources?**

  Surface supplies physically connected to the water system may contaminate finished water through a cross-connection. For example, any feed lines that are used to treat raw and finished water can easily create a cross-connection if the treatment inlet to the raw water does not have a sufficient air-gap to prevent siphoning of raw water to finished water in the event of a pump or power failure. Has the PWS physically disconnected transmission lines from abandoned sources?

- **Is there an emergency spill response plan?**

  Some industries (e.g., petroleum) are required to have emergency spill plans. The water system should identify potential spill sites and develop contingency plans to respond to any spills. The water system's response plan must include detailed procedures and list the necessary equipment and personnel to implement the response plan. In addition, water systems must be an integral part among relevant response agencies (e.g., fire, police, etc.) including the participation in drills prior to any emergency.

4.7 Source Water Protection

The SDWA Amendments of 1996 required states to develop and implement SWAPs to analyze existing and potential threats to the quality of the public drinking water throughout the state. Using these programs, many states have completed source water assessments for most if not every PWS – from major metropolitan areas to the smallest towns. Even schools, restaurants, and other public facilities have surface water supplies previously assessed by surveyors.

A source water assessment is a study and report unique to a specific water system that provides basic information about the water used to provide drinking water. States should work with local communities and PWSs to identify protection measures to address potential threats to sources of drinking water. The surveyor should review the results of the PWS's source water assessment before source survey. The report may provide valuable information that will aid the surveyor in evaluating the source water protection practices of the water system.

In general, PWSs should follow the steps below to protect the water source:

- Define the source water protection area.
- Inventory actual or PSOCs in the defined area.
- Determine the susceptibility of the PWS to sources of contamination.
- Develop a Source Protection Plan with protection measures and include contingency measures and a plan for the future.
- Implement measures to control sources of contamination.

During the sanitary survey, the surveyor should determine the adequacy of the PWS's source water protection program that may include an evaluation of resources devoted to the effort. The surveyor may also have to consider:

- Does the PWS have an actual program?
- Is the program active?
- Is the program able to control sources of contamination identified in the source water assessments?

- Did the PWS discontinue a program because the PWS was unable to implement tasks such as identifying or controlling sources of contamination?

Figure 4.1 shows a delineated source water area with surface water intakes and wellheads, and potential contaminant threats.

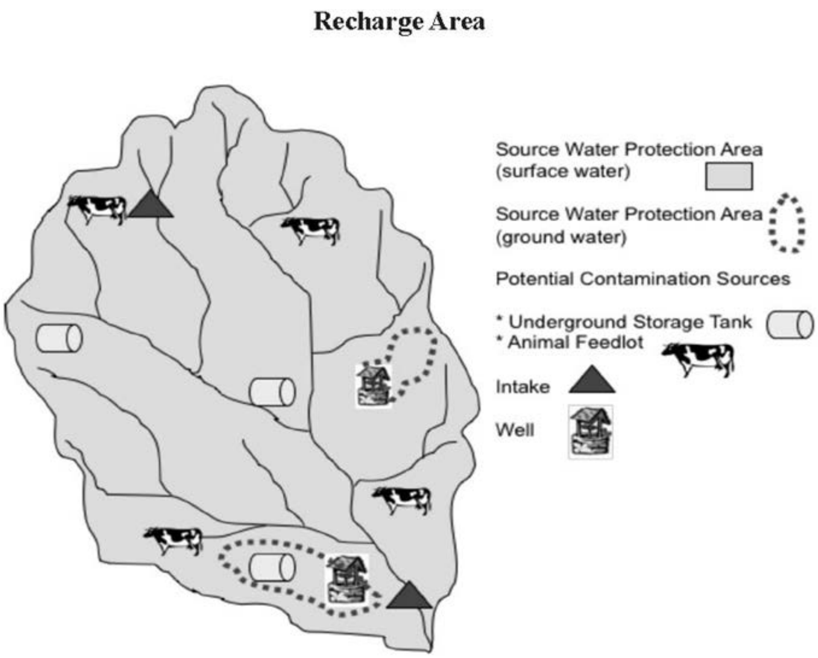

Figure 4-1: Source water protection map

4.7.1 Sanitary Deficiency Questions and Considerations – Source Water Protection

- **Has the PWS identified possible sources of fecal contamination and addressed them?**

  Sources of fecal contamination may include animal manure, septic systems, and sewage pipelines. *E. coli* is a type of fecal coliform bacteria that is considered an accurate indicator of fecal pollution. The surveyor should ask the operator if any sources of fecal contamination have been identified.

- **Is the PWS implementing a plan to protect watershed or aquifer-recharge areas?**

  Source water protection plans for ground water or surface water sources are an effective way for PWSs to protect source recharge areas from contamination. The surveyor should determine if such a plan is in place and evaluate its effectiveness.

- **What is the size of the protected area and who owns it?**

  To reduce the extent of contamination of their watersheds or recharge areas, many utilities have chosen to purchase a portion of these areas. Another method is to restrict activities through zoning ordinances or regulations that prohibit certain land uses within a certain area. Ownership with restricted access is the most stringent measure, but it is also the most costly. If ordinances are used, the surveyor should determine how they are enforced.

- **Are surveys or inspections of the watershed conducted regularly?**

  The surveyor should ask the operator about ownership and management of watershed lands, and whether the water system keeps track of watershed activities through surveys or inspections. For example, if private homes are located along the shore of the water supply reservoir, does the water system periodically check on the condition of septic systems or lawn management practices that could potentially affect water quality? If a water system has a source water protection plan, the surveyor should discuss any impediments to the plan and its effective protection of the source.

- **What is the nature of the protection area?**

  Is the protection area industrial, agricultural, forest, or residential? As previously noted, activities in the watershed affect the water quality of runoff. The potential for spills from industrial activities, herbicides and pesticides from agricultural land uses, organics from plant decay, and animal-borne diseases are a few problems associated with land use in a watershed.

- **Has the PWS surveyed the watershed area?**

  If the PWS has had a survey conducted, the surveyor may be able to answer many of the above questions by referring to the report. The fact that a PWS has conducted such a survey indicates it is concerned about protecting its water supplies.

- **Is there an emergency spill response plan?**

  Some industries (e.g., petroleum) are required to have emergency spill plans. The PWS should identify potential spill sites and develop contingency plans to deal with any spills. However, because a plan is only paper, the PWS must also identify the necessary equipment and personnel. In addition, water systems must be an integral part among relevant agencies (e.g., fire, police, etc.) including the participation in drills prior to any emergency.

4.8 Reservoirs

The type of surface water source (e.g., lake, stream, etc.) is an important factor that can affect raw water quality. A stream with a large watershed in which a land use is predominantly farming, may experience large swings in raw water turbidity, particularly after a rainfall event. The use of a lake or reservoir with the same general watershed characteristics greatly reduces the potential for large raw water turbidity swings due to the dilution and settling that occurs.

Reservoirs, compared to rivers, may offer several advantages:

- As described above, reservoirs should be capable of storing large quantities of water that can provide water for an extended amount of time. These raw water reserves provide operators with an opportunity to better plan for the future and provide a more stable water quality.
- While rainstorms, snow melt and flooding events create an inconsistent and rapidly changing raw water quality, these conditions are not as prevalent in reservoirs. In addition, because of the large quantity of water, large area, and minimal flow variations in a reservoir, settling of particles results in better water quality.

- Natural settling takes place in a reservoir, providing better raw water quality. Water systems also have the option to construct multiple intakes at different levels in a reservoir, which allow an operator to select a level that provides the best raw water quality. With the more prevalent extreme weather events, operators should understand the importance of the ability to select the best water quality.

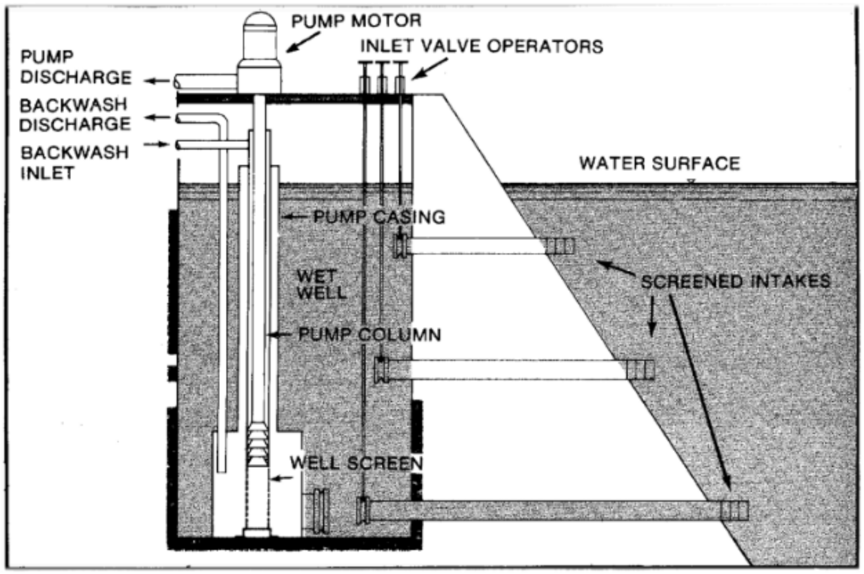

Figure 4-2: Reservoir intake structure with different intake levels

4.8.1 Sanitary Deficiency Questions and Considerations - Reservoirs

- **Is the area around the intake restricted?**

  Restricting contact sports (e.g., swimming and water skiing) and the use of powerboats near the intake is important. These restrictions help reduce the microbiological and organic pollution of the intake water. The surveyor should note whether the water system is following any restrictions.

- **Are there any pollution sources near the intakes?**

  Identify any sources of pollution such as wastewater discharges, feedlots, marinas and boat launching ramps. The PWS should restrict these activities around their intakes by distance or defensive measures. Does management have records and understand the results from their source water monitoring for *Cryptosporidium* under LT2ESWTR?

- **Is the intake structure designed to draw water from different levels?**

  Because of fluctuating water surface elevation and variable water quality, PWSs should have intake structures designed to draw water from different depths. Seasonal turnover of the reservoir, algae blooms, and thermal stratification can cause water quality problems. These concerns apply to deep reservoirs. Streams and shallow reservoirs generally are not subject to stratification. If the structure can draw water from different levels the operator should regularly exercise and maintain the valves.

- **Is the PWS drawing the highest quality water?**

  The operator should perform monitoring tests to determine the water quality at various depths in order to draw the best quality water. The surveyor should ask the operator how the intake level is selected, what tests are performed, and at what frequency. Suggested tests are algae counts, dissolved oxygen, metals (e.g., iron and manganese), turbidity, and nitrogen values.

- **How often are intakes inspected?**

  As with all components, the PWS must periodically perform maintenance on the intake structure. Removal of debris and survey of intake screen integrity prevents damage to piping valves and pumps. This is particularly important during winter if there is a possibility of ice buildup, or anytime if zebra mussels, etc., are a problem.

  Ask the operators what their survey schedule is and what they are supposed to be inspecting and maintaining.

- **Does the PWS add any chemicals to the reservoir?**

  Determine if the PWS adds any chemicals to the reservoir and why. Typically, the only chemicals added are for algae or aquatic weed control. However, in some drought stricken areas, there are chemicals that water systems can apply to reduce evaporation rates. Many states require people applying chemicals for algae or weed control to have pesticide applicator licenses. Ensure only approved chemicals are used and that they are properly applied by properly licensed personnel.

- **When did the PWS last have the dam inspected for safety (if applicable)?**

  Routinely have dams inspected to avoid conditions that may endanger their integrity. Many states require such surveys; however, operators should routinely check for signs of leakage, erosion, sinkholes, burrowing animals, and trees growing in the face of the dam.

  The surveyor should visually check to see if any of these conditions exist.

4.9 Streams and Rivers

4.9.1 Impact on Treatment

Streams that receive runoff from large uncontrolled watersheds may be the only feasible sources of water supply. The physical, chemical, and bacteriological quality of streams and rivers varies and may impose unusually or abnormally high loads on the treatment facilities. Figure 4.3 shows a stream impoundment.

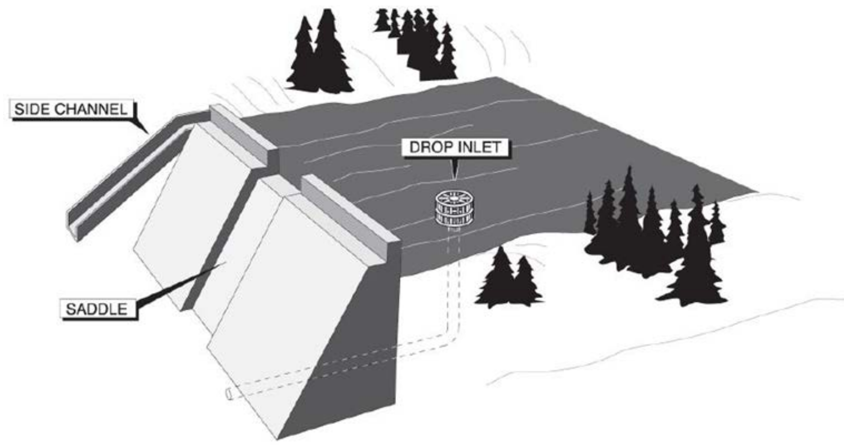

Figure 4-3: In-stream drop inlet location

4.9.2 Intake Location

Stream and river intakes should be located upstream from wastewater discharges, storm drains, and other sources of contamination. If possible, a water system should pump water when the silt load is low. A low-water stage usually means that the temperature of the water is higher than normal and the water is of poorest chemical quality. Maximum silt loads, however, occur during maximum runoff. High-water stages shortly after storms are usually the most favorable for diverting or pumping water to storage. These conditions vary and PWSs should develop operating plans for the various conditions for the particular stream. Many PWSs have no raw water storage facilities and have to meet daily demands with run-of-the-river water quality.

4.9.3 Sanitary Deficiency Questions and Considerations – Streams and Rivers

- **Is the area around the intake restricted and clearly marked?**

  Restricting areas around intakes in streams and rivers may be more difficult than for those in reservoirs. Whenever possible, the operator should identify the location of the intake with an appropriate buoy or other form of demarcation, and should inspect the location daily and reposition the marker if necessary. Watercraft do not have as much room on rivers as they do on reservoirs to navigate around intakes and their markers as well as any other restriction areas.

- **Are there any pollution sources near the intakes?**

  Identify any sources of pollution such as wastewater discharges, feedlots, marinas and boat launching ramps. Whenever possible, the PWS should restrict these activities around their intakes by distance or defensive measures. Does management have records from their source water monitoring for *Cryptosporidium* under LT2ESWTR?

- **How often are the intakes inspected?**

  As with all components, the PWS must periodically perform maintenance on the intake structure. Removal of debris and survey of intake screen integrity prevents damage to piping valves and pumps. This is particularly important after significant rain events and during the winter, if there is a possibility of ice buildup. Significant rain events can wash large debris into the stream and increase the flow rate, which creates a powerful destructive force.

- **What conditions cause fluctuations in water quality?**

  Conditions such as significant rain events (including those events miles upstream from the intake), algae blooms (but to a lesser extent than in reservoirs), ice formation, drought and low water level, on-shore winds, flooding, and changing rates of flow may adversely change river water quality. Identify the conditions creating such problems along with the measures the PWS is taking to mitigate them.

- **Are any chemicals being added at the intake structure?**

  The water system may add a chemical at the intake structure to control zebra mussels or Asiatic clams that could potentially clog the intake screens. The surveyor should document any chemical addition at the intake structure including the chemical name, dosage rate, certification information, and manufacturer.

4.10 Infiltration Galleries (Riverbank Filtration)

4.10.1 Use and Location

Periods of heavy rainfall or spring thaws can adversely affect the quality of water available to infiltration galleries. Debris and turbidity may cause problems at the water intake and can increase the required degree of treatment. If the conditions are suitable, the water system can avoid this problem by constructing the intake in an underground chamber (infiltration gallery) along the shore of the stream or lake.

Operators of infiltration galleries must be cognizant of activities within the watershed where unexpected incidents can adversely affect the quality of water at the intake structure. Clear, mountain streams in areas once considered pristine, may now have experienced various development activities – recreational or residential areas, logging (deforestation), etc. Whether conditions in the watershed have changed or not, and even in the absence of all human activity, never consider these "clear" streams pristine as they may harbor contaminants such as *G. lamblia* or *Cryptosporidium*, which are passed through warm-blooded animals.

4.10.2 Use with Streams and Lakes

Water systems may consider the use of infiltration galleries where porous soil formations adjoin a stream or lake to intercept water underground and take advantage of natural filtration. PWSs should locate any gallery access structures above the level of severe flooding.

4.10.3 Components

A typical installation generally involves the construction of an under-drained, sand filter trench, parallel to the streambed and about 10 feet from the high-water mark. The sand filter is usually located in a trench, sufficient to intercept the water table. At the bottom of the trench, perforated or open joint tile lays in a bed of gravel, with graded gravel over the tile to support the sand., coarse sand covers the embedded tile, and fairly impervious material backfills the remainder of the trench. The collection tile drains to a watertight, concrete chamber from which water may flow to the distribution system by gravity or pump, whichever is appropriate.

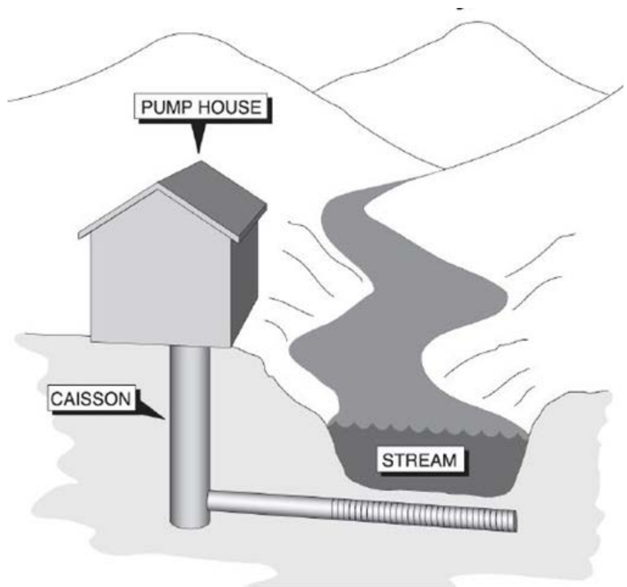

Figure 4-4: Example of an infiltration gallery

Where soil formations adjoining a stream are unfavorable for the location of an infiltration gallery, PWSs may control the debris and turbidity occasionally encountered in a mountain stream by constructing a modified infiltration gallery in the streambed.

4.10.4 Using a Dam

If there is no natural pool in the streambed, the state or other applicable government agency may issue a permit to construct a dam across the stream to form a reservoir. Clean, coarse sand covers the filter that consists of perforated pipe in a bed of graded gravel in the reservoir. There should be free board between the surface of the sand and the surface water level. The collection lines may terminate in a watertight, concrete basin located adjacent to the upstream face of the dam through which gravity or pumps divert the water to chlorination and treatment facilities.

4.10.5 Ranney Well Collector

Ranney well collectors are located in the flood plain to draw water from a riverbed water table. These are similar to infiltration galleries in that perforated or screened collection lines extend radially from the bottom of a caisson. The water level in the caisson rises to that of the river and serves as the chamber from which pumps from a pump house above the collector draw the raw water.

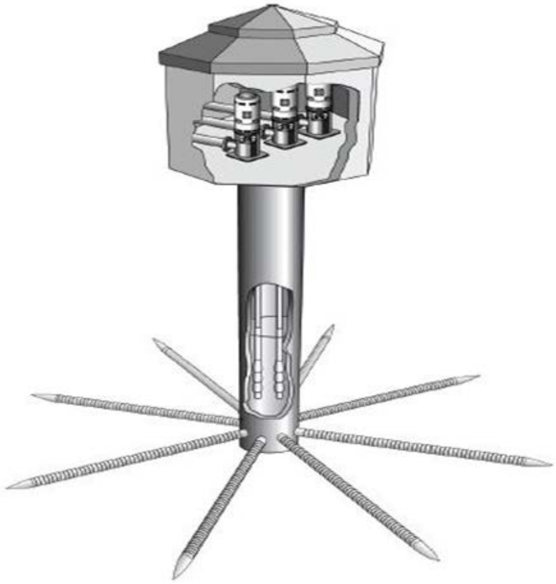

Figure 4-5: Ranney well

4.10.6 Sanitary Deficiency Questions and Considerations – Infiltration Galleries

Note: The sanitary deficiencies related to streams and rivers also apply to this section.

- **Does the PWS provide adequate security for the pump house and the area around the collection area?**

  The water system should provide security for the pump house and the surrounding collection area, the same as they would for a ground water system with wells. The surveyor should determine what measures the PWS employs for notification of operators for various problems including pump failures, loss of disinfection, general power failure, etc.

- **What triggers a more thorough survey of the collection system?**

  Significant rain events, flooding and winter freezes can adversely affect the collection of water. Large debris, ice and floods can wash out areas above the collection laterals and actually wash away or damage the laterals. Water systems should also consider inspecting the PWS with a camera every few years to determine the condition of the screens and laterals.

- **If the supply is impounded behind a dam, when was the dam last inspected by the state or a consulting engineer?**

  Water systems should routinely have dams inspected to avoid conditions that may endanger their integrity. Many states require, and may conduct, such inspections; however, operators should routinely check for signs of erosion, sinkholes, burrowing animals and trees growing in the face of the dam.

4.11 Possible Significant Deficiencies for Surface Water Sources

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The primacy agency determines both significant deficiencies and the corresponding corrective actions:

- No or inadequate access buffer (restricted area) around surface water intake structure.
- Inability to draw water from different depths at surface intakes.
- No emergency or secondary source.
- Cross-connections between treated and untreated water.

5 Water Supply Pumps, Pumping Facilities and Controls

Pumps and pumping facilities are essential components in nearly all water systems. Improper design, operation, or maintenance of pump systems can pose serious sanitary deficiencies, including a complete loss of the water supply. To assess the safety, adequacy, and reliability of the entire water system, the surveyor must include water supply pumps and pumping facilities as an integral part of the sanitary survey. Pumps, pumping facilities and controls are one of the eight essential elements of a sanitary survey.

The primary purpose of reviewing the pumping systems is to verify they are in proper working order, to ensure they are the best fit for their intended use, to determine their reliability, and to establish if there are any sanitary risks. The primacy agency will obtain information about the pumps, including available data from previous sanitary surveys, the emergency power system (if available), pump tests and remote monitoring controls and alarms.

5.1 Learning Objectives

By the end of this chapter, students will be able to:

- List the regulatory standards that apply and key data required to conduct a sanitary survey of a pumping facility.
- Identify various types of water supply pumps, their appropriate uses, and their associated components.
- Recognize sanitary deficiencies and safety hazards associated with physical facilities and water system operations and maintenance practices.
- Provide sanitary deficiency examples of pumps, pump facilities, and controls the primacy agency may identify as significant.

5.2 Data Collection

The surveyor should review the following data, if available, prior to conducting the on-site survey of a pumping facility:

- Review descriptions of pumping systems and pump controls in last sanitary survey report.
- Operating records provided by the water system.
- The PWS’s construction, O&M specifications.

If this information is not available in advance, the surveyor should collect it during the survey. Once in the field, during the initial interview with the operator, the surveyor should develop a list of the pumps that are used by the water system ensure that all of these pumps are evaluated during the sanitary survey.

5.3 Regulations and Standards to Consider

Prior to the survey, the surveyor should review and consider as part of the sanitary survey the following resources:

- State design standards for pumping systems.
- ANSI/NSF Standards 60 and 61.
- Ten States Standards.
- Chapter 2 (Drinking Water Regulations) of this Guide.

5.4 Basic Information on Water Supply Pumps and Pumping Facilities

Water systems use both positive displacement and variable displacement pumps. Positive displacement pumps deliver the same volume for each pump cycle whereas variable displacement pumps deliver a different volume depending on operating conditions (e.g., pressure). Variable displacement pumps (e.g., centrifugal pumps) are used for many water pumping applications. Positive displacement pumps are used for chemical feed, sludge removal, sampling, and air compression. This chapter covers the prime movers of water in the water system and the facilities that house them. Chemical feed pumps are discussed in Chapter 6. Water Pumping Applications

Pumps are used to transport raw water to treatment facilities and treated water to the distribution system. Booster pumps are sometimes used in the distribution system to increase water pressure. The most common applications are:

- Well pumps (vertical turbine and submersible turbine).
- Gas chlorine system and vacuum booster pumps.
- Backwash water pumps are used to pump finished water to the filters for backwashing (centrifugal pumps).
- Raw water pumps may be used to pump surface water from the source of supply to a treatment facility (Vertical turbine or centrifugal).
- Finished water pumps (high lift) may pump finished water from the water treatment plant clearwell to a finished water storage facility in the distribution system (Vertical turbine or centrifugal).
- Booster pumps in distribution system are used to increase water pressure in select areas of the distribution system (centrifugal).

5.5 Pumping Equipment and Appurtenances

The surveyor should evaluate the pumping equipment and appurtenances. This includes pumps, motors, drives, valves, piping, meters, gauges, electrical controls, and alarm systems. The integrity of the multiple barriers is dependent on the proper function and maintenance of this equipment. Pumps are critical to get water where it is needed, including higher elevations such as storage tanks, to maintain the pressures needed to protect the distribution system barrier. Operators cannot visibly see much of a ground water pumping system, so they must rely on the various appurtenances such as valves, gauges, meters and other controls. If these do not function properly or are missing, operators cannot reliably assess the integrity of the barriers.

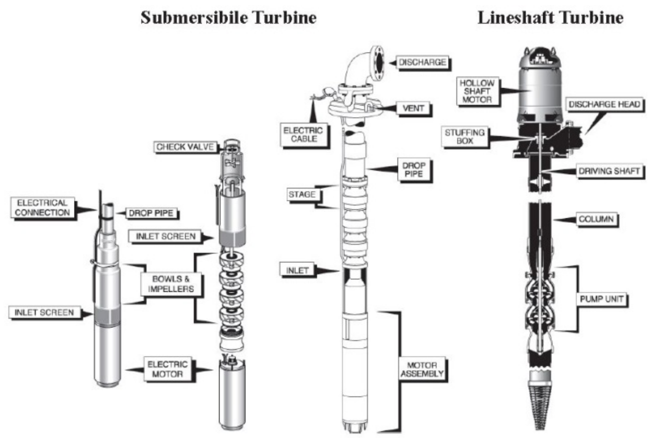

Figure 5-1: Submersible turbine and lineshaft turbine pumps

5.5.1 Variable Displacement Pumps, Applications, and Components

Variable displacement pumps are high-efficiency pumps that are usually utilized when an even flow rate is required (e.g., transporting water through the treatment and distribution systems). Their discharge rate varies with the head (i.e., as the lift or head increases, the pump output decreases). These pumps are not self-priming. Consequently, they depend on a positive suction head or an airtight seal on the intake side of the pump if the level of the water is below the impeller. The most common class of variable displacement pump is the centrifugal pump.

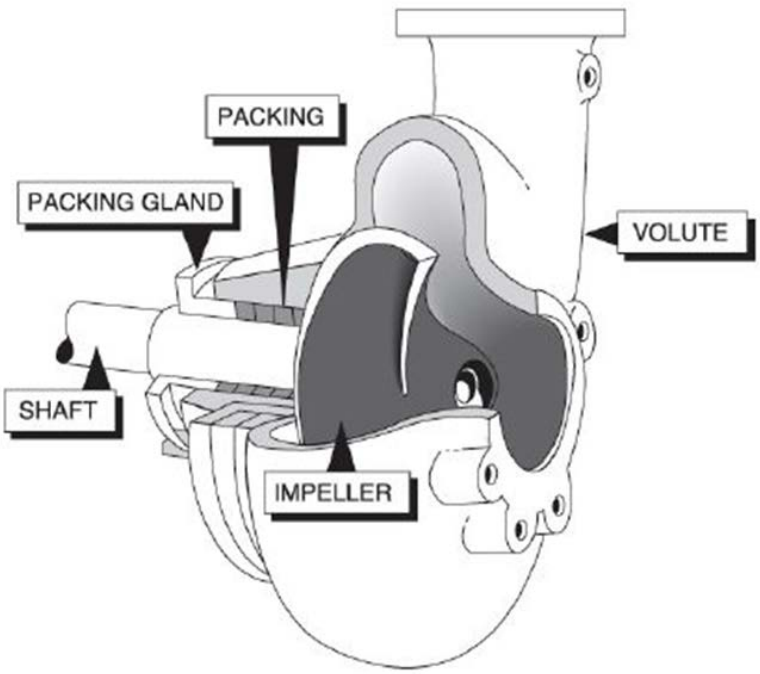

Figure 5-2: Cutaway illustration of a centrifugal pump

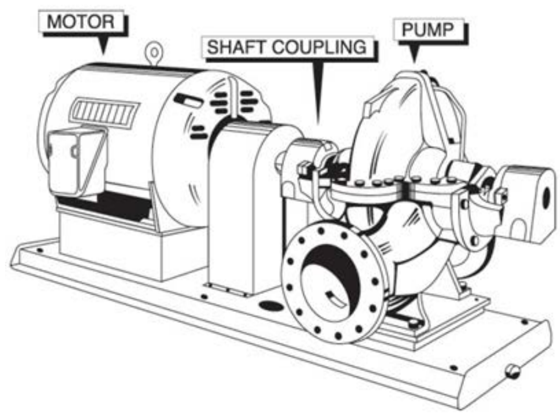

Figure 5-3: Centrifugal pump: Horizontal-split case

A centrifugal pump has a rotating impeller mounted on a shaft turned by the power source. The rotating impeller increases the velocity of the water and discharges it into a surrounding casing (volute) designed to slow its flow and convert the velocity to pressure. Centrifugal pumps classified as single-stage are equipped with one impeller, and multi-stage pumps contain two or more impellers. Multi-stage pumps are capable of pumping against greater discharge heads, but do not increase the volume of flow.

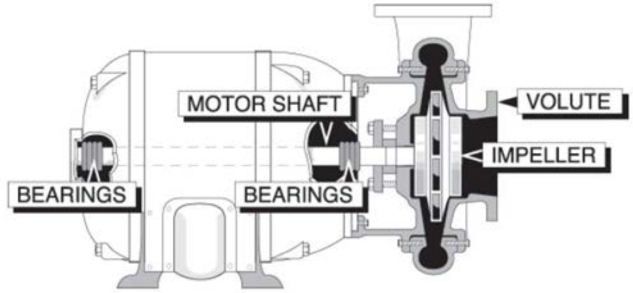

Figure 5-4: Centrifugal pump: Horizontal close-coupled

5.5.2 Appurtenances

In addition to the general review of pumping equipment, the surveyor needs to review and evaluate any appurtenances such as check valves, air release valves, isolation valves, backflow prevention assembly, installed on the PWS. The surveyor should also note any missing appurtenances that are critical to the operations of the pump and pumping equipment.

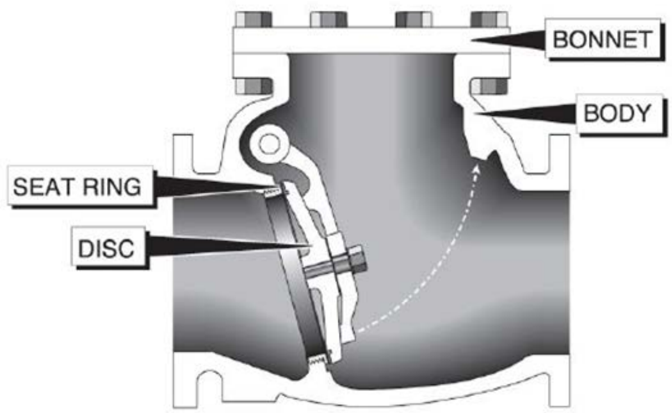

Figure 5-5: Swing check valve

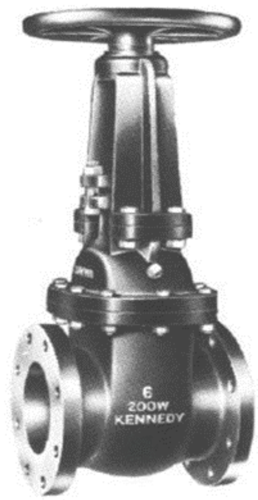

Figure 5-6: Gate valve

5.5.3 Sanitary Deficiency Questions and Considerations – Pumping Equipment and Appurtenances

- **What are the number (including reserves), location, and type of pumps?**

  There should be sufficient redundancy of pumps and spare pump parts for each pumping application to ensure water can be reliably and completely treated and distributed without interruption or reduction of pressure. The PWS may use pumps for various reasons, and the operator should match the type of pump to the application. For example, do not use centrifugal (variable displacement) pumps to feed liquid chemicals when precise delivery is required against a variable head. The surveyor should gather or check information about pump models and motors and, if readily available, pump curves. In addition to observing the pumps, talking to the operator and reviewing plant schematics can help provide this information.

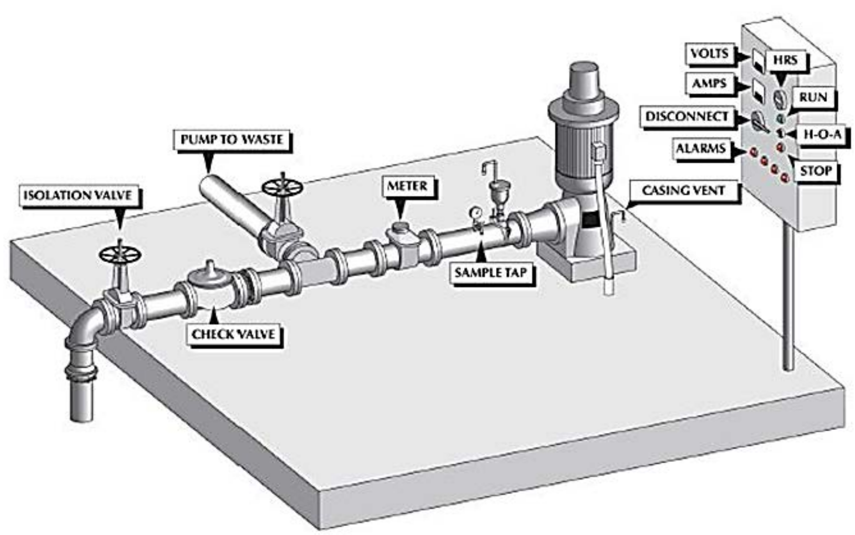

Figure 5-7: Lineshaft turbine pump station

- **Is the actual capacity of the pumping facility adequate to meet the demand?**

  In the case of on-demand water systems, pumps should have the capacity to supply enough water to meet peak demand. For water systems that pump to storage tanks, this may not be a requirement. The required reserve capacity for pumps may vary from state to state, but a rule of thumb for a water supply/multiple unit/constant speed pump application is: With the largest pump out of service, the remaining available pumps should supply the average daily demand within a maximum combined pumping time of 18 hours. A review of pump system operating records should provide this information.

- **When and how are pump capacities determined?**

  The surveyor should review the results of any pump tests and the last date of each pump rating. The surveyor should also verify that the method used was correct. This is particularly important when the water system uses elapsed-time meters (pumping time) to estimate water production. For example, 10 years ago the pump may have operated at an average of 8 hours per day. Now the same pump averages 12 hours per day. Is the increase in run time due to an increase in water demand or a change in operational strategy, or has pump output capacity been reduced because of an increase in operating head or mechanical wear? Comparing current flow rates with historical records can show whether there has been a decrease in pumping capacity. However, a change in pumping capacity can only be determined using a functioning flow meter, pressure gauge, and pump curve. Upon reviewing pump operating records, the surveyor should determine if duplicate pumps are equally productive.

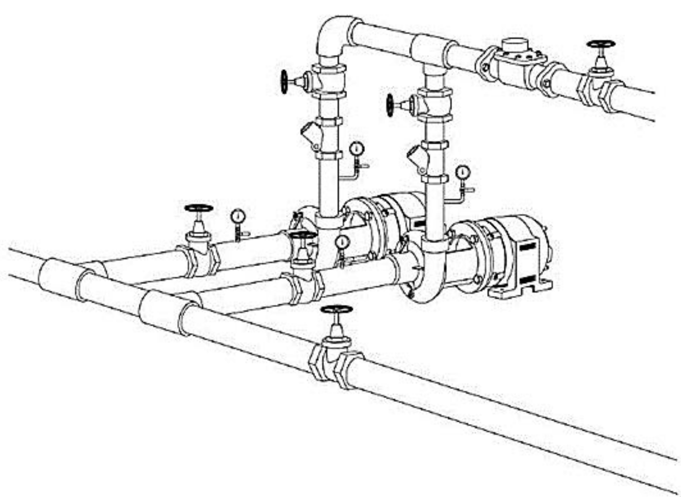

Figure 5-8: Booster pump station

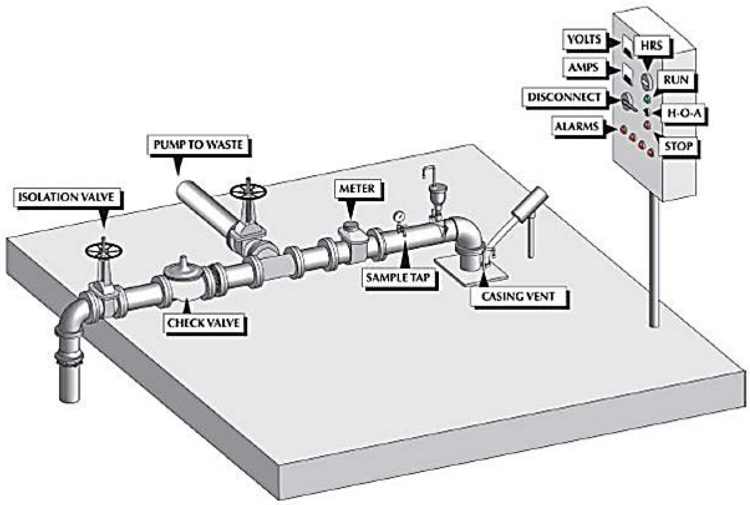

Figure 5-9: Submersible turbine pumping station

- **What is the condition of the equipment?**

  Are all units operable?

  All pumps should be operable. A serious sanitary deficiency exists, for example, if only one of two raw water pumps is functional. The surveyor should inquire about the operation strategy of the pumps. For example, does the operator use multiple pumps that run in sequence (i.e., a lead-lag pumping configuration) where one pump is always the lead pump, running alone until it cannot meet demand on its own, when another lag pump turns on to ensure demand is met? If so, alternating which pump is the lead pump can increase the overall reliability of the pumping system by promoting more even wear. Are pumps equipped with variable frequency drives? If so, how are they being used? Ask how often backup units are exercised. If there is no disruption to the operation, the surveyor should ask the operator to run each unit, one at a time, to observe it. While each pump is operating, the surveyor should examine the state of repair by looking and listening for excessive noise, vibration, heat, odors, and leaking water or lubricant. The surveyor should also look for signs of moisture and dirt around motor cooling inlets.

  Excessive noise, vibration, heat or odors?

  While running, the pump and motor should have a smooth sound and should not be excessively hot. Excessive noise, vibration, and heat indicate serious problems such as bearing failure, shaft misalignment, pump cavitation, impeller wear, or motor breakdown. Heat and the smell of ozone or burning insulation can indicate many problems including motor winding failure, poor power supply, excessive current draw, loose connections, and motor control system deficiencies. Any one of the items cited above is an indicator that immediate maintenance is required.

  Leaking water?

  A pump stuffing box requires a constant drip of water through the packing gland, not an excessive spray. Leaking water can produce moisture around the motor, unsafe conditions around the pump room, and a pathway for contaminants to enter the water supply if vacuum conditions occur at the stuffing box when the pump shuts off.

Dirt and grime?

The surveyor should look for signs of dirt around the motor cooling fins and air intake ports. Dirt and grime can inhibit the flow of air necessary to cool the motor windings.

Leaking lubricant?

Over lubrication of pumps and motors may cause bearing failure and motor burnout. Signs of improper or excessive lubrication are grease pushing out of bearing seals and grease or oil accumulating around the pump and motor.

- **Are the pumping systems equipped with:**

  Check valves?

  On centrifugal pump systems, each pump should have an operating check valve. When observing the operation of each pumping unit during the sanitary survey, the surveyor should pay particular attention to the check valve during the start-up and shutdown periods. The check valve should not slam open or shut. If it does, pressure surge or water hammer conditions could be occurring in the distribution system, resulting in breaks in the mains or service lines. When the pump is not running, the drive shaft should not spin backwards. Backspin is an indicator that the check valve is not functioning which, could lead to the impeller spinning off the drive shaft.

  Isolation valves?

  Each pump should have an isolation valve on the discharge line. In PWSs where the intake water level is above the pump impeller (an application known as “flooded suction” or “suction head”), an isolation valve is also required on the intake side of each pump. Isolation valves facilitate removing the pump for maintenance. Simply because a valve is present does not mean it is working. The surveyor should ask the operator how frequently they exercise the valves and should request the opening and closing of one or more isolation valves.

  Pressure gauges?

  Each pumping system should have a discharge pressure gauge so the operator can measure the actual operating head conditions. A pressure gauge and flow meter are critical for determining pumping system capacity and detecting changes in operating conditions. In addition to a discharge pressure gauge, distribution system booster pumps should also be equipped with compound gauges on the intake side of the pumps. Compound gauges measure positive and negative pressures.

  Flow meter?

  The surveyor should note if the pump has a flow meter and if the meter is functioning properly. A meter can help the operator detect changes in the system and take corrective action before a serious problem develops as well as provide more accurate accounting of water production. Depending on the location of the metered pump, knowing the flow can make determining contact time for disinfection a simple process. Flow meters should be equipped with totalizers to record the total amount of water pumped over a given time period.

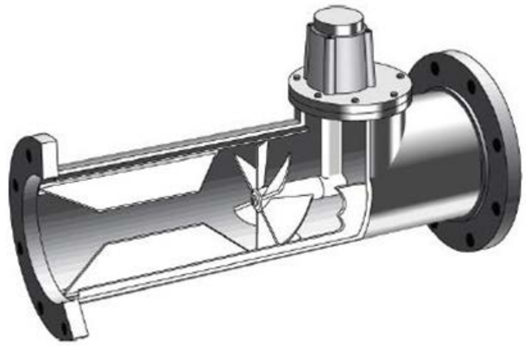

Figure 5-10: Turbine flow meter

Blow-off line?

Raw water pumping systems should be fitted with isolation valves and piping that can direct the discharge to the open air and not into the water supply line. Blow-off lines facilitate flushing the immediate water source and testing the pump.

Air release valve?

To prevent air from entering the distribution system at startup, well pumping systems should be equipped with an air release valve. The surveyor should determine whether the air release valve closes properly following startup and opens properly following shutdown. A properly installed discharge pipe on the release valve points downward, has a screen, and terminates with a suitable air gap (as needed to prevent cross-connection).

Some water systems may use snifter valves to vent flowing wells. Snifter valves used on flowing well pitless adapter spools are prone to failure due to hard water encrustation or scaling. Failure of the snifter valve can result in the leakage of water above the spool and above the frost line. Consequently, freezing and damage to the upper casing can occur. Water discharging out of a casing vent or between the casing and the well cap are indicators that the flow control mechanism within the casing is malfunctioning. Problems associated with snifter valve leakage outweigh the benefits of venting in this case.

- **How often are all pump stations visited?**

  For each pump station, the surveyor should ask if the facility is normally manned or unmanned. During unmanned periods, how often do staff visit the facility to check on equipment and security?

- **Are there any cross-connections present?**

  Surveyors may find cross-connections in:

  - Water lubricated bearing systems.
  - Pump seal water lubrication systems.
  - Air/vacuum release discharge lines.
  - Priming lines for suction-lift pumps.
  - Discharge lines to floor drains or sumps.

  In each case, if the source water for these systems is treated water, the potential for backflow exists. Water systems must protect themselves by using air-gaps or approved backflow prevention devices. Chapter 12 – Cross-Connections provides a thorough description of cross-connections and examples.

- **Are the correct types of lubricant used?**

  Many primacy agencies require water systems to use ANSI/NSF-approved lubricants where parts come in contact with the water supply (i.e., stuffing box, oil-lubricated well shaft bearings, and check valves). Use of such approved lubricants is not usually required on components that do not come into direct contact with the water supply (i.e., motor bearings, shaft, and external pump bearings). Ensure the PWS uses any lubricants according to the manufacturer's recommendations and primacy agency requirements.

- **Is the frequency of addition and amount of lubrication adequate?**

  The surveyor should observe the level and appearance of oil in pump and motor lubricant reservoirs to determine if the operator properly maintains the condition of lubricants. For example, moisture has contaminated oil that has a milky appearance.

  In the case of well pumps, the type and amount of lubrication are particularly important. Some manufacturers design vertical turbine pumping systems with oil-lubricated shaft bearings. If the sealing tube surrounding one of these bearings fails, oil will enter the water supply. The surveyor should find out how much oil the operator regularly adds and compare that to the amount used when the equipment was new. A significant increase in oil addition is a sure sign of a broken seal.

  An indication that the operator does not properly lubricate or grease pumps are unbroken painted surfaces covering the grease fittings and exit port plugs. A schedule for lubrication should be part of a PM program.

5.6 Pumping Facilities

The surveyor should also evaluate the facilities that house pumping systems. These facilities include well houses, booster stations, and raw and finished water pumping stations.

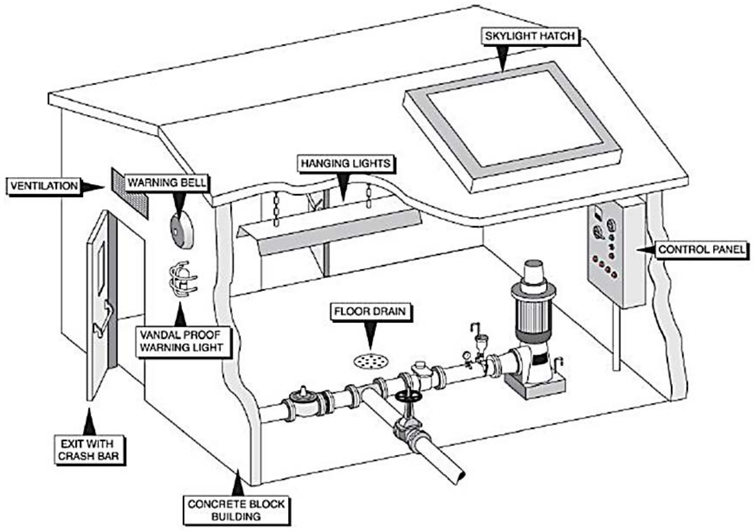

Figure 5-11: Pumping station/well house

5.6.1 Sanitary Deficiency Questions and Considerations – Pumping Facilities

- **Is security adequate?**

  Pumping facilities should be protected against vandalism and unauthorized entry. The perimeter of the property should be fenced, and the building's doors and windows locked. Check around the outside of the building for electrical panels, switches, and valves. Make sure there is no public access. Also, ensure the water system has protected structural drain and vent openings in the building to prevent insects and animals from entering.

- **Is the building and equipment protected from flooding?**

  The pumping station should be above the highest flood level, and surface runoff should drain away from it. Pumping stations should have adequate drains to protect the pumping equipment from flooding if a pipe breaks inside the facility. Water systems should have compartments that are below grade, such as wet wells and dry pits, properly sealed to prevent the entry of undesirable water, either through the walls or from surface runoff. Dry pits should include a sump and sump pump. Check to make sure that electrical controls and motors are not subject to flooding.

- **What is the structural condition of the building?**

  Check the condition of the walls, roof, windows, and doors to make sure that rain cannot enter the building, and check concrete floors and masonry walls for cracks. The control panel should be located near the door and not across the room as shown in the illustration. The operator should be able to shut off power without having to cross through water to access the panel. Cracks around pump piping indicate water hammer conditions when pumps start or stop. This can result in pressure surges that cause breaks in the distribution system.

- **Can the operator access and remove equipment from the building for maintenance?**

  Check to see that there is access to the equipment for survey and maintenance. In addition, there should be a way to remove large equipment from the building. For example, a well house should have a removable access hatch in the roof directly over the well. This makes it easier to use a crane to remove mechanical equipment.

- **Is the building orderly and clean?**

  The surveyor should observe the order and cleanliness of the pumping facility. Dirt can combine with lubricants and reduce bearing life. In addition, dirt and moisture form an insulating coating on motor windings and can cause the motor to burn out. Are there signs of animal activity (e.g., mouse or bird droppings, nests, etc.)? Poor housekeeping is in most cases a sign of poor O&M. However, do not automatically assume that an orderly and clean room indicates the water system follows good O&M practices.

- **Does the PWS use the pumping station for storage?**

  The operator should not be using the pumping equipment room to store hazardous, flammable, or corrosive materials. Chemicals (including water treatment chemicals such as chlorine, hypochlorite, fluoride, and sodium hydroxide) or materials and equipment not associated with the water system (e.g., lawn mowers, lawn chemicals, paint) should be stored in and fed from a room separate from the pumping equipment and electrical controls. (For more information on chemical feed and storage, see Chapter 6 – Chemical Feed systems.)

- **Is safety equipment adequate?**

  Each pumping station should be equipped with a fire extinguisher rated at minimum for class B (flammable liquids) and class C (electrical equipment) fires. Also, check if the water system has identified all confined spaces and has provided proper ventilation. The operator should activate the vent fans and test the atmosphere prior to entry. Follow all confined-space entry procedures when entering any confined space, if allowed. Check that all access ladders are firmly anchored and structurally stable.

5.7 Controls

Automatic systems are widely used to control pumps. The surveyor should understand how pumps are automatically turned on and off. The most common methods are tank level, PWS pressure, and time. For example, a pump may turn on when the PWS pressure is 40 psi and turn off when the pressure is 65 psi. Or the pump may turn on when the finished water storage tank reaches its low level setpoint, and turn off when the tank level reaches its high level setpoint. The surveyor should ask the operator if the control system is functioning properly, and if it has enough flexibility to meet the range of expected operating conditions. It should be possible to control pumps manually.

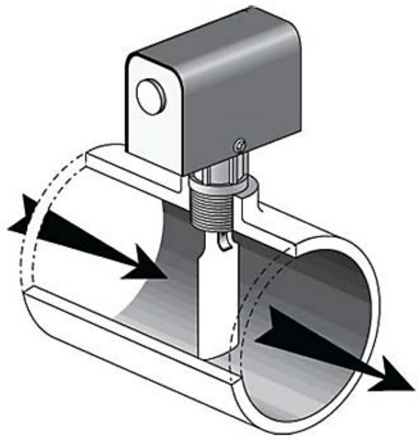

Figure 5-12: Low-flow switch

5.7.1 Sanitary Deficiency Questions and Considerations - Controls

- **Is the motor control system adequately designed and reliable?**

  An example of unsuitable application of a control system is the use of timers alone to control finished water pumps. In this case, the pumps would not supply additional water if demand were unusually high, for example if a main breaks or firefighters must connect to a hydrant. This could result in low pressure or a total loss of supply. The surveyor should ask the operator how frequently he or she resets the motor controls or operates the pumps manually in order to maintain the system pressure.

  A hydropneumatic system typically uses a simple pressure switch to cycle pumps off and on. The surveyor should check to see that the system is operating properly in that the pumps are turning on and off at set pressure levels.

- **Is the pump system equipped with an adequate failure alarm system?**

  The pump control system may be equipped with failure alarms. If the pump fails to start, or stops for any reason other than normal shutdown on the automatic cycle, an alarm system should activate to notify the operator that the system has failed. The surveyor should consider the type of alarm and whether it is suitable for the water system, its setting and its operation. Many pumping stations are equipped with a flashing light or a horn situated outside the building and activated when the system fails. This type of alarm depends on someone actually seeing the light or hearing the horn and calling the water system operator.

- **Does the auxiliary equipment have fail-safe devices?**

  The surveyor should evaluate the control sequence for equipment that operates in conjunction with the main pump and motor. For example, the electrical supply to a chemical feeder that activates automatically with the water pump motor should be equipped with an automatic shutdown device in case the pump fails to produce water for any reason. The PWS can do this by installing a “low-flow” or “low-pressure” cutout switch between the pump and the check valve. This device must sense water flow or pressure in order to energize the chemical feeder. The absence of such a device has led to a significant overfeed of chemical in many cases.

- **Are controls equipped with elapsed time meters?**

  Motor control systems should be equipped with an elapsed time meter for each pump. This meter is similar to an automobile odometer and registers the cumulative running time of the pump motors. The operator can use this information to schedule maintenance, estimate pump output, and compare duty cycles and efficiency of equal pumping units.

- **Does the PWS adequately protect controls?**

  The surveyor should take note of the general condition of the control devices and that protective cabinets house the devices and equipment. Control enclosures that are outside buildings should close tightly and be weatherproof. Control switches such as hand, off, or automatic switches, disconnects, and resets should not be accessible to the public.

- **Does the PWS adequately maintain control systems?**

  The control systems should be included in the water system's PM program. Maintenance of these systems requires a particular expertise in industrial controls. A thoroughly trained operator or another expert in this area should be available to respond to system malfunctions.

5.8 Auxiliary Power

The surveyor should evaluate the need for auxiliary power and, if provided, should evaluate the design, condition, and O&M of auxiliary power units (APUs). Many states require either auxiliary power or two power sources.

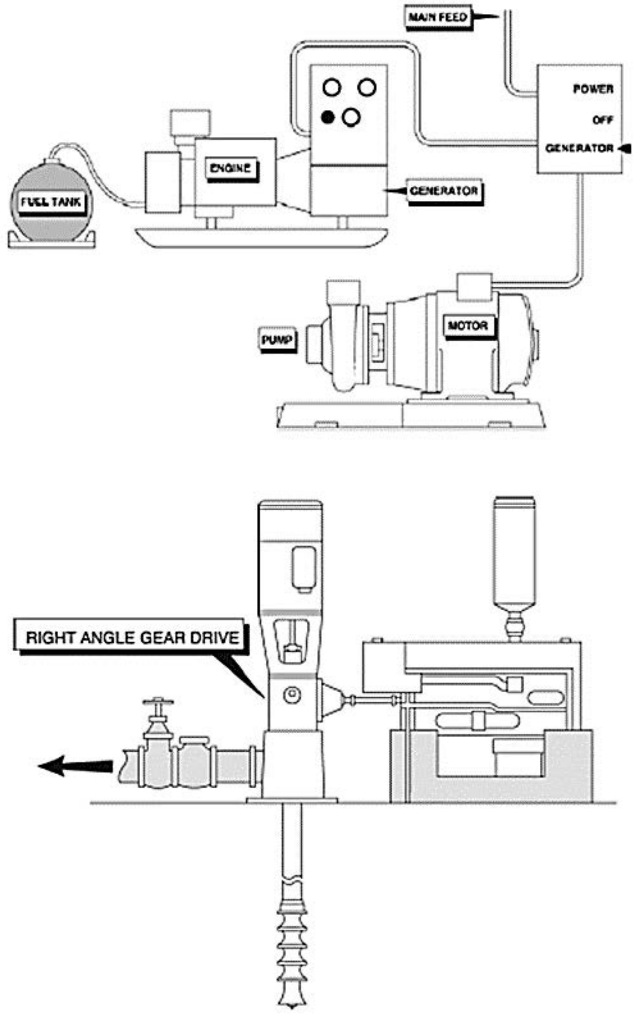

Figure 5-13: Auxiliary power arrangements for water system pumps

5.8.1 Sanitary Deficiency Questions and Considerations – Auxiliary Power

- **Is auxiliary power needed and, if so, is it provided?**

  Auxiliary power may be necessary for the continuous operation of a water system. It is especially critical if outages are frequent or if a PWS has limited capacity for storing finished water. The surveyor should ascertain the frequency and duration of previous power outages and what effect they have had on the water supply. The PWS should consult state design guidelines when determining the need for auxiliary power.

- **What type of auxiliary power does the PWS provide? What conditions activate auxiliary power?**

  The PWS may provide emergency power by an auxiliary generator driven by diesel, natural gas, gasoline engines, or by engines directly connected to the pump drive shaft by a right-angle drive mechanism. Activation of the APU should be automatic upon the loss of primary power. There should be an "automatic transfer switch" that transfers the current load to the APU. Upon loss of power, the system should not require the operator to manually start the APU and transfer the load, although the system should allow manual operation.

- **Does the APU supply ALL electrical systems at the pumping station?**

  In addition to the pump motor, the APU should operate all electrical functions in the pumping station, including lights, heat, ventilation, automatic controls, and – most importantly – any chemical feed systems that are connected. This is a problem when mechanically driven (right-angle drive) type systems operate only the pump during primary-power outages; consequently, untreated or partially treated water is pumped to the distribution system.

- **If the emergency generator is located inside the building, is a carbon monoxide detector installed?**

  If the generator is indoors, carbon monoxide may accumulate to an unsafe level if the building ventilation system is inadequate. The surveyor should check that a carbon monoxide detector is installed and it is functional.

- **Where is the fuel tank located?**

  Is the fuel tank for the APU underground? If so, is there a risk of fuel leaking into the water supply? If the fuel tank is above ground, is it mounted inside a spill containment vessel or equipped with a double-walled fuel tank?

- **Does the PWS regularly exercise and properly test the APU?**

  The surveyor should ascertain how and how often the operator exercises and test the APU. Operators should exercise and test the auxiliary power system according to manufacturer's recommendations. If an actuator automatically exercises APU without an operator in attendance, there is no way to monitor the system's performance and no way to detect small problems before they escalate. Furthermore, operators need to exercise auxiliary systems under a load. The APU should be the source of power for the pumping facility during the exercise period. This procedure ensures that all functions of the APU are tested and working properly. Water systems should keep records of APU exercising, and these records should include engine and generator gauge readings.

- **Is the APU secure and maintained in good condition?**

  The surveyor should check to see that the APU is included in the PM program. Water systems should perform regular maintenance according to the manufacturer's recommendations. The surveyor should visually check the general condition of the unit for signs of leaking fluids or lubricants. Water systems should protect the APU from lightning and other elements as well as from public access. Ensure screens protect vent openings and openings around piping to prevent the entrance of animals. Generators will not run with a blocked exhaust port.

- **Are there any cross-connections between the auxiliary power system and potable water?**

  Some APU engines use potable water for cooling. The surveyor should determine how the unit cools the engine. If potable water is used, the coolant should not return to the potable system, and an air-gap or approved backflow-prevention device should protect the connection between the water supply and the engine.

5.9 Operation and Maintenance

Earlier, this chapter addressed equipment-specific O&M concerns. During the sanitary survey, the surveyor should also assess the overall O&M approach as it relates to the pumping systems from a programmatic standpoint. From this aspect of the sanitary survey, water systems should have written asset management plans for all pumps and associated equipment that includes estimated life expectancies, purpose, budgeting and other information (e.g., pumping capacities, sizing requirements, etc.) needed for their eventual replacement. There should also be a current inventory and location of spare parts available so operators can minimize down time in case of a failure.

5.9.1 Sanitary Deficiency Questions and Considerations – Operation and Maintenance

- **Are the number and skill level of the staff adequate for operating and maintaining the pumping facilities?**

  Chapter 14, Water System Management, discusses recommendations on evaluating the management and operations staff. Only individuals trained in electrical and mechanical systems should be responsible for troubleshooting and maintaining pumping systems. If no one on the staff is competent in these areas, contractors should perform maintenance.

- **Does the operator maintain adequate operational records for pumping facilities?**

  The PWS should maintain, at a minimum, the following operating records for each pumping unit:

  - Suction and discharge pressures.
  - Operating hours.
  - Flow meter readings.
  - Amperage and voltage readings.

- **How are the pump stations monitored?**

  The surveyor should ask the operator how pump operating status and facility security information are monitored and reported to operators and managers at other locations. If the pump station is not manned, operations staff need to know if pumps are currently on or off, and if any alarms have been triggered. Also, it is important to know if a building's intrusion alarm has been triggered, or if the building's heating or power system has triggered an alarm.

- **How often are the pump stations visited?**

  For each pump station, the surveyor should ask if the facility is normally manned or unmanned. During unmanned periods, how often do staff visit the facility to check on equipment and security?

- **Are the pump stations protected against vandalism and intrusion?**

  Because pump stations are often located in remote areas and unmanned, they should be protected from vandals and other intruders. The type and level of security at each pump station depends on water system preferences and budget, the neighborhood characteristics and history of vandalism. Security measures may include locks on doors and windows, cameras, exterior lights, fencing and locked gates, and intrusion alarms on buildings.

- **Does the water system have written SOPs available, and do all operators follow them?**

  All operators should follow the same written operational procedures. This may be as complex as a comprehensive operations manual, or as simple as a one-page list of instructions. Written procedures should cover items such as daily operations and inspections (including a checklist), start-up and shutdown procedures, and responses to equipment failure and other emergencies. A well-managed water system should include contingency plans in their procedures.

- **Is there an established and documented PM program?**

  Improper maintenance can lead to system failures and sanitary deficiencies. A written PM program (also called an Asset Management program – see Chapter 15, Other Considerations) should be established and followed for each piece of equipment in the pumping facility. Water systems should base these programs on manufacturers' recommended maintenance tasks and record maintenance information immediately upon completion. In general, smaller water systems need much less sophisticated PM programs; however, all water systems should have a program in place, even if it is very basic. The surveyor should determine if specific components of a PM program exist and ask to see records. Critical components of a PM program include:

  - **Equipment inventories:** A record that includes data plate information such as model and serial numbers, manufacturer's ratings, and performance specifications for each piece of major equipment.
  - **Manufacturers' technical literature:** Provided with new equipment by its manufacturer. This includes O&M specifications, schematics, and spare parts lists.
  - **Written PM tasks and schedule:** A written list of PM tasks (from the O&M manuals), a schedule, and instructions for performing these tasks. This can be part of a computer program, or smaller water systems can simply record tasks on index cards.
  - **Records of maintenance performed:** In small water systems, the operator can record completed maintenance on index cards. The surveyor should look for recent dates and make spot comparisons to the task schedule.
  - **List of technical resources:** This should include manufacturers' representatives for service and parts, local specialists for instrumentation maintenance, electrical and mechanical repair specialists, and construction contractors.
  - **Tools:** The operator should have a complete set of tools for performing basic maintenance.
  - **Spare parts inventory:** Critical and frequently replaced parts for pumping equipment should be included in the water system's inventory. Materials not maintained in stock should be readily available from local suppliers or factory authorized representatives.

5.10 Safety

Inspecting pumping facilities also includes observing any unsafe conditions that could pose a safety risk to the operator or other staff involved in the operation of the PWS.

5.11 Possible Significant Deficiencies for Pumps and Pumping Facilities

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The state (primacy agency) determines both significant deficiencies and the corresponding corrective actions. Inadequate pump capacity.

- Cross-connections.
- Inadequate/inoperable or unsecure control system.
- Inadequate alarm system for failure of booster pumps.
- No pressure gauge on pump discharge line or on pump suction side.
- No cut off for low pressure on pump suction side.
- No emergency power as required by the state.
- No readily available replacement pump or pump repair parts.

6 Chemical Feed and Storage Systems

The surveyor should evaluate water treatment processes to ensure the production of a safe, adequate, and reliable supply of water for consumers. The water treatment plant is an important barrier against unsafe water for many water systems, and any malfunction in the treatment process could result in water quality problems. The consistent and continual feed of water treatment chemicals is an important component of most treatment systems. The surveyor should therefore evaluate the operation, maintenance, design, and location of the chemical feed systems to identify any sanitary deficiencies.

6.1 Learning Objectives

By the end of this chapter, students should be able to:

- Identify key data items required to evaluate sanitary survey risks associated with chemical feed systems at water treatment plants, such as whether liquid, gas, or dry chemicals are being used.
- Review chemical feed systems as key components of water treatment processes, such as coagulation, flocculation, sedimentation, filtration, and disinfection.
- Recognize chemical feed system sanitary deficiencies as they relate to the physical facilities, O&M, and management. Issues may include inadequate treatment, inadequate application of water treatment concepts to process control, lack of secondary containment in chemical storage areas, hydraulic surges, poor maintenance procedures (lack of O&M manual or failure to implement what is in the manual), staffing and funding deficiencies (lack of training), and cross-connections.
- Identify safety issues that affect the operations staff, and could affect the facility's ability to perform effectively. Safety issues may include chemical handling, chemical storage, and confined spaces.
- Review regulatory issues that are appropriate to each specific process to determine their relationship to sanitary deficiencies.

6.2 Data Collection

The surveyor needs to obtain as much of the following information about the water system as possible before the sanitary survey; otherwise, the water system should provide any missing or updated information during the survey.

6.2.1 Chemical Usage in Treatment Processes

The surveyor should evaluate the following to assess the appropriateness of chemical usage in treatment processes:

- Specific chemicals used and purpose of addition.
- Use of properly certified chemicals.

- Quantities added.
- Application points used.

6.2.2 Chemical Feed Equipment

The surveyor should evaluate the following to assess the efficacy of chemical feed equipment and processes:

- Type of feed system in operation (i.e., liquid, gas, solid).
- Chemical appropriate for application.
- Correct dosage rate.
- Chemical feed pumps.
- Chemical storage tanks (bulk storage and day tanks).
- Condition of feed system equipment.
- Calibration procedures used.
- Available redundancy for all systems.
- Provision of safe and adequate chemical storage.

6.2.3 Process Control Data

The surveyor should verify the following to assess the quality of process control data:

- Type and frequency of testing throughout treatment processes.
- Availability and operability of on-line monitoring equipment.
- Adequacy and consistency of data recording procedures.

6.2.4 Physical Facilities Information

The surveyor should evaluate the following about the water system's physical facilities:

- Buildings and rooms where chemical feed systems are located with respect to accessibility, safety, and overall maintenance.
- Operation, maintenance and design of chemical feed systems, such as adequately sized chemical feed pumps, proper ventilation, appropriate feed points, and adequate chemical storage.

6.3 Regulations and Standards to Consider

The surveyor should consider and review the following information prior to the survey:

- Applicable primacy agency design guidelines.

- Ten States Standards.
- Specific regulations that apply to the facility (See Chapter 2 of this Guide).
- Past survey reports to identify previous compliance problems.

6.4 Purpose of Water Treatment

The purpose of water treatment is to condition, modify, or remove contaminants or pathogens in order to provide water that is safe, palatable, and acceptable to consumers. National standards for some of the contaminants considered important to the health of consumers are set under the federal SDWA (specified in Title 40 CFR Part 141 with MCLs and TT). If the levels of contaminants present exceed the established MCLs, water systems must provide the treatment necessary to reduce the levels. The regulations specify TT when MCLs are not appropriate for public health protection.

40 CFR Part 143 specifies secondary standards for some substances that affect the aesthetic qualities of water. These standards are not enforceable by the federal government, but primacy agencies may choose to adopt and enforce them. Treatment or modification of the water to comply with secondary standards is highly recommended.

6.5 Chemical Feed Systems

Chemical feed systems are common to all types of treatment plants. They may feed treatment chemicals such as coagulants and disinfectants into the water, as well as corrosion inhibitors, pH adjustment chemicals, chemicals for taste and odor control, oxidants, and fluoride. Types of chemical feed systems include liquid feed pumps and dry feeders.

6.5.1 Liquid Feed Pumps

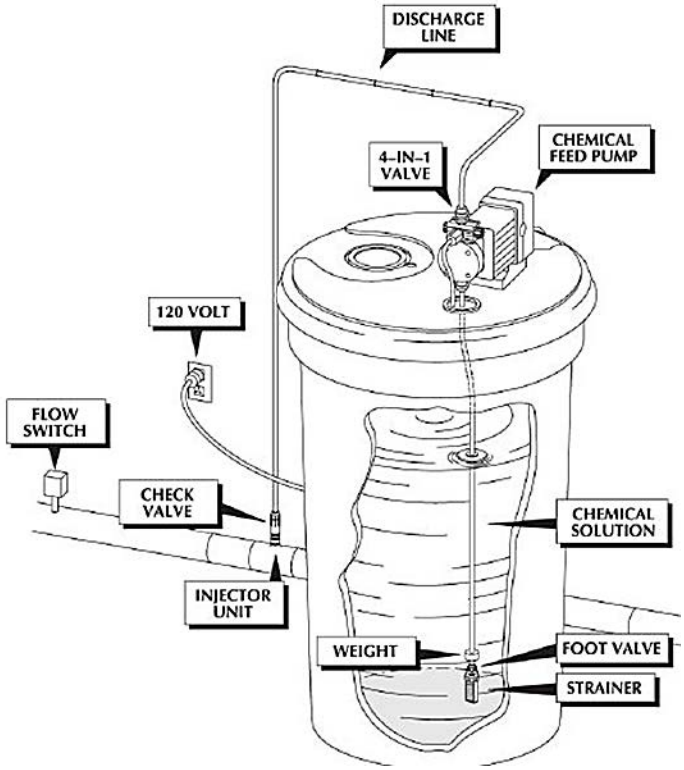

Figure 6-1: Liquid feed pump (Hypochlorinator)

These systems are relatively simple and are usually composed of these basic components:

- Tank to hold the chemical solution.
- Chemical feed pump (the illustration shows a diaphragm pump).
- Injection valve with check valve.
- Electrical control system with fail-safe flow switch.
- Chemical storage area.

6.5.2 Dry Feeders (Volumetric)

In these feeders, operators base the feed rate on the volume of chemical rather than weight. Volumetric feeders can achieve acceptable performance for materials with stable density and uniformity, particularly at low feed rates.

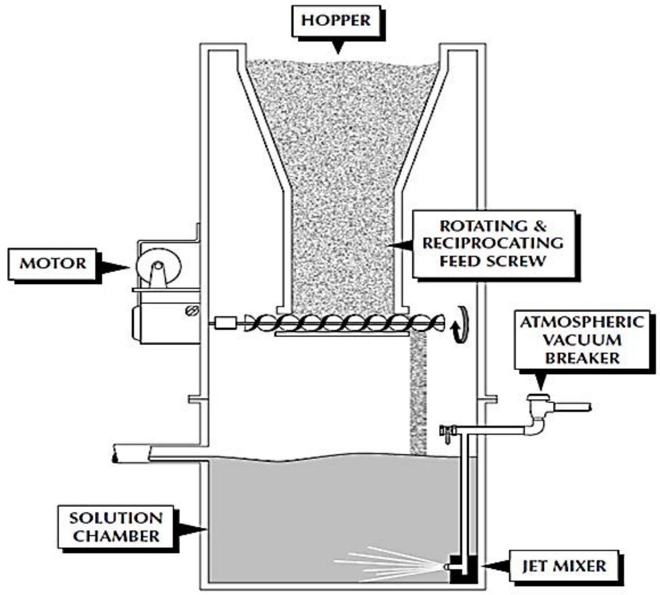

Figure 6-2: Volumetric dry feeder

6.5.3 Dry Feeders (Gravimetric)

This type of system feeds dry chemicals based on actual weight.

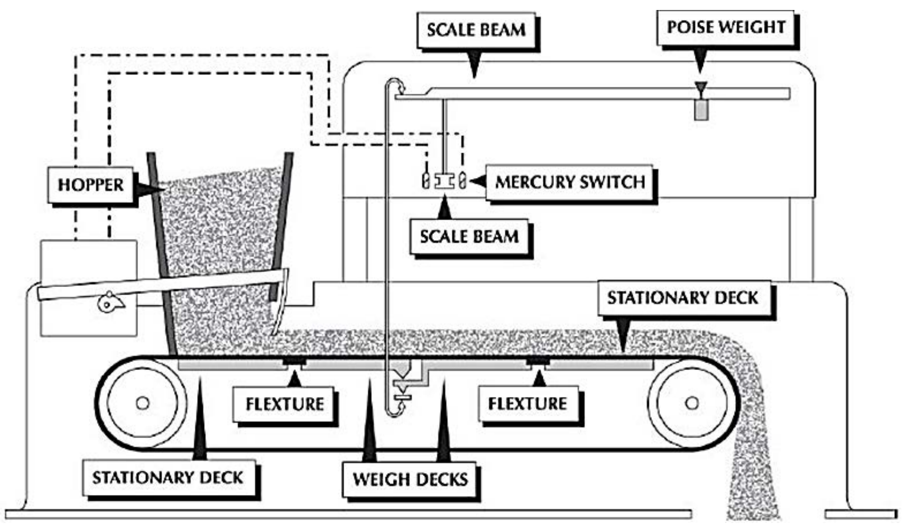

Figure 6-3: Belt gravimetric dry feeder

6.5.4 Operation and Maintenance of Chemical Feed systems

The proper O&M of chemical feed systems is critical to the overall performance of the treatment plant. For example, a conventional SWTP cannot consistently achieve optimum performance unless its chemical feed systems are functioning properly. Issues the surveyor should address for all chemical feed systems include:

- Adequate maintenance, including a PM program, spare parts for critical components, components that need regular replacement, and repair budgeting.
- Back-up pumps for redundancy, particularly for critical processes, such as coagulation and disinfection.
- Check chemical solution tanks (i.e., day tanks) for cross-connection with water supply line.
- Physical condition of buildings and areas housing feed equipment.
- How often the operator calibrates the feed pumps.
- Secondary containment for chemical storage tanks.
- Separation of different types of chemicals.

Storage of chemicals, including the segregation of incompatible chemicals that should not be stored together. For example, storing powdered activated carbon (PAC) and potassium permanganate ($KMnO_4$) in the same area could result in explosion or fire hazards. Chemicals should not be stored where they could contaminate the PWS's water supply in the event of a spill. Appendix B of this Guide provides helpful guidance on incompatible chemicals.

- A hazardous communication program in place to deal with the handling of all chemicals.
- Containment of chemical spills and the location of proper drains in chemical areas.
- Safety in terms of the handling and feeding of chemicals and the availability and proper use of safety equipment, such as chemical goggles and respiratory protection.

6.5.5 Sanitary Deficiency Questions and Considerations – Chemical Feed systems

- **What chemicals are used?**

  The surveyor should determine what chemicals the operator uses, if a certifying organization or agency has approved them for water treatment, and if the operator applies them properly. The operator should be aware of possible adverse effects of adding the chemicals, such as the development of disinfection byproducts (DBPs) because of disinfection practices.

- **What are the amounts of chemicals used?**

  The operator should base the amount of chemicals used on process-control testing. The operator should be able to explain how the dosage is determined (such as by jar testing, pH measurement, or streaming current detectors) and the frequency with which this determination is made. The water system should only be using chemicals approved for use in potable waters by ANSI/NSF Standard 60 or other acceptable federal or state standards.

- **Where is the application point of each chemical?**

  The surveyor should note the application points and evaluate them in light of the purpose of the chemical addition. Chemicals may counteract each other if not applied in the proper sequence. For example, PAC will remove chlorine if it is fed downstream of the chlorine injection point. This situation will reduce chlorine levels as well as waste chlorine and PAC.

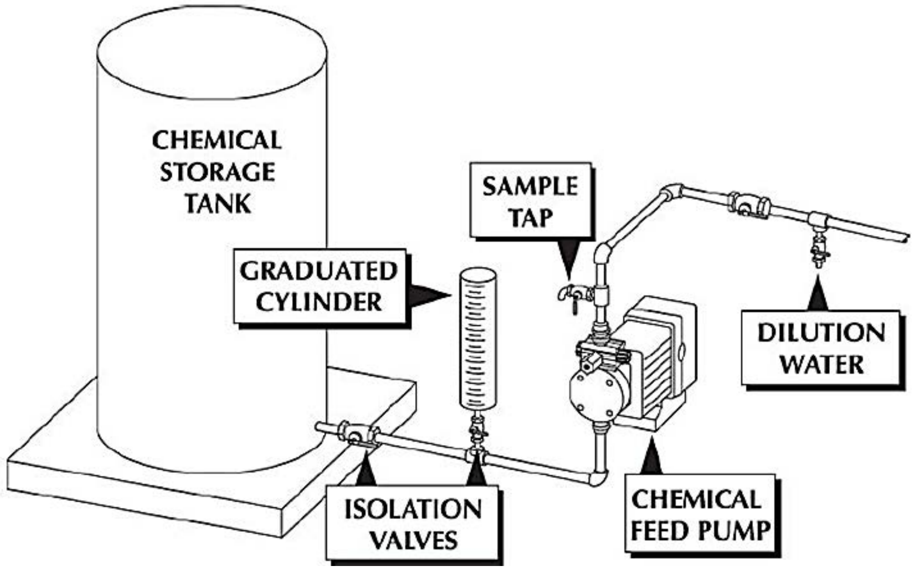

Figure 6-4: Chemical feed system

Similarly, operators should add sequestering agents to control iron or manganese ahead of chlorine because the chlorine oxidizes the dissolved metals and renders the sequestering chemicals less effective. Insoluble calcium fluoride may precipitate out of the water if the addition of fluoride compounds and lime are in close proximity to each other. In general, water systems should apply certain chemicals, such as corrosion inhibitors or fluoride, at the end of the treatment process.

As a rule, the surveyor should know the application points and feed rates of all the chemicals used in the water system's treatment plants. The surveyor should understand the purpose of the chemicals in order to evaluate the feed locations and rates. Therefore, the surveyor will often need to perform, either before or after the sanitary survey, some research on the chemicals used by the PWS.

Chemical addition should not result in a cross-connection. For example, there may be a dilution water feed line taking finished water below the filters in order to provide disinfection to the top of the filters (i.e., unfinished water). This line would terminate below the maximum water level of a filter or the channel feeding water to the filter beds. This creates the possible back-siphon hazard of unfinished water entering the fresh water supply.

- **Does the PWS have adequate process control monitoring and testing procedures?**

  PWSs should monitor for the chemicals added as well as for the chemicals targeted for removal. This monitoring requires following standard testing procedures, using properly calibrated and maintained monitoring and testing equipment. The PWS should have adequate facilities to undertake this monitoring and testing.

- **What is the condition of the chemical feed equipment?**

  The equipment must be functional and properly maintained. For example, with dry chemical feeders, the surveyor should watch for problems with arching or bridging of the chemical in the hopper; the hopper should be designed to accommodate discharge of the chemical without interruption. The operator should routinely check liquid feeder lines to ensure there are no obstructions. There should also be chemical feeder redundancy.

Operators should replace chemical feed pump diaphragm foot valves, injection valves, and control valves as needed. Inspect the suction and discharge piping for discoloration and clogging. The surveyor should determine if there is a preventative maintenance program in place and should examine PM and repair records. The chemical addition program is vital to ensuring proper treatment, and the operator should have adequate spare parts or redundant equipment to prevent interruptions due to equipment malfunctions.

- **Does the operator routinely calibrate the chemical feed equipment?**

  The operator should calibrate the equipment each time they start using a new batch of chemicals. They should also check the equipment feed rate at least daily.

  Ideally, the operator should calibrate chemical feed pumps at least annually. An alternative method is to use a graduated cylinder to verify the feed rate on a weekly or monthly basis.

- **Are instrumentation and controls for the process adequate, operational, and used?**

  Controlling processes is difficult when instrumentation such as flow meters, turbidimeters, and chlorine residual analyzers are not functional or properly calibrated. The surveyor should observe the controls and ask the operator about calibration checks and how they make process control decisions based on the measurements. The instrumentation is useless if the operator does not know the significance of the measurement.

- **Is chemical storage adequate and safe?**

  As a recommendation, water systems should maintain a minimum of a 30-day supply of chemicals. To address safety concerns, liquid chemical storage needs level indicators, overflow protection, and spill containment. This is particularly important to prevent contamination of the aquifer by tanks located near a well. Chemicals stored in the same area should be compatible. For example, petroleum-based oils and lubricants must not be stored near oxidizers such as $KMnO_4$ because of fire and explosion hazards. Chemicals must be stored in a manner that precludes a spill from entering the water undergoing treatment or the raw water source.

  PAC storage areas need to be dry and equipped with an explosion-proof electrical system.

  Make sure that sodium fluoride is stored in a separate area and not with any other chemicals. Sodium fluoride is very corrosive.

  Check on access to the chemical storage. If access is difficult, the operator may not be diligent in transferring chemicals from storage to use.

  See Chapter 8 (section 8.6.2) for chlorine gas storage and safety requirements.

- **Do daily operating records reflect chemical dosages and total quantities used?**

  It is critical that the operator monitor daily chemical use and dose rates. Overfeeding chemicals can be as detrimental as under-dosing. The monitoring of feed rates is a key component to the optimized performance of any chemical feed system.

- **Is the chemical feed system tied to flow (i.e., flow-paced)?**

  A four to 20 milliamp (mA) signal from a flow recorder can control the rate of the chemical feed pump, or it can activate another pump (e.g., well or service pump) which, in turn, can activate the feed pump when there is flow in the line.

  For chemical feeders tied to a pump, it is very important that water systems use some type of flow sensor as a failsafe measure. The chemical feeder should not activate until there is flow in the pipe. Without flow control, a pump motor starter may engage but not start the pump. If the signal that engages the starter also starts the chemical feed system, the feeder could pump highly concentrated chemicals into the line and on to a customer.

- **Is there an operating 4-in-1 valve or equivalent on each feed pump?**

  This valve reduces the possibility of siphoning the chemical into the water system and protects the pump from damage due to shutdown of the discharge piping. Ask the operator to show you how it works.

- **Is there a hazardous chemicals protection and communication program in place?**

  The PWS should have an inventory of all hazardous chemicals, a Safety Data Sheet (SDS) for each chemical, and written procedures for using, transporting, and handling these chemicals. The PWS also should have an emergency response plan in the event of a spill of hazardous chemicals.

- **Is there appropriate safety equipment (e.g., cartridge respirator for calcium hypochlorite) and PPE (e.g., goggles and gloves) available and in use? Do operators have the training needed to use the safety equipment?**

  The PPE should be in good condition; respirators should be clean and stored in a sealed bag. All PPE should be readily available in an appropriate location (e.g., right outside a chlorine room instead of inside the room).

  When respiratory protection is required, the PWS should have a written respiratory protection program. This program includes a fit test of the device and training in selection, use, and care of the device. In addition, the program requires annual physical exams of all personnel required to use the devices.

- **Is the building as clean and dry as possible?**

  Keeping the interior of the building clean and dry reduces the opportunity for spills of liquid or powdered chemicals to react with water, increasing corrosion in the building. When calcium hypochlorite mixes with water, chlorine gas escapes into the atmosphere. This gas increases the rate of corrosion and deterioration in the facility.

- **Is any outside chemical storage protected?**

  Any water treatment chemical that is stored outside in a bulk storage tank should be protected from the weather, flooding, and vandals. Some treatment chemicals need additional protective measures. For example, PAC storage tanks should be equipped with an explosion-proof electrical system.

- **Are all chemicals labeled and listed as NSF or UL approved for drinking water?**

  What is the procedure for ensuring that the chemicals delivered on the truck match the chemical listed on the SDS? Do staff perform periodic checks, such as specific gravity measurements to ensure that the chemical delivered on the truck matches the SDS?

- **How many days of chemical use are stored?**

  The Ten States Standards states that water systems should have at least 30 days' worth of chemicals available on site. Water systems should adhere to their state's guidelines or requirements.

6.6 Specialty Treatment: Fluoridation

Drinking water systems may add fluoride to their water as a public health measure to prevent tooth decay. The surveyor's responsibility is to focus on the sanitary risk of the fluoridation system in the same way that he or she focuses on the sanitary risk of any chemical feed system in a public water supply.

This section discusses the following four topics:

- General application of the fluoridation processes.
- Use of fluoride saturators (sodium fluoride).
- Use of sodium silicofluoride (dry feeder fluoride).
- Use of hydrofluorosilicic acid (fluoride acid feed).

6.6.1 General Application

Fluoridation is the addition of fluoride to a water supply in order to obtain an optimum fluoride concentration in drinking water. There are three chemicals used in the application of fluoride to drinking water:

- Sodium fluoride, a powder.
- Hydrofluorosilicic acid, a liquid.
- Sodium silicofluoride, a powder.

The most common chemical used in small water systems is sodium fluoride.

Traditionally, states have based their optimum fluoride concentration on the ambient temperature; the assumption being that as the ambient temperature increases so does the volume of water consumed. However, acceptable ranges may vary among states, and the surveyor is responsible for being familiar with local and state regulations on fluoride. In 2015, the U.S. Public Health Service (PHS) finalized its recommendation of an optimal fluoride concentration of 0.7 milligrams/liter (mg/L). The earlier PHS recommendation for fluoride concentrations was based on outdoor air temperature of geographic areas and ranged from 0.7–1.2 mg/L (US DHHS, 2015).

Fluoride in a sodium fluoride solution is fairly stable, so there is little noticeable difference between the dosage and the residual. The notable exception is calcium. Fluoride reacts with calcium, reducing the fluoride residual. This is most noticeable when the concentration of calcium in the water exceeds 75 mg/L.

Fluoride is one of two chemicals that have both a primary and a secondary MCL. The primary MCL is 4.0 mg/L, and the secondary MCL is 2.0 mg/L. At concentrations above 4.0 mg/ L fluoride will cause skeletal fluorosis. At a concentration of 2.0 mg/L fluoride will cause dental fluorosis.

6.6.2 Fluoride Saturator System

Water systems use up-flow and down-flow saturators to feed sodium fluoride. Up-flow saturators are the most common method in small water systems. Saturator systems are very simple, as seen in the drawing below, and are comprised of these basic components:

- Saturator tank connected at its top to a water supply and equipped with a manifold at its bottom.
- Float switch used to maintain the water level in the saturator.
- Water inlet system, which contains a water meter, solenoid valve, vacuum breaker, and a softener if the feed water is relatively hard.
- Chemical feed pump.
- Electrical system including fail-safe controls.

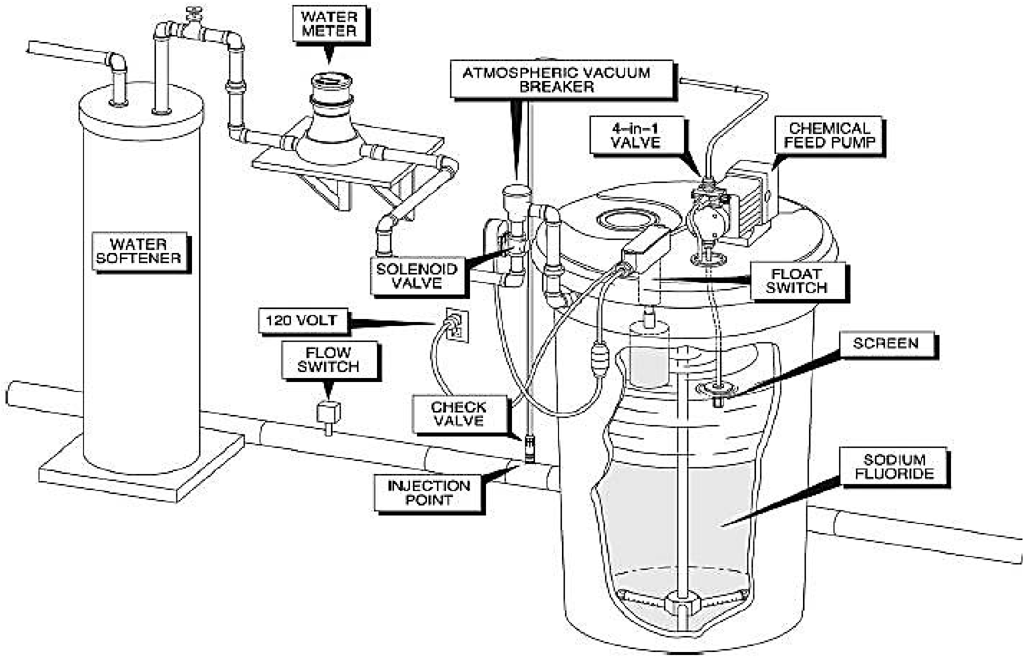

Figure 6-5: Fluoride saturator

Sodium fluoride crystals at the bottom of the tank dissolve and saturate the water filling the tank. A pump feeds the fluoride solution from the tank into the water flow, eventually dropping the water level in the saturator. When the solution drops to a certain level, a float switch opens a solenoid valve. The valve's opening sends make-up water down through the distributor and up through the fluoride crystals, maintaining the level in the tank and preventing the solution's concentrations from changing significantly.

The only way to determine the amount of fluoride fed each day is from the water meter readings on the make-up water. Low-flow systems may need to stir or mix the solution to ensure consistent concentration of fluoride. A low-flow or low-pressure switch must control the chemical feed pump so fluoride can be fed only when there is adequate flow in the water line.

6.6.3 Dry Feeder Fluoride System

Volumetric and gravimetric dry feeders feed sodium silicofluoride or sodium fluoride crystals. Due to its lower cost, sodium silicofluoride is most commonly used. Water systems typically use dry feeder systems where flows exceed 1 million gallons per day (gpd).

Note: See drawings and descriptions of volumetric and gravimetric dry chemical feeders earlier in this chapter.

Metered water system flow determines the dry chemical feed rate into the solution tank. Operators adjust the feed rate using a 4 to 20 mA signal from a flow meter. Usually, gravity flow feeds the solution to the clearwell, or a chemical feed pump injects the solution into a water line.

6.6.4 Fluoride Acid Feed system

Acid feed systems are one of the simplest fluoride feed systems used. They feed hydrofluorosilicic acid directly from a shipping container into the water system flow.

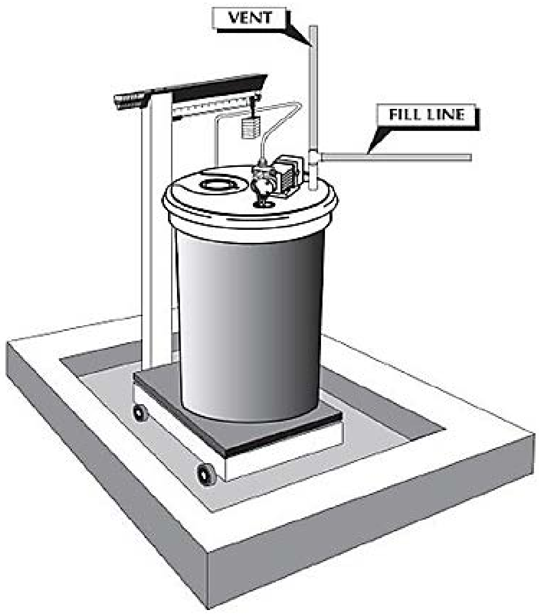

Figure 6-6: Fluoride acid feed system

These basic components comprise an acid feed system:

- Set of scales to determine the quantity of chemical feed.
- Chemical feed pump system.
- Electrical system including fail-safe controls.
- Spill containment.

An acid feed system uses a chemical feed pump with an anti-siphon valve to pump concentrated acid directly into the system flow. The only way to determine the amount of fluoride fed each day is by weighing the solution. A low-flow or low-pressure switch should control the chemical feed pump so the pump only injects fluoride when there is a flow in the water line.

Special care should be taken with these water systems; hydrofluorosilicic acid leaks are a hazard and very corrosive.

6.6.5 Sanitary Deficiency Questions and Considerations – Fluoridation

- **Can the operator answer basic questions about the fluoridation process, including what they need to do, when, and why?**

  An operator's lack of knowledge about the process and equipment is an indication that failures of equipment or the effectiveness of the process may not be resolved in a timely manner.

Management is responsible for ensuring only well-trained staff operate and maintain the fluoridation equipment. Surveyors may consider a lack of knowledge of this key process a significant sanitary deficiency.

- **Is there a proper concentration of fluoride in the distribution system at all times?**

  Historically, states based the residual on the ambient temperature of the area. They assume the public consumes more water as the temperature increases. Make sure the water system follows current state requirements.

- **Does the operator test fluoride concentrations in the PWS daily?**

  A key way to prevent overfeeding of fluoride is to test its concentration in the PWS. The fact that there are primary and secondary MCLs for fluoride also indicates that a prudent operator would perform this test daily. In addition, if there is any natural fluoride in the raw water, the operator should test daily because the concentration may vary from day to day, requiring adjustments of the feed system.

- **Does the fluoride concentration vary from day to day?**

  If there is a change, check to see that the operator is correctly conducting tests at the same time of day and under the same conditions. For example, are pumps on or off? What is the concentration of fluoride in the raw water?

- **Does the operator perform testing correctly?**

  There are three common procedures for testing fluoride: the SPADNS method, the ALIZARIN-VISUAL test, and the specific ion probe method. The surveyor should verify that the operator knows the proper test procedure and that the chemicals are not past their expiration date.

- **How often does the operator calibrate the testing instrument? When was the last calibration?**

  The operator should perform both color tests against a standard that is part of the routine test procedure. The surveyor should determine whether the operator is performing this portion of the test. If a specific ion probe is used, the surveyor should check to see how it is used and how often the operator replaces it.

- **Is there a water meter on the inlet line when using a fluoride saturator?**

  The amount of fluoride solution fed each day can be determined only by reading the water meter on the dilution tank inlet water supply. The surveyor should determine whether the operator records this reading and calculates the total amount of water used each day.

- **How often does the operator clean the fluoride saturator tank?**

  The fluoride saturator should be disassembled and cleaned once a year. The operator should remove all the crystals and replace them with new ones. This annual cleaning and crystal replacement helps maintain the stability of the fluoride solution.

- **Is there a scale for weighing the solution tank for a liquid acid system?**

  The amount of acid fed each day can be determined only by daily weighing of the solution tank. The surveyor should check to see that the operator records this reading and calculates the total amount of fluoride used each day.

- **How often are the scales calibrated?**

  For weight-based only dosages, the operator should calibrate the scales at least annually.

- **Does a fail-safe switch control the fluoride feed system?**

  A low-flow or low-pressure switch must control the pump used to feed fluoride to the water flow. The fluoride feed pump should not be allowed to come on until there is flow in the pipe. Without a fail-safe flow detection system, a pump motor starter may engage but not start the pump. If the signal that engaged the pump starter also starts the fluoride feed pump, the feed pump may feed a highly concentrated fluoride solution into the line and into the distribution system.

6.7 Possible Significant Deficiencies for Chemical Feed and Storage systems

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The state (primacy agency) determines both significant deficiencies, and the corresponding corrective actions.

- The chemical feed pump is the wrong size, not working, or needs repair.
- No “4-in-1” valve if the pump supports a critical chemical feed process (i.e., fluoride, coagulant feed, or chlorine).
- The chemical feed control system is inoperable.
- There are interruptions in the requisite disinfection process.
- There are cross-connections present.
- Operator lack of knowledge on fluoride chemical feed system.
- There is no means to determine fluoride residual (e.g., a flow meter and associated saturator to calculate the feed rate or a fluoride test kit).
- Failure to use NSF or ANSI-approved chemicals.
- Improperly labeled chemicals or missing labels.
- Operator is not performing tests daily for treatment chemicals added.
- There is no check valve between metering pump and inlet pipe to prevent siphoning of chemical to drinking water.

7 Chemical Contaminant Removal

The surveyor should thoroughly evaluate all water treatment processes to ensure the production of a safe, adequate, and reliable supply of water for consumers. The water treatment plant is the primary barrier against unsafe water, and any malfunction in the treatment process could result in water quality problems. Of major importance is the consistent and continual removal of chemical contamination. The surveyor must evaluate the operation, maintenance, and management of advanced removal systems used at the water treatment plant to identify any existing or potential sanitary deficiencies.

7.1 Learning Objectives

By the end of this chapter, students should be able to:

- Recognize sanitary deficiencies of advanced water treatment processes as they relate to the physical facilities, O&M, and management. Issues may include inadequate treatment, inadequate application of water treatment concepts, process controls, and cross-connections.
- Identify safety issues that affect the operations staff as well as those that could affect the facility's ability to perform effectively. Safety issues may include handling and storage of hazardous chemicals, high voltage equipment, air quality, and confined spaces.
- Review regulatory issues that are appropriate to each specific process to determine their relationship to sanitary deficiencies.

7.2 Data Collection

The surveyor needs to obtain as much of the following information about the water system as possible before the sanitary survey, otherwise the water system must provide any missing or updated information during the survey.

7.2.1 Treatment Processes Information

The surveyor should evaluate the following to assess the appropriateness of treatment processes:

- Schematics of complete treatment facilities showing the type of treatment processes used and application points of all chemicals.
- USEPA *Chemical Contaminant Rules for Primacy Agencies:* https://www.epa.gov/dwreginfo/chemical-contaminant-rules-compliance-primacy-agencies-state-and-tribal-agencies
- USEPA *Chemical Contaminant Rules for Community Water Systems:* https://www.epa.gov/dwreginfo/chemical-contaminant-rules
- USEPA *Drinking Water Treatability Database:* https://www.epa.gov/water-research/drinking-water-treatability-database-tdb

7.2.2 Process Control Data

The surveyor should verify the following to assess the quality of process control data:

- Type and frequency of testing throughout the treatment process.
- Availability and operability of on-line monitoring equipment.
- Adequacy and consistency of data recording procedures.

7.2.3 Physical Facilities Information

The surveyor needs to evaluate the following regarding the water system's physical facilities:

- Buildings and rooms where treatment processes are located, with respect to accessibility, safety, and overall maintenance.
- Operation, maintenance, and design of treatment units.

7.3 Regulations and Standards to Consider

The surveyor needs to consider and review the following information prior to the survey:

- Specific regulations that apply to the facility (see Chapter 2 of this Guide).
- Past survey reports to identify previous compliance problems.

7.4 Purpose of Water Treatment

The purpose of water treatment is to condition, modify, or remove undesirable impurities or pathogens in order to provide water that is safe, palatable, and acceptable to consumers. National standards for some of the impurities considered important to the health of consumers are set under the federal SDWA (specified in 40 CFR Part 141 with MCLs and TT). If the levels of contaminants present exceed the established MCLs, water systems must treat the water to reduce the levels. Regulations specify TT when MCLs are not appropriate for public health protection.

Title 40 CFR Part 143 establishes secondary standards for some impurities that affect the aesthetic qualities of water. These standards are not enforceable by the federal government, but primacy agencies may choose to adopt and enforce them. Treatment or modification of the water to comply with secondary standards is highly recommended because consumers may seek out unsafe sources if the drinking water supplied by the PWS has an undesirable appearance, taste, or odor.

7.5 Removal Processes

The types of chemical removal processes covered in this section include:

- Reverse osmosis.
- Corrosion control treatment.
- Iron and manganese removal.

- Organics removal.
- Aeration.
- Water softening.

7.5.1 Reverse Osmosis

Water systems use reverse osmosis (RO) to demineralize salt water, brackish water, and water with high concentrations of total dissolved solids (TDS), as well as for microbial removal.

When a semipermeable membrane separates a solution that has a high TDS concentration from a solution of low TDS, fluid flows from the dilute solution to the concentrated solution, a process called osmosis. Osmotic pressure is the pressure created by the difference in concentration of the two fluids.

RO occurs when pressure on the concentrated solution forces the fluid backward through the membrane. The membrane removes (rejects) the TDS in the concentrated solution, thus producing fresh water from brackish water.

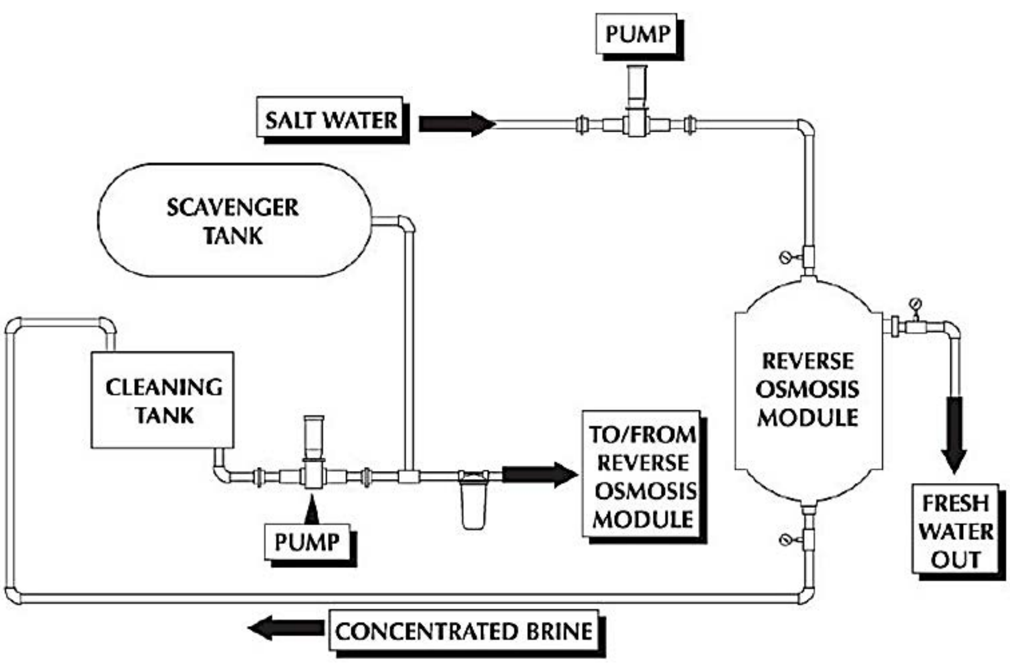

Figure 7-1: Reverse osmosis

7.5.1.1 Equipment

A typical RO facility is composed of the following components.

- A high pressure pump (typically 350 to 500 psi).
- Membranes that are commonly made of cellulose acetate.
- A pump, usually peristaltic or positive displacement, that injects acid into feed water, which blends with the raw or partially treated water flow to control or adjust pH. Sulfuric acid is

commonly used. Adjusting the water to a low pH is normal as it reduces the natural destruction of the membrane (called hydrolysis) and retards the buildup of calcium carbonate ($CaCO_3$) scale on the membrane.

- A scale inhibitor feeder. While pH adjustment controls $CaCO_3$ scale, the low pH has little effect on calcium sulfate. To control calcium sulfate, water systems need to add a polyphosphate chemical.
- Cleaning tank, pump, and solution. Typical cleaning solutions include citric acid, sodium tripolyphosphate, and proprietary products.

7.5.1.2 Performance

The primary advantage of the RO process is that it rejects a high percentage of dissolved solids from the raw water. The rejection of the dissolved solids from contaminated, brackish, and saline water produces water suitable for potable use. Problems associated with RO plants include:

- High initial and operating costs.
- Need for pre-treatment of turbid raw water with cartridge filters, acid and other chemicals to prevent fouling of the membranes by slimes, suspended solids, iron, manganese, and precipitates of $CaCO_3$ and magnesium hydroxide.
- Need to stabilize finished water with pH adjustment chemicals to prevent corrosion in the distribution system.
- Disposal of reject waste stream.

7.5.1.3 Sanitary Deficiency Questions and Considerations – Reverse Osmosis

Note: The sanitary deficiencies related to chemical feed systems in the previous chapter also apply to this section.

- **What performance testing is the PWS conducting?**

  The PWS should be testing for TDS, pH, temperature, turbidity, and alkalinity.

- **What operational data is the PWS collecting?**

  The operator needs to observe, record, and respond to pressure pump suction, discharge pressure, and RO unit pressure differences between feed and product water. The difference between feed and product water pressures over time is a key to determining scale and biological buildup on the membrane.

- **Is the PWS using RO to provide microbial removal?**

  If so, the operator should record daily integrity test and process control results for all membrane units in use that day as required by the primacy agency.

- **What chemicals are being fed and at what dosages?**

  The water system's operator should calculate feed rates and dosages for the feed acid, scale inhibitor, and cleaning solutions.

- **Is there a pretreatment filtration step?**

  Before the RO process, water is typically treated to remove particles so that the filters do not become plugged prematurely. The surveyor should ask what type of pretreatment is used and ask for details on the filter make/model, and pore openings (i.e., what particle size in microns can be removed). If cartridge filters are used, the surveyor should ask the operator how their effectiveness is monitored and confirm that extra cartridges are available on-site.

- **Is adequate protection readily available to operators?**

  Because these units require the feeding of various acids, operators need rubber gloves, eye protection, breathing protection, rubber aprons (worn when mixing or pouring the acids), and a safety shower in case of accidents or spills.

- **Are all automatic controls in operation?**

  RO facilities have various shutdown alarms and automatic systems to control the facility. Because of the high pressures and the presence of acids, this equipment tends to fail frequently. All automatic equipment, safety shutdowns, and alarms must be in working order.

- **If the PWS blends RO-treated water with water that bypasses RO treatment, how is the blending ratio determined and is the final water satisfactory?**

  PWSs still must provide full treatment of water that bypasses RO treatment and must blend the different streams in a ratio where the PWS meets all applicable compliance measures. These ratios must account for any contaminants in the "bypassed water" and must result in contaminant concentrations in the blended water that meet all applicable water quality standards.

7.5.2 Corrosion Control Treatment

Corrosion causes the deterioration of pipe materials. It generally occurs in drinking water distribution systems by the principle mechanism of dissolution. The dissolution of pipe materials occurs when favorable water chemistry and physical conditions combine.

7.5.2.1 Need for Treatment

Altering water quality characteristics through treatment can extensively reduce some forms of corrosion activity, but may have less significant effects on pipe corrosion results. Many PWSs must implement optimal corrosion control treatment to meet the lead and copper action levels established by the federal LCR.

7.5.2.2 Corrosion Control Treatment

The primary goal of corrosion control treatment is to inhibit dissolution. The objective is to alter the water quality so that the chemical reactions between the water supply and the pipe materials favor the formation of a protective layer on the interior of the pipe walls. Corrosion control treatment attempts to reduce the contact between the pipe and the water by creating a film that is:

- Present throughout the distribution and home plumbing systems.

- Relatively impermeable.
- Resistant to abrupt changes in velocity.
- Less soluble than the pipe material.

Two general approaches characterize corrosion control technologies used to inhibit lead and copper dissolution:

- Precipitation of insoluble compounds on the pipe wall because of adjusting the water chemistry.
- Passivation[2] of the pipe material itself through the formation of less soluble metal compounds (carbonates or phosphates) that adhere to the pipe wall.

In general, the available corrosion control treatment technologies are passivation by pH/alkalinity adjustment or the addition of a corrosion inhibitor. Calcium hardness adjustment is another available technology; however, it not considered an effective form of corrosion control (USEPA, 2019).

7.5.2.3 Sanitary Deficiency Questions and Considerations – Corrosion Control

Note: The sanitary deficiencies related to chemical feed systems in the previous chapter also apply to this section.

- **What are the results of lead and copper sampling during the current monitoring period?**

  The water system may need to consider different corrosion control strategies if they have exceeded lead or copper action levels.

- **What are the characteristics of the water entering and leaving the treatment plant?**

  The operator should be able to provide test data that indicate the chemical characteristics of the water entering and leaving the treatment plant. Typical water quality characteristics associated with corrosion control treatment include pH, alkalinity, temperature, calcium, conductivity, and a corrosion inhibitor (e.g., phosphate- or silicate-based inhibitor) when used. These data should be the basis for developing an appropriate corrosion control program and for demonstrating chemical additives are accomplishing the desired goals.

- **What corrosion control is being used?**

  In general, the available corrosion control treatment technologies are passivation by pH/alkalinity adjustment or the addition of a corrosion inhibitor. As stated above, calcium hardness adjustment is another available technology; however, it is not considered to be as effective (USEPA, 2019). The surveyor should ask what treatment chemicals are being used and make sure they are appropriately certified (i.e., primacy agency standard and/or NSF) for contact with drinking water.

[2] Passivation is a generic term referring to the process whereby a dense protective layer forms on the surface, which then protects that surface from corrosion.

- **Is the PWS required to provide Optimal Corrosion Control Treatment?**

  Federal drinking water regulations (40 CFR 141.2) define optimal corrosion control treatment (OCCT) as "the corrosion control treatment that minimizes the lead and copper concentrations at users' taps while insuring that the treatment does not cause the water system to violate any national primary drinking water regulations." Section 40 CFR 141.81(a) of the LCR describes the conditions under which water systems are required to install and maintain OCCT. The surveyor should review federal and primacy agency requirements regarding OCCT.

- **If applicable, is the PWS meeting the state-designated water quality parameters at both the customer's taps and the distribution system entry point(s)?**

  Before leaving for the field survey, the surveyor should review the water system's files to learn what water quality parameter conditions the PWS is required to maintain. Once at the PWS, the surveyor should review recent water quality results and ensure they fall within the range of values required for the customer's taps as well the distribution system entry point(s).

- **What process-control sampling does the operator conduct at the plant and throughout the distribution system as part of the corrosion control program?**

  The operator should sample appropriate locations in the distribution system to ensure they meet and maintain corrosion control goals and to prevent problems possibly associated with overfeeding chemicals. For example, excessive feeding of a phosphate inhibitor could encourage the growth of undesirable biological slimes in the distribution system piping.

- **Is the test equipment to monitor the data appropriate and in good working order?**

  Since pH is generally a critical parameter in corrosion control, the test equipment must be accurate and properly calibrated.

7.5.3 Iron and Manganese Removal

7.5.3.1 Iron and Manganese in Surface Water

Iron and manganese may be present in surface water due to their dissolution from the associated geologic formations or from the decomposition of organic materials. Nearly all of the available methods for iron and manganese removal, except ion exchange, rely on the oxidation of the soluble forms to insoluble forms along with, or followed by, clarification or filtration to remove the resulting precipitates. Therefore, the processes discussed in the section on surface water treatment (pre-treatment, chemical addition, coagulation, flocculation, sedimentation, and filtration) are generally adequate to deal with iron and manganese problems in surface water.

7.5.3.2 Iron and Manganese in Ground Water

Ground water drawn from underground formations of shale, sandstone, and alluvial deposits are particularly prone to containing iron and manganese. Iron in ground water is normally in the range of a few hundredths to about 25 mg/L with the majority of wells drawing water in which the iron concentration is less than 5 mg/L. Manganese is usually present in ground water in a concentration less than 1 mg/L, although, in some places, levels have been significantly higher.

7.5.3.3 Treatment Processes

Processes for removing iron and manganese from ground water are generally one of the following:

- Oxidation (aeration, chlorination, chlorine dioxide, or potassium permanganate) followed by filtration.
- Oxidation, clarification, and filtration.
- Ion exchange.
- Manganese green sand filtration.

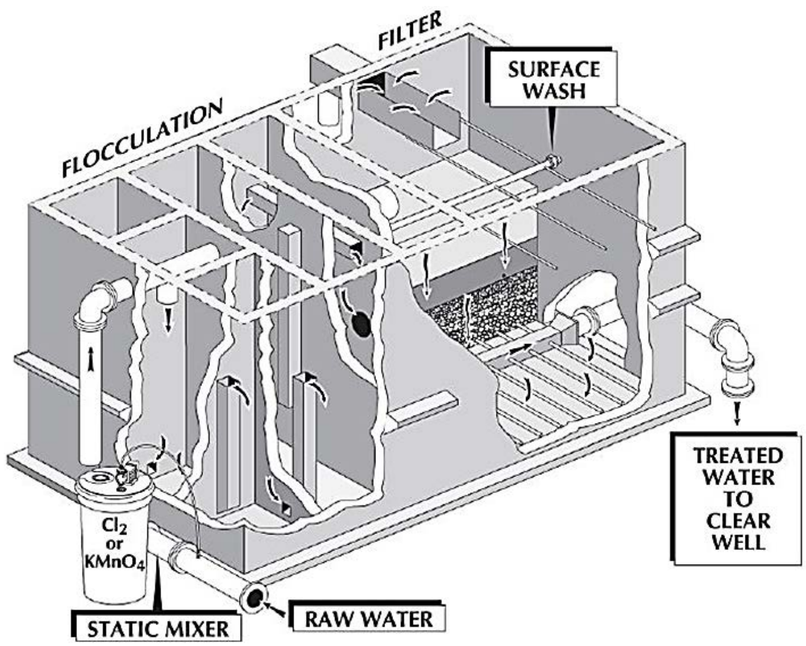

Figure 7-2: Oxidation – filtration

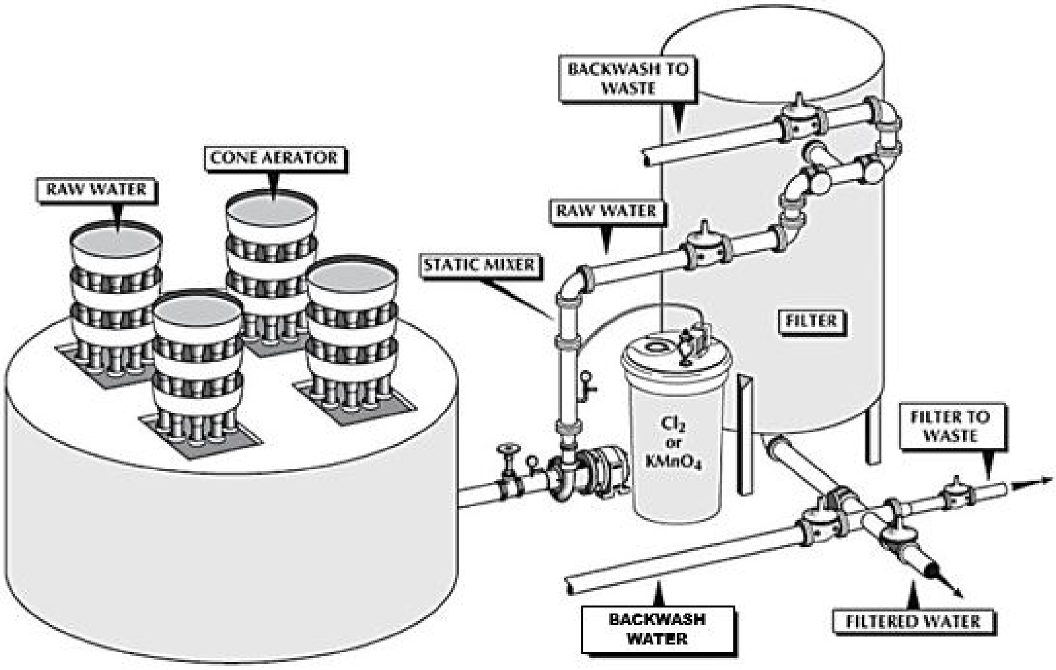

Figure 7-3: Aeration – filtration

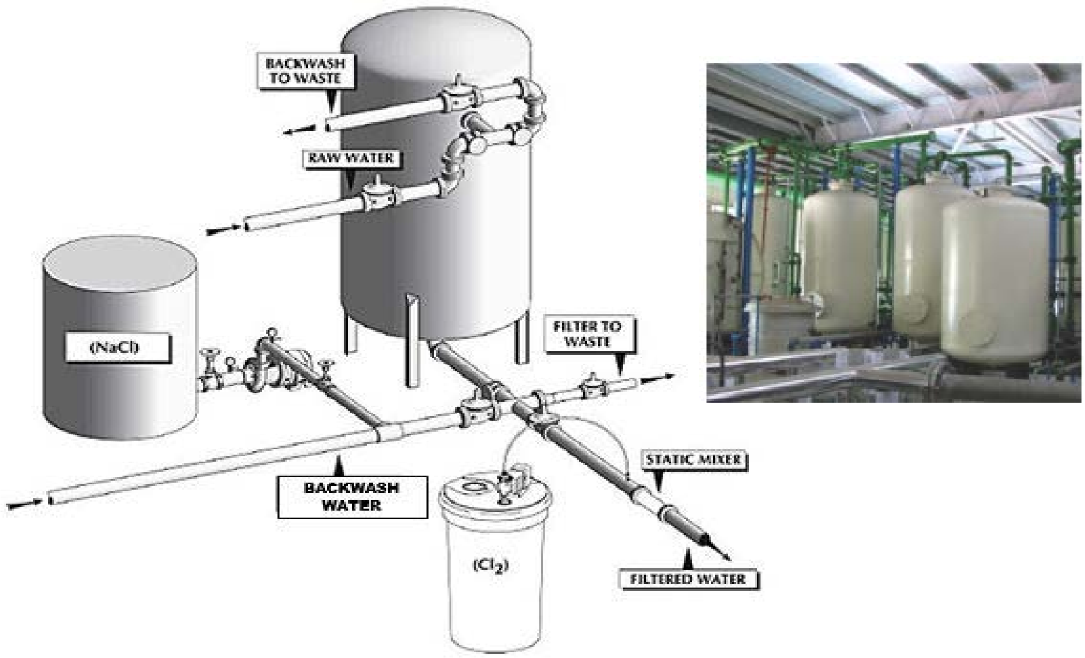

Figure 7-4: Ion exchange

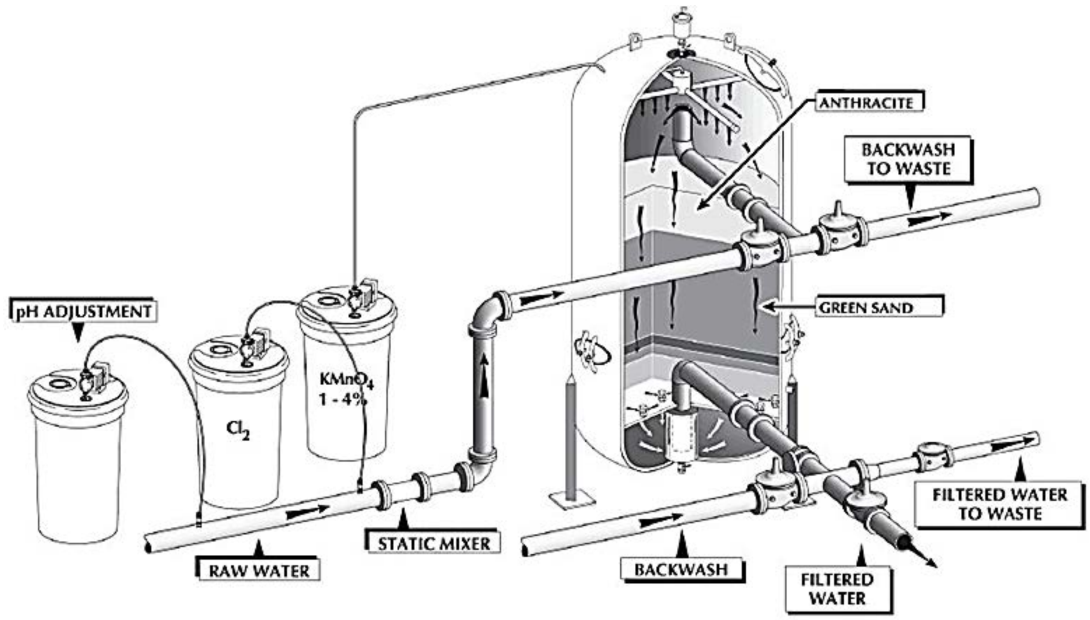

Figure 7-5: Manganese green sand filtration intermittent regeneration (IR)

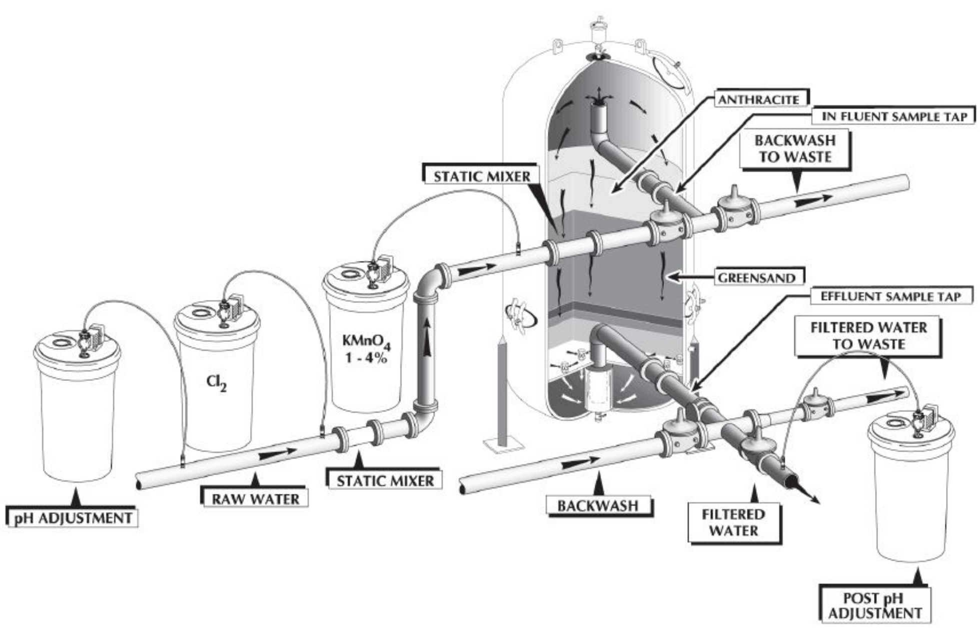

Figure 7-6: Manganese green sand filtration continuous regeneration (CR)

7.5.3.4 Application

The applicability of each of the above processes and the sequence of chemical addition depend on the raw water quality and plant capacity at each water treatment facility. For specific information on the design and operation of each of these processes, consult the suggested references at the end of this guide.

7.5.3.5 Sanitary Deficiency Questions and Consideration – Iron and Manganese Removal

Note: The sanitary deficiencies related to chemical feed systems in the previous chapter also apply to this section.

- **What treatment process is used?**

  A number of processes, as well as variations on some of the standard processes, are available for iron and manganese removal. The operator should be able to describe the process used and why the plant is operating in that particular mode.

- **Do visual observations confirm the removal process is performing adequately?**

  The surveyor should examine the filtered water to determine if any color is evident. Discolored finished water could indicate iron or manganese breakthrough or an overdose of potassium permanganate, which could result in water with a pink color.

- **Are analyses conducted to assess removal?**

  The surveyor should ask the operator what water quality analyses are conducted to assess the performance of treatment systems for removing iron and manganese. Different water quality analyses may be performed depending on the treatment technology being used. Analytical parameters may include iron, manganese, pH, and color.

- **What chemicals are used and in what amounts?**

  In a manganese green sand filtration plant, the operator may be using some combination of chlorine, potassium permanganate ($KMnO_4$), and a chemical for pH adjustment (caustic soda, soda ash, or lime). The quantity of each chemical is critical to consistent plant performance.

- **Where does the operator apply chemicals and how are they monitored?**

  The sequence of chemical addition in a manganese green sand filtration plant greatly influences the effectiveness of the system in removing iron and manganese. The surveyor should determine whether the plant operates in the continuous regeneration (CR) or intermittent regeneration (IR) mode and ask the operator their objectives for operating in a particular mode.

  Generally, water systems operate in CR mode when iron removal is the main objective, with or without the presence of manganese, and requires the continuous feeding of an oxidizer, such as chlorine, $KMnO_4$, or a combination of the two, into the raw water prior to the filter.

  Operators run the treatment process in IR mode when the water contains all or mostly manganese, with lesser quantities of iron. In this mode, manganese oxidation occurs directly using the properties of the freshly regenerated manganese green sand. After treating a specific amount of water, the removed manganese depletes the oxidation capacity of the media and regeneration is required. A normal backwash cycle regenerates the filter bed by the down-flow passage of a dilute $KMnO_4$ solution through the filter bed.

  When polyphosphate is used to sequester lower concentrations of the metals, the surveyor should check to be sure the sequestering agent has sufficient time and mixing prior to chlorine addition.

7.5.4 Organics Removal

Commonly used methods to remove organic contaminants from drinking water include granular activated carbon (GAC), powdered activated carbon (PAC), aeration, and enhanced coagulation.

7.5.4.1 Carbon Adsorption

Water systems primarily use carbon adsorption to reduce organics that contribute to taste and odor and to reduce organics that contribute to trihalomethanes (THMs) formation, some of which may be carcinogenic. The two forms of activated carbon used in the water works industry are PAC and GAC.

7.5.4.1.1 Powdered Activated Carbon

Powdered activated carbon (PAC) is primarily used to remove taste and odor caused by organic compounds as well as serve as a flocculation aid. Because of its high density, PAC helps to form the nuclei of the floc particles. PAC can also be effectively used to remove cyanotoxins and disinfection byproduct (DBP) precursors. PAC is commonly delivered to the site in 50-pound bags and can be fed dry or as a slurry. The most common method of application is the use of special dry chemical feeders where it mixes approximately 1 pound of PAC per gallon to create a slurry. This slurry then feeds into the plant flow. Because a chemical feeder can add PAC, it is more effective than GAC when the concentration of organics varies. However, filtration must remove the carbon before the water enters the distribution system.

PAC requires special handling and storage. Because PAC produces large amounts of fine powder, it is highly combustible and explosive.

Contact time and concentration determine the effectiveness of PAC. The most important of these, however, is contact time. Because PAC reacts with chlorine, it loses its effectiveness if fed after the introduction of chlorine. For both these reasons, the PAC feed for surface water systems is frequently found at the intake structure. Injection of the PAC before water travels from the intake structure to the treatment plant provides additional contact time before any chlorine or other treatment chemicals are added. For best results in reducing taste and odor, cyanotoxins, and DBP precursors, operators often feed PAC into the raw water at the front end of the plant prior to the introduction of chlorine (Cl_2), with a lesser dosage fed just prior to filtration.

7.5.4.1.2 Granular Activated Carbon

GAC is primarily used to remove organic compounds that may be associated with taste and odor, cyanotoxins, and DBP formation. Water systems may also use GAC to remove DBPs after they have formed and to remove VOCs and synthetic organic contaminants. GAC does not require post-treatment filtration.

GAC is usually delivered to the site in 60-pound bags or in bulk. Common uses are as a filter medium or as media in contactor columns or vessels. The placement of GAC in a typical filter can also enhance turbidity removal. A common filtration rate for a GAC filter is 2 gallons per minute (gpm)/ft^2. Life expectancy of GAC filters ranges from up to 3 years for taste and odor removal to as little as 1 month for DBP removal. Due to GAC's lower specific gravity, operators must change backwashing procedures when using GAC in their filter beds.

GAC contactors are composed of enclosed beds of GAC. Parallel operation allows operators to replace media in one bed while the other remains on-line. Alternatively, columns may operate in series so that the contaminant is entirely contained within the downstream column after the lead column becomes saturated. After replacing the activated carbon in the saturated (upstream) column, the operators reverse the flow so it goes through the freshest column last. This arrangement helps maximize the usefulness and longevity of the activated carbon. Water systems often use these contactors when the life expectancy of the GAC is only a few months. It is easier to change the GAC in a contactor than in a filter bed. PWSs usually install contactors after filtration and size them based on empty bed-contact time and regeneration frequency.

7.5.4.2 Sanitary Deficiency Questions and Considerations – Organics Removal

Note: The sanitary deficiencies related to chemical feed systems in the previous chapter also apply to this section.

- **What contaminant is the treatment used for?**

  There should be some documentation of the need, such as an engineering study or a management decision. The reasons could include taste and odor, cyanotoxins, DBP precursors, or the removal of other organic contaminants. In any case, there should be defined reasons (goals and treatment objectives) for the use of activated carbon.

- **Which removal process does the water system use?**

  Is the PAC or GAC process used? It is important to remember that PAC is most effective when the concentrations of the contaminants vary. Many water systems use PAC seasonally.

- **What testing does the operator conduct to determine the effectiveness of the removal process?**

  The testing should be directly associated with the defined need for activated carbon. If the presence of an odor compound such as geosmin is the reason for using activated carbon, the operator should conduct tests to determine its effectiveness. Some water systems use GAC as a media layer in a filter to solve a specific problem but fail to monitor and maintain it so it serves its original purpose. Without proper maintenance and testing, the GAC media can become ineffective without the operator knowing it.

- **How are the treatment processes monitored and maintained?**

  The testing should be directly associated with the defined need for the treatment (e.g., GAC, PAC). If the presence of an odor compound such as geosmin is the reason for using activated carbon, the operator should conduct tests to determine its effectiveness. Without proper maintenance and testing, the activated carbon media can become ineffective without the operator knowing it.

- **How often is GAC or ion exchange resin replaced?**

  Life expectancy of GAC filters ranges from as little as 1 month for DBP removal up to 3 years for taste and odor removal. The surveyor should ask the operator when they last replaced their GAC and how they monitor its effectiveness.

If the water system feeds PAC:

- **Have they had any problems with black water?**

  PAC passes through some filter media, especially pressure filters.

- **How often are the feeders calibrated?**

  The operator should calibrate chemical feeders feeding PAC with each new batch of PAC and conduct daily feed rate checks by measuring the output.

- **Does the operator have proper safety equipment?**

  They should have dust masks, sealed safety glasses, and shower facilities.

- **Is the PAC stored properly?**

  PAC is an explosive dust. Storage should include an explosion-proof electrical system and adequate ventilation.

When water systems add GAC to a filter:

- **Is the backwash adequate?**

  Check for the presence of mud balls, filter surface cracking, or compaction.

- **What is the depth of the GAC?**

  Since it is lighter than most other media, the backwash process can easily wash away GAC. The surveyor should also check to see that the operator replaces carbon on a schedule that ensures proper treatment.

- **Is the PWS using GAC contactors?**

  Ask the operator what the empty-bed contact time is, as well as the regeneration or replacement frequency.

7.5.5 Aeration

Water systems may use aeration to:

- Reduce VOCs, radon gas, and taste and odor-producing compounds such as hydrogen sulfide.
- Oxidize organic and inorganic chemicals such as iron, manganese, and organic matter.

It is primarily used at ground water systems. Aeration forces contact between water and air, often for transferring volatile contaminants from the water into the air.

7.5.5.1 Packed Tower Aeration

There are many types of aeration devices. Packed towers in particular are becoming widely used to reduce VOCs. The objective is to contact a small volume of organic-contaminated water with a large volume of contaminant-free air. Packing material, typically a plastic media about the size of a ping-pong ball, fills the tower.

- Water and airflow: Water flows into the top of the tower and falls over the balls while nozzles at the bottom of the tower force pressurized air up through the cascading water – commonly referred to as countercurrent tower aeration. The packing material creates very fine droplets of water in the downward flow. This aids in diffusing dissolved gases into the upward flow of air.
- Air-to-water ratio: The air-to-water ratio typically ranges from 20-to-1 to 50-to-1 (air-to-water, volume-to-volume).
- Problems: There are two major problems associated with this process: contamination of the water from contaminated air and violation of air quality standards from the tower. (The output from the tower may contain a high VOC level.)

7.5.5.2 Sanitary Deficiency Questions and Considerations – Aeration

- **What type of aeration system is used?**

  Different types of units (cascade, tray, mechanical, packed tower, spray) are used, depending on the purpose of treatment. The operator should be able to explain the reason for the type of system in place.

- **What contaminants is the treatment used for?**

  Aeration treatment can be used to reduce or remove VOCs, radon gas, taste and odor-producing compounds such as hydrogen sulfide, iron, manganese, and organic matter. The surveyor should ensure the operator understands the role of aeration in the PWS's treatment process, how it is monitored for effectiveness, and how operational decisions are made.

- **What process-control parameters does the operator monitor to evaluate performance?**

  The operator should routinely evaluate the efficiency of the tower. Failure to do so is an indication that the tower may not be performing as designed. The surveyor should determine if the frequency at which the operator evaluates tower efficiency meets local and state requirements for the facility.

  Parameters typically monitored include pH, moisture, VOCs, odor, and color. If used to reduce odor and taste, the tower may release methane gas. If this is the case, there should be a systematic monitoring program to determine the level of methane in the area.

- **Are there contaminants nearby that the blower could draw into the air supply?**

  If the air intake is next to the chlorine room, lime storage area, or in a dusty environment, the water supply may become contaminated. There should be a filter on the blower through which the air is drawn, and the operator should be able to explain the maintenance of the filter including any cleaning or replacement requirements.

- **What types of operational problems has the facility experienced that could contribute to poor performance of the aeration device?**

  Typical problems include plugged nozzles on the air system, algae and other biological growth on the media, failure of the air blower, dirty air filter that restricts flow, and breaking up of the floc, which causes high floc carry-over onto the filters.

- **After aeration, does the PWS adequately disinfect the effluent before it enters the water distribution system?**

  Contamination by wind-borne pollutants and biological growth in the packing material requires diligent post-treatment disinfection.

- **What is the condition, both inside and outside, of the aerator?**

  If the aerator is not accessible for close examination, the surveyor should review the maintenance records to determine the status of the equipment.

7.5.6 Water Softening

7.5.6.1 Purpose

The primary purpose of water softening is to reduce the content of dissolved minerals, particularly calcium and magnesium, in order to minimize scale formation.

Softening hard water may provide additional benefits, such as:

- Biological growth control.
- Enhancement of use for boiler feed and cooling processes.
- Removal of many trace inorganics.
- Organics (e.g., DBP precursor) removal.

The terminology and degrees of hardness vary among water treatment and supply professionals when categorizing the concentrations of hardness in water. Table 7-1 on the next page shows two common severity scales used to categorize hardness.[3]

Table 7-1: Water Hardness Values

Description	Sanitary Engineers (mg/L of $CaCO_3$)	Water Conditioning Industry (mg/L of $CaCO_3$)
Soft	0 – 75	0 – 50
Moderate	75 – 150	51 – 100
Hard	150 – 300	101 – 150
Very Hard	Above 300	Over 150

Softening water may also have the following negative results:

- The plant effluent pH of a lime soda softening facility is usually about 8.9. At pH 7.5, only one-half of the chlorine residual is hypochlorous acid (HOCl). At pH 8.9, it is down to approximately 10 percent. This means disinfection capabilities diminish as pH increases.
- The water may become aggressive, thus corroding metal pipes.

[3] Source: New Hampshire Department of Environmental Services fact sheet (WD-DWGB-3-6)

- Disposal of the sludge is a problem.
- THM levels may increase due to elevation of the pH.

Table 7-2: Definitions Pertaining to Water Softening

Term	Definition
Hardness	A characteristic of water caused by divalent metallic cations, mainly calcium and magnesium, but also strontium, ferrous iron, and manganous ions. These cations are typically associated with anions such as bicarbonate, carbonate, sulfate, chloride, and nitrate.
Calcium Hardness	Hardness caused by calcium ions (Ca^{2+}).
Magnesium Hardness	Hardness caused by magnesium ions (Mg^{2+}).
Total Hardness	The sum of the hardness caused by calcium and magnesium.
Carbonate Hardness	Hardness caused by the divalent metallic cations and the alkalinity present in the water, up to the level of the total hardness.
Non-Carbonate Hardness	That portion of the hardness in excess of an amount equal to the alkalinity.
Alkalinity	The buffering capacity of water to retard the change of pH; the result of carbonate, bicarbonate, hydroxide, and occasional bicarbonate, silicate, and phosphate; commonly expressed as an equivalent concentration of calcium carbonate ($CaCO_3$).
Calcium Carbonate ($CaCO_3$) Equivalent	An expression of the concentration of specified constituents in water in terms of their equivalent value of $CaCO_3$.

7.5.6.2 Softening Processes

There are two common softening techniques: lime soda and ion exchange. A number of factors associated with operating costs, operating effectiveness, and construction costs determine the basis for process selection.

7.5.6.2.1 Lime Soda Softening

There are three common lime soda softening processes: conventional, excess lime, and split treatment.

7.5.6.2.1.1 Conventional Removal of Carbonate Hardness

Water systems can use a lime soda process to remove carbonate hardness by precipitation. When magnesium hardness is high, operators can feed excess lime to raise the pH and cause the precipitation of magnesium hydroxide. After precipitation, addition of carbon dioxide to the flow in a process called re-carbonation reduces the pH and stabilizes the water. The amount of lime required depends on the concentration of the hardness and the type of hardness (calcium or magnesium). Water systems use the conventional lime soda process when there is only a small amount of magnesium hardness and feed excess lime to reduce higher levels of magnesium hardness.

7.5.6.2.1.2 Removing Noncarbonate Hardness

In this process, soda ash addition follows excess lime softening. This second step is effective in removing noncarbonate hardness, but additional treatment units and associated capital costs often dissuade a water system from using it.

7.5.6.2.1.3 Split Treatment Process

The split treatment process is an adaption of the excess lime process. A portion of the water is treated and added back into the untreated water to dilute it to the desired level of hardness. This process reduces the amount of chemical required to soften the water and thus reduces operating costs.

7.5.6.2.2 Ion Exchange Softening

When needed, small ground water systems and individual homes primarily use ion exchange softeners. The unit is composed of a pressurized vessel resembling a pressure filter and primarily filled with a resin creating a filter bed. An excess of sodium ions desorb from the resin in exchange for the calcium and magnesium ions in the plant flow. Once the plant flow depletes the resin of sodium ions, the treatment process reverses where a brine solution regenerates the resin by removing excess calcium and magnesium and leaves excess calcium adsorbed onto the resin. The hardness of the effluent of this type of facility is zero or near zero. Common ion exchange resins include synthetic zeolites and organic polymers (polystyrene resins).

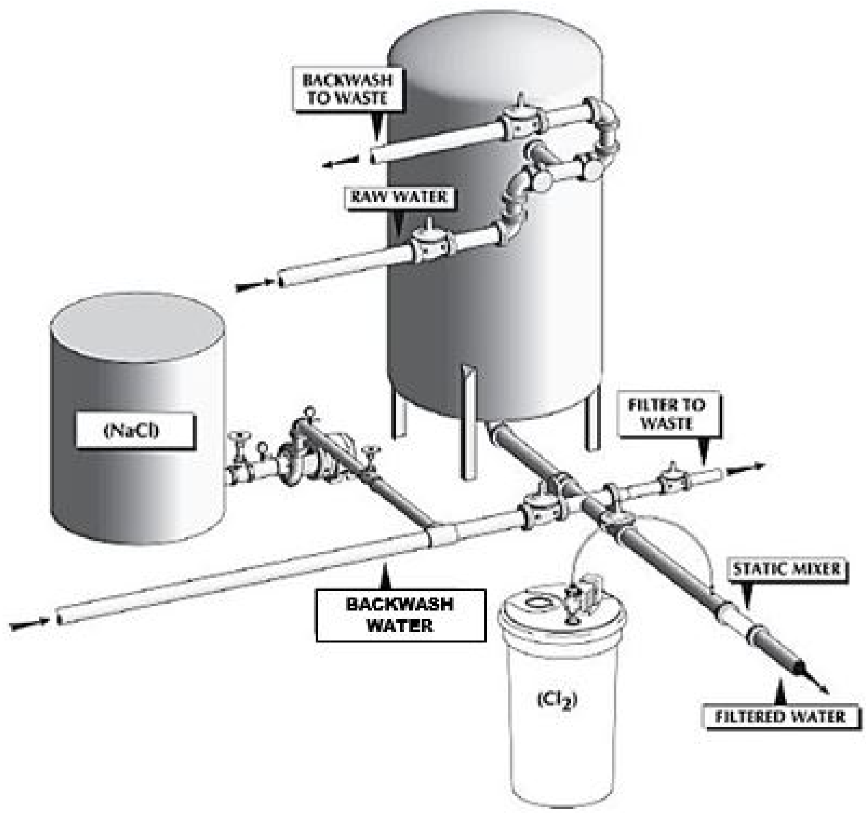

Figure 7-7: Ion exchange

Any water treated by an ion exchange process must be relatively free of particulate matter in order to prevent plugging the medium and subsequent operational problems. Iron, manganese or other heavy metals, if present at high levels, may cause problems with ion exchange resins by binding permanently to the medium, thereby reducing the exchange capacity over time. One problem in the operation of an ion exchange system is the disposal of spent brine from the regeneration of the medium. Severe limits may be in place relating to the proper discharge of this high salinity water.

7.5.6.3 Sanitary Deficiency Questions and Considerations – Water Softening

Note: The sanitary deficiencies related to chemical feed systems in the previous chapter also apply to this section.

Lime Soda Process:

- **What are the treatment goals?**

  The operator should have finished water quality targets for parameters such as pH, alkalinity, and hardness. It is important that these targets are clear to all operators in order to obtain optimum plant performance.

- **Is the facility performing adequate process control testing?**

  Testing at each stage of the process should include at least the following process control tests:

  - Alkalinity.
  - Hardness.
  - pH - Carbon Dioxide.

- **Is the facility tracking the chemicals used?**

  The operator should monitor this process carefully as it involves the use of a number of chemicals that may conflict with other treatment functions. For example, too high a finished pH could cause disinfection or DBP problems.

- **Is the facility meeting the Total Organic Carbon (TOC) removal requirements (if applicable) of the Stage 1 DBPR?**

  Surface water systems that employ lime softening must meet Stage 1 DBPR TOC removal requirements. The surveyor should check the PWS's operating records and state reports to make sure the water system is in compliance.

Ion Exchange:

- **What are the treatment goals?**

  This treatment process can reduce water hardness to a very low level. This may result in aggressive water quality that could contribute to lead and copper problems in the distribution system. The operator should understand the implications of their treatment goals in light of other possible problems.

- **What is the condition of the equipment?**

  The operator should understand the importance of monitoring the condition of the media. Without careful monitoring, media fouling can result, and process efficiency reduction can result. Also, the overall condition of the filter units and valves is important to proper operation.

- **What is the operator's knowledge of the softening process?**

  Softening chemistry is typically more complicated than other treatment processes, and, therefore, the operator may have little understanding of the processes. Operators need to understand the softening process in order to handle problems when they arise. Chemistry training is available, and management is responsible for providing this training to operators.

Water systems can use the treatment processes discussed above for a variety of contaminants. NPDWRs have established best available technologies for all of the contaminants regulated under part 40 CFR 141. These regulations define the term Best Available Technology (BAT) as the technology, TT, or other means identified by the EPA for use in complying with a NPDWR. Appendix C lists the best available technologies for different contaminants and Appendix A lists more information on publications on regulated contaminants and their best technologies for treatment.

In addition, NPDWRs has identified technologies that are feasible to small communities. EPA has also established the Small System Compliance Technology lists and has published the three corresponding guidance documents listed below. These lists present options for small systems regarding NPDWRs set prior to the 1996 SDWA amendments.

Guidance Documents:

- Small System Compliance Technology List for the Surface Water Treatment Rule and Total Coliform Rule (EPA 815-R-98-001).
- Small System Compliance Technology List for the Non-Microbial Contaminants Regulated Before 1996 (EPA 815-R-98-002).
- Variance Technology Findings for Contaminants Regulated Before 1996 (EPA 815-R-98-003).

As directed by SDWA, EPA provides small system technology assessments for both existing and future regulations. These tables are in *Small Drinking Water Systems: State of the Industry and Treatment Technologies to Meet the Safe Drinking Water Act Requirements* (EPA 600-R-07-110 (September 2007)).

7.6 Possible Significant Deficiencies for Chemical Contaminant Removal

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The primacy agency determines both significant deficiencies, and the corresponding corrective actions.

- Improper storage and handling of PAC (combustion/explosion hazard).
- Proximity of compressors to PSOCs for aeration processes.
- No or inoperable low flow/low pressure switches on acid, chemical, corrosion control, or scale inhibitor feed lines.
- Missing or improper backflow prevention for chemical feed lines.
- No process control monitoring.
- No regular testing to determine removal performance.

8 Disinfection

The water treatment plant is the primary barrier against unsafe water, and any malfunction in the treatment process could result in water quality problems. Of major importance is the consistent and continual feed of disinfection chemicals to assure proper inactivation of bacteria, viruses, *G. lamblia* and perhaps *Cryptosporidium*. The surveyor should evaluate the operation, maintenance, and design of the disinfection process, including the feed systems, to identify any sanitary deficiencies.

8.1 Learning Objectives

By the end of this chapter, students should be able to:

- Identify key data items required to evaluate sanitary survey risks associated with the disinfection process at water treatment plants, such as whether liquid or gas is being used.
- Review the disinfection feed system and determine if it is adequately sized and in good operating condition.
- Recognize disinfection treatment process sanitary deficiencies as they relate to the physical facilities and O&M. Issues may include inadequate disinfection, inadequate application of water treatment concepts to process control, lack of understanding the purpose of disinfection, inadequate understanding of disinfection process, poor maintenance procedures, staffing and funding deficiencies, and cross-connections.
- Identify safety issues that affect the operations staff, and could affect the facility's ability to perform effectively. Safety issues may include chemical handling, chemical storage, inadequate safety precautions for gas chlorination, and confined spaces.
- Review regulatory issues that are appropriate to each specific process to determine their relationship to sanitary deficiencies.

8.2 Data Collection

The surveyor should obtain as much of the following information about the water system as possible before the sanitary survey; otherwise, the water system should provide missing or updated information during the survey.

8.2.1 Disinfectant Usage in Treatment Processes

The surveyor should evaluate the following to assess the appropriateness of the PWS's disinfection practices:

- The types of disinfection systems in operation (i.e., liquid, gas, ultraviolet light (UV)).
- The specific chemicals used and purpose of addition.
- If gas chlorination is under vacuum or pressure.

- The quantities of disinfectant added.
- The application points.

8.2.2 Process Control Data

The surveyor should verify the following to assess the quality of process control data:

- Type and frequency of testing throughout treatment process.
- Availability and operability of on-line monitoring equipment.
- Adequacy and consistency of data recording procedures.

8.2.3 Physical Facilities Information

The surveyor should evaluate the following regarding the PWS's physical facilities:

- Buildings and rooms where disinfection feed systems are located with respect to accessibility, safety, and overall maintenance.
- Operation, maintenance and design of disinfection feed systems such as adequately sized chemical feed pumps, proper ventilation, appropriate feed points, and adequate disinfectant storage.

8.3 Regulations and Standards to Consider

The surveyor should consider and review the following information prior to the survey:

- Specific regulations that apply to the facility (see Chapter 2 of this Guide).
- Past survey reports to identify previous compliance problems.
- ANSI/NSF Standards 60 and 61.
- Ten States Standards.
- Monthly operating reports submitted to the state.

8.4 Purpose of Disinfection

Disinfection is the process of killing or inactivating a large portion of the microorganisms in water, with the probability that the process will inactivate all pathogenic bacteria and viruses. Inadequate disinfection directly relates to many water system compliance failures. In addition, chlorine, the most widely used disinfectant, must be stored and handled properly for the protection of operators and the public. The surveyor should determine if the disinfection system is adequate and reliable.

Primary disinfection refers to disinfection that is achieved before anyone consumes the water. Depending on the water source, quality, and the primacy agency's regulations, PWSs have different disinfection inactivation requirements. For most disinfectants, these are referred to as "CT requirements." Disinfection CT is addressed in more detail later in this section. Primary disinfection requirements must be achieved at or before the first consumer.

Secondary disinfection refers to disinfection that is achieved in the distribution system. Under the SWTR (40 CFR Part 141, Subpart H), surface water and GWUDI water systems are required to maintain a detectable residual throughout their distribution systems. There are no federal secondary disinfection requirements for ground water systems; however, many primacy agencies do have such requirements.

8.5 Understanding Disinfection

Chlorination is the most common disinfection method used by water systems in the United States. However, PWSs also use other disinfection systems such as:

- Ozone.
- UV.
- Chlorine dioxide.
- Chloramination.

For surface water systems, ozone and UV usually require the addition of chlorine or chloramines to meet the residual requirements of the SWTR, 40 CFR 141.73.

8.5.1 Dosages and Residuals

8.5.1.1 Review of Terms

The standard term for the concentration of chlorine in water is mg/L. The concentration of chlorine gas in the atmosphere is measured in parts per million (ppm).

8.5.1.2 Dosage

The total amount of chlorine fed into a volume of water by the chlorinator is the dosage. This value should be calculated daily. Operators may record chlorine usage as pounds or gpd. While the number of pounds or gallons used per day is important, the feed rate is of greater importance. As flows vary, the amount of disinfectant that is fed into the water must be adjusted to prevent over- or under-dosing.

Changes in disinfection practices may affect the production of DBPs, such as trihalomethanes and haloacetic acids, and have a significant impact on the disinfection benchmark. Therefore, the surveyor should **not** suggest changes to treatment practices without fully understanding the PWS's specific situation.

8.5.1.3 Chlorine Demand

Chlorine is a very active chemical oxidizing agent. When injected into water, it combines readily with certain inorganic substances that are oxidizable (e.g., hydrogen sulfide, nitrate, and ferrous iron), and organic impurities including microorganisms, and organic nitrogen compounds such as protein and amino acids. The definition of "chlorine demand" is the amount of chlorine consumed by these reactions. Temperature, pH and other factors can extend the reaction time between chlorine and most organic compounds to hours or days. That is, the measurable demand at the end of 20 minutes could be less than the measurable demand at the end of one hour of contact time.

8.5.1.4 Chlorine Residual

Chlorine residual, measured in mg/L, is the amount of chlorine present in the water after the chlorine dose has reacted with organics and other substances present in the water.

Chlorine Residual (mg/L) = Chlorine Dose (mg/ L) - Chlorine demand (mg/L)

8.5.1.5 Contact Time

The contact time is the interval in minutes (T) that elapses between the dosage point into the water and a downstream sampling point. Completion of the disinfection process requires a certain minimum period of time, depending on the disinfectant and its residual concentration (C), water temperature, pH, and flow rate.

In general, the contact time for ground water systems should be adequate to ensure inactivation of 4-log viruses under peak flow conditions and must be sufficient to achieve 4-log virus inactivation if the PWS is required to meet the virus treatment requirements of the GWR. The contact time for surface water systems must be adequate to ensure compliance with the requirements of the SWTR. More contact time may be desirable under unfavorable water quality conditions, such as when the raw water is known to have high levels of microbial contamination.

To determine if disinfection is adequate to inactivate viruses and *G. lamblia* cysts, the SWTR requires unfiltered PWSs to determine contact time (CT) values and show they ensure inactivation of 4-log viruses and 3-log *G. lamblia* under peak flow conditions. Under the LT2ESWTR, unfiltered PWSs using chlorine dioxide or ozone must determine CT values daily, to show they are meeting their required *Cryptosporidium* inactivation.

Filtered surface water or GWUDI water systems must show that the combination of filtration and disinfection provides the required 2, 3 and 4-log treatment for *Cryptosporidium*, *G. lamblia* and viruses, respectively. Under LT2ESWTR, filtered water systems may be required to provide additional *Cryptosporidium* removal and/or inactivation. The SWTR and LT2ESWTR and their respective guidance manuals provide additional information on the requirements and methods for calculating disinfection CT.

8.5.2 Chlorine Chemistry

Regardless of the form of chlorination that is used – chlorine gas or hypochlorite – the chemical reaction in water is similar. Chlorine mixed with water generally produces two compounds, HOCl (hypochlorous acid) and OCl^- (hypochlorite ion). The free chlorine residual is the measurement of both compounds. If organic or inorganic compounds, especially nitrogen compounds, are available in the water, the HOCl combines with them to produce chloramines or chloro-organic compounds. The combined chlorine residual measures these particular compounds in the water.

8.5.2.1 Germicidal Effectiveness

The consensus among water professionals is that a free chlorine residual of HOCl and OCl^- is more effective as a primary disinfectant than a combined chlorine residual. Therefore, it is common for water systems using chloramines as their secondary disinfectant to wait until primary disinfection requirements have been met by using chlorine before adding ammonia to create the chloramines.

8.5.2.2 Breakpoint Chlorination

To produce a free chlorine residual, operators must add enough chlorine to destroy the nitrogen compounds through a process called breakpoint chlorination. While this process destroys most of the nitrogen compounds, it does not destroy all of them. Those that remain combine with the chlorine, which produces the "irreducible combined residual."

Free chlorine residual + Combined chlorine residual = Total chlorine residual

For many PWSs, this results in a residual in the distribution system that includes free and combined residuals. The "total chlorine" residual is the measurement of both of these residuals. The combined residual can be a primary contributor to taste and odor problems in a PWS.

8.5.2.3 Taste and Odor Considerations

As can be seen in Figure 8-1, chlorine-related taste and odor complaints result primarily from combined residuals that form after the PWS has added enough chlorine to produce dichloramines and nitrogen trichloride. If the PWS operates with a free chlorine residual but receives chlorine-related taste and odor complaints, the surveyor should suggest that the operator measure both free and total residuals. As a general rule of thumb, if the free chlorine residual is less than 85 percent of the total residual, the odor and taste problem may result from the combined residuals, which may be resolved in two ways:

- Remove the precursors that cause the combined residuals.
- Increase the chlorine dosage. There may be an insufficient quantity of chlorine to destroy the organic compounds sufficiently to avoid the problem.

When a PWS uses chloramines as disinfectant, the operator should pay close attention to the chlorine-ammonia feed ratio to ensure the residual being produced is monochloramine.

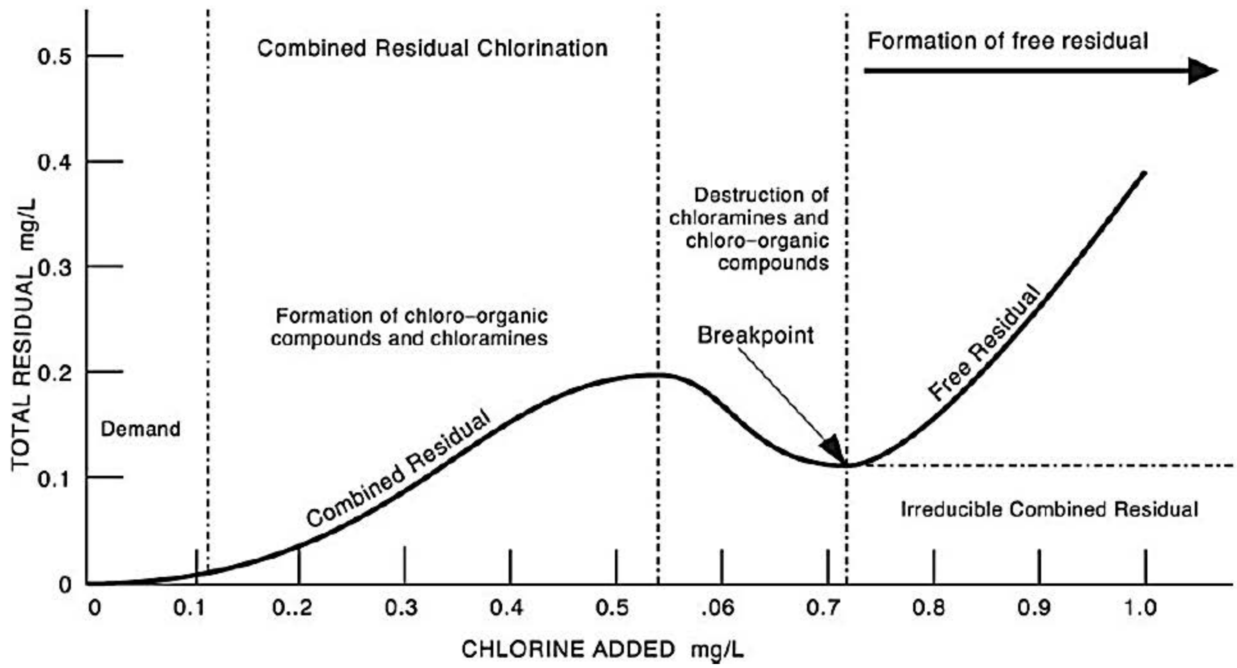

Figure 8-1: Reactions of chlorine in water

8.5.3 Stage 1 and Stage 2 Disinfectants and Disinfection Byproducts Rules

Considerations for the surveyor should include the concentrations of DBPs and MRDLs at the water system. In addition to and HAAs, treatment plants using ozone or chlorine dioxide can produce other regulated DBPs – bromate and chlorite, respectively. The surveyor should review the water system's DBPRs compliance information (MRDLs, DBP MCLs, and TT requirements related to DBP precursor removal (i.e., enhanced coagulation and enhanced softening)).

8.5.4 Sanitary Deficiency Questions and Considerations – Disinfection Methods

- **Can the operator answer basic questions about the specifics of their disinfection process? Do they know when and where disinfection occurs and why they are dosing at particular sites?**

  An operator's lack of knowledge of the process and equipment indicates that equipment failure or process effectiveness may not be resolved in a timely manner. Management is responsible for ensuring operators are well trained in the use and maintenance of disinfection equipment.

- **Have there been any interruptions in disinfection? If so, why?**

  If the PWS provides disinfection because a surface water source is being used or the water system has had a bacteriological problem, then interruption of service is a significant consideration. Interruptions in disinfection often occur when a chemical feed pump fails or during gas chlorine cylinder changeovers when operators connect only one cylinder at a time.

- **Does the operator measure and record the temperature and pH of the water at the point of chlorine application?**

  The CT value required for proper inactivation of *G. lamblia* and viruses depends on the pH and temperature of the water. An operator should take these two measurements regularly and use them to determine the water system's CT at peak hourly flow. The operator should measure pH with a meter, not with litmus paper or a color comparator, and temperature with a calibrated thermometer. CT values for the inactivation of *Cryptosporidium* with chlorine dioxide or ozone depend on water temperature and are not dependent on pH.

- **Are spare chemical feed pumps and repair kits available?**

  The water system should have a spare chemical feed pump on hand in case the in-service chemical feed pump fails. Water systems that use surface water supplies or disinfect because of a bacteriological problem must provide continuous disinfection. For these water systems, an interruption in the disinfection process presents a public health risk. Therefore, any failure of a chemical feed pump should be corrected as soon as possible.

- **Is the contact time between the point of disinfection and the first customer adequate to meet the required inactivation?**

  The SWTRs and in some cases the GWR require sufficient disinfectant residual and contact time prior to or at the first customer to achieve the disinfection CT needed to inactivate viruses and *G. lamblia*. The surveyor should ask questions about disinfectant residuals, contact time, how peak flow is measured, and the first customer's location. Often the operators and other employees at the treatment plant are the first customers; care should be taken during the survey to ensure they are being provided water that has been fully treated.

- **Was the PWS required to prepare a disinfection profile? Is the profile available for review?**

  The surveyor should review the PWS's disinfection profile and check to ensure that adequate CT is available to meet the SWTR removal/inactivation requirements. The surveyor should inquire about any planned or potential changes in disinfection practices. The water system may need to complete disinfection profiling and benchmarking before changing its disinfection practice.

- **How is disinfectant residual measured and recorded?**

  The SWTR requires water systems measure residuals at the same time and place as coliform samples are collected. Many states require daily monitoring of disinfectant residuals in the distribution system. The surveyor should determine what instrument the operator uses for measuring disinfectant residuals. The surveyor should also review the operator's standard operating practice for performing field measurements and recording field data.

- **Is test equipment maintained and are reagents replaced?**

  The surveyor should review the operators' standard operating practice for calibrating field instruments and recording calibration data. Reagents should be replaced before they expire.

- **Is a proper residual entering the distribution system at all times?**

  The SWTR requires that a disinfectant residual of at least 0.2 mg/L be present at the entry point to the distribution system for surface water systems. This residual must occur after sufficient disinfection CT has been achieved to meet SWTR inactivation requirements. Some primacy agencies may require a higher residual at the entry point to the distribution system. The surveyor should verify where the entry point is to the distribution system and that an operator measures the chlorine residual at this point at least daily.

- **What disinfectant residual does the PWS maintain?**

  The SWTR includes requirements for a detectable disinfectant residual to be present at coliform sampling points in the distribution system, but some primacy agencies may require a higher value and may require a free chlorine residual. The surveyor should verify that testing sites are representative of the distribution system and thus provide sufficient information to ensure the PWS meets the disinfectant residual requirements but does not exceed the MRDLs of the DBPRs. During the sanitary survey, the surveyor may wish to measure residuals at points of high residence time to confirm that a detectable residual is present throughout the distribution system.

  In addition to verifying that there is a proper residual, the surveyor should determine whether the equipment and testing methods being used by the water system are adequate. See the Distribution and Process Control chapters (11 and 13, respectively) for more details on testing.

8.6 Common Types of Disinfection

8.6.1 Hypochlorination System Facilities

8.6.1.1 Introduction

Modern hypochlorination systems are very reliable and effective. With the implementation of new regulations regarding chlorine, many small and medium-size facilities have switched to this safe, easy method of disinfecting water. The primary disadvantage of hypochlorination systems is their higher annual operating costs compared to gas systems. However, as a result of new safety and environmental regulations, the cost of using chlorine gas has continued to rise, making hypochlorination systems more desirable. Water systems should list hypochlorites in their hazardous materials inventories, and they should have written procedures for handling and using hypochlorites, including procedures for responding to spills.

8.6.1.2 Sodium Hypochlorite Considerations

Of all the chlorine disinfection products, liquid sodium hypochlorite presents the least handling hazard to the operator. Sodium hypochlorite is available in concentrations from 5 to 15 percent. PPE for handling sodium hypochlorite includes chemical goggles and gloves.

8.6.1.3 Calcium Hypochlorite Considerations

Calcium hypochlorite is a powder containing chlorine in concentrations up to 67 percent. Operators mix enough of the powder in a solution tank using finished make-up water to create a 1 percent to 3 percent solution, which feeds into the water flow. Calcium hypochlorite can be difficult to dissolve in hard water (above 125 mg/L total hardness). It is also available in tablet form with flow-through contactors for residual formation.

PPE needed for handling includes a cartridge respirator for chlorine with a dust filter, chemical goggles, and gloves.

8.6.1.4 Sanitary Deficiency Questions and Considerations – Hypochlorination Systems Facilities

Note: The sanitary deficiencies related to Disinfection Dosages and Residuals earlier in this chapter also apply to this section.

- **What kind of hypochlorite is used (e.g., calcium, sodium, or others)?**

  Sodium hypochlorite is vulnerable to a loss of available chlorine over time. The deterioration of sodium hypochlorite solutions is more rapid with increasing concentrations and increasing temperatures. Thus, the surveyor should ask how much chemical is on hand and how old it is. Table 8-2 shows the half-life (in days) deterioration of sodium hypochlorite. Water systems can use this information to determine the concentration of solution that best fits their needs.

Table 8-1: Half Life Deterioration in Days of Sodium Hypochlorite

Percent	Temperature		
	140 °F	77 °F	59 °F
10.0	3.5	220	800
5.0	13.0	790	5,000
2.5	28.0	1,800	
0.5	100.0	6,000	

Source: Pennsylvania DEP, 2019

  Sodium hypochlorite is a corrosive liquid. It should not be stored with dry chemicals or other liquids with which it can react, such as petroleum products.

  Calcium hypochlorite has a long life, but feed equipment requires greater maintenance than when sodium hypochlorite is used. The calcium hypochlorite solution contains a great deal of abrasive material that deteriorates the chemical feed pump suction and discharge valves. Units that create hypochlorite solution by spraying water onto calcium hypochlorite tablets can get clogged sprayers if not maintained regularly.

  Calcium hypochlorite is a fairly reactive oxidizer that should not be stored with other chemicals with which it can react. Under no conditions should petroleum products be stored with calcium hypochlorite. The reaction between chlorine and petroleum products is quick and violent. See Appendix B for a discussion of incompatible chemicals.

- **Is there a cover on the solution tank to minimize corrosive vapors?**

  If the tank is not covered, chlorine gas escapes into the room and could deteriorate the equipment.

- **Is there adequate spill containment?**

  Water systems should use a double tank or a secondary containment area around all chemical storage tanks.

- **What safety procedure does the operator follow during chemical handling and mixing?**

  Observe operator and the space where chemicals are stored and used. If PPE is missing, damaged, located in inappropriate areas, or the space is not clean, the surveyor should ask the operator if they are actually following safety procedures.

8.6.2 Gas Chlorination Systems

8.6.2.1 Gas Systems

Various manufacturers produce an array of gas chlorination systems, but the surveyor need not be familiar with all of these systems. The systems used by water utilities fall into one of three general categories:

- Pressure systems.
- Remote vacuum systems.
- Cylinder-mounted systems.

The easiest way to tell a remote vacuum system from a pressure system is to look at the line from the cylinder to the chlorinator. If the line is metal, the system uses gas under pressure between the cylinder and the chlorinator. If the line is plastic, a remote vacuum system is in use and the gas is under a vacuum between the cylinder and the chlorinator.

8.6.2.2 Facility

Figure 8-2 shows the key points of a small gas-chlorine facility. In general, these include:

- Containment of the chlorine, should there be a release or leak.
- Air treatment system.
- Gas leak alarm system.
- Crash bars on doors.
- Negative pressure in the room when the air treatment system is operating.
- Overhead sprinkler system.
- Containment of the air treatment system and sprinkler water.
- Emergency power for the air treatment system.
- Booster pump to provide pressure to the injector.
- Scales to weigh the cylinders.

8.6.2.3 Gas Containers

Manufacturers provide gas chlorine in 100 and 150 pound cylinders, 1-ton containers, and tank cars. These values refer to the net weight of liquid chlorine in the container. Most small systems use 100 and 150 pound cylinders.

Note: Classification of gas chlorine has changed. As a result, different regulations apply to gas chlorine.

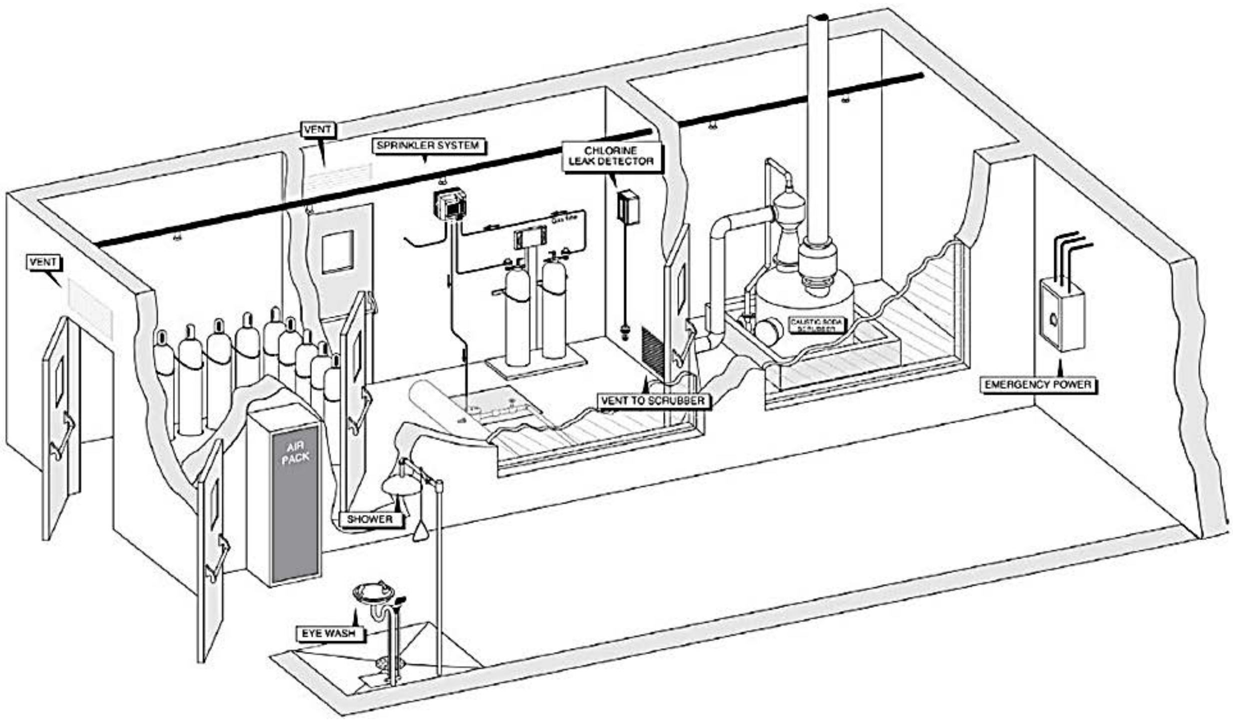

Figure 8-2: Chlorine gas treatment room

8.6.2.4 Safety Consideration for Operators

The surveyor should focus on the adequacy and reliability of the chlorination system to provide disinfection. However, the threat of injury or illness to the operator caused by the chlorination system means a review of the major safety considerations for gas chlorination systems is also advisable.

8.6.2.5 Sanitary Deficiency Questions and Considerations – Gas Chlorination Systems

Note: The sanitary deficiencies related to Disinfection Dosages and Residuals earlier in this chapter also apply to this section.

- **How does the operator detect leaks? Are automatic detectors or some manual form of detection used?**

  If the water system uses automatic detectors, at what detection concentration does the operator set the instruments? The operator should also test them at least monthly. For manual detection methods, some operators may have a squeeze bottle of diluted liquid soap to squirt around fittings, which detect leaks if bubbles form. Others may use a dilute ammonia solution. Figure 8-3 shows 26° Baume ammonia water (ammonium hydroxide) and strips from a cellulose acetate cleaning sponge in a squeeze bottle[4] that operators can use to create ammonia vapor to detect leaks. If chlorine gas is present, a dense white cloud or fume will develop.

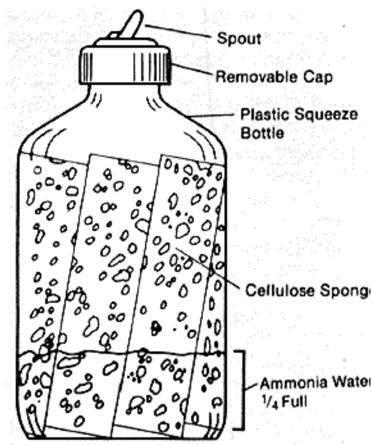

Figure 8-3: Ammonia squeeze bottle used to detect chlorine gas leaks (Norvelle 1986)

- **Is the sensor tube for the automatic detector near the floor level? Is there a screen on the end of tube?**

  Look at the leak detector. Some new detectors use solid-state sensors which the operator must replace each year. The sensor tube should be located no more than 12 inches from floor level.

- **Is the chlorination equipment properly contained?**

  The design of the room that houses the chlorination equipment should fully contain a chlorine release or leak.

  One common deficiency of these rooms are floor drains. The surveyor should ask the operator if he keeps the drain sealed when not used for floor cleaning especially if the drain connects to others in different areas of the facility.

  Many organizations have classified chlorine rooms as confined spaces. [Note: Do not enter if you are not sure that the air handling system is operating properly.]

[4] Source: Norvelle, 1986

- **Are there any cross-connections in the chlorine feed make-up water or injection points?**

  A common cross-connection problem in chlorination facilities is a drinking water connection to the injector and the make-up water for hypochlorination systems. There should be a physical separation or an acceptable backflow preventer between the drinking water system and the feed water to the injector.

- **Is there an alarm tied to interruptions in the chlorine feed?**

  Low system vacuum and low cylinder pressure are the two most common alarm systems. If there is an alarm system, does it work? Does the system shut down the flow of water, or just initiate an alarm?

- **Does the PWS use automation, flow pacing, chlorine residual analyzer, or another system to adjust feed rates? Does it work?**

  Finding automatic equipment that does not work is fairly common. Determine whether the system provides adequate residual during high flows and whether the residuals are higher during low flows. Failure of the system to dose according to varying flow rates is usually a significant sanitary deficiency.

- **Is there more than one cylinder, and are they equipped with a manifold and an automatic switch-over to avoid running out of chlorine?**

  The surveyor should determine whether the switch-over devices work. If there is only one cylinder, determine if the operator shuts off water flow when the cylinder is changed. Failure to shut off the flow of water interrupts disinfection.

- **Are the cylinders on a working scale?**

  The operator should use a scale to determine the amount of chlorine used each day. To calculate dosage and signal the amount of chlorine remaining in the cylinders, the operator should also routinely maintain and calibrate the scales.

- **Are the valves on the tanks only open a quarter turn and have a wrench in place for quick turnoff?**

  Cylinders can provide a full feed of 40 pounds per day by opening the valve one-quarter of a turn. Opening the valve more is not necessary. By opening it only one-quarter of a turn and leaving the wrench in place, the operator can quickly shut down the cylinder if there is a release.

- **Does the operator properly mark all cylinders and restrain them to prevent falling?**

  The operator should clearly mark and store cylinders in a manner that clearly indicates which cylinders are full and which are empty.

  All cylinders should each be restrained to an immovable object (e.g., a wall) with their own chain at a height of about two-thirds their height from the bottom to prevent falling. A single chain restraining multiple cylinders is not sufficient or safe. In an earthquake zone, also restrain cylinders with their own chains at or near the bottom.

- **Does the operator follow safe practices during cylinder changes and maintenance?**

  Has the PWS provided detailed training on handling and changing cylinders? Managers should document this training, and operators should practice safety training at least yearly.

  Check to see if there is a written SOP for changing cylinders. The operator may use ammonia to check if there is a proper seal when replacing or installing a chlorine gas tank. Determine if the operator uses the proper strength of ammonia for chlorine leak detection (see the first question of this section).

- **How many individuals are present when the chlorine cylinders are changed?**

  Industry standards call for two people, one to change the cylinder and one to watch. If this is not possible, switching to hypochlorination may be a safer option.

- **What type of respiratory protection is used?**

  When respiratory protection is required, the PWS should have a written respiratory protection program. This program usually includes a fit test of the device and training on its selection, use, and care.

- **Is there an emergency plan, and when was it last practiced?**

  The facility should have a written emergency evacuation plan and should practice implementing the plan at least annually.

- **What is the operating condition of the chlorinator?**

  The operator should disassemble, clean and rebuild all gas chlorination equipment every year. The rotameter can provide a clue as to the frequency of cleaning. If there is a heavy green or blackish film coating on the inside, the machine is past due for cleaning.

  General appearance can also be a key. Check preventative maintenance and repair records and determine if the operator routinely performs preventative maintenance. Some indicators of problems for gas chlorination are valves, piping, and fittings that are damaged, badly corroded, or loose; no gas flow to the chlorinator; and frost on tank, valves or piping.

- **Is redundant equipment available, and are there adequate spare parts?**

  Disinfection should be continuous. Therefore, the PWS's SOPs should have provisions for stand-by equipment of sufficient capacity to replace the largest unit. If stand-by equipment is not available, the operator should stop flow to the water system during any interruptions in disinfection and should have critical spare parts on hand for immediate replacement. At a minimum, the system should have spare diaphragms and a set of gaskets.

- **Are the appropriate lighting, guards, and railings in place? Are there other safety concerns, such as electrical hazards?**

  There should be no exposed wiring, and equipment should not be hard-wired into the electrical system unless designed to do so. The breaker box should be located outside the building and locked. These are safety concerns. The operator should have feed pumps properly mounted and secured to prevent moving or falling from the vibrations. As with all other water system facilities, the operator should keep the building adequately secured from public access.

8.6.3 Disinfection with Chloramines[5]

8.6.3.1 Introduction

The reaction of ammonia with aqueous chlorine forms chloramines. Initially, chloramines were used for taste and odor control. Concern over DBPs (e.g., TTHM and HAA5 formation) in water treatment and distribution systems has increased interest in chloramines because they form very few DBPs. However, because of chloramine's relatively weak disinfecting properties for inactivation of viruses and protozoa pathogens, it is rarely used as a primary disinfectant, and even then, only with long contact times.

Chloramines are a good choice for secondary disinfectant because of the following potential benefits:

- Chloramines are not as reactive with organics as free chlorine in forming DBPs.
- The monochloramine residual is more stable and longer lasting than free chlorine or chlorine dioxide, providing better protection against bacterial regrowth in distribution systems.
- Research has shown that a monochloramine residual is more effective in controlling biofilms, because of its superior ability to penetrate the biofilm. Controlling biofilms also tends to reduce coliform concentrations and biofilm induced corrosion.
- Because chloramines do not tend to react with organic compounds, many systems experience less taste and odor complaints when using chloramines.

8.6.3.2 Ammonia Feed Facilities

Water systems may locate ammonia feed facilities on-site at the water treatment plant or at remote locations in the distribution system. Most ammonia feed facilities use either gaseous (anhydrous ammonia) or liquid (aqueous) ammonia. Though anhydrous ammonia is a gas at ambient temperature and pressure, it is commonly stored and transported as a liquid in pressure vessels. In this phase, ammonia is highly soluble in water. Water systems should keep storage facilities and handling equipment dry and store anhydrous ammonia in portable cylinders or stationary tanks.

An ammoniator is a self-contained modular unit with a pressure reducing valve (PRV), gas flow meter, feed rate control valve, and miscellaneous piping for controlling the flow of ammonia into the water flow. Water systems can use an evaporator when they need large quantities of ammonia. Operators should have an anti-siphon valve or check valve installed to prevent water from entering the ammoniator.

Anhydrous ammonia is usually applied by direct feed or solution feed. Typical application points are at open channels and basin facilities. Since excessive temperatures cause ammonia gas to vaporize, each storage tank should be equipped with a water trap or ammonia scrubber to keep vapors from escaping to the atmosphere.

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[5] For more information on disinfection with chloramines, please refer to the publication, *EPA Guidance Manual on Alternative Disinfectants and Oxidants* (USEPA, 1999a).

Aqueous ammonia feed systems are similar to other liquid chemical feed systems. They require a storage tank, chemical metering pump, relief valve, pulsation dampener, flow meter, and back-pressure valve. Typically, the feed pumps are positive displacement or progressive cavity type metering pumps (eccentric screw pumps).

Operators should place feed pumps fairly close to the storage tank to minimize chances of ammonia vaporization in the piping. The pump design should compensate for changes in ambient temperatures, different aqueous ammonia solutions, and changes in the chlorine-to-ammonia ratio.

8.6.3.3 Nitrification

Nitrification is a biological process that occurs when microbes oxidize available ammonia to form nitrite and then nitrate. Nitrification can occur when a water system has excess ammonia present in the distribution system; since they add ammonia, chloraminating systems are especially at risk. The excess ammonia encourages the growth of nitrifying bacteria that convert ammonia to nitrates. An intermediate step in this conversion results in the formation of a small amount of nitrite. The nitrites rapidly reduce free chlorine, accelerate decomposition of chloramines, and can interfere with the measurement of free chlorine. Nitrification can have various adverse effects on water quality, including a loss of total chlorine and ammonia residuals, and an increase in heterotrophic plate count bacteria numbers.

8.6.3.3.1 Factors

Factors contributing to nitrification include low chlorine-to-ammonia ratio, long detention times, and elevated temperatures. Nitrifying bacteria are generally more resistant to disinfection by monochloramine than free chlorine. Nitrifying bacteria exhibit slow growth and the sediment of distribution systems may have higher numbers of the bacteria than in the biofilm.

8.6.3.3.2 Control Measures

Nitrification may pose a potential problem for any PWS using monochloramine as a disinfectant. Thus, water systems should carefully assess and control nitrification. For the distribution system, operators should identify and evaluate low-flow or dead-end sections and minimize the detention times (i.e., water age) throughout the system as well as managing turnover rates of floating storage tanks (those with single inlet-outlet configurations).

For systems that chloraminate, the surveyor should ask whether the system does any water quality monitoring to determine if nitrification is occurring. If the system does monitor, the surveyor should ask what water quality parameters are monitored, how frequently they are monitored, and where they are monitored in the distribution system. Water quality parameters used to evaluate nitrification include nitrate, nitrite, pH, temperature, free chlorine, monochloramine, total chlorine and free ammonia. In addition, the surveyor should ask if the system has established trigger levels for these water quality parameters and corrective actions (e.g., flushing) that would be conducted if a trigger level is exceeded. The pH, temperature, and free and total chlorine, monochloramine and free ammonia parameters are all measured using calibrated field instruments. Nitrite and nitrate are generally analyzed in the lab, so the sampler or operator would collect a water sample and deliver it to a certified laboratory according to the water system’s standard operating practice. However, test kits are available to analyze for low levels of nitrite in the field.

Operators should minimize the amount of free ammonia and maximize monochloramine production leaving the plant through process control monitoring. Measuring total chlorine and monochloramine is required where the desired result involves both measurements being close to the same value (e.g., no more than 0.1 mg/L difference as a goal). Systems also typically revert to straight chlorine disinfection annually to switch to free chlorine (i.e., a chlorine “burn”) which, along with flushing, helps reduce biofilm growth that may have developed while using chloramines.

8.6.3.4 Sanitary Deficiency Questions and Considerations – Chloramines

- **What are the treatment objectives for chloramination?**

  The primary use of monochloramine in water systems is as a secondary disinfectant for maintaining a residual in the distribution system. Because the germicidal effectiveness of monochloramine is less than that of free chlorine, monochloramine requires extremely long contact times in order to meet disinfection CT requirements.

- **What type of process control monitoring does the operator conduct?**

  The reaction time to form chloramine residuals varies for each water source since the reaction rate between chlorine and ammonia nitrogen depends on the temperature and pH of the water. It is important for the PWS to develop operational procedures including a comprehensive monitoring program that alerts the operator to implement nitrification control measures when required. The monitoring strategy should include monitoring of the following parameters:

  - Total chlorine residual.
  - Monochloramine residual.
  - Dichloramine residual.
  - Naturally occurring ammonia.
  - Free ammonia.
  - pH.
  - Temperature.
  - Total organic carbon.
  - Nitrate/nitrite.

- **What are the points of application for the chlorine and ammonia?**

  Depending on the treatment objective, adding ammonia and chlorine in either order forms monochloramine. The operator may add ammonia first where formation of objectionable taste and odor compounds caused by the reaction of chlorine and organic matter are a concern. However, most drinking water systems add chlorine first in the treatment plant to achieve primary disinfection (i.e., to achieve the required disinfection concentration and CT, to meet primacy agency requirements).

  Imbalances in chlorine and ammonia concentrations can cause breakpoint chlorination reactions to occur when encountered in distribution systems. Monochloramine addition upstream of filters reduces biological growth on filters. This has a favorable impact on the filters by keeping them clean and reducing the backwash frequency. It also has the undesirable impact of reducing biodegradable dissolved organic carbon removal in the filters, when operators run the filters in a biological mode.

- **Where is chloramine residual being monitored?**

  Water systems using chloramine for secondary disinfection typically monitor total and free chlorine residual at each entry point to the distribution system, and at coliform sampling sites. Because there is no direct chemical method for measuring chloramine residual, the water system can approximate the monochloramine residual by subtracting the measured free chlorine residual from the measured total chlorine residual. If the system experiences nitrification in the distribution system, monitoring of actual chloramine residual may be conducted at distribution system locations.

- **Does the PWS sell water to communities that use chlorine instead of chloramines?**

  When chlorinated water blends with chloraminated water, the chloramine residual decreases after the excess ammonia combines with the chlorine and monochloramine converts to dichloramine and nitrogen trichloride. This can deplete the entire residual and cause taste and odor issues. Therefore, the operator needs to know how much chlorinated water can blend with a particular chloraminated water stream without significantly affecting the monochloramine residual.

- **Has management provided for the safety of the operator responsible for the O&M of the chloramination processes?**

  Anhydrous ammonia is lighter than air, so any leaking vapor will rise quickly. Under pressure, anhydrous ammonia is a liquid. Great amounts of heat are absorbed when the pressurized liquid reverts to a gas.

  For storage tanks and/or chemical feed equipment installed indoors, ventilation and vapor detection devices should be located at high points in the room. The ventilation rates vary, depending on the appropriate regulatory agency's requirements.

  Utilities should protect ammonia gas storage tanks from direct sunlight or direct sources of heat to avoid pressure increases in the tank. Otherwise, the tanks may release ammonia gas into the atmosphere through the pressure relief valves. In warm regions, water systems should cover outdoor tanks with a shelter or outfit the tanks with a temperature-controlled sprinkler system.

  Where fugitive emissions of ammonia are a concern, fume control may be required. If the accidental release from a storage container is a concern, the water system should consider installing an emergency scrubber system, similar to a chlorine gas scrubber system.

- **Has the water system notified critical populations of the use of chloramines?**

  Users of kidney dialysis equipment are the most critical group affected by chloramine use. Chloramines can cause methemoglobinemia and adversely affect the health of kidney dialysis patients if hospitals do not remove chloramines from the dialysate water. Chloramines can also be toxic to fish. The water system should notify hobbyists, pet stores, and other establishments regarding the water system's use of chloramines, so they can take measures to remove or neutralize chloramines from the water, prior to contact with any fish or other aquatic species.

8.6.4 Disinfection with Ozone[6]

8.6.4.1 Introduction

Utilities use ozone in water treatment for disinfection and oxidation. Early application of ozone in the United States was primarily for non-disinfection purposes such as color removal or taste and odor control. However, since the implementation of the SWTR and DBPRs, ozone usage for primary disinfection has increased.

Ozone, a gas at room temperature, is highly corrosive and toxic. It is also a powerful oxidant, second only to the hydroxyl free radical among chemicals typically used in water treatment. Therefore, it is capable of oxidizing many organic and inorganic compounds in water. These reactions with organic and inorganic compounds present an ozone demand in the water flow, which should be satisfied during ozonation, prior to developing a measurable residual. Typical concentrations of ozone found during water treatment range from <0.1 to 1 mg/L, although conditions can produce higher concentrations.

Because ozone is an unstable molecule, water systems generate it at the point of application for use in water treatment. The source of oxygen needed to produce ozone can be from oxygen present in air or high-purity oxygen. The most common method for generating ozone is corona discharge, but systems may use other methods as well.

Corona discharge, also known as silent electrical discharge, consists of passing an oxygen- containing gas through two electrodes separated by a dielectric and a discharge gap. Voltage applied to the electrodes causes an electron flow across the discharge gap. These electrons provide the energy to disassociate the oxygen molecules, leading to the formation of ozone. Figures 8-4 and 8-5 depict a basic and a simplified ozone generator, respectively.

[6] For more information on disinfection with ozone, please refer to the publication, *EPA Guidance Manual on Alternative Disinfectants and Oxidants* (USEPA, 1999a).

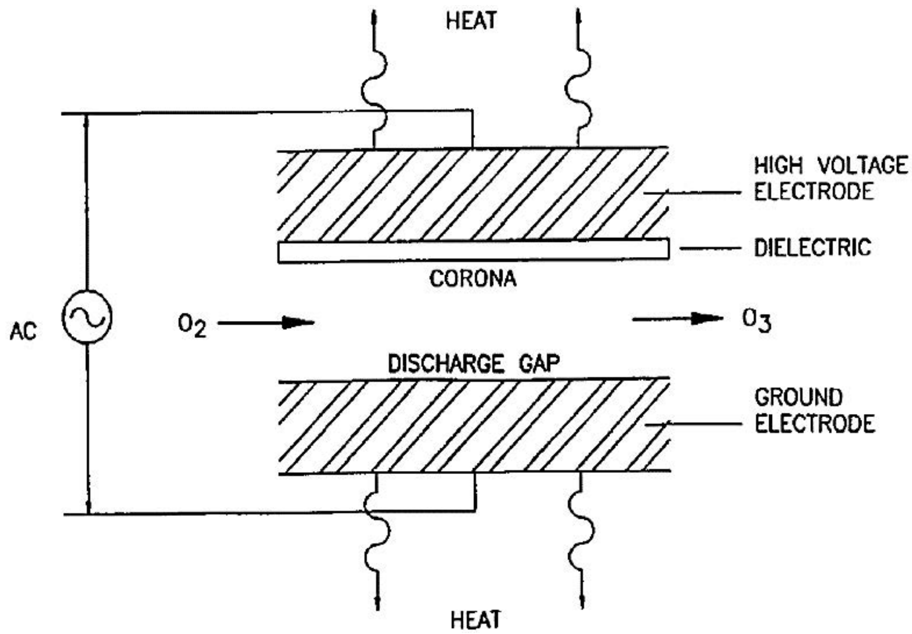

Figure 8-4: Basic ozone generator

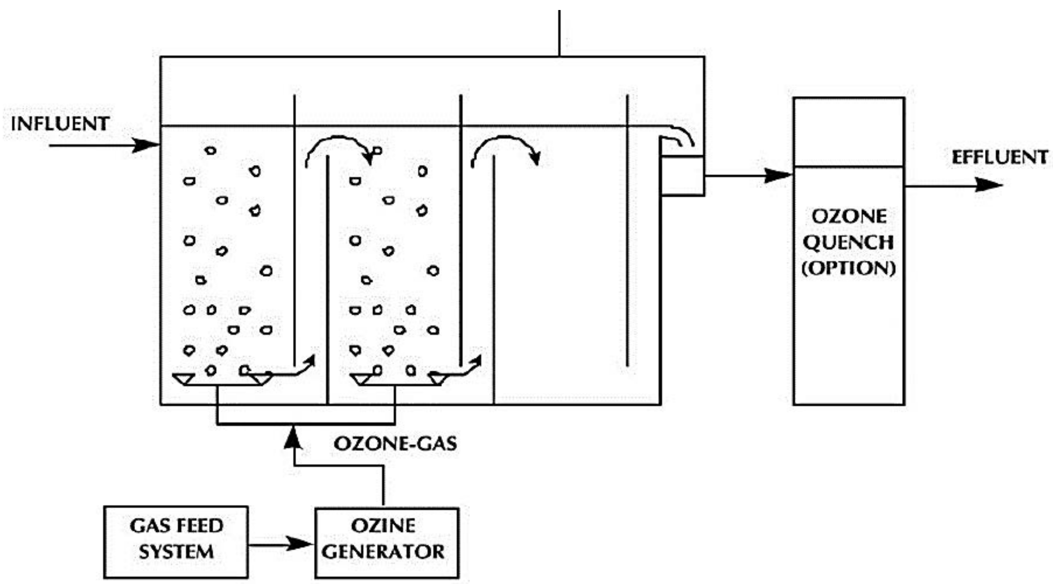

Figure 8-5: Simplified ozone system schematic

8.6.4.2 Systems

Ozone water treatment systems have four basic components: a gas feed system; an ozone generator; an ozone contactor; and an off-gas destruction system. The gas feed system provides a clean, dry source of oxygen to the generator. The ozone contactor transfers the ozone-rich gas into the water to be treated, and provides contact time for disinfection (or other reactions). The final process step, off-gas destruction, is required, as ozone is toxic in the concentrations present in the off-gas. Some plants include an off-gas recycle system that returns the ozone-rich off-gas to the first contact chamber to reduce the ozone demand in the subsequent chambers. Some systems also include a quench chamber to remove ozone residual in solution.

8.6.4.3 Facilities

As mentioned above, systems can generate ozone from oxygen present in air or high purity oxygen. Following is a description of the two types of ozone generation systems and other components.

8.6.4.3.1 Oxygen Feed Systems

Liquid oxygen feed systems are relatively simple, consisting of a storage tank or tanks, evaporators to convert the liquid to a gas, filters to remove impurities, and pressure regulators to limit the gas pressure to the ozone generators.

8.6.4.3.2 Air Feed Systems

Air feed systems for ozone generators are fairly complicated as water systems need to properly condition the air to prevent damage to the generator. Air preparation systems typically consist of air compressors, filters, dryers, and pressure regulators.

8.6.4.3.3 Ozone Contactors

After injection into the water flow, the dissolved ozone reacts with the organic and inorganic constituents, as well as any pathogens. Common ozone dissolution methods include bubble diffuser contactors and injectors.

8.6.4.3.4 Bubble Diffuser Contactors

The most commonly used ozone contactor is the bubble diffuser. This method offers the advantages of no additional energy requirements, high ozone transfer rates, process flexibility, operational simplicity, and no moving parts. The Ozone Bubble Contactor (Figure 8-6) illustrates a typical three stage ozone bubble diffuser contactor. This illustration shows a countercurrent flow configuration (ozone and water flowing in opposite directions), an alternating cocurrent/countercurrent arrangement, and a cocurrent flow configuration (ozone and water flowing in the same direction). Bubble diffuser contactors use ceramic or stainless steel diffusers that are either rod-type or disc-type to generate bubbles.

8.6.4.3.5 Injector Contactors

Typical injector contactors rely on a venturi section of the water stream which creates a negative pressure that draws the ozone into the water. In many cases, a higher pressure side-stream of the total flow increases the available vacuum for ozone injection. After injection into this side-stream, the water containing all the added ozone blends with the remainder of the plant flow under high turbulence to enhance dispersion of ozone into the total flow of water. Figure 8-7 illustrates typical in-line and side-stream ozone injection systems.

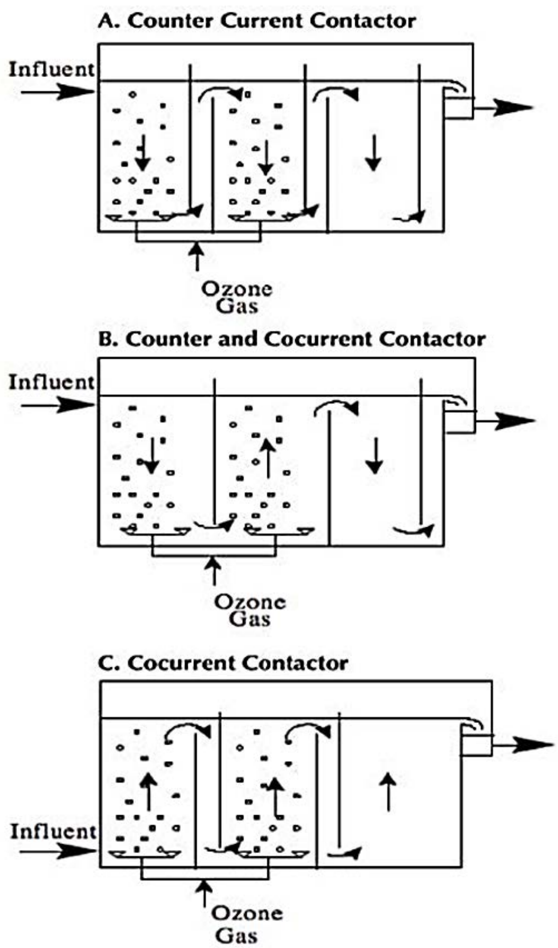

Figure 8-6: Ozone bubble contactors

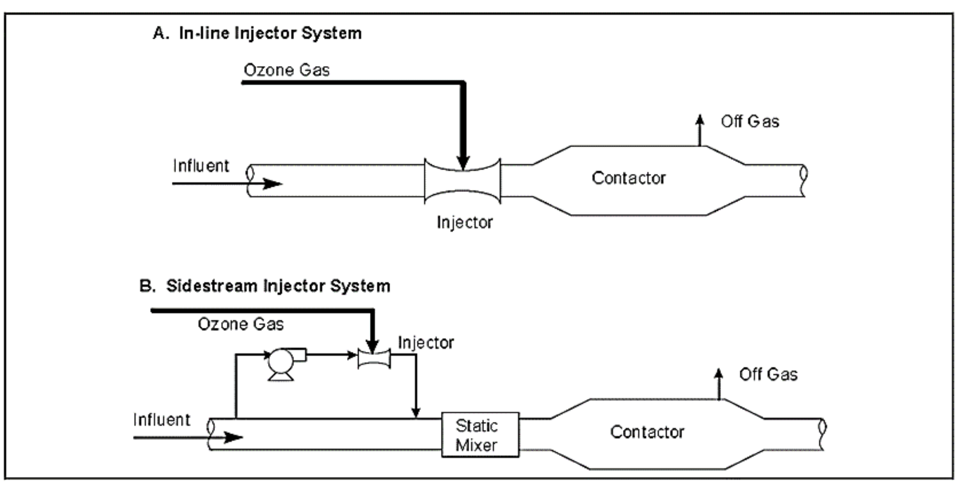

Figure 8-7: In-line and side-stream ozone injection systems

To meet the CT disinfection requirements, additional contact time is required after the injector in a plug flow reactor or after the diffusers in an ozone contactor. The additional contact volume is determined in conjunction with the applied ozone dosage and estimated residual ozone concentration to satisfy the disinfection CT requirement.

8.6.4.3.6 Off-gas Destruction Systems

Destruction systems collect the off-gas from an ozone contactor and convert the ozone back to oxygen prior to release to the atmosphere. A blower on the discharge side of the destruct unit pulls the air from the contactor, which places the contactor under a slight vacuum to ensure no ozone escapes.

8.6.4.4 Sanitary Deficiency Questions and Considerations – Ozone

- **Why is the PWS using ozone?**

  The operator should be able to discuss the purpose for using ozone and the treatment objectives.

- **What secondary disinfectant does the water system use?**

  Water systems use ozone only as a primary disinfectant since it cannot maintain a residual in the distribution system. Therefore, these systems are usually required to use a secondary disinfectant, such as chlorine or chloramine, for a complete disinfection system.

- **What type of process control monitoring does the PWS conduct?**

  Operators can use raw water quality, turbidity and ozone demand (the amount of ozone required for all oxidation requirements of the water) to assess how to effectively use ozone in the treatment process (see discussion on question 8). Water temperature, pH and alkalinity are also important in some of the other treatment objectives.

- **How and where does the PWS generate ozone?**

  Water systems should have a properly constructed building to protect ozone generators from the environment and to protect personnel from leaking ozone in the case of a malfunction. This generator room should be equipped with adequate ventilation to control the temperature and for exhausting the room in the case of a leak. The room should also have adequate space to remove the tubes from the generator shell and to service the generator power supplies. Air prep systems tend to be noisy; therefore, it is desirable to separate them from the ozone generators. Off-gas destruct units can be located outside, if the climate permits. If placed inside, the room should have an ambient ozone detector installed in the enclosure. All rooms should have properly installed ventilation, heating and cooling to match the equipment-operating environment.

- **Is there an ozone monitoring plan to address the entire ozonation process?**

  During operation of an ozonation system the water system should analyze for ozone in both the liquid and gas phase to determine the applied ozone dose, ozone transfer efficiency, and (for primary disinfection) residual ozone level. A monitor, where the gas stream exits the ozone generator, measures the applied ozone dose. A second monitor, where the off-gas exits the ozone contactor, measures the amount of ozone transferred to the liquid phase in the contactor which determines the ozone transfer efficiency. A third monitor measures the residual ozone in the disinfected water, exiting the ozone contactor or cells within the contactor, to ensure the process meets any CT requirements.

- **What are the application points for the ozone?**

  The typical locations for feeding ozone in a water treatment plant are at the head of the treatment plant (raw water), pre-ozonation and after sedimentation.

- **How is ozone inactivation (CT) determined?**

  There are several methods of determining ozone inactivation credit. The methods differ in the level of effort needed and in the ozone dose needed to achieve a level of inactivation. The operator should be able to explain the method used, as well as the contactor sampling locations used in inactivation calculations. Methods for determining ozone inactivation are included in the EPA's *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water* (USEPA, 1991) and in the EPA's Long Term 2 *Enhanced Surface Water Treatment Rule: Toolbox Guidance Manual* (USEPA, 2010).

- **Does the PWS have an O&M plan for the ozone system?**

  Even though ozone systems are complex and use technical instruments, the process is highly automated and very reliable. Maintenance of ozone generators requires skilled technicians. The operator should check generators daily when in operation and periodically change filters and desiccant in air preparation systems, where the frequency depends on the quality of the inlet air and the number of hours in operation. Compressors require periodic service, depending on the type and operating time.

  Certified professionals should periodically pressure-test liquid oxygen tanks as well. Ask the operator how often they inspect piping and contact chambers for leaks and corrosion and how often they clean the dielectric tubes. The water system should have procedures in place and provide the equipment needed for cleaning operations as well as storage space for spare tubes.

- **Is the PWS complying with the MCL for bromate and the monitoring requirements under the DBPRs?**

  Ozone does not form halogenated DBPs (THM and HAA) in reactions with natural organic matter, but it does form a variety of organic and inorganic DBPs. However, if bromide ions are present in the raw water, ozone may react with them to form bromate. The DBPRs requires CWSs and NTNCWSs using ozone for disinfection or oxidation to monitor for bromate and comply with the bromate MCL.

- **Has management provided for the safety of the operators responsible for the O&M of all ozonation processes?**

  The water system is responsible for providing necessary instrumentation for ozone systems to protect both personnel and the equipment such as gas phase ozone detectors installed in generator rooms, where ozone gas may exist and personnel are routinely present. Systems should also have an ozone detector installed on the outlet from the off-gas destruct unit, to ensure the unit is working properly.

8.6.5 Disinfection with Ultraviolet Light

8.6.5.1 Introduction

The use of UV for disinfection of drinking water continues to grow in PWSs, due to its ability to inactivate pathogenic microorganisms without forming regulated DBPs. UV light is effective against some pathogens, such as *Cryptosporidium*, that are resistant to common disinfectants (e.g., chlorine). UV can achieve significant inactivation of *Cryptosporidium*, as well as *G. lamblia*, at relatively low doses of UV light. Unlike some other disinfectants, inactivation using UV is not dependent on temperature or pH.

Some viruses, particularly adenoviruses, are much more resistant to UV light than *Cryptosporidium* and *G. lamblia* and require higher doses of UV light. The EPA has published a table providing UV dosages required for differing log inactivation of pathogenic microorganisms (40 CFR 141.720). These doses are appropriate for ground water, filtered water or waters that meet the turbidity requirements for unfiltered surface water systems. However, ground water that is high in iron, manganese, or hardness may require pretreatment.

Water systems can only use UV light as a primary disinfectant since it cannot maintain a residual in the distribution system. Therefore, these systems are often required to use a secondary disinfectant, such as chlorine or chloramine, for secondary disinfection.

8.6.5.2 Ultraviolet Lamps

UV lamps operate in much the same way as fluorescent lamps. UV radiation emitted from electron flow through ionized mercury vapor produces the ultraviolet energy in most units. The difference between the two lamps is that the fluorescent lamp bulb has a phosphorus coating, which converts the UV radiation to visible light. There is no coating on the UV lamp, so it transmits the UV radiation generated by the arc.

Both low-pressure and medium-pressure lamps are available for disinfection applications. Low pressure lamps emit their maximum energy output at a wavelength of 253.7 nm, while medium pressure lamps emit energy with wavelengths ranging from 180 to 1370 nm. The intensity of medium-pressure lamps is much greater than low-pressure lamps. Thus, fewer medium pressure lamps are required for an equivalent dosage. For small systems, the medium pressure system may consist of a single lamp.

Recommended specifications for low-pressure lamps include:

- L-type ozone-free quartz.
- Instant start (minimal delay on startup).
- Designed to withstand vibration and shock.

Typically, a quartz sleeve enclosure around the low-pressure lamps separates the water from the lamp surface. This arrangement is required to maintain the lamp surface operating temperature near its optimum of 40°C.

8.6.5.3 Ballasts

Ballasts are transformers that control the power to the UV lamps. Ballasts should operate at temperatures below 60°C to prevent premature failure. Typically, the ballasts generate enough heat to warrant cooling fans or air conditioning.

The two types of transformers that are commonly used with UV lamps are electronic and electromagnetic. Electronic ballasts operate at a much higher frequency than electromagnetic ballasts, resulting in lower lamp operating temperatures, less energy use, less heat production, and longer ballast life.

8.6.5.4 UV Reactor Design

Most conventional UV reactors are available in two types; closed vessel and open channel. For drinking water applications, the closed vessel is generally the preferred UV reactor for the following reasons (USEPA, 1996):

- Smaller footprint.
- Minimized pollution from airborne material.
- Minimal personnel exposure to UV.
- Modular design for installation simplicity.

Microbial response to UV light (UV 254 nanometers at 40 mJ/cm^2) can vary significantly among microorganisms. Among the pathogens of interest in drinking water, viruses are most resistant to UV disinfection followed by bacteria, *Cryptosporidium* oocysts, and *G. lamblia* cysts.

Additional design features for conventional UV disinfection systems include:

- UV sensors to detect any drop in UV lamp output intensity.
- Alarms and shut-down systems.
- Automatic or manual cleaning cycles.
- Telemetry systems for remote installations.

8.6.5.5 General Application and Review

Water systems cannot directly measure UV dosage. UV reactors should undergo validation testing to determine the operating conditions under which the reactor delivers the UV dose required for the necessary inactivation levels. In general, the operating conditions determined in validation testing should include flow rate, UV intensity as measured by a UV sensor, and UV lamp status. These monitoring and operating conditions would both be a part of primacy agency approval of an alternative treatment process and associated compliance monitoring.

Other important operating considerations include reliability, redundancy, lamp cleaning and replacement, and lamp breakage. For systems using UV for compliance with LT2ESWTR, validation testing is required and must meet minimum requirements established in that rule. The *Ultraviolet*

Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule (EPA 815-R-06-007) provides additional information on UV disinfection, planning and design of UV facilities, validation of UV reactors, and start-up operation and monitoring of UV facilities.

8.6.5.6 Sanitary Deficiency Questions and Considerations – Ultraviolet Disinfection Systems[7]

- **Is the PWS meeting its UV dose and inactivation requirements?**

  The surveyor should confirm that the system is operating within the validated conditions for range of flow, UV intensity lamp status, and UV transmittance. There should be records documenting episodes of operating outside of validated conditions. The surveyor should confirm that the UV dose equation or UV set points and any other critical parameters are consistent with the validation and primacy agency approval.

- **If required, has the PWS met the requirement to treat at least 95% of the water delivered to the public within validated conditions for each month?**

  The surveyor should review periods where the UV system was operating outside of validated conditions or "off-spec" and what causes the operator identified. If extended periods of "off-spec" operations are noted, the surveyor should review what changes the operator has made to address these episodes.

- **Does the operator monitor the UV reactor for validated conditions?**

  Monitoring should include UV intensity, transmittance, reactor flow rate, lamp status, and any state designated parameters.

  The surveyor should confirm that the system is verifying UV sensor calibration and recalibrating consistent with the primacy agency-approved protocol. The surveyor should also confirm that a reference UV sensor is present and operating. The surveyor should verify regular maintenance of UV and flow monitoring equipment. Procedures for testing of critical alarms should be in place.

- **Are UV reactor maintenance procedures in place and followed?**

  Maintenance procedures would include cleaning of UV sleeves and maintenance of sleeve cleaning equipment, ultraviolet transmittance analyzer cleaning and maintenance and maintenance, of ballast cooling systems, water level indicators, and thermometers.

- **Is upstream treatment performance meeting the requirements?**

  The surveyor should review the performance of treatment processes upstream of UV disinfection that could have an impact on UV effectiveness. These processes would include turbidity reduction, iron removal, and softening.

- **Have there been changes to the treatment train?**

  The surveyor should review the current plant configuration and operating conditions that could affect the delivery of UV disinfection. This would include changes to:

[7] See Chapter 6 "Start-up and Operation of UV Facilities" in the USEPA *Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule*. EPA 815-R-06-007 (November 2006).

- ○ Inlet and outlet piping or channel conditions.
- ○ Plant hydraulics or in plant flows.
- ○ Any upstream treatment.
- ○ UV lamps or sensors-make/models should match those approved by the state.

- **Have there been changes in the source water?**

  The surveyor should review the source(s) of supply and any changes that could affect the delivery of UV disinfection. Those changes include:

  - ○ New sources.
  - ○ Changes in watershed conditions.
  - ○ Turbidity events/ increases.
  - ○ Algae blooms, lake turnover or other limnology/water quality changes.
  - ○ Changes in UV absorbance of the source.

- **Is compliance reporting and recordkeeping meeting requirements?**

  The surveyor should review the records being maintained by the water system to assure they are in compliance with their disinfection requirements, including but not limited to the validation test results and percentage of water per month not being treated with UV.

8.6.6 Disinfection with Chlorine Dioxide[8]

8.6.6.1 Introduction

Chlorine dioxide (ClO_2) is a neutral compound of chlorine and a strong oxidant. It is a relatively small, volatile, and highly energetic molecule, and a free radical even while in dilute aqueous solutions. Today, the major uses of chlorine dioxide for drinking water treatment are:

- CT disinfection credit.
- Pre-oxidant to control tastes and odor.
- Control of iron and manganese.
- Control of hydrogen sulfide and phenolic compounds.

Chlorine dioxide cannot be compressed or stored and shipped commercially as a gas because it is explosive under pressure. Therefore, water systems must generate it on-site. Most commercial generators use sodium chlorite ($NaClO_2$) as the common precursor feedstock chemical to generate

[8] For more information on disinfection with chlorine dioxide, please refer to the publication, *EPA Guidance Manual on Alternative Disinfectants and Oxidants* (April 1999).

chlorine dioxide for drinking water application. Chlorine dioxide can be formed by sodium chlorite reacting with gaseous chlorine ($Cl_2(g)$), HOCl, or hydrochloric acid (HCl).

The conventional chlorine-chlorite solution method generates chlorine dioxide in a two-step process. First, chlorine gas is reacted with water to form HOCl and hydrochloric acid. These acids then react with sodium chlorite to form chlorine dioxide. Water systems should carefully control the ratio of sodium chlorite to HOCl. Insufficient chlorine feed results in a large amount of unreacted chlorite. Excess chlorine feed may result in the formation of chlorate ion, which is an oxidation product of chlorine dioxide and not currently regulated.

8.6.6.2 Facilities

There are several methods for generating chlorine dioxide. Following are schematics of two of the more common methods used.

8.6.6.2.1 Aqueous Chlorine-Chlorite Solution

Chlorite ion (from dissolved $NaClO_2$) reacts with hydrochloric acid and HOCl to form chlorine dioxide in these systems, commonly referred to as conventional chlorine dioxide systems. Figure 8-8 shows a typical chlorine dioxide generator using aqueous chlorine-chlorite solution.

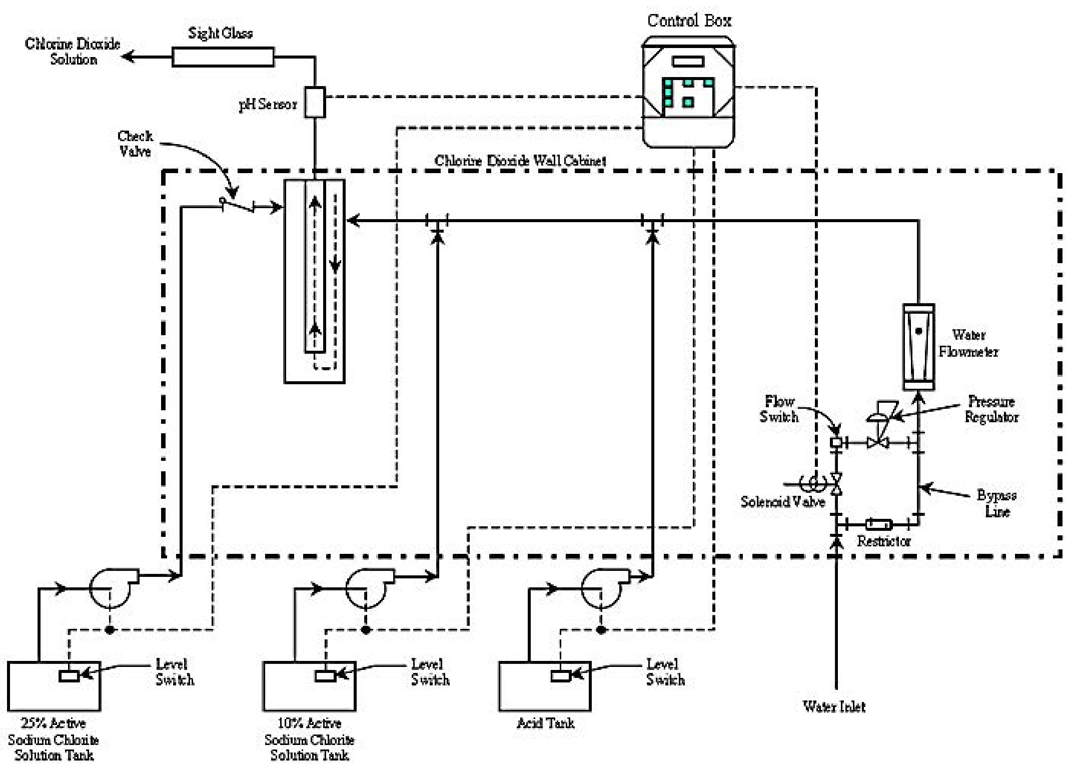

Figure 8-8: Conventional chlorine dioxide generation

When chlorine gas and chlorite ion react under ideal conditions (not usually formed in aqueous chlorine type systems), the resulting pH of the effluent may be close to seven. To fully utilize sodium chlorite solution, excess chlorine is often used. This approach lowers the pH and drives the reaction further toward completion. The reaction is faster than the acid-chlorite solution method, but much slower than the other commercial method.

8.6.6.2.2 Recycled Aqueous Chlorine

In the aqueous chlorine design (Figure 8-9), the injection of chlorine gas occurs in a continuously circulating water loop. This eliminates the need for a great excess of chlorine gas feed to the generator, since the molecular chlorine dissolves in the feed water, and thus maintain a low pH level of the feed water. Loop-based generators keep chlorine at or above saturation levels. The low pH condition results in high yields of chlorine. Chlorine in the generator effluent may react with chlorine dioxide to form chlorate, if allowed to stand in batch storage too long.

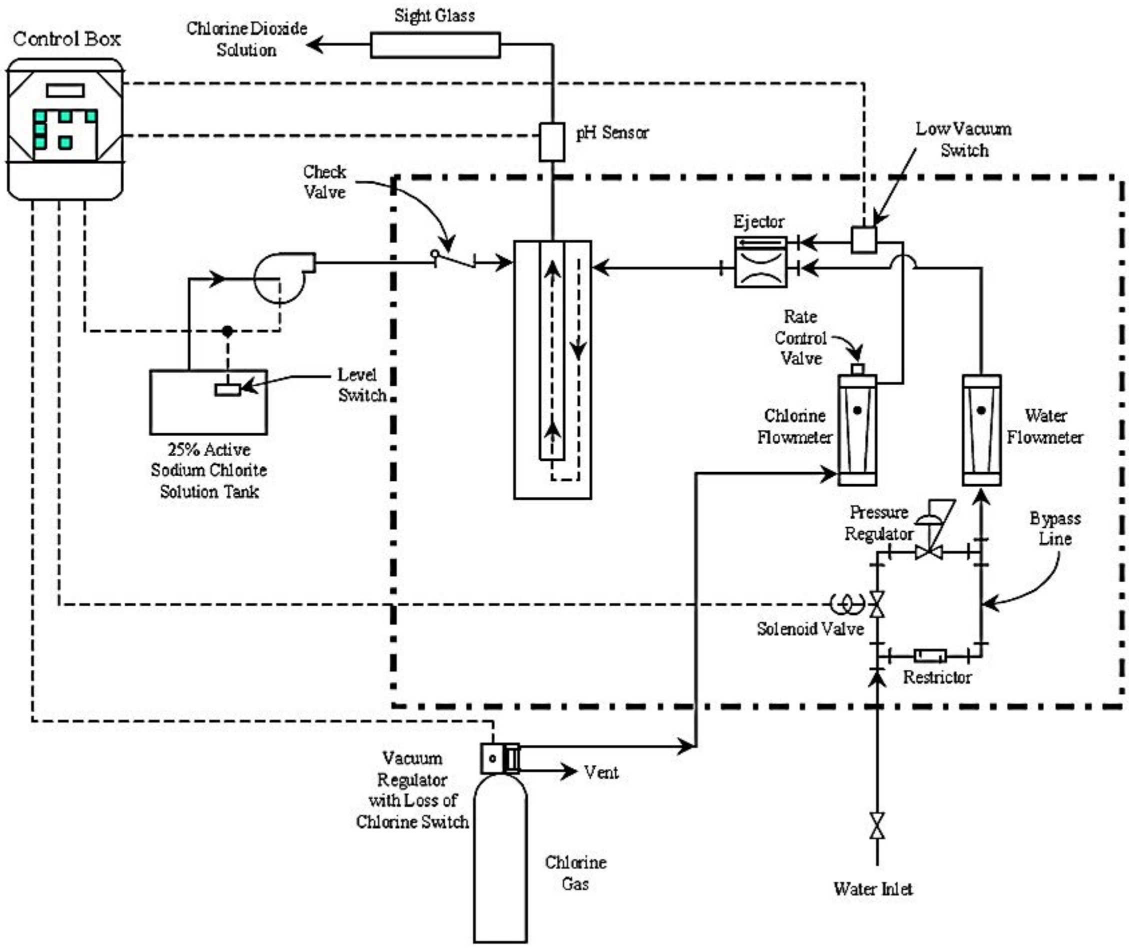

Figure 8-9: Chlorine dioxide generator: Recycled aqueous chlorine method

8.6.6.3 Sanitary Deficiency Questions and Considerations – Chlorine Dioxide

- **Why is the water system using chlorine dioxide and what are the treatment objectives?**

  Water systems can utilize chlorine dioxide as a primary disinfectant, for taste and odor control, THM/HAA reduction, iron and manganese control, color removal, sulfide and phenol destruction, and zebra mussel control.

- **Is the water system using sodium chlorite and, if so, at what percentage?**

  Most commercial generators use $NaClO_2$ as the common precursor feedstock chemical to generate chlorine dioxide for drinking water application.

- **What is the secondary disinfectant being used?**

  Concerns with chlorite and chlorate formation, as well as high levels of chlorine dioxide, limit the use of chlorine dioxide to provide a disinfectant residual in the distribution system. Consequently, systems that use chlorine dioxide for oxidation and primary disinfectant applications will need an alternate disinfectant for residual or secondary disinfection.

- **What is the purity of the chlorine dioxide produced?**

  Water systems operate chlorine dioxide generators to obtain the maximum production (yield) of chlorine dioxide while minimizing free chlorine or other residual oxidant formation. The specified yield for chlorine dioxide generators is typically greater than 95 percent.

- **Does the operator adjust the chlorine gas feed rate as required and recalibrate the equipment according to manufacturer specifications?**

  In all generators, large excess amounts of chlorine may result in the over-oxidization of chlorite and directly form chlorate in aqueous solution. The operator should always adjust the precursor chemical feed rates for the generators according to the chart settings supplied with generators, notably with the continuous flow, direct gas injection systems. Sometimes the operator will need to recalibrate these systems on-site, if feed stock sodium chlorite is not of the correct strength, or if the PWS has replaced pre-calibrated flow devices.

- **Are sample petcocks available to perform the required sampling?**

  Chlorine dioxide generators are relatively simple mixing chambers. Some type of media, which is usually Teflon™ chips, ceramic or raschig rings, usually fills the reactor chamber to generate hydraulic turbulence for mixing. A sample petcock valve on the discharge side of the generator allows the operator to monitor the generation process.

- **How and where is the sodium chlorite stored?**

  Chlorine dioxide storage and feed systems typically include the following:

  - Storage and feeding in a designated space.
  - Use of non-combustible materials such as concrete for construction.
  - Storage in clean, closed, non-translucent containers. Exposure to sunlight, UV light, or excessive heat reduces product strength.
  - Avoid storage and handling of combustible or reactive materials, such as acids or organic materials, in the sodium chlorite area.
  - Secondary containment for storage and handling areas to handle the worst-case spill with sumps provided, to facilitate recovery.
  - A water supply near storage and handling areas for cleanup.

- ○ Any material in contact with the strong oxidizing and/or acid solutions involved in chlorine dioxide systems should be inert.
- ○ Storage tanks with vents to outside.
- ○ Adequate ventilation and air monitoring.
- ○ Gas masks and first aid kits outside of the chemical areas.
- ○ Reactor with glass view ports if it is not made of transparent material.
- ○ Flow monitoring on all chemical feed lines, dilution water lines, and chlorine dioxide solution lines.

- **What are the application points for the chlorine dioxide? Is the CT value properly calculated?**

  The calculation of CT for chlorine dioxide is similar to other disinfectants, with accurate determinations of residual concentrations being a prerequisite for effective disinfection. Water systems receive primary disinfectant credit from the residual concentration and the effective contact time. For CT disinfection credit, operators may add chlorine dioxide before clearwells or transfer pipelines. However, DBPs may continue to form and chlorine dioxide residual will degrade rapidly under atmospheric conditions. The systems should have ample sampling points installed to allow close monitoring of residual concentrations.

- **Is the PWS complying with the MRDL for chlorine dioxide and MCL for chlorite as well as the monitoring requirements under the DBPRs?**

  The MRDL for chlorine dioxide is 0.8 mg/L and the MCL for chlorite is 1.0 mg/L per the DBPRs. All PWSs that use chlorine dioxide for disinfection or oxidation, are required to take daily chlorine dioxide samples at the entrance to the distribution system. For any daily sample that exceeds the chlorine dioxide MRDL of 0.8 mg/L, the system must take additional samples in the distribution system the following day at the locations specified in the DBPRs, in addition to the daily sample required at the entrance to the distribution system.

  For chlorite monitoring, CWSs and NTNCWSs that use chlorine dioxide for disinfection or oxidation are required to take daily samples at the entrance to the distribution system. For any daily sample that exceeds the chlorite MCL of 1.0 mg/L at the entry point, the system must take additional samples in the distribution system the following day at locations specified in the DBPRs. These additional samples are to be collected at: (1) a location as close to the first customer as possible, (2) a location representative of average residence time, and (3) a location as close to the end of the distribution system as possible (reflecting maximum residence time in the distribution system). These are some of the monitoring requirements. The operator should be familiar with their water system's DBPRs monitoring requirements.

- **Has management provided for the safety of the operators responsible for the O&M of the chlorine dioxide generation processes?**

  At high concentrations, chlorine dioxide reacts violently with reducing agents. However, it is stable in dilute solution, in a closed container in the absence of light. The major safety concern for solutions of sodium chlorite is the unintentional and uncontrollable release of high levels of chlorine dioxide. Another concern when handling and storing sodium chlorite solutions is crystallization, which occurs because of lower temperatures and/or higher concentrations.

8.7 Possible Significant Deficiencies for Disinfection

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The primacy agency determines both significant deficiencies and the corresponding corrective actions.

- Missing no-flow/fail-safe device for the chlorination system.
- Incompatible storage of chemicals with chlorine.
- No redundant chemical feed pumps for disinfection system.
- Inoperable chemical feed pump that cause interruption in disinfection process.
- Cross-connection in disinfection process.
- No backflow/back siphonage devices for make-up water.
- UV lamps are not cleaned routinely or problems meeting inactivation requirements.
- No process control monitoring.
- Gas chlorine cylinders are not properly restrained.
- No determination of inactivation.
- There are interruptions in the requisite disinfection process.

9 Turbidity Removal

The surveyor should thoroughly evaluate all water treatment processes to ensure the production of a safe, adequate, and reliable supply of water for consumers. The water treatment plant is a primary barrier against unsafe water, and any malfunction in the treatment process could result in water quality problems. Of major importance is the consistent and continual removal of solids that can interfere with disinfection and some pathogens, typically using turbidity as an indicator. The surveyor should evaluate the operation, maintenance, and management of turbidity removal systems used at the water treatment plant to identify any existing or potential sanitary deficiencies.

9.1 Learning Objectives

By the end of this chapter, students will be able to:

- Identify different methods for turbidity removal.
- Identify source water conditions that limit removal options.
- Understand what process control is needed for different treatment options.
- Identify deficiencies related to each treatment option.

9.2 Data Collection

If available, review the following data prior to conducting the on-site survey of a turbidity removal treatment facility:

- Type of turbidity removal system.
- Monthly operation reports.
- Turbidity level goals for treatment units (e.g., for settling basin effluent).
- Types of coagulant used.
- Designed treatment criteria for plant.

9.3 Regulations and Standards to Consider

Prior to the survey, review and consider the following regulations as part of the sanitary survey:

- Primacy agency design standards for surface water treatment systems
- ANSI/NSF Standards 60 and 61
- Ten State Standards
- AWWA standard (e.g., B100, B112)
- CFR Part 141 Subpart H

- CFR Part 141 Subpart L
- CFR Part 141 Subpart P
- CFR Part 141 Subpart T
- CFR Part 141 Subpart W

9.4 Basic Information about Turbidity Removal

PWSs that use a surface water source or a ground water source under the direct influence of surface water must meet NPDWR for the removal or inactivation of *Cryptosporidium*, *G. lamblia* and viruses. For surface water systems required to filter, the removal of turbidity is a key step in complying with these requirements.

9.5 Conventional Filtration Treatment

The most widely used technology for removing turbidity and microbial contaminants from surface water supplies is conventional treatment which includes coagulation, flocculation, and sedimentation, followed by filtration. Coagulation and flocculation are chemical and physical processes to improve the particulate and colloid reduction efficiency of subsequent settling or filtration processes. Coagulation involves feeding chemicals to destabilize the similar charges on suspended particles, allowing them to coalesce and thereby begin to form floc. Flocculation, which partly overlaps the coagulation process, requires gentle mixing of destabilized particles to form floc that can settle or filter out of the water. Conventional treatment plants typically use aluminum or iron compounds in the coagulation processes and, in some cases, use polymers to enhance coagulation and filtration. Generally, gravity filters with sand, dual, or mixed media filters are used. The filtration rates may be from 2 gpm/ft^2 with sand as the single medium up to 4 gpm/ft^2 (or higher in some cases) for dual and mixed media filters. For higher rates, states may require pilot or performance testing to demonstrate satisfactory filtration results.

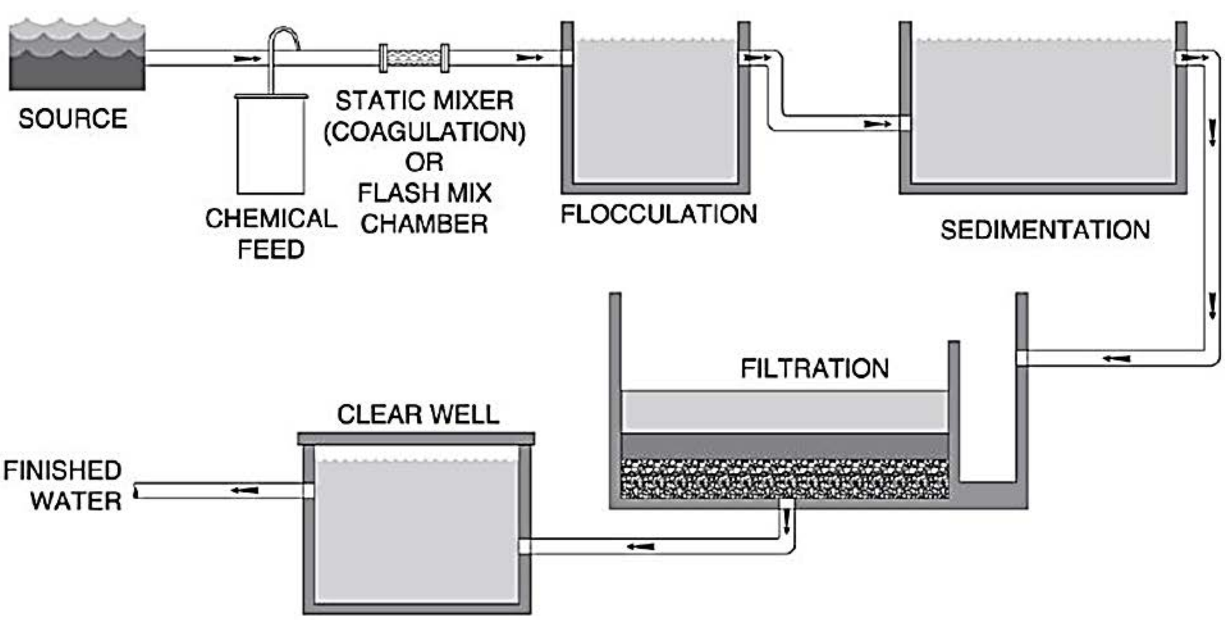

Figure 9-1: Conventional filtration treatment

9.5.1 Sanitary Deficiency Questions and Considerations – Conventional Treatment

9.5.1.1 Coagulation - Rapid Mix

Note: The sanitary deficiencies related to chemical feed systems in Chapter 7, Chemical Contaminant Removal, also apply to this section.

- **Does treatment include continuous coagulant feed when the plant is in operation?**

  The surveyor should ask if treatment includes a continuous coagulant feed when the plant is in operation. Lack of coagulant addition is often considered a significant deficiency that needs immediate attention. The surveyor should check that there are redundant feed pumps for the primary coagulant and polymers and that spare parts are readily available. They should also review what devices, alarms and notification procedures the operator has in place in the event of a failure of the feed systems.

  In answering the questions below, the surveyor should observe the operator's level of skill and understanding.

- **What type and combination of coagulants are used?**

  Water systems typically use aluminum or ferric salts as primary coagulants. If alum is being used, the operator should control the pH, because alum's effectiveness decreases when the water's pH exceeds 8.0. The operator should also be aware of any alkalinity requirements for the particular additives they use. Systems using low molecular weight cationic polymers as primary coagulants typically have raw water that is low in turbidity. This form of treatment is generally more applicable to direct filtration.

  Polyaluminum chloride is another popular coagulant that works well in cold water and across a broader spectrum of pH values. Water systems may also use nonionic and anionic polymers as coagulant, flocculent, filter, and backwash-water aids.

- **Does the operator understand the purpose of each coagulant chemical used?**

  The operator should be able to fully explain the purpose of each coagulant chemical and why injection of the chemical occurs at a particular point. For example, "This low molecular weight polymer which is injected immediately downstream of rapid mix is used as a coagulant aid, and this high molecular weight polymer is added at a bend in the pipe prior to the filters as a filter aid."

- **How does the operator determine the dosage of each coagulant chemical?**

  The surveyor should determine whether the operator uses a streaming current monitor, jar tests, pilot studies, or combinations of such tests to determine dosage. The surveyor should ask the operator how to make up stock solutions for jar tests for both alum and polymers, how to run and dose a jar test, how to calculate mL/min from mg/L, how to calibrate the feed pump, and how to prepare the proper dilution for day tanks.

- **Is there a process control plan for coagulation addition?**

  What type of process control plan has the water system developed to control chemical dosages during routine and emergency levels of raw water turbidity or other water quality problems? Do the filters have shortened runs due to filter-clogging algae, and what does the operator do to control this and other special problems? How does the operator track changes in raw water quality with changes in process control in order to keep the quality of finished water high?

- **Is the rapid mix process adequate?**

  The rapid mix process is a critical part of the coagulation process. Water systems can achieve thorough mixing in a variety of ways, such as mechanical units, diffusers, in-line mixers, and baffles. The surveyor should note the type of mixer and determine if the mixing equipment is functioning properly for all flows and all ranges of coagulant. Inadequate mixing can severely affect the performance of downstream processes, particularly when raw water quality is deteriorating.

- **Is the flocculation process adequate?**

  The surveyor should note any problems with short circuiting in the flocculation basin and observe if there is good floc formation at the effluent end of that basin prior to entry into the sedimentation basin. The paddles of mechanical flocculators should be in place and turning at the appropriate speed.

9.5.1.2 Sedimentation

- **Is the sedimentation process performing adequately?**

  The surveyor should ask the operator to describe the sedimentation process (e.g., tube settlers, lamella plates) and should note problems with short circuiting or excessive turbulence. The surveyor should evaluate the relative thickness (i.e., surface contour) of the sludge blanket throughout the different sections of the basin, as compared to his or her expectations of how the blanket should appear, based on the design and direction of flow toward the weirs.

- **Is the clarifier performing adequately?**

  The inlet to the clarifier should reduce the flow (kinetic energy) of the water such that the current does not re-suspend settled solids. For upflow solids-contact clarifiers, does the operator keep the mixer in operation to keep the blanket in suspension after shutting down the unit?

  The surveyor should determine if the plant's operational procedures adequately address sludge removal. Those procedures should include removal of sludge from the sedimentation basins and ultimate sludge disposal from the treatment plant.

- **How does the PWS start and stop operations?**

  Treatment trains are subject to start up and shut down problems, and most unit operations operate best at steady state conditions. For systems that operate intermittently, the surveyor should ask to see how the treatment process works during startup and shut down, and should look for a reduction in performance if the system stops and starts often during the day.

- **Is there visible floc carryover onto the filters?**

  There should be little or no carryover of floc from the sedimentation basin to the filters. The surveyor should ask the operator what their turbidity goals are for settled water, and how they measure and track them. What actions do they take if the unit is not meeting these goals? The surveyor may want to calculate the surface overflow rate under peak flow conditions and compare the calculated value with the primacy agency's design standards.

- **Does the operator monitor settled water turbidity?**

  Turbidity monitoring in the sedimentation process is not required by regulations. However, some water systems monitor settled water turbidity to help manage treatment performance during different source water quality conditions, and achieve operational goals.

9.5.1.3 Filtration

- **Is the filtration process performing adequately?**

  The primary purpose of filtration is to remove solids. Measuring the reduction in turbidity through each filter is critical to determine particulate removal effectiveness. The surveyor should be concerned with the turbidity removal characteristics of each filter in service. Turbidity measurements of the combined effluent from multiple filters are not sufficient to assure adequate removal of pathogens as high performing filters tend to average out or mask the performance of a poorly functioning filter. If available information indicates that turbidity spikes move through the plant from source to clarifier to filter effluent, the surveyor should discuss with the operator how to investigate and find the cause.

- **Is there adequate pretreatment?**

  Water systems should monitor the quality of water entering the filters to ensure the filters will perform according to design guidelines. The filtration process, regardless of type, cannot perform effectively if the influent's characteristics are unacceptable. Note that this condition is also critical in slow sand, diatomaceous earth (DE), and membrane filtration systems.

- **Are there rapid fluctuations in the flow through the filter?**

  Rapid changes in flow can reduce removal efficiency and potentially cause filter breakthrough. The surveyor should record causes of rapid flow fluctuations such as operation procedures, recycling of backwash water, or a cycling rate control valve. The surveyor should determine if the operator maintains proper filtration and backwash rates, where applicable.

- **What controls and assessments does the operator use to evaluate filter performance?**

  The surveyor should determine what methods the operator employs, such as continuous turbidity and other monitoring, to evaluate performance, including raw and settled water turbidity, pH, alkalinity, and hardness. The surveyor should also determine the frequency of the evaluations. Surface water systems using conventional treatment or direct filtration must continuously monitor the turbidity of each individual filter and keep a record of the measurements taken at 15 minute intervals (40 CFR Part 141 subparts P, T, and W).

At each stage of the process, the surveyor should ask what the operational goals are, how they are measured, and how the operator responds when the filtration process is not meeting these goals. The surveyor should request those records and inspect them to make sure the filters are operating properly and that the system has not exceeded triggers that would require follow-up action.

- **Are instrumentation and controls for the process adequate, operational, and in service?**

  Because turbidimeters must be extremely accurate, they should be calibrated (secondary and primary standards) regularly, according to manufacturer's recommendations. Head loss through the filter is also important to filter operation, as is the use of rate of flow controllers. The instruments for these measurements and controls should be checked to ensure they are functioning properly.

  - Does the operator properly operate and maintain filters and related equipment?
  - Is there sand in the clearwell indicating underdrain failure or severe media problems?
  - Does the operator use a surface wash or air scour to break up the mat on top of the filter?
  - Does the operator check the media for accumulation of mud on the surface and mud balls within the media?
  - Does the operator manually clean the top layer of sand regularly if mud accumulation is a problem?
  - Is the media expansion during backwash adequate at all water temperatures?
  - Does the backwash rate increase and decrease slowly to avoid damaging the filter?
  - Does the operator probe through the media to check for adequate media depth and to find uneven gravel levels or dead spots where damage to the underdrain is not allowing bed expansion?
  - During operation, are there depressions, cracking, or other indications of short-circuiting in the media?
  - Is there filter-to-waste capability, and, if so, is it used? Ask about treatment goals for this phase of treatment, too.
  - Does the PWS have a maintenance plan for the filter and all related appurtenances?
  - Pressure filters are a special concern due to the difficulty of opening the bolted hatch for inspection and assessment; the surveyor should ask when the system last opened the hatch and inspected the filter for the above items.

- **What initiates a backwash, and is there a SOP in place?**

  The operator may initiate backwashing based on any number of factors including head loss, filter run time, or effluent turbidity. It is important that all operators of a system use the same criteria. In addition, the system should have a written SOP for backwashing and for returning the filter to service, to ensure that all staff do these tasks in the same way.

Backwashes initiated on filter run times are a default industry standard. Water systems in arid or drought stricken areas should evaluate whether filter run time is the best metric for determining when to backwash to ensure they are not wasting water and energy by backwashing their filters too often.

The surveyor should ask the operator to backwash a filter during the sanitary survey, if feasible, in order to determine the existence of any of the conditions noted above. The surveyor should also examine preventative maintenance and repair records.

- **What is the return to service process for filters?**

  Many water systems experience a turbidity spike if a filter is put back on line immediately after backwashing. To avoid this, systems filter to waste or let the filter sit for a while before returning it to service (i.e., filter ripening). The surveyor should discuss the process used by the water system for bringing filters back into service after a backwash and should ensure that this process is captured in the water system's SOP.

- **How is the backwash water treated and returned?**

  The surveyor should check how backwash water is disposed of to ensure compliance with state and federal regulations and to determine its impact on the treatment process. Research shows that recycling backwash water may concentrate *G. lamblia* cysts, *Cryptosporidium* oocysts, and DBPs.

  If the water system recycles its backwash, equalization or treatment of the backwash water and other recycle streams prior to their injection at the plant head-works helps minimize these risks. The surveyor should ensure the system is in compliance with the Filter Backwash Recycling Rule and any returned water is introduced before all of the treatment steps.

- **What is the rate of backwash water return flow?**

  Some water treatment facilities recycle some or all of the water used to backwash filters. The spent filter backwash water is delivered to the raw water pipeline prior to adding any treatment chemicals. The surveyor should ask how the rate of backwash return is controlled and if it is adjusted when plant flow rate changes. The surveyor should make sure the treatment plant complies with the Filter Backwash Recycling Rule's recordkeeping requirements.

- **If the plant is a conventional plant, is it meeting the DBP precursor removal requirements of the Stage 1 DBPR?**

  The surveyor should review the system's operating records and quarterly reports to the state to make sure the conventional plant is meeting its total organic carbon (TOC) removal requirements based on the water's alkalinity and raw water TOC measurements. Otherwise, the system should be using one or more of the alternative criteria to meet the TT requirement of the Stage 1 DBPR. The surveyor should request a copy of the system's DBP monitoring plan and review it as well.

- **Is there a plan for media replacement and filter inspection?**

  The surveyor should review the system's operating records to check that lost filter media is replaced with appropriate material to ensure the entire bed of media approximates the original filter media specifications. Occasional circumstances, such as a filter media upset or underdrain problems, may necessitate filter media replacement (AWWA, 2016a). Routine operations can result in filter media loss associated with the design and operation of the facilities such as the spacing of wash troughs, excess backwashing and air binding (Kawamura, 1991). AWWA B100 discourages the reuse of filter media because it may be worn, damaged, or contaminated during handling and thus create potential filtering problems if not properly combined with the other filter media to obtain a desired gradation.

9.6 Direct Filtration

This process is similar to conventional treatment, except for the absence of sedimentation. Direct filtration generally consists of coagulation, flocculation, and filtration using dual or mixed-media filters. A variation of this process, sometimes called "in-line filtration," includes only filters preceded by chemical coagulant application and mixing. Primacy agencies generally do not consider in-line filtration adequate treatment before disinfection. Direct filtration is best suited to systems that have high quality and seasonally consistent influent supplies with relatively low raw turbidity levels (e.g., consistently 25 NTU or less).

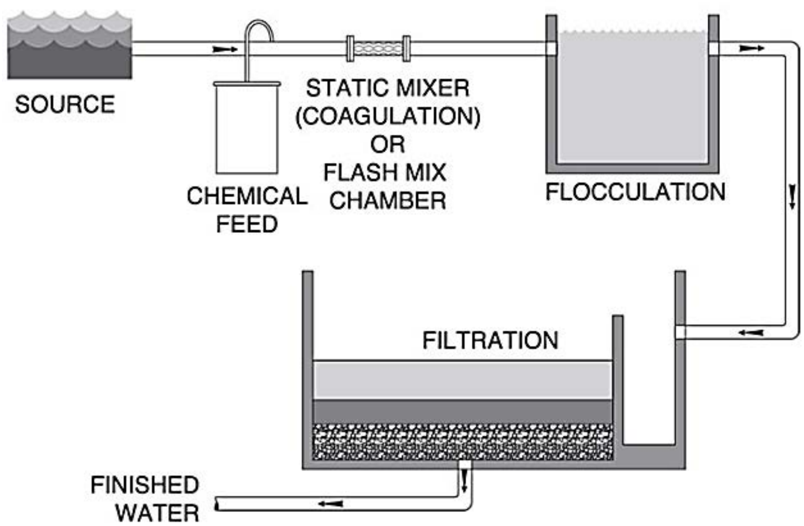

Figure 9-2: Direct filtration

9.6.1 Sanitary Deficiency Questions and Considerations – Direct Filtration

- **See the discussion above (9.5.1.1) on considerations for coagulation-rapid mix.**
- **See the discussion above (9.5.1.3) on considerations for filtration.**
- **Does the source water or treated water quality still justify direct filtration?**

  Because direct filtration does not include a sedimentation process step, this treatment technology is best suited to systems that use high quality sources of supply and have seasonally consistent water quality with relatively low turbidity levels (e.g., consistently 25 NTU or less).

9.7 Package Filtration

This technology generally includes the processes found in a conventional treatment plant. The manufacturer combines the unit processes in a "package" delivered to a site, where a simple hook up of pipes is all that is necessary to provide treatment. Package filtration may be cost effective for small communities, but requires skilled operators to achieve consistent performance. In addition, operators must pay particular attention to common walls between water at differing stages of treatment to ensure cross-connections do not develop, due to rust or over flow. This is particularly true when the raw water is susceptible to rapid changes in quality.

The surveyor must be able to determine if the operators are using proper process control procedures to ensure removal of turbidity and associated pathogens. A careful review of the system's operating records and logs will help make such determinations.

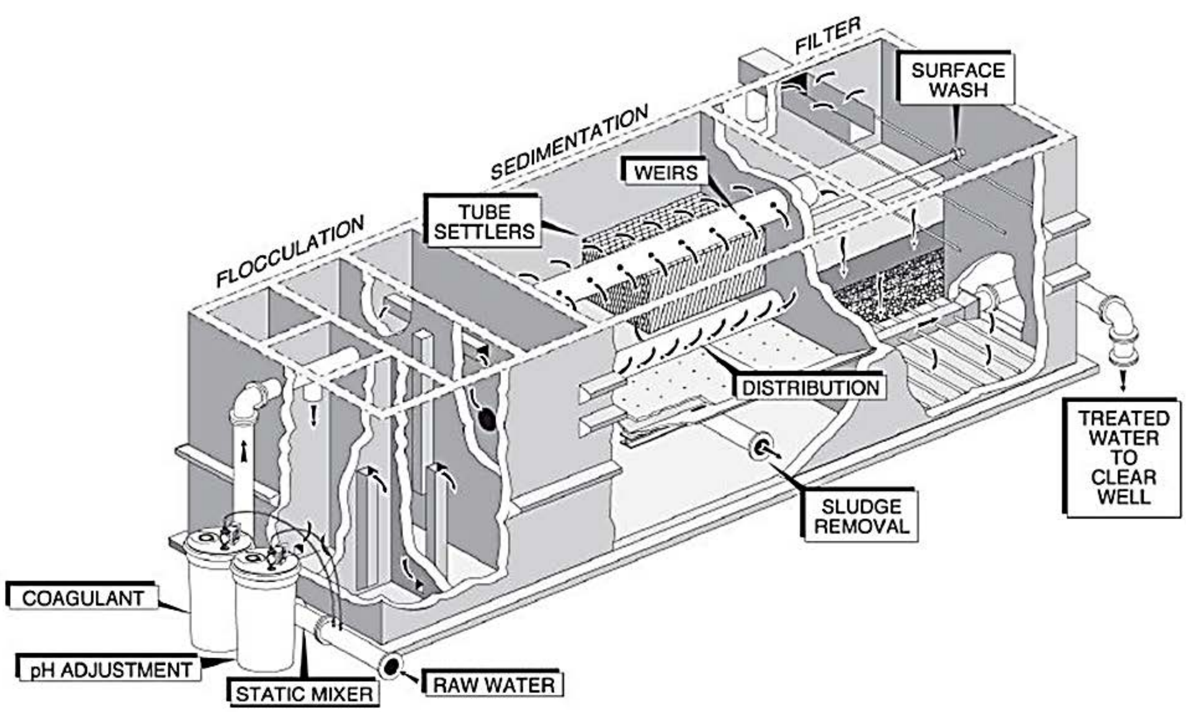

Figure 9-3: Package plant

9.7.1 Sanitary Deficiency Questions and Considerations – Package Filtration

- **See the discussion in 9.5.1.1 for considerations for coagulation-rapid mix.**
- **See the discussion in 9.5.1.2 for considerations for sedimentation.**
- **See the discussion in 9.5.1.3 for considerations for filtration.**
- **Is there any cross-contamination at common walls between water at different stages of treatment?**

  The operator should pay attention to common walls within the package plant between different treatment processes to ensure cross-connections do not develop due to rust or overflow. This is particularly true when the raw water is susceptible to rapid changes in quality.

- **Is the package plant operated within design criteria or state requirements or limits?**

  The surveyor should compare current operating criteria (e.g., flow rate, detention time) with plant design criteria and regulatory requirements.

- **Is the operator maintaining the plant according to manufacturer recommendations?**

  The surveyor should review the manufacturer's guidelines for operating and maintaining the package plant, and compare them with current operating and maintenance practices.

- **Are repair and replacement parts still available from the manufacturer?**

  The surveyor should review the system's inventory of spare and replacement parts, as recommended by the manufacturer, for the operation of the package filtration system. For package plants that have been in place for several years, the surveyor should also check with the operator about the continuous availability of replacement parts from the manufacturer.

9.8 Slow Sand Filtration

This process consists of a single medium of fine sand, approximately three to four feet deep. The medium is not backwashed as it is in a rapid sand filter; instead, operators manually clean it by removing the surface of filtration medium.

Slow sand filters operate in the range of 0.03-0.10 gpm/ft^2, and therefore require extensive land area. These filtration systems may be appropriate for small communities, but must include adequate (physical, not chemical) pretreatment. They are not suitable for raw water with high turbidities and rapidly changing quality. These filters operate under continuous submerged conditions and function using biological mechanisms (schmutzdecke) and physical-chemical mechanisms. Pre-chlorination is discouraged because it may impair the schmutzdecke.

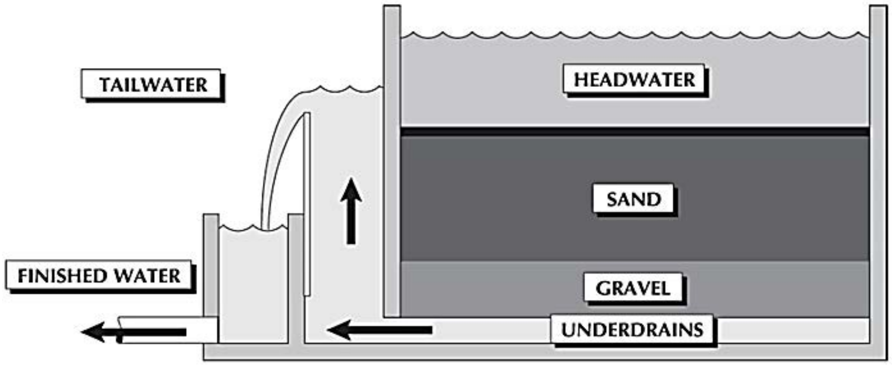

Figure 9-4: Slow sand filtration

9.8.1 Sanitary Deficiency Questions and Considerations – Slow Sand Filtration

- **What pretreatment does the water system use, if any?**

  What pretreatment, if any, does the PWS use? Do they use a screen or a roughing filter (coarser sand) prior to slow sand?

- **What method does the operator use to clean the slow sand filters?**

  What is the average and worst-case time between cleaning the filters? Is cleaning accomplished by scraping (the most common method) or by harrowing (low backwash rate while turning the medium)? What is the sand depth? The system should replace the sand when repeated scrapings have reduced the depth of the sand to approximately one half of its design depth.

- **Are there redundant slow sand filters?**

  Following scraping, slow sand filters perform poorer at the beginning of filter runs so filter-to-waste capability or a ripening period of 1 or 2 days is usually recommended. The operator should monitor filter effluent turbidity or particle monitoring to determine the end of the ripening period. The facility should have redundant units to allow the cleaned filter to build up a biological mat, or schmutzdecke, which builds on the top of the sand layer. Filters can return to service sooner when the harrowing technique of cleaning is used. Slow sand filter removal performance depends on microbes, and a lack of moisture reduces microbial growth. The surveyor should ask if the operator ever leaves the filter unsubmerged and, if so, for how long.

- **Is the slow sand filter covered and light-free?**

  Systems should enclose these types of filters in a light-free building to eliminate or minimize algae growth, to facilitate cleaning and to avoid ice build-up in the winter.

- **Are some filters taken out of service seasonally?**

  Slow sand filters are usually taken out of service for cleaning based on head loss. The surveyor should ask the operator what criteria are used to take a filter out of service.

- **What is the filter maintenance schedule and return-to-service process?**

  The surveyor should ask the operator the typical maintenance schedule for each filter and how long the return-to-service process takes. The surveyor should use this information to evaluate whether water demand can be met by the system when filters are being maintained.

9.9 Diatomaceous Earth Filtration

Diatomaceous earth (DE) filtration, also known as precoat or DE filtration, is appropriate for direct treatment of surface waters to remove relatively low levels of turbidity and microorganisms. Filters consist of a layer of DE (about 1/8-inch thick) supported on a septum or filter element and operate either in pressurized vessels or under a vacuum in open vessels. Manufacturers generally design these units for a filtration rate of 1 gpm/ft^2.

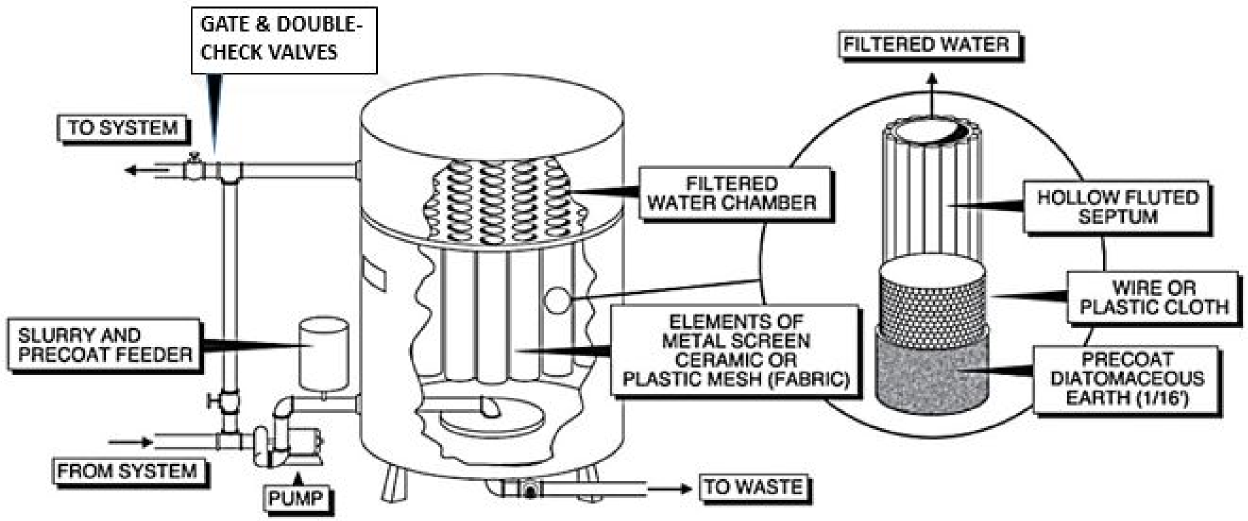

Figure 9-5: Diatomaceous earth filtration

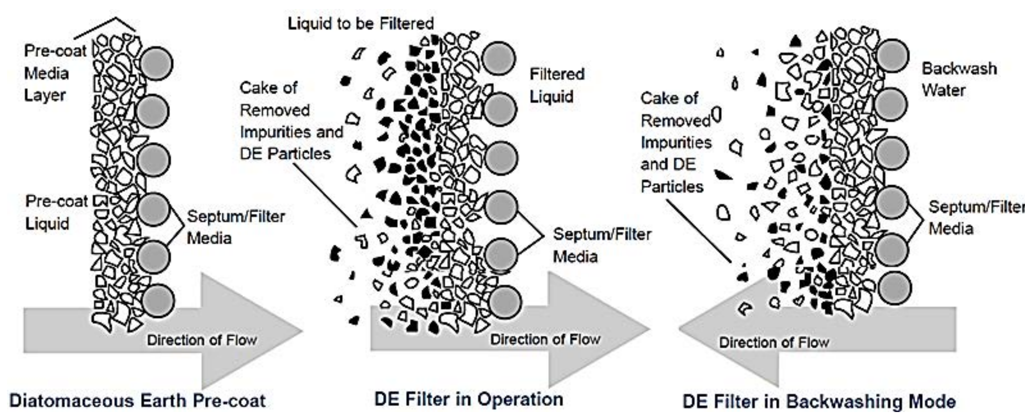

Figure 9-6: Filter mechanics of diatomaceous earth

Before a filter is ready for use, a pre-coat filtration process recirculates a DE slurry through the filter septum. This creates a thin, protective layer of DE. The septum is typically plastic or metal cloth mounted on a wire mesh-covered steel frame. After the pre-coat forms, the filter is ready for use.

Operators must feed a low dose of DE, called body feed, into the raw water to help reduce the rate of head-loss through the filter. The pre-coat surface separates the particulates, including the body feed, from the raw water flow where these particulates actually become part of the filter media.

9.9.1 Sanitary Deficiency Questions and Considerations – Diatomaceous Earth Filtration

- **What levels of pre-coat and continuous body feed does the operator maintain?**

  The recommended amount of filter precoat is 0.2 lb. per square foot of filter area or an amount sufficient to apply a 1/8 inch coating (10 States Standards, 2012). An EPA report recommended a minimum thickness of precoat filter cake of 3 millimeters (mm) to 5mm to enhance *G. lamblia* cyst removal (Lange et al. 1984).

  The filtration process must include a continuous body feed into the raw water to maintain the porosity of the filter cake. Also, if there is no body feed, there is a rapid increase in head loss due to buildup on the surface. Some water systems have found the addition of a coagulant coating (alum or a suitable polymer) to the body feed improves removal performance. What dosage does the operator maintain for body feed, and is the body feed continuous? Can the operator verify the dosages?

- **How does the operator handle flow interruptions?**

  Interruptions of flow cause the filter cake to fall off the septum, allowing pathogens to pass through the DE filter. For this reason, DE is not a recommended technology for on/off operation. Do the operator reestablish the pre-coating any time there is an interruption of flow at this facility?

- **When does the operator initiate backwashing?**

  The rate of body feed and size of the media are critical for determining the length of the filter run. Filter runs typically range from 2 to 4 days. Shorter runs minimize filtered water taste and odor problems arising from the decomposition of organic matter trapped in the filter. DE is effective for removing algae, but if prechlorination is used, the operator can expect increased taste and odor issues. The surveyor should determine whether this facility has taste and odor problems that are attributable to prechlorination or long filter runs. How often is the septum inspected and cleaned? How is spent filter cake disposed?

9.10 Bag and Cartridge Filtration

Manufacturers of bag filters typically construct them of non-rigid fabric filtration media housed in a pressure vessel. The filter is usually a woven fabric or felt made of materials such as polypropylene, polyester, nylon or Teflon. Typically, only felt filters have nominal pore sizes as low as 0.5 to 1 micrometer (µm), which are values likely to be associated with removal of *Cryptosporidium* and *G. lamblia*. Bag filters also include a sealing system on the open end of the filter at the connection to the water inlet.

Typical designs of cartridge filters include fiberglass or ceramic membranes supported by a rigid core or a rigid core wrapped with strings of polypropylene, acrylics or nylon. Nominal pore sizes range from 0.3

to 200 microns. The advantage of these microporous filters to small systems is that no chemicals, other than the disinfectant, are required and they are relatively simple to operate.

Pore size is a critical element in bag and cartridge filters, and primacy agencies usually require challenge testing to demonstrate the microbial removal capability. Use of bag or cartridge filters to meet *Cryptosporidium* removal requirements under the LT2ESWTR requires challenge testing and removal credits are limited because direct integrity testing cannot be used to verify the integrity of system seals while the filters are in use. Seal integrity is another critical element in bag and cartridge filters because faulty seals can allow pathogens to partially or completely bypass filtration. Bag and cartridge filters may be suitable for producing potable water from raw water supplies containing low levels of turbidity, algae, and microbiological contaminants. The use of this type of filtration is usually limited to low-turbidity waters (e.g., <1.0 NTU) because of susceptibility to rapid head loss buildup. Some installations address these limitations by using bag or cartridge filters after sand or multi-media filters, or by using preliminary bag or cartridge filters with larger pore sizes (e.g., 10 µm).

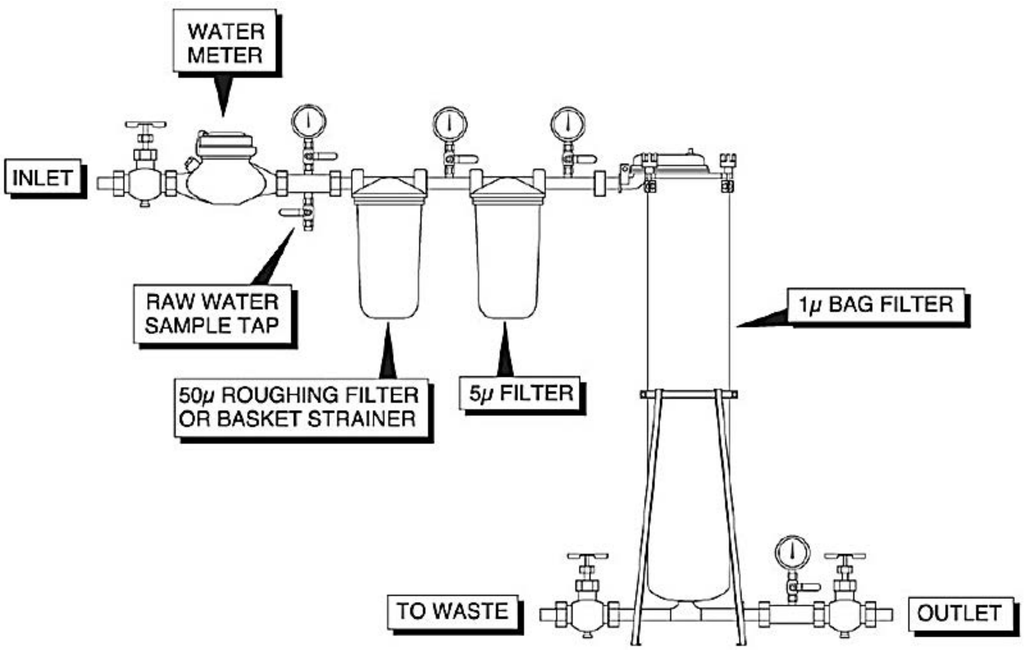

Figure 9-7: Bag and cartridge filtration

9.10.1 Sanitary Deficiency Questions and Considerations – Bag and Cartridge Filtration

- **What type of pretreatment is used?**

  Water systems can use bag and cartridge filters on raw water of any quality, depending on the degree of pretreatment provided. The surveyor should verify the pretreatment used at the facility and whether the system uses bags, cartridges or both as the primary treatment or as an extra level of physical removal to ensure public health protection (for example, filters added after a poorly performing conventional treatment plant).

- **Have the bags or cartridges undergone a demonstration study to show removal achieved?**

  Use of bag or cartridge filters to meet *Cryptosporidium* removal requirements under the L2 requires challenge testing. Removal credits are limited because direct integrity testing cannot be used to verify the integrity of system seals while the filters are in use.

- **Does the final unit provide the required level of removal?**

  The surveyor should verify the filters in use were challenge tested and approved by the state for microbial removal for the system. Challenge testing must be performed on full-scale bag or cartridge filters, and the associated filter housing or pressure vessel, that are identical in material and construction to the filters and housings the system uses for removal of *Cryptosporidium*. Bag or cartridge filters must be challenge tested in the same configuration that the system uses, either as individual filters or as a series configuration of filters. Have there been changes in operation, sources or quality of supply that suggest review of the level of treatment required?

- **What are the average and the shortest times between filter replacements?**

  The surveyor should ask the operator what seasonal site-specific conditions might shorten filter runs. The surveyor should verify that the facility has met the turbidity standard for finished water at all times. Is bag replacement so frequent that upgrades to the pretreatment are justified? The surveyor should make sure the system never operates without the filter cartridges or bags in place. There should be a supply of replacement filters and procedures in place for changing filters without bypassing filtration.

  Note: Replacement filters and bags must be identical to those used during challenge testing.

- **How is filter integrity and the need for filter replacement monitored?**

  Indirect indicators of leaks or loss of seal integrity include turbidity and pressure measurements. The operator should monitor and record turbidity, head loss and total number of hours in service to determine filter replacement cycles. Are there any indirect integrity tests required by the state and have they been performed?

- **Is the filter being used the same model as was approved by the state?**

  Because challenge testing is required before using this treatment technology, the water system should be currently using the same make and model of filters as was originally approved.

- **Is there an inventory of replacement filters and are replacement filters readily available from the manufacturer?**

  The water system should have replacement filter cartridges on hand to minimize service interruptions. If the manufacturer has discontinued or is planning to discontinue the product, the water system should conduct challenge testing on a new filter make and model.

9.11 Membrane Filtration

Membrane filtration processes act as selective barriers in water treatment, allowing some constituents to pass through the membrane filter while blocking the passage of larger constituents. Pressure driven membranes can achieve significant reductions in microbial contaminants and, in some cases, inorganic and organic compounds. Membrane filtration has become an attractive alternative for water systems because of its small footprint, lack of need for chemical coagulants and feasibility for both DBP precursor and microbial control. Membranes do produce a concentrated waste stream and some membranes are backwashed, resulting in a need for treatment and/or disposal. Periodic chemical cleaning is required, and the resulting product requires proper disposal.

There are four general types of pressure driven membranes discussed below. Site specific treatment goals provide the basis for membrane selection. Examples of site specific goals may include removal of inorganics, natural organic matter, particulates or pathogens.

The advantage of membranes is they can maintain filtered water quality even with changes in turbidity, microorganism burden, algae blooms, pH, temperature, or other influent water characteristics that would require treatment changes and operator action in other filtration processes. Under most circumstances, membrane systems lose operational performance such as increasing pressure differentials across the membrane and shortening of the time between cleanings with changes in influent water quality. Membrane integrity and the monitoring of membrane integrity, as well as waste stream and backwash treatment or recycle are the main concerns in the operation of membranes. Fouling and scaling of the membranes are also concerns, especially for high-pressure membranes.

9.11.1 Reverse Osmosis

RO uses high pressure to reverse the natural osmotic flow of dissolved minerals from the high concentration side of the membrane to the low concentration side of the membrane. The increased pressure on the high concentration side of the membrane forces the solute water through to the low concentration side of the membrane. Water systems typically use RO to remove salts from brackish water and seawater. The membrane excludes particles less than 0.001 microns and provides a barrier for cysts, bacteria and viruses so operators must maintain its integrity and the seals, which are common points where breakthrough can occur.

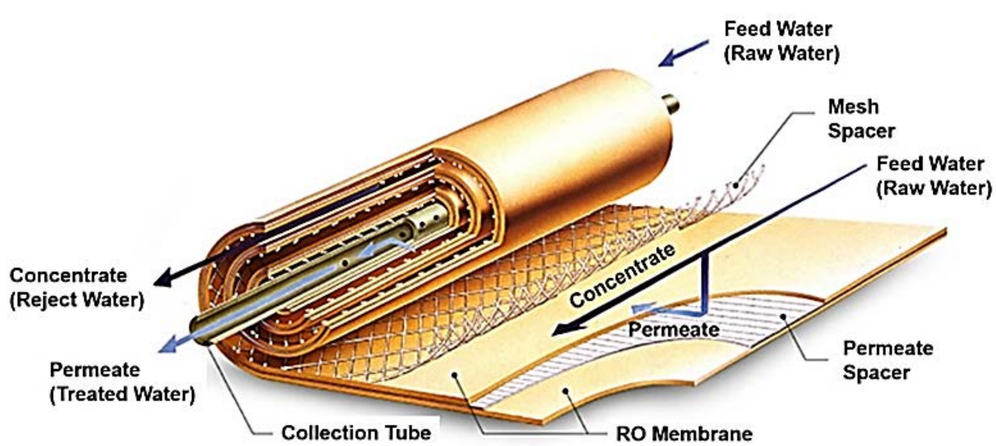

Figure 9-8: Spiral wound RO filter core[9]

[9] Source: http://www.aquanext-inc.com/en/product/desalination02.html

9.11.2 Nanofiltration

Nanofiltration (NF), also called membrane softening and low pressure RO is effective in the removal of calcium and magnesium ions (multivalent cations or hardness). It is also a very efficient membrane for removing natural organic matter to control DBPs. The membrane excludes molecules larger than 0.001 microns, the organic compound range, and provides a barrier for cysts, bacteria and viruses.

9.11.3 Ultrafiltration

Ultrafiltration (UF) uses low-pressure membranes to remove natural organic matter and particulates. UF excludes molecules larger than 0.01 microns, the molecular/macromolecular range, and is a barrier to cysts while providing partial removal of bacteria and viruses.

9.11.4 Microfiltration

Microfiltration (MF) uses low-pressure membranes to remove particulates and suspended solids. The membrane excludes molecules larger than 0.1 microns, the macromolecular/micro particle range and is a barrier to cysts and provides partial removal of bacteria. It does not provide significant removal of viruses.

9.11.5 Membrane Challenge Testing

Because the removal efficiency of a membrane is product specific, manufacturers or water systems must conduct challenge testing on full scale membrane modules that are identical in material and construction to those the water system uses in its treatment plant to demonstrate the removal efficiency. During challenge testing, feed water to the unit must include the organism itself or a surrogate that the membrane cannot remove more efficiently than the target organism. The results of the challenge testing establish a quality control release value (QCRV), used for a non-destructive performance test that demonstrates the removal capability of production units. Operators should conduct additional challenge testing and establish a new QCRV value for significant changes to the membrane.

9.11.6 Membrane Integrity Testing

In order for a membrane process to be an effective barrier, the filtration system must be free of integrity breaches. Operators must understand the importance of evaluating membrane integrity on an ongoing basis. Direct integrity testing is a very accurate means of assessing the integrity of a membrane filtration process, as it is a physical test applied to a membrane unit to identify and isolate integrity breaches. This assessment subjects all the physical components of the entire membrane unit, including the membranes, seals, potting material, and associated valves and piping to the testing. Commonly used direct integrity tests are an applied pressure or vacuum and measurement of a particulate or molecular marker.

Operators should conduct direct integrity tests on a regular basis (LT2ESWTR requires testing at least once per day) then compare the results to a system specific control limit. If the direct integrity test exceeds the control limit, the operator removes the membrane from service for repair then conducts another test to verify the repairs.

Since operators only conduct direct integrity testing periodically, they should also implement some level of continuous monitoring to measure process performance between direct integrity tests. Operators can conduct continuous indirect integrity testing to monitor membrane performance between direct integrity tests using turbidimeters or particle counters.

9.11.7 Sanitary Deficiency Questions and Considerations – Membranes

Note: The sanitary deficiencies related to chemical feed systems earlier in this chapter are also applicable to this section.

- **What type of membrane is used, and what is its intended purpose?**

  The surveyor needs to identify which of the above categories of membranes the system uses and why the system selected that type. What are/were their treatment goals? For example, they may have chosen NF to remove the organic compounds that are precursors to DBPs.

  The surveyor should verify that the membranes in use are the same as what the state approved for the system and that the system is operating the units consistent with any state required operating conditions or restrictions.

- **What type of pretreatment is used?**

  Systems may use a fine mesh screen or cartridge for pretreatment to protect MF and UF membranes from large particles. For RO and NF systems to operate economically, pretreatment processes have to remove suspended solids, microorganisms, and colloids. Systems often use MF and UF as pretreatment for RO and NF. The operator should describe what pretreatment the system uses prior to the final membrane.

- **How is membrane integrity being determined?**

  The surveyor should ask the operator about any procedures and frequency for direct integrity testing. What control limits has the operator defined to determine the removal of a membrane from service? If membranes frequently need repair or replacement, has the system investigated the cause? The surveyor should assess the type of indirect integrity testing used, including the calibration and maintenance of instrumentation. What criteria does the operator use to determine when they need to conduct direct integrity tests?

- **What measures does the operator use to control membrane fouling?**

  Are redundant units available, in case one of the units fails or the operator remove it for cleaning or membrane replacement? What are the fouling rate and life of the membranes?

  The degree of pretreatment and pH control helps minimize the fouling rate. The smaller the pore size of the membrane, the greater the concerns about fouling. MF usually does not need pH adjustments since it does not remove uncomplexed dissolved ions. The surveyor should ask the operator to describe the fouling problems that the facility experiences and how they affect membrane life.

- **What is the percentage recovery and what technique does the operator employ for backwash?**

  The surveyor should determine the percentage recovery (the percentage of raw water that makes it through the membrane) for the membranes used at the facility. The surveyor should also discuss how backwashing is accomplished (for example, gas backwash), how often it is performed, and how the raw water quality affects the volume required.

- **If backwash is recycled, how is it treated and what is the percentage added to the raw water supply?**

  The spent filter backwash water could be recycled back to the raw water piping entering the treatment facility. The surveyor should review regulatory requirements and check that any recycled backwash water is pretreated as required. The surveyor should ask the operator what percentage of the backwash water is recycled.

- **What is the frequency of cleaning and disposal of cleaning fluids and brines?**

  How often do the membranes require cleaning? The operator should describe what chemicals are used and how the system disposes of them. Several methods are available for brine disposal: sanitary sewers, surface water streams, lagoons or holding ponds, land application, underground injection, and recycling back to the head-works. The surveyor should check to see that brine is properly disposed. Some contaminants, if present in high concentrations in the raw water, may create a brine that is a hazardous waste.

- **What is the condition of the plant, gauges, and appurtenances?**

  Membrane plants are mechanically complex and have many automatic valves and many more connections that require o-rings to achieve a tight water seal. The surveyor should determine whether all the valves are operating properly and whether there are leakage problems throughout the piping network.

- **Is the membrane filtration plant's operation consistent with primacy agency conditions or limits?**

  The surveyor should review primacy agency requirements for membrane filtration operations and check that current operating criteria meet these requirements.

- **What is the replacement schedule for the membranes?**

  The surveyor should ask the operator about the membrane replacement schedule and the expected service life.

9.12 Possible Significant Deficiencies for Turbidity Removal

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The state (primacy agency) determines both significant deficiencies and the corresponding corrective actions.

- Failure to calibrate turbidity monitoring equipment or to <u>record</u> above the regulatory threshold (i.e., "capped").

- Inadequate process control testing or record keeping.
- Key chemical feeds are not flow-paced.
- No overfeed protection of a chemical feed (lack of flow-control switch).
- Inadequate process control sample locations (e.g., no way to measure dosages).
- Insufficient or missing backflow prevention for surface wash or air scour filters.
- Intermittent coagulant feed.
- Insufficient mixing or too vigorous mixing at chemical feed points.
- Exceeding any of the NPDWRs turbidity performance requirements resulting in TT violations.
- No integrity testing of membranes.
- Membrane, bag, or cartridge filters replaced with unapproved models.
- Alternative filtration technologies not approved by the state or not operated according to state-approved conditions.

10 Finished Water Storage Facilities

Finished water storage facilities ensure that the distribution system is under constant positive pressure and that there is a reserve of drinking water to meet peak demands and emergencies such as fires. These water storage tanks must be designed, operated, and maintained to protect the water from contamination or degradation as it passes through the tank into the distribution system to the customers' homes.

Storage facilities are one of the eight essential elements of a sanitary survey. Failure to maintain the structural integrity of a storage facility could potentially lead to structural failure of the tank, service interruption, environmental damage, injuries, and loss of property. Failure to maintain the sanitary integrity of the tank could lead to water contamination, degradation of water quality, illness, or death.

10.1 Learning Objectives

- Identify key data needed regarding design, maintenance, and operation of storage facilities, in order to determine their adequacy and reliability.
- Understand the difference between water treatment clearwells and finished water storage facilities.
- Understand the various types of finished water storage facilities and their typical applications.
- Review the major components of ground, elevated, and hydropneumatic finished water storage facilities.
- Evaluate operator safety practices (e.g., fall protection, confined space) and equipment in relationship to storage facilities.
- Recognize sanitary deficiencies related to the capacity, physical condition, contamination risks, and operation of storage systems.

10.2 Data Collection

To evaluate finished water storage for sanitary deficiencies, the surveyor should gather the following information:

- Type and volume of finished water storage facilities.
- The results of the last inspection by a structural engineer.
- Maximum and minimum pressures at high and low elevations in the system.
- Maximum and minimum pressures in each pressure zone.
- Documentation of state approval for changes to or installation of the tanks.
- Number of pressure zones in the distribution system.

- Verification of the presence of a hydraulic model of the system.
- The type of chlorine residual testing method used by operators.

10.3 Regulations and Standards to Consider

The surveyor should consider and review the following information prior to the survey:

- Occupational Safety and Health Administration (OSHA) regulations and OSHA-approved state plans for fall protection and confined space.
- AWWA Standards for Storage Tank Design and Construction (e.g., D100, D103, D115).
- AWWA Standards for Tank Appurtenances (e.g., D106, Cathodic Protection Systems).
- AWWA C652-11 - Disinfection of Water Storage Facilities.
- AWWA G200 Standard, Distribution Systems Operation and Maintenance.
- System construction standards.
- State construction standards.

10.4 Basic Information About Finished Water Storage Facilities

10.4.1 Types of Finished Water Storage Facilities

Types of finished water storage tanks include standpipes, elevated tanks, ground level tanks, and buried tanks.

A gravity storage system offers several advantages over other (e.g., hydropneumatic) systems.

- Greater flexibility to meet peak demands with less variation in pressure.
- Storage for fire-fighting use.
- One to five days of storage, to meet needs.
- Use of lower capacity wells (well not required to meet peak demand by itself).
- Sizing of pumps, to take better advantage of electric load factors (able to pump during discount hours).
- Reduced on-and-off cycling of pumps.
- Reduces or prevents water hammer.

10.4.2 Vulnerability of Tanks

Tanks are the most vulnerable part of the distribution system. Although tanks protect against contamination entering the network of distribution pipes, the positive pressure they create does not protect the tanks themselves, because the positive pressure is negligible at the air/water interface. This makes tanks a potentially vulnerable part of the distribution system, not only because there is no pressure at the top, but also because there are designed openings to the atmosphere via vents, overflows, hatches, roof to sidewall connections, attached appurtenances and unplanned openings.

A very small system will often use a pressurized tank known as a hydropneumatic tank to provide pressure and limit the cycling frequency of pumps.

10.4.3 Adequate Volume and Pressure

Water systems should be able to provide safe water at all times, in adequate volumes, with sufficient pressure. The surveyor should review the primacy agency requirements for storage tank capacity (i.e., volume) and system pressure. Low pressure, inadequate volumes, and contaminated water from storage facilities are a result of poor design, construction, operation, or maintenance.

10.4.4 Varying Demand for Water

Demand for water in a distribution system changes significantly throughout each day. As the demand varies, a properly operated finished water storage facility acts as a reserve, or buffer, that prevents sudden changes in water pressure in the system, and helps to meet peak demand periods that exceed the available pumping rate. Table 10-1 is an example of using the average daily demand to evaluate pumping and storage operations. In addition to storage tank capacity, the surveyor needs to know the capacity of each pump used to fill the tank, and the hours of operation. Pumps are typically not operated 24 hours per day. From the data collected and summarized in Table 10-1, it appears that Pump #2 could meet the average day demand without using any finished water storage by pumping for 12 hours per day. However, water demand varies throughout a day (Table 10-2 gives one example). The example data in Tables 10-1 and 10-2 show that neither pump is capable of providing enough water to meet peak demands, and therefore, the finished water storage tank is needed to meet these demands.

Because each water system has unique water demand characteristics, system configuration (i.e., relationship of tanks to distribution piping to customer locations), and operating conditions (e.g., pressure, flow, tank operating levels, pump cycling), the surveyor should review average and maximum daily water demand data, and operating practices with the system operator to help assess the adequacy of the available finished water storage tanks.

Table 10-1: Example of Average Daily Demand for One System

System Population		800 persons
Average daily per capita usage		100 gallons
Average Daily Demand (ADD)		800 x 100 = 80,000 gpd = 56 gpm
100,000 gallons elevated storage (tower); 2 pumps supply the system and fill the tower		
Pump #1	85 gpm	61,200 gpd (12-hour pumping)
Pump #2	120 gpm	86,400 gpd (12-hour pumping)

Note. gpm = Gallons per minute, gpd = Gallons per day

Table 10-2: Example of Varying Daily Water Demands for One System

Time of Day	Average Demand	Demand
3 a.m.	Low	30 gpm
7 a.m.	Showers, Dishes	56 gpm
3 p.m.	House Fire	750 – 1,000 gpm

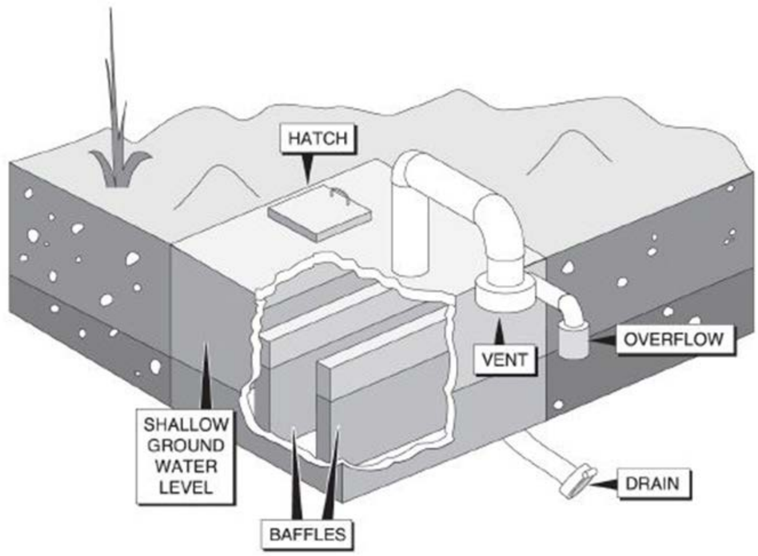

Figure 10-1: In-ground storage

10.4.4.1 Gravity Storage

Many of the following items apply to clearwells, as well as to storage in the distribution system. Gravity storage facilities (tanks) should be elevated to maintain sufficient pressure to all customers within the service area. The needed elevation can be achieved by constructing the tank on structural supports above ground or by erecting the tank on a hill.

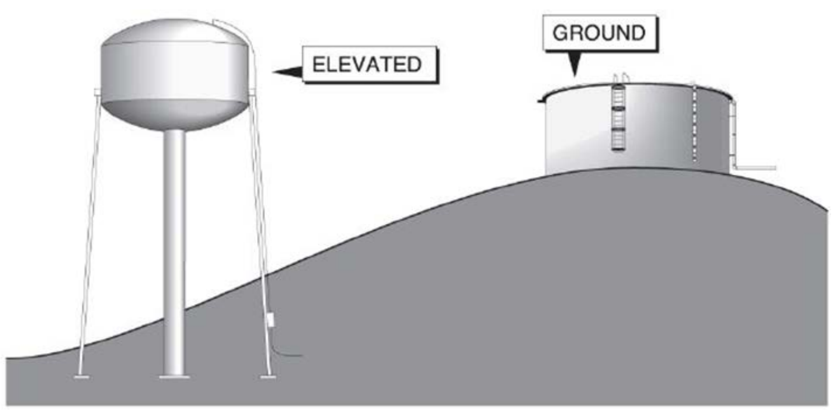

Figure 10-2: Elevated storage and ground level storage

10.4.5 Tank Shape

When gravity storage is used, the pressure at the head of the distribution system fluctuates with the water level in the tank. Shallow, large-diameter storage tanks are preferred over deep, small-diameter tanks because the larger diameter tanks have more water per foot of drawdown and are thus less prone to pressure fluctuations.

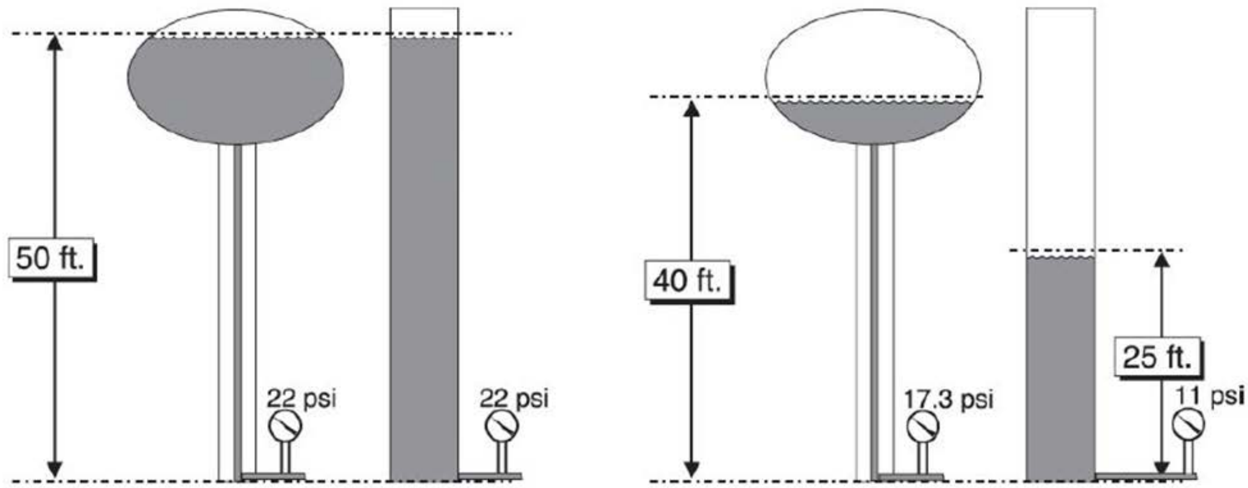

Figure 10-3: Large vs. narrow diameter tanks

10.4.6 Materials of Construction

Buried and partially buried tanks are typically constructed of reinforced or pre-stressed concrete, designed to withstand the pressure from the surrounding ground, or they could be earthen reservoirs with some concrete structures. Ground level tanks may be constructed of concrete or steel. Elevated tanks and standpipes are typically constructed of steel.

10.4.7 Components

Typical tank components include:

- Air Vent:

  Gravity tanks should be equipped with a rooftop air vent to allow air to move in and out as the tank is filled and emptied. If the vent is not designed and maintained to allow adequate air flow in and out, the tank could be damaged from either a vacuum or an excess pressure condition. The vent design should prevent rain, snow, and wind from carrying contaminants into the finished water. The vent opening should be protected with a non-corrodible screen to keep birds and insects from entering the tank. The screen should meet primacy agency requirements. The Ten State Standards specify a 24 mesh screen for ground level tanks and a four mesh for elevated tanks and standpipes. Elevated tanks should have a vacuum/pressure relief mechanism to protect them against excessive pressure or vacuum that can damage the tank.

- Overflow:

  The overflow pipe is used to discharge water from the tank when it is overfilled. The overflow pipe does not provide venting of the tank; each tank should be equipped with a separate vent. The diameter of the overflow pipe should allow a free flowing discharge. The overflow pipe should be extended to a set distance above the ground level according to primacy agency requirements. The overflow outlet should be equipped with a non-corrodible screen to prevent rodents, birds, and insects from entering the finished water. The screen should meet primacy agency requirements. The Ten State Standards specify a 24 mesh screen for ground level tanks and a four mesh for elevated tanks and standpipes. Some water systems also install a flapper valve or a duckbill valve on the overflow pipe outlet but in cold weather, these valves may not work properly due to ice or snow. The surveyor should always inspect the overflow outlet to make sure the screen is intact and meets primacy agency standards. The tank overflow should not be directly connected to a sanitary sewer, storm or tank drain. The tank overflow outlet should not be submerged into any type of drain. If the overflow discharges above a storm sewer, horizontal displacement of the overflow outlet should provide a suitable air gap from the storm sewer. The overflow should discharge over a splash plate or engineered outlet (concrete or riprap) that will not submerge the overflow when spilling.

  Note: The spilling of water through the overflow should be a rare event that initiates an immediate response. An overflow usually means the tank alarm and control system has failed (e.g., pump control, Supervisory Control and Data Acquisition (SCADA)/telemetry systems).

- Drain pipe:

  The drain line is used to remove water from the tank for inspections and maintenance. Before the tank is taken out of service, most of the finished water is discharged to the distribution system through the tank outlet pipe. The remaining water is discharged through the drain line to either a storm drain or sewer, or to the ground. The drain line should not be directly connected to the storm drain or sewer. It should be equipped with a gate valve that is normally closed. An insect screen is not needed for the drain line since the valve can only be opened manually and would only be opened for short time period when the operator is on-site. The outlet should visibly terminate some distance above the ground, as required by the state (typically, 24 inches).

- Access Hatch:

  Each finished water storage facility should be equipped with two access hatches large enough for a person to enter the tank to conduct inspections or maintenance. One access hatch should be on the roof and one on a sidewall. The rooftop access hatch should have a shoebox design and a gasketed, lockable, watertight hatch cover.

- Inlet and outlet piping:

  Inlet and outlet piping connect the tank to the distribution system. Tanks that “float” on the system typically have one pipe that serves as both the inlet and outlet pipe. Separate inlet and outlet pipes are preferred because they help to circulate water within the tank and provide uniform water quality.

- Isolation valve:

  Isolates the tank from the distribution system. Water utilities need to design their distribution system such that they will not lose pressure when operators take a tank offline for cleaning and repairs.

- Mixer:

  Some water systems install mixers within the finished water storage tank to improve water circulation, make water age more uniform, and improve water quality. The surveyor should check primacy agency requirements or recommendations regarding mixers.

- Water quality sample taps and monitoring station:

  Some water systems install sample taps or water quality instruments at the tank outlet or within the tank to measure pH, temperature, and disinfectant residual.

- Cathodic protection system:

  Steel tanks may be equipped with a cathodic protection system to minimize corrosion. The cathodic protection system requires routine inspection and maintenance per the manufacturer's recommendations.

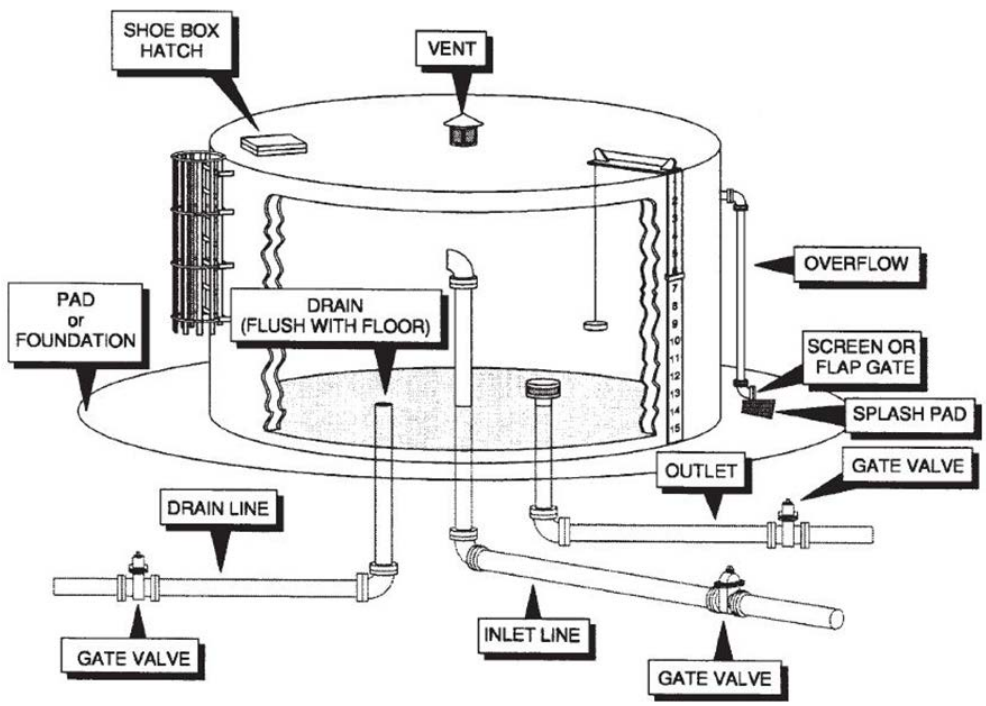

Figure 10-4: Tank components direct pumping (dedicated inlet and outlet)

- Ladders and walkways:

  Ladders and walkways facilitate inspection and maintenance of the tank interior and exterior. The exterior ladder should be locked, and the lower section removed to prevent unauthorized access. Internal catwalks should have a solid floor with raised edges to keep dirt out of the water. Operators need to maintain these structures to avoid failure due to rust. Ladders and walkways should be equipped with fall protection systems (e.g., railings, cages) as required by OSHA regulations.

- Security Measures:

  Because a finished water storage tank is typically in a remote location and not manned by an operator, it may be subject to vandalism. The security requirements for each tank site are dependent upon the tank location, the relative risk of vandalism, and water system preferences and available budget. Security measures may include fencing and gates; lights; locks on hatches, ladders, vaults, and buildings; intrusion alarms; and cameras.

- Water level instrument:

  Every tank should be equipped with an instrument that can measure water level. There are different types of level instruments. The floating type of level instrument floats on the surface of the water and is connected to a counter-weight that shows the water level on a gauge on the tank exterior wall (manual reading of water level only). A pressure sensor can be used to measure water pressure and converts the pressure to an electrical signal that represents tank level. Ultrasonic and radar level sensor determine the water level by transmitting and receiving a signal from the sensor to the water level. Level instruments that provide water level readings as an electronic signal can be connected to a Supervisory Control and Data Acquisition (SCADA) or telemetry system to provide current readings to the operators' control room. They can also be configured to trigger an alarm for low level and high level setpoints, and to set operating levels that are used to turn pumps on and off.

- Altitude valve:

  For tanks that float on the system, an altitude valve is needed to control tank filling operations and prevent the tank from overflowing.

- Valve pit:

  A below-grade vault that contains an altitude valve, isolation valve, and drain valves.

- Impermeable Membrane Liner for Buried Concrete Tanks:

  Buried tanks should be equipped with an impermeable membrane layer on top of the concrete roof to prevent untreated surface water from entering the finished water.

10.4.7.1 Tank Filling Operations

Direct pumping: Ideally, finished water enters at the top of the tank and the water must flow through the tank to the outlet at the bottom.

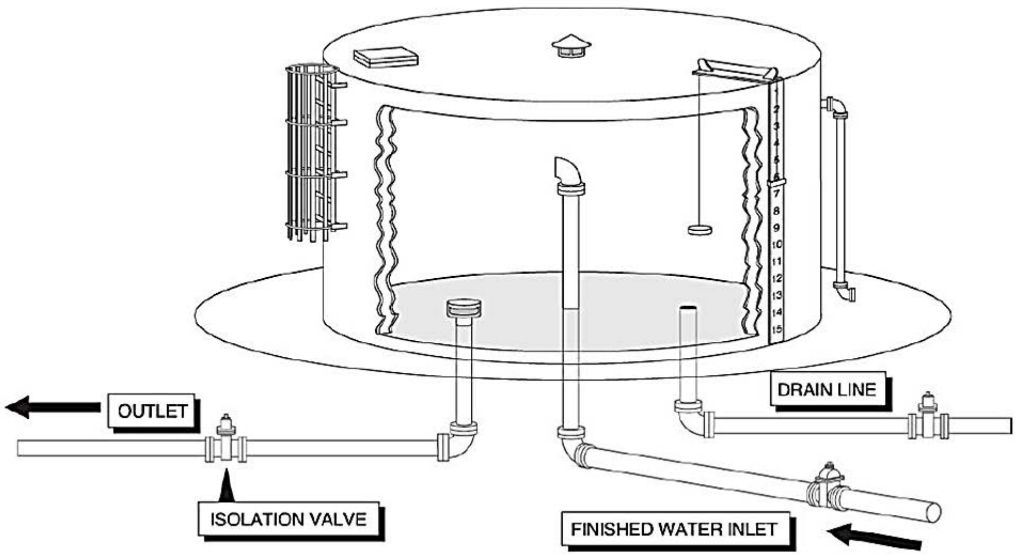

Figure 10-5: Direct pumping

Floating tank: Service pumps may send water directly into the distribution system before filling a storage tank. These tanks usually ride or float on the system and may be located several miles from the treatment facilities. This type of tank has a single inlet and outlet, so finished water can actually bypass the tank.

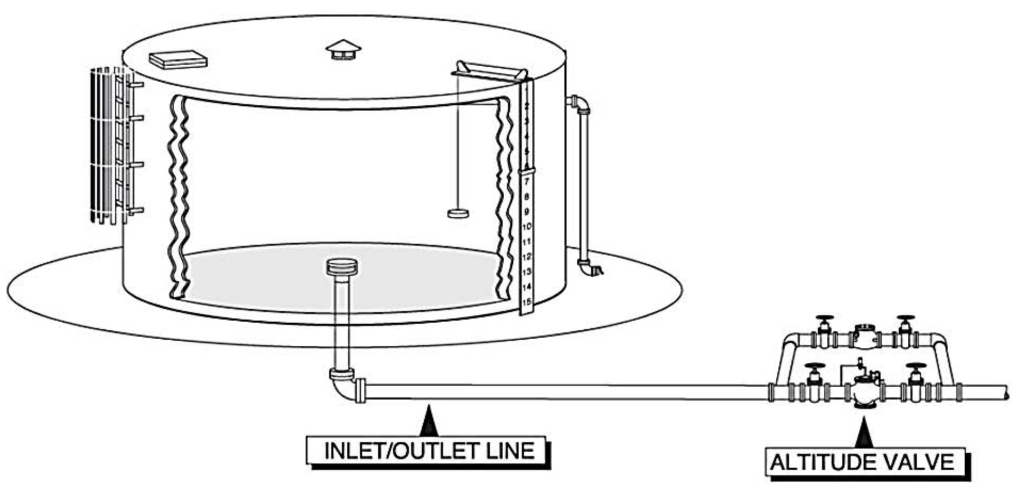

Figure 10-6: Side stream components for tank with single inlet/outlet

10.4.8 Sanitary Deficiency Questions and Considerations - Gravity Storage

- **Is the storage system designed for direct pumping or floating on the distribution system?**

  Direct pumping systems offer an advantage over floating systems in that the storage tank provides additional chlorine contact time, while minimizing DBPs. Direct pumping systems, however, tend to have higher fluctuations in head pressure than floating systems. In floating systems, the service pumps may send treated water directly to the customer through the distribution system, when the demand is high.

- **Is the storage capacity adequate?**

  The total storage capacity for gravity storage systems should be sufficient, as determined by engineering studies or state standards, to meet domestic demands. These systems should have enough reserve capacity to meet fire flow demands (if fire protection is provided) and allow for extreme conditions such as power outages where the pumps would be unavailable unless the system were to provide auxiliary power. Utilities that lack adequate storage run the risk of losing system pressure.

- **Is the storage over-sized?**

  Conversely, storage facilities that are over-designed run the risk of depleting the chlorine residual and creating DBPs, as well creating taste and odor problems. The water system should balance the capacity needs for fire protection with those required for adequate tank turnover, to prevent stagnation. Failure to use and replace water on a regular basis (tank turnover frequency) can cause the depletion of disinfectant residuals and cause the production of DBPs. In addition, ice buildup can be a threat to the tank.

- **Do storage tanks turn over regularly?**

  Finished water storage tanks should be designed to minimize stagnation and water age using either separate inlet and outlet pipes or mixing. Water that is not turned over on a regular basis can become stagnant, causing taste and odor complaints, a reduction in chlorine residuals, and/or an increase in bacteriological activity and DBP formation.

- **Is the pumping capacity adequate?**

  The pumping capacity must be able to supply water for both normal peak demand and potential fire demand, while preventing the excessive loss of head pressure in the tank. (Many small systems are not designed to meet fire demands.)

- **Is the elevation of the tank sufficient to maintain pressure throughout the distribution system?**

  The surveyor should review the primacy agency requirements for system pressure, and make sure each finished water storage tank delivers water at the appropriate pressure. The Ten States Standards specify a minimum of 35 psi and a normal working pressure of approximately 60-80 psi.

- **Is there a need for separate pressure zones?**

  In communities that have varying topography, customers in the higher elevations could experience low water pressure if the gravity storage system lacks separate pressure zones. The surveyor should determine if the operator is meeting minimum and maximum allowable pressures throughout the distribution system.

  The surveyor should not assume the operator is actually managing a well-designed storage capacity properly. During the sanitary survey, the surveyor should evaluate the operational strategy of the storage system, to ensure the operator is maintaining minimum pressures, while minimizing water age (tank turnover).

- **Does the operator understand the controls that regulate tank water levels?**

  The operator should understand the functions of the water level control systems and should be capable of making minor adjustments. There should be a record of control pressures and elevation for each phase of the pumping cycle. The record should include the pressures that activate the alarms.

  The operator of a system that has altitude valves and multiple tanks should be capable of taking pressure and water-level readings, and adjusting the valves to control tank levels.

- **Are there adequate settings for tank operating levels?**

  The difference in the tank operating levels should be sufficient to allow for mixing of the water to minimize stagnation while also maintaining the required distribution system pressure.

  The tank level fluctuations should be sufficient to prevent excessive pump cycles during hours of peak usage. Controllers should allow the water in the tank to rise to the high-level set point that turns off the pump. If the control fails and the pump does not turn off, it will trigger the overflow level alarm.

- **Are control systems reliable and properly protected?**

  Determine if the controls are suitable for the application and are functioning properly. Each storage facility should be equipped with a manual override and an alarm system to warn of pump failures, as well as overflow and low water levels. The surveyor should note the general condition of the control devices and wiring, and determine if the system has installed adequate protection from lightning and other outside elements.

- **Is the water level indicator operational?**

  Every storage tank should have a reliable means of measuring the water level. If properly maintained, a float and staff gauge is a reliable level indicator in warmer climates; however, this type of level instrument provides only a manual reading and not an electronic signal that can be transmitted to another location via telemetry or SCADA. Level instruments that directly contact the water do not work reliably in cold weather. Other types of level instruments include pressure transducers, ultrasonic, and radar. Level instruments should be calibrated at least annually.

  Pressure gauges are acceptable for determining the water level, but operators need to perform occasional visual checks inside the tank to verify the pressure gauge accuracy.

  (Note: 1 psi = 2.31 ft.; 1 ft. = 0.433 psi.)

- **Is there a cleaning, inspection, and maintenance program?**

  Water systems should complete a comprehensive inspection of each finished water storage tank every three to five years (AWWA, 2013) to assess the condition of the structure and coatings, and to identify any cleaning and maintenance needs. The recommended inspection frequency is unique to each tank and dependent upon its age and condition. The structural and coating evaluations should be completed by an engineer with proper training and certification credentials. During the sanitary survey, the surveyor should ask for a copy of the latest inspection report and check whether the recommended maintenance items were addressed.

If excessive sediment or other issues are detected during the inspection, the tank should be removed from service for cleaning and any repairs. The tank can be cleaned by draining water from the tank and cleaning it manually. Alternatively, the tank can remain full of water and be cleaned with a diver or a remotely operated vehicle.

If the tank is equipped with a cathodic protection system, it requires routine maintenance according to the manufacturer's guidelines.

In between these comprehensive surveys, the operator should also conduct daily to biweekly surveys to observe the condition of the tank and to check the tank site for signs of vandalism or unauthorized access. The operator should periodically climb each tank to check the condition of rooftop appurtenances (e.g., vent screen, hatch seal).

- **Is all finished water storage covered?**

  Water systems should cover finished-water storage tanks to prevent airborne contamination, such as that from birds, insects, small animals and algae. The NPDWRs require all finished water storage to be covered; otherwise systems must treat the discharge from the reservoir to achieve inactivation or removal of viruses, *G. lamblia*, and *Cryptosporidium* using a protocol approved by the State (40 CFR 141.714). Covers should be watertight, made of permanent material, and constructed to drain freely and prevent contaminants from entering the stored water. The water system should not use the top surface of the storage tank for any purpose that may damage the cover or result in contamination of the stored water. The operator should maintain the seal between the roof and sidewall joint. If a water system has an uncovered finished water reservoir, the water must be treated according to requirements in 40 CFR 141.714 before the water is delivered to the distribution system.

  Air Vents:

  - Is the vent equipped with a non-corrodible screen that meets state or other standards?
    - All vents (ground level and elevated) should have a screen that meets primacy agency standards, to keep birds, rodents, and insects from entering the tank. Metal elevated tanks should have a pressure/vacuum relief mechanism (e.g., movable palette, flexible inner screen, low pressure vacuum/pressure relief valve, etc.) to prevent tank damage. Extreme vacuum events should not be able to draw the screen into the tank.
  - Does the vent terminate above the roof and meet state or other standards?
    - Vents allow air to enter and exit the tank. The vent should also protect against rain and snow, and minimize light and dust from entering. If the vent is down-turned, it should be an inverted "U" shape or adhere to primacy agency standards.
    - If the vent is not down-turned, it should have a water-proof cover down to the bottom of the screen. One secure configuration for a screen on a pipe is between two flanges, which brings the screen inside the pipe and protects it against vandalism. The operator

may need to add screening or other deterrents to prevent birds from nesting on a horizontally placed screen or to protect flexible screens.

Overflows:

- Does the overflow outlet terminate above the ground and is it protected against flooding and animal intrusion?
- Is the overflow outlet protected with a non-corrodible screen or flapper valve?
  - The Ten State Standards (2018) specify a 24 mesh screen for ground level tanks and a four mesh screen for elevated tanks. Tanks equipped with a flapper valve at the overflow outlet should also be equipped with a 24 mesh screen.
- Are the tank drain and overflow pipe directly connected to a storm drain or sanitary sewer?
  - The tank drain and overflow pipe should not be directly connected to a storm drain or sewer because this is a cross-connection that could allow sewage or storm water to backflow into the finished water. The overflow pipe outlet should have an air gap to prevent backflow from occurring. The overflow should discharge over a splash plate or engineered outlet (concrete or riprap) that will not submerge the overflow when spilling.
  - The drain line is equipped with an isolation valve which is normally closed.

- **What is the design and condition of the rooftop access hatches?**

For ground level tanks (buried and partially buried), is the hatch at least 24 inches above the ground?

For elevated tanks, does the access hatch design meet criteria listed in Ten State Standards (2018) as follows: is the hatch framed at least four inches above the surface of the roof at the opening? Is the lid solid and watertight, as well as hinged at one side? Is the lid a shoebox design that overlaps the rim by at least two inches and have a locking device?

The lid must seal tight to prevent the inhalation or blowing of dust, dried bird droppings, and feathers into the hatch opening. Improperly fitted hatch covers are a common problem, but an operator may only need to make minor modifications to make many of them acceptable.

Is there a gasket between the rim and lid and does the latch pull the lid tight against the gasket? When shut, push down on the lid to see if it moves. Movement indicates it is not tight against the gasket creating a pathway for insects, bird droppings, dust, feathers and mice.

Hatches flush with the roof need to be raised to the minimum heights discussed above to protect against rain, wind, and snow washing sediment, bird droppings, and other debris into the tank.

Constructed tanks may have large double doors that meet in the middle (for removing construction materials) that do not create a watertight and insect proof seal.

- **Is the seal on the rooftop access hatch in place and in good condition?**

  The surveyor should either climb the tank and open the hatch to check on the condition of the seal, or ask the operator to climb the tank and collect photo documentation. If the seal is deteriorated or missing, it should be replaced with a new seal.

- **Does the operator keep the access hatch locked, and do authorized personnel have access to the keys or combinations?**

  What type of locking device does the operator use to secure the hatch? Is the locking system sturdy? Is the hatch alarmed or under video surveillance to discourage swimming, vandals and others?

  Was the operator easily able to find the keys or combination to open the hatch? Operators should secure access hatches with a solid watertight cover and a sturdy locking device. It is not unusual for the wind to lift open an unlocked cover. Operators often lose keys or forget combinations and cut the padlocks. Unauthorized individuals may also cut the locks then swim in or throw things in the storage facilities.

  Note: you can use a mirror to reflect sunlight into the tank to help with observations.

  After opening the hatch, determine if there are spider webs, indications of other insect intrusions, floating debris, or sediment buildup in the tank.

- **Condition of tank drain pipe?**

  Water will only be exiting a drain pipe when an operator opens the gate valve for planned maintenance. The surveyor should check the drain outlet to make sure there is an air gap and no direct connection to a storm or sanitary sewer.

  The drain outlet should discharge over a splash plate or an engineered outlet (concrete or riprap) that will not submerge the drain when it is flowing. The drain can indirectly discharge to a sanitary sewer or storm drain, but only if there is an air gap that meets the primacy agency's standards.

- **Are there any other openings in the tank walls, wall-to-roof connections, or the roof?**

  There should be no other hole larger than that afforded by the vent screen. The surveyor should document any physical gaps in the roof, walls, or wall-to-roof connection that require maintenance.

- **Are the cathodic protection access plates watertight?**

  Access plates that are not sealed allow bird droppings to wash directly into the drinking water.

- **If there is a roof penetration for a water level indicator cable, is it sealed to prevent contamination?**

  This penetration for the cable allows bird droppings to wash into the storage facility unless the cable is in conduit, sealed at the opening and designed to cause rainwater to flow away from the cable opening.

- **Are there other unsealed roof penetrations?**

  Roof penetrations for water lines, chlorine lines, and electrical devices are all opportunities for contamination, if operators do not maintain the seals.

- **Are there sewer lines in the vicinity of an in-ground storage tank and does the separation distance meet state requirements?**

  Any sewer lines located near a storage facility, especially a buried tank with a floor below ground level, should be constructed of extra-heavy or service-weight cast iron pipe, with tested, watertight joints. Sewer lines should be located a sufficient distance from the storage facility that they meet any primacy agency setback distance requirements.

- **Are there cracks in the walls or covers of the in-ground concrete storage tanks?**

  Cracks in the tank can allow ground or surface water into the tank. Operators should include sealing or repairing of cracks as part of their routine (e.g., daily, weekly) checks of their tanks.

- **Is there evidence of foundation pad damage or foundation to tank connection damage?**

  Concrete foundations should be inspected to ensure that there is minimal spalling (ground level tanks) and no cracks (elevated tanks). Anchor bolts should not be rusted so much that their material strength has been compromised. Column shoes should be clean and painted, and grout under the shoes and riser plates should be in good condition. There should not be any pooled water, erosion, weeds, or shrubs around a tank's foundation.

- **Is there protection from flooding?**

  Would a flood event submerge the drains, overflows, valve pits or other critical infrastructure? If the drain would be flooded, does it have a duckbill valve to prevent the flood water from entering the drain pipe to the gate valve?

  Is the tank above the 100, 500 and 1,000-year flood event? If the tank is in a flood plain, is there long-term planning to move it to higher ground to avoid any damage during a flood?

  Is the ground graded away from the tank and is large rock used to protect against the flood waters damaging the foundations of the tank? The water system should maintain any ground above an underground tank, such that the grade directs surface water away from the tank and prevents pooling near it. Underground drainage should discharge away from the structure.

- **Can the tank be isolated from the PWS? Are there procedures to sustain the water supply when the storage tank is out of service for maintenance?**

  The tank should have gate valves to bypass water directly into distribution or into another tank, as well as a drain pipe to empty to the tank. The operator should exercise these valves regularly to ensure their integrity.

  The system must be able to maintain pressure in the distribution system, when the operator removes a tank from service for routine cleaning and surveys, or drains it during an emergency (vandals or terrorist). This is important, because some repairs may take weeks to a month, such as recoating the inside of a metal tank.

Prior to removing the tank from service for maintenance, the water system staff should coordinate and practice procedures for sustaining the distribution system pressure. This can be relatively simple in systems that are equipped with adequate back-up storage facilities. A small system that has only one storage tank or limited reserve storage would require a more complex means of maintaining the water supply. This could include operating high-service pumps manually and positioning fire hydrant relief valves at various locations within the distribution system.

Water systems should establish temporary measures that they thoroughly test and practice, before actually removing the storage tank from service for maintenance. They should notify all water system customers and the fire department well in advance, to establish conservation and alternative plans, to decrease stress on the water system. When necessary, the water system should notify high-consumption customers and ask them to conserve voluntarily.

- **Has the PWS protected the site against vandalism?**

  Is the storage site fenced with a locked gate, alarmed or under video surveillance? Ladders to the tops of storage tanks should terminate 10 feet above the ground to deter unauthorized climbing. Many ladders have a section that "telescopes" up into the cage. In such cases, the operator should have the ladder and access hatch to the ladder cage locked.

- **Does the PWS use approved interior surface coatings?**

  Water systems should use coatings that meet NSF/ANSI Standard 61 (NSF, 1988) on surfaces in contact with potable water. Unapproved coatings can create problems such as organic and inorganic contamination of stored water. Certified professionals should apply coatings to steel water tanks in accordance with State or AWWA *Standard D102-11 Coating Steel Water Storage Tanks*.

- **Does the PWS monitor for coliform and VOCs before returning the tank to service?**

  Tanks must have time for interior coatings to properly cure. Before returning a tank into service, the water system should disinfect and flush the tank, refill it with water, and analyze water samples for coliform and VOCs. There should a protocol that meets state requirements for testing recoated tanks before they are returned to service.

- **Has the PWS protected the tank against icing?**

  When temperatures fall below zero for several days, ice may form in underground and elevated storage tanks. In underground tanks, ice formation is usually limited to surface ice. In elevated tanks, icing may be more severe where thick accumulations may form. Serious damage to walls and structures may result. Tanks have blown their tops due to the pressures that result; in less severe cases, the ice may damage cathodic protection and tank interiors.

  The operator should prevent tanks from freezing and not allow them to remain idle by using heaters, circulators, or bubblers in the tanks. The water system should have insulation around standpipes installed in very cold climates.

- **Are there indications that the tank may not be structurally sound?**

  The surveyor should base the answer to this question on previous cleaning and survey reports, as well as visual observation of washouts, signs of foundation failure, cracking or spalling concrete, tank leakage, buckling of steel, slack in support rods, corrosion, and signs of other problems.

- **Has the PWS protected the tank against corrosion?**

  Note: Coatings can fail for several reasons, including improper surface preparation, application, and curing, use of the wrong type of coating, removal by ice or other environmental exposure, and lack of maintenance.

  The surveyor should ask if the water is corrosive and has damaged the tank coatings. If it is corrosive, what steps are the operators taking to protect metal tanks, i.e., corrosion control treatment at the plant, cathodic protection and frequent minor coating repairs. Corrosive water can seriously damage a steel storage tank if the protective coating is not completely intact.

  The rise and fall of water in the tank can affect corrosion. Exposed metal surfaces that are submerged and then exposed to air (oxygen) corrode at an increased rate. Cathodic protection devices may provide corrosion control for metal storage tanks. Qualified staff should inspect and maintain these devices annually.

- **Has the tank been protected for seismic events?**

  Water systems located in seismic areas may have developed design and construction standards to protect their storage facilities from damage due to earthquakes. Earthquake hazards may include shaking and permanent ground deformation. The surveyor should also check to see if the primacy agency has any requirements. The industry standard, AWWA D-100 includes seismic design requirements for finished water storage tanks (AWWA, 2011).

- **Does the operator or contractors properly disinfect storage tanks following interior maintenance?**

  Water systems must disinfect reservoirs and elevated tanks on the distribution system, before being put into service and after extensive repairs or cleaning.

  Operators should disinfect the tank according to primacy agency standards. If there are no primacy agency standards, the EPA recommends AWWA standard *C652-11: Disinfection of Water Storage Facilities*.

- **Are emergency procedures established?**

  The surveyor should learn about the procedure to detect and respond to low tank levels (low pressure) and high tank levels (overflow or high pressure) and determine if the procedures are adequate. Low levels in the tank can scour sediments off the bottom and send them into the distribution system so it is important to know when the water system last had the tank cleaned and if they had any breaches into the tank. Is there a high water level and overflow alarm to alert the operator?

A resource list should be available that contains information on where to obtain essential storage repair materials and services, in the event of an emergency. An alternative source of water should be available. Are they part of the state WARN system?

- **Does the operator follow safety precautions?**

  There are climbing and atmospheric hazards associated with water storage tanks. Ladders should be in good condition and secure. The surveyor should determine whether safety gear is available for climbing and for entry into confined spaces.

- **If the tank is wooden, does the operator manage it in a manner to minimize an increase in bacterial count?**

  During the sanitary survey, the surveyor should ask the operator for information on daily water level fluctuation, water turnover rate, booster disinfection, water quality monitoring, and water quality data for the stored water.

10.4.9 Hydropneumatic Tanks

Hydropneumatic tanks are commonly used to maintain distribution system pressure in small water systems. These tanks do not provide sufficient water quantity needed for firefighting, and provide only enough storage to prevent excess cycling of the pumps. These systems combine the energy from a pump with the principle of compressed air pressure, to force water into the distribution system. Understanding how the hydropneumatic tank is susceptible to sanitary risks requires an understanding of basic system operation and the role of system components.

10.4.9.1 Hydropneumatic Tank Operation

The hydropneumatic tank operates in the following manner:

- The lower half of the tank is filled with water and the upper half of the tank is filled with air.
- The water supply pump starts when the system pressure (downstream from the tank) drops to a predetermined level (cut-in pressure). Water is pumped into the tank and compresses and pressurizes the pocket of air (air volume) at the top of the tank.
- When the system pressure increases to a predetermined level (cut-out pressure), the pump stops and the compressed air expands as it forces the stored water into the distribution system in response to system demand.
- When the pressure falls to the “pump-on” level (often 35 to 40 psi), the pump starts again, and the cycle repeats. The cycle rate is the number of times the pump starts and stops in 1 hour and varies based on the system demand.

10.4.9.2 Components

A typical hydropneumatic system consists of:

- Steel pressure vessel: Stores water.
- Air volume control: Regulates air volume in the tank.

- Relief valve: Prevents excessively high pressure.
- Inlet and outlet piping: Allows flow of water in and out of the system.
- Sight glass (tube): Allows direct observation of air-to-water ratio, generally one-third air to two-thirds water.
- Pressure gauges: Monitor pressure, generally a 100-psi gauge.
- Pump motor controls: Control pump operation.
- Low pressure or flow controls: Maintain balance between water and air pressure.
- Air compressor: Forces additional air into tank to increase pressure (pre-pressurization).
- Master flow meter: Measures quantity of water pumped.
- Cycle counter: Counts number of pump cycles.
- Elapsed time meter: Records hours of operation.

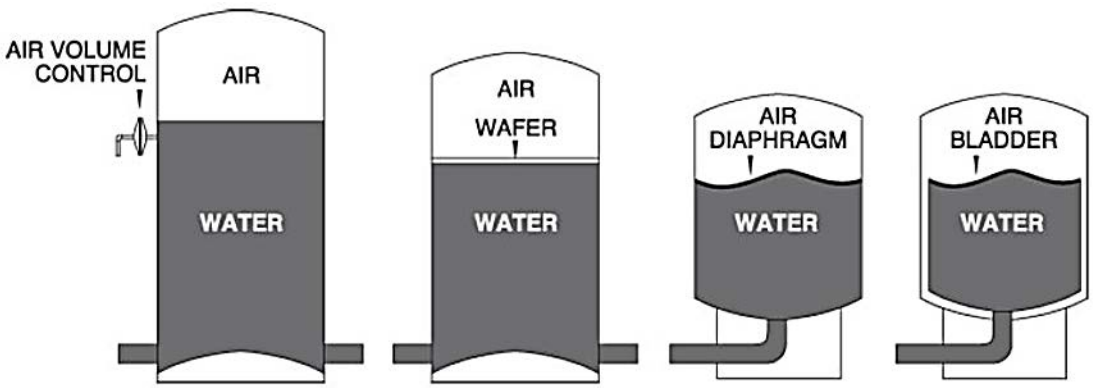

Figure 10-7: Styles of pressure tanks

10.4.9.3 Different Styles of Hydropneumatic Tanks

Most hydropneumatic tanks differ only in the kind of pressure storage tank used. Primary differences in tanks include:

- Size.
- Orientation (horizontal or vertical).
- Methods of separating water and air.

All these factors may contribute to the degree of vulnerability to sanitary deficiencies. The three kinds of tanks are described below.

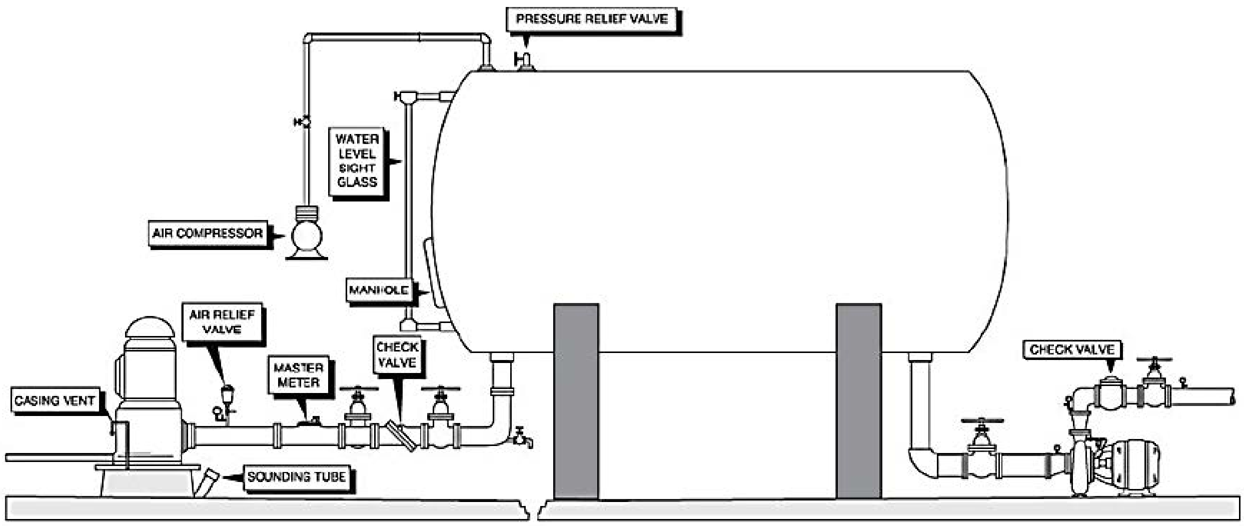

Figure 10-8: Lineshaft turbine pump and hydropneumatic tank

10.4.9.3.1 Conventional Tank

Characteristics of conventional tanks include:

- Air cushion in direct contact with water; air volume controls are necessary.
- Capacity ranges from a few to several thousand gallons.
- Vertical or horizontal placement.
- Outlet located near bottom of tank. Combined inlet-outlet or inlet-outlet separated on opposite sides of tank to provide disinfectant contact time.
- Air volume control located at the water/ air interface of tank; provisions available for pre-pressurizing.

10.4.9.3.2 Floating Wafer Tank

Characteristics of a floating wafer tank include:

- Floating wafer (rigid floats or flexible rubber or plastic) separates water and air, but separation is not complete. Expect some loss of air, which requires occasional recharging.
- Vertical placement limits tank capacity.
- Inlet and outlet combined at bottom of tank.
- Internal air check valve to prevent premature loss of air due to electric outage or excess water demand.

10.4.9.3.3 Tank with a Flexible Separator

Characteristics of tanks with a flexible separator include:

- Separator fastened around inside of tank for complete separation of air and water, either flexible diaphragm or bladder type.
- Vertical placement limits tank capacity.
- Supercharged at factory or on-site to pressures just below pump starting pressure.

10.4.10 Sanitary Deficiency Questions and Considerations - Hydropneumatic Storage Tanks

- **Is tank capacity adequate?**

  Note: to ensure against stressing facilities at peak demand, the surveyor should check that the operator is aware of the pumping capacity and peak demand rates.

  The surveyor can use a simple formula (i.e., rule-of-thumb) to estimate the adequacy of a hydropneumatic storage tank's capacity. The surveyor should also review primacy agency requirements for tank capacity. The system information needed to evaluate tank capacity include capacity of each pump, peak demand, and pump operating setpoints (i.e., system pressures that turn the pump on and off). The simple formula or rule-of-thumb is the tank capacity should equal 10 times the capacity of the largest well pump that is used to fill the tank. The surveyor should also determine if the tank has become waterlogged (i.e., the air-water interface in the tank is too high) which can affect the working capacity of the tank.

  The surveyor should be especially concerned about the adequacy of supply capacity and tank size in communities that have substantially increased their service population without upgrading the water system.

  The active storage volume of the hydropneumatic tanks should be sufficient to limit pump cycling to manufacturer's and industry recommendations.

  Maximum cycling frequency should be determined for the largest pump, when demand is one-half the capacity of the largest pump or combination of pumps operated by the same pressure switch.

- **Does the low pressure "pump-on" level maintain adequate distribution system pressure?**

  Maintaining adequate pressure is especially important to keep the water flowing from storage facilities to serviced areas. This is because the pump and source have to be capable of meeting the system's maximum momentary water demands or the potential for low pressure situations and backflow or back-siphonage is substantially increased. To prevent backflow and back-siphonage, the system must maintain a minimum pressure at all times.

  Too little pressure can cause the water flow to reverse, allowing water from a polluted source to enter potable, stored water. Low pressure can indicate improper connections, or cross-connections, made from storage to serviced facilities. Too much pressure, on the other hand, can strain system components, can cause high leakage rates, and force air out with water.

- **Are system pressures adequate?**

  Surveyors should check engineering records to assess potential backflow hazards in the water of facilities served by the system. They also should consult operating records to see whether pressure is adequate, and they should determine whether and how often breakdowns and pressure losses occur.

- **Are instruments and controls adequate and operational? Does the operator use and maintain them?**

  Proper O&M of the storage system is also essential. Failure to adjust gauges and controls properly can lead to inadequate pressure or inadequate supplies of water. Airborne or waterborne foreign matter may pollute tanks equipped with air compressors. Careful installation and maintenance of air filters and cross-connection control devices can prevent the entry of foreign material into the hydropneumatic system.

  Evaluating components: To ensure proper O&M of the system, the operator should routinely check and adjust the following components to meet changes in the peak demand:

  - Air volume control.
  - Relief valves.
  - Motor controls.
  - High and low water level controls.
  - Low pressure flow controls.
  - Air compressor and controls.
  - Check records: Frequently, operators do not adjust controls after the equipment arrives from the factory. Operating records should report the original calibration and if peak demand has changed.

- **What is the cycle rate and air-to-water ratio?**

  Cycle rate: The water supply pump should not cycle more frequently than the pump's manufacturer specifications. Frequent or constant operation of the pump indicates a "waterlogged" tank, improper settings on the pressure controls, or system demand that is close to exceeding the supply pump capacity.

  Air-to-water ratio: The air-to-water ratio in conventional hydropneumatic tanks should be approximately one-third air to two-thirds water at "pump off" pressure. If the air volume is too high, the tank could lose water before the pump starts, which would send air into distribution system.

- **Does the operator properly protect the tank and the controls?**

  The tank should be located in a secure building or surrounded by a fence, to protect it from vandalism. House controls should be in a waterproof and secure structure that is easily accessible for maintenance. Lightning protection should also be included.

- **Are emergency procedures established?**

  A control system should detect pump failure (in either a low- or high-pressure situation) which then activates an alarm. Some alarm systems consist of a light or horn at the facility. This type of alarm is not as reliable as an automatic telephone dialer alarm, programmed to call several numbers, until an operator responds.

- **Are there back-up systems?**

  Many water systems, especially small ones, do not have redundant equipment. Inadequately maintained hydropneumatic systems are extremely prone to malfunction, and pressure is usually lost before an operator can correct the problem. Back-up systems can substantially reduce the sanitary deficiencies of pressure loss, due to equipment failure. Water systems should establish contingency plans for an emergency source of safe water.

  Service contract: The PWS should have a service contract for maintenance and trouble-shooting if operators or maintenance staff are unable to perform these functions.

  CAUTION: Hydropneumatic tanks are pressure vessels. A pressure of 50 psi is equivalent to 3.5 tons per square foot of tank surface area. DO NOT TAP ON THE TANKS!

- **Are the interior and exterior surfaces in good condition?**

  The interior and exterior should be in good physical condition. The surveyor should check for signs of coating failure and corrosion. The surveyor most likely will not be able to examine the interior surfaces, but should emphasize to the operator the importance of regular inspections.

  By reviewing maintenance records, the surveyor may determine if the operator is inspecting the water system's tanks. Some states require all pressure vessels to undergo regular hydrostatic testing. Water systems should not bury the tank.

- **Are tank supports adequate and structurally sound?**

  A proper and permanent structure should support the tank. An inadequately supported tank may shift and damage the piping connections, or, worse, the tank could rupture.

- **Is the recharge air free of pollutants such as oil from an air compressor?**

  Air compressors can introduce lubrication oil as an aerosol, into the hydropneumatic pressure tank. The surveyor should ask about the maintenance of the air filter, as well.

- **What is the physical condition of the outside hatch?**

  An outside access hatch that is in poor physical condition can compromise the integrity of the pressure vessel, causing safety and sanitary deficiencies.

- **Are the pump and source capable of meeting the PWS's maximum momentary demand?**

  The system's maximum momentary demand can occur when the hydropneumatic tank has exhausted its stored water (at the "pump-on" pressure), therefore, the system can lose pressure if the pump and source cannot meet peak demands.

- **Where and how often is disinfectant residual measured?**

  Water systems often measure disinfectant residual in water leaving finished water storage tanks to ensure a sufficient amount of disinfectant is still available in the water. The surveyor should ask the operator if any such surveillance residual monitoring is being done and how operations are adjusted as a result of the measurements.

10.5 Possible Significant Deficiencies for Finished Water Storage Facilities

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The state (primacy agency) determines both significant deficiencies, and the corresponding corrective actions.

- Access hatches not locked or hatch improperly designed (shoebox lid with intact seal).
- Holes left in tank by removal of cathodic protection rods or any other reason.
- Missing or damaged screen on air vents or overflow outlets. Overflows with flapper covers should still have a screen since debris, ice, and snow, etc., can prevent them from closing.
- Erosion around the foundation of storage tanks, which could lead to instability and eventual collapse of the tank (elevated or ground storage).
- Cracks in the walls of concrete storage facilities.
- Inadequate venting or missing air vents. No or improper screening of vents; vents do not terminate adequate distance above the surface.
- Evidence of animals, insects in the storage facility, or signs of tampering.
- No regular inspection, cleaning, or PM schedules.
- Exterior corrosion or damage on hydropneumatic tanks.
- Inadequate site security.

11 Distribution Systems

The surveyor should evaluate the water distribution system to determine if it can provide a safe, adequate, and reliable supply of water. Because most piping is buried, this evaluation needs to rely on other sources information such as operations data, maintenance records, written plans and SOPs, and staff interviews. Distribution system piping and appurtenances have contributed to the deterioration of water quality and introduction of contaminants into the distribution system. In addition, operations and maintenance practices (e.g., main repair, valve operation, flushing) may introduce contaminants or negatively affect distribution system water quality. The surveyor should evaluate each practice that influence the quality of the water in the distribution system, in order to evaluate the sanitary deficiencies and to determine if the deficiency is significant, or provides an imminent and substantial risk to public health. To perform this evaluation, the surveyor should be able to meet the following objectives.

11.1 Learning Objectives

By the end of this chapter, students should be able to:

- Identify data collection requirements necessary for evaluation of sanitary deficiencies of a water distribution system.
- Review the major components of a water distribution system, including pipes, valves, meters, meter and valve vaults, fire hydrants, and thrust blocks or pipe restraints.
- Describe how the types of materials, selection standards of water distribution system components and operations can affect system reliability or water quality.
- Identify the standards used to select water distribution system components, and describe how these standards protect public health and the reliability of the distribution system.
- Identify factors that contribute to reduction in water quality in a distribution system.
- Identify the information that should be included on water distribution system maps.
- Describe the proper monitoring of a water distribution system.
- Identify O&M tasks, such as flushing, necessary to maintain the integrity of the water distribution system.
- Describe the safety practices that should be in place to protect the operator and public during distribution system operation, construction, and repair.
- Describe the proper methods, based on primacy agency or AWWA standards, for disinfecting new and repaired water distribution system lines and appurtenances.
- Identify construction techniques that can be a positive influence on distribution system integrity.

11.2 Data Collection

To evaluate and assess a water distribution system for sanitary deficiencies, the surveyor should gather or evaluate the following data:

- How the system evaluates and tracks distribution system data (e.g., Supervisory Control and Data Acquisition, or SCADA).
- Maps or diagrams showing locations of transmission and distribution piping, pump stations, tanks, pressure zones, valves, and hydrants.
- For each pipe material: total length installed, and if known, age and condition.
- Standards used for the construction of the system.
- Maximum and minimum pressures at high and low elevations in the system.
- Maximum and minimum pressures in each pressure zone.
- Number of water main breaks per year.
- Number of service outages per year.
- Number of power outages per year.
- Water quality data including coliform bacteria, chlorine residual, DBPs, lead, and copper.
- Documentation of state approval for changes to or installation of the system.
- Staffing for construction (i.e., in-house staff or by contractors).
- Number of pressure zones in the system.
- Method used to separate pressure zones.
- Hydraulic model of the system.
- Chlorine residual testing technique used.
- The system's procedures for responding to main breaks, and, if required, whether they have followed regulations or policies for reporting to the state.
- Routine maintenance tasks performed by outside contractors.
- 24-hour call-out procedure.
- Flushing program procedures.

11.3 Regulations and Standards to Consider

The surveyor should consider and review the following information prior to a survey:

- 29 CFR 1926.650 - Excavation safety.

- 29 CFR 1926.146 – Confined space entry.
- AWWA G200 – Distribution systems Operations and Management.
- The AWWA standard for the type of piping materials used in the system.
- System construction standards.
- State construction standards.
- Ten States Standards.
- 40 CFR 141.72 and 141.132 – Chlorine residual requirements.
- 40 CFR 141.86 – Lead and Copper Rule.
- 40 CFR 141.621 – Stage 2 Disinfectants and Disinfection Byproducts Rule.
- 40 CFR 141.853-141.858 – Coliform Sampling.

11.4 Causative Factors of Water Quality Issues in the Distribution system

Sanitary deficiencies or poor O&M of the distribution system contribute to water quality deterioration and contaminant entry. Examples are listed below.

- Insufficient treatment.
- Cross-connections.
- Physical gaps at finished water storage facilities.
- Inadequate main disinfection after main installation or repair.
- Unsatisfactory main construction, including improper joint-packing.
- Close proximity of sewers to water mains.
- Improperly constructed, maintained, or located blow-off, vacuum, and air-release valves.
- Negative pressures or pressure transients in the distribution system.
- Lack of tracking and mapping of distribution system events.
- Lack of valve inspection and maintenance program.
- Lack of distribution system flushing or ineffective flushing.
- Insufficient funding for water main replacement.

11.5 Distribution System Components

A typical water distribution system may contain the following components:

- Transmission and distribution mains.

- Service lines and service meters.
- In-line valves for isolation.
- Blow-offs.
- Air relief, air release, and combination air vacuum valves.
- PRVs.
- Pumping stations.
- Fire hydrants.

Piping and pumping stations are essential components of a distribution system. As water systems age or grow, water systems may use different types of pipe materials to replace old pipes, or in the installation of new portions of the distribution system. Water system personnel must understand the importance of knowing what type of piping materials are in place throughout the distribution system. The surveyor should determine what type of pipe materials are used and determine how their failure may affect the quality of water.

11.5.1 Water Mains

Typical water main materials include:

- Cast iron.
- Ductile iron.
- Asbestos cement.
- Steel.
- Polyvinyl chloride (PVC–pressure and class pipe, also called C-900).
- Wood.
- High-density polyethylene (HDPE).

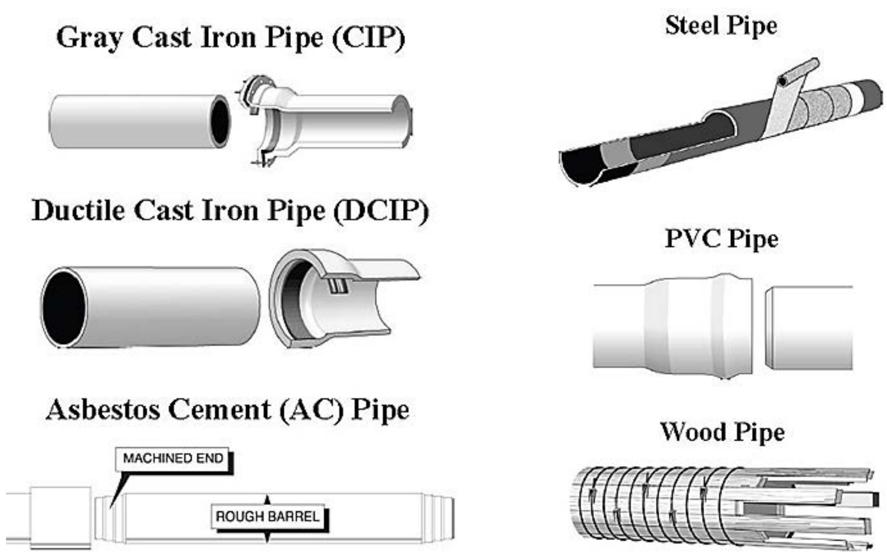

Figure 11-1: Types of pipes

11.5.2 Services Line Materials

Typical service line materials include:

- Galvanized steel.
- Copper.
- HDPE.
- PVC.
- Lead.

11.5.3 Service Meters

There are three points where water systems use meters in distribution systems:

- Connection to other water systems where water is purchased or sold.
- The introduction to a pressure zone.
- At major crossings to detect leaks.
- The customer’s service line connection.

Water systems use these meters to determine the amount of water sold, to determine non-revenue water, and to identify leaks. The surveyor should evaluate the security and condition of below grade meter vaults. Customer meters may be located either in their basement or a buried vault.

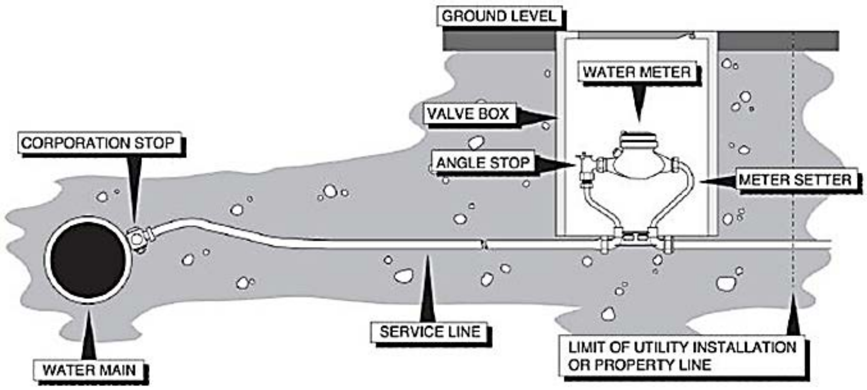

Figure 11-2: Service meter installation graphic

11.5.4 In-Line Valves and Blow Offs

Gate and butterfly valves are the two most common in-line valves used in a distribution system. Operators use these valves to isolate portions of the system during repairs. Because these valves are installed underground in the buried pipeline, they are accessed through a small diameter valve box using a long wrench tool called a valve key. The surveyor should review the water system's valve program and evaluate whether system valves are in an operable condition. When an emergency occurs such as a water main break, the water system needs to quickly shut valves to isolate the problem area. The surveyor should check that the location of all valves is known and documented; critical valves have been identified; and all valves are operated on a routine basis. Valve records should include location, make/model, direction of operation (left or right), number of turns to open, normal position (open or closed), and repair history.

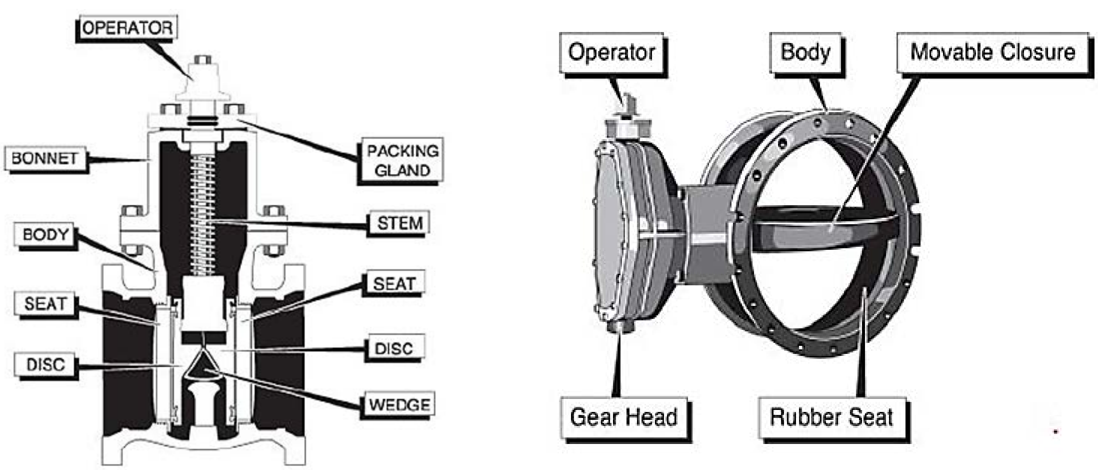

Figure 11-3: Gate and butterfly valves

Blow-offs are gate, butterfly, or globe valves, installed at the end of dead-end lines or in other locations to flush water from the distribution system. The surveyor should find out whether blow-offs are operated automatically or manually, and if the flushing is based on time or water quality (e.g., chlorine residual, customer complaint).

11.5.5 Air Valves

Air relief, air release, and combination air vacuum valves remove air that accumulates in the distribution system and relieve any vacuum conditions caused by line flushing, line breaks, or other high-flow conditions. Accumulated air can cause physical blockages in the pipe that cause system pressure and flow variations. Vacuum conditions can contribute to the failure of a pipe joint and intrusion of untreated water into the system.

Many water systems install air release valves in pits or below grade. If an air valve is open and the air outlet discharges into the below-grade vault, untreated water could enter the distribution system if the vault is flooded. The outlet for these valves should be protected by extending the piping above ground level with a gooseneck terminating above the surface and covering the outlet with a non-corrodible screen.

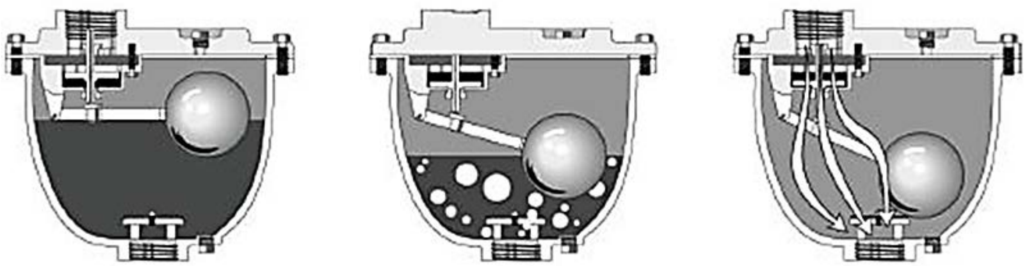

Figure 11-4: Air release valves

11.5.6 Pressure Control

Pressure-reducing valves are globe valves, used to reduce or maintain the pressure in a specific zone of the distribution system.

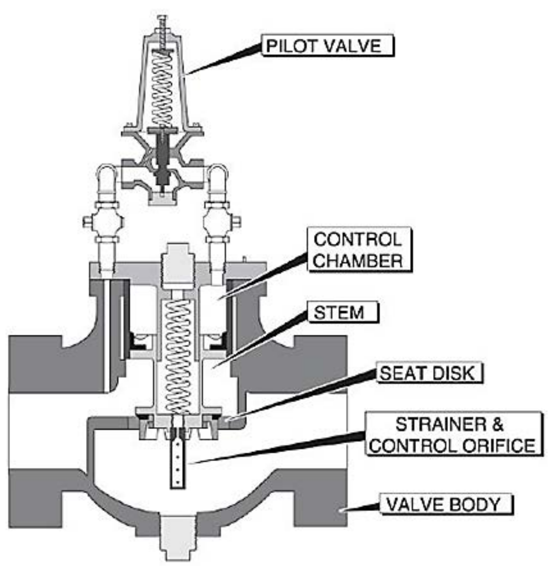

Figure 11-5: Pressure control valve

11.5.7 Pumping Stations

High service (or lift) pumping stations, which supply water to the distribution system are located near the water treatment facility or a finished water storage facility (e.g., clearwell or ground storage tank), and will pump directly into the distribution system from that storage facility.

Booster pumps may be located anywhere in the system to increase the pressure in the pipeline, but are usually located remotely from the main pump station, as in hilly topography, where pressure zones are required. Operators may need booster pumps to handle peak flows in a distribution system, which can otherwise handle the normal flow requirements.

Before a water system adds a pump station to an existing distribution system, operators should consult previous plans and designs that are based upon a total system hydraulic analysis. New or updated studies will determine station location, and present and future demand requirements.

Locating permanent pumps so that there will be a positive head on pump suctions will eliminate many operational problems. Water systems should determine site selection from evaluations of a topographic survey and flood plain analysis, to determine if there are any flooding probabilities of the proposed plant site. The site must not be subject to flooding.

11.5.8 Fire Hydrants

Fire hydrants are used in the water distribution system as a water source for fighting fires, construction projects, and flushing the water system or sewers. The two general styles of fire hydrants used in the United States are wet barrel and dry barrel. There are four types of dry barrel hydrants, as shown below: two compression types, toggle, and slide gate. Fire hydrants should be installed on water mains that are at least 6 inches in diameter.

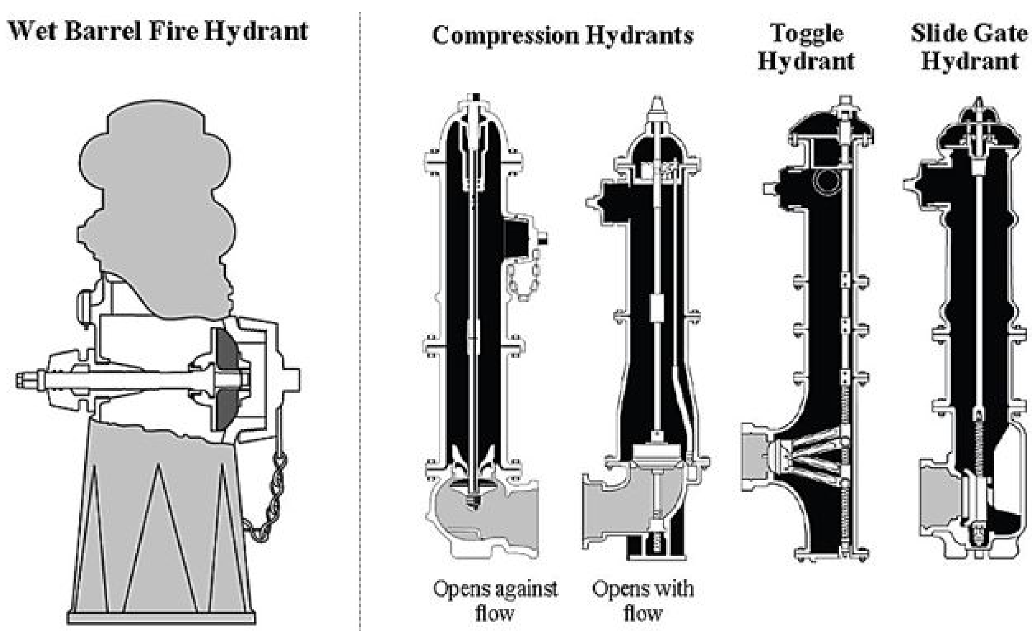

Figure 11-6: Fire hydrants

11.5.9 Sanitary Deficiency Questions and Considerations - Distribution system Components

- **Does the PWS have an inventory of pipe materials used?**

  The surveyor should ask the water system operator what materials of construction are used for distribution mains, transmission lines, and customer service lines. Ideally, the water system records include the total length of installed pipe for each pipe material, and the date of installation for each pipe section.

- **Are there materials of concern such as lead service lines, wood pipe, unlined cast iron, thin wall PVC, pipe not approved for potable water use?**

  Wood pipe is easily contaminated and, once contaminated, is difficult to disinfect thoroughly. Unlined cast iron pipe is susceptible to corrosion, creating a rough pipe surface (i.e., tuberculated) that can harbor bacteria, reduce the pipe's capacity, and cause red water complaints. Gray cast-iron pipe is prone to failure from sudden internal or external shock loads. All pipe materials should be selected with an appropriate wall thickness and pressure class to meet the system's pressure requirements. All pipe installed for drinking water service should be certified to the NSF/ANSI-61 standard and should meet requirements in the applicable AWWA standard.

- **How many service connections are there? Does the PWS meter all service connections?**

  This number of residential and other service connections gives the surveyor an idea of the size of the system, in terms of number of homes and businesses served by the system. Meters allow the system to calculate a water balance that may aide the system in determining water loss, as well as determine demand estimates. There is also a correlation between metered service connections and water conservation (i.e., the cost of water as a function of the amount used).

- **Who owns the water meters?**

  The surveyor should ask the operator if the water meters are owned by the city, the water system, or the customer. This information will help the surveyor understand who is responsible for maintaining the meters and replacing them as needed.

- **If the water meters on customer service lines are located in below grade vaults, who is responsible for maintaining the sanitary condition of the vault – the water system or the customer?**

  Ownership of the vault used to house the water meter may not be the same as the ownership of the meters themselves. The vault should be maintained in a sanitary condition to prevent any untreated water from entering the piping or the meter, potentially contaminating the drinking water. Vault maintenance should provide safe access for the person who enters to read or maintain the meter. The owner of the vault is also responsible for maintaining the piping and valves connected to the meter.

- **How old are the water meters? Does the water system replace water meters at the frequency recommended by primacy agency or AWWA standards?**

  The surveyor should be familiar with primacy agency requirements and industry standards on frequency for replacing various sizes of water meters. The surveyor should ask the operator when the meters were installed, and determine if they are overdue for replacement.

- **Is there a main replacement program?**

  The surveyor should ask the operator to describe the water main replacement program in terms of the percent of water main length or the length of pipe (feet or miles) replaced annually. Further, the surveyor should ask for information on the number of main breaks per year and the overall age of water mains. This information can be used to determine if the water system is replacing older water mains at a sufficient rate.

- **Does the PWS have or follow standards for separation distances between potable water mains and storm or sanitary sewers?**

  The surveyor should be familiar with primacy agency requirements and industry standards (e.g., Ten States Standards) about separation distances for water mains and sewers. The surveyor should ask the operator if the system complies with primacy agency requirements. If time allows, the surveyor could review recent construction plans and specifications to check that these requirements are incorporated.

- **Are there any lead goosenecks still in place and used for service connections? If yes, how many? Are there plans to remove these? If yes, by what date?**

  Identified as contributors of lead to finished water, these gooseneck-shaped lead lines connect the water main to the customer service line. They typically prevent line breakage by allowing for expansion and contraction during temperature changes.

- **Does the water system use HDPE pipe for main lines or service connections?**

  Petroleum products travel through HDPE and other polyethylene and polybutylene piping material and into the water system. Contamination can occur if the lines are adjacent to a leaking underground fuel storage tank or from fuel spills on the ground above the line.

- **Does the PWS contain any steel pipe?**

  If the system has steel pipe, the surveyor should ask about the frequency of leaks and breaks, when the pipe was installed, the presence of corrosive soils, and the water system’s plan for replacing those pipes.

- **Does the PWS contain any solvent-weld PVC pipe larger than 2 inches in diameter?**

  If information is available, the surveyor should document the diameter, length, and joint type for PVC pipe installed in the system. The year of installation and the failure rate should also be documented. Large-diameter solvent-weld PVC pipe may have a higher failure rate than push-on joint pipe. This is due to the expansion and contraction of the pipe, caused by temperature changes during construction or operation.

11.6 Material Standards

Water systems must use materials in their distribution systems approved for potable water use. Most states require that piping materials meet NSF Standard 61 or AWWA standards. The surveyor should determine what standards the system uses for approval of piping and other materials in the distribution system. In addition, states and water utilities may have different construction standards. Surveyors should determine what construction standards the system uses and whether they are in accordance with state requirements.

11.6.1 Sanitary Deficiency Questions and Considerations – Material Standards

- **What standards does management use to select materials? Are all materials ANSI/NSF certified?**

  Water systems should select distribution system components that meet current standards, such as NSF Standard 61 for indirect additives. The surveyor should consider the corrosive effects of finished water on metal service line pipe resulting in the dissolution of metals into the water, together with possible toxicological effects on consumers. Water systems that use plastic pipe should use pipe that meets primacy agency standards. Caulking materials should not support pathogenic bacteria and should be free of tar or greasy substances. Joint-packing materials should meet the latest primacy agency-approved (e.g., AWWA) specifications.

- **Does the operator only use materials manufactured according to industry standards such as AWWA and NSF?**

  The purchaser should obtain proof from the manufacturer or supplier that the material meets the applicable standards (e.g., NSF/ANSI-61).

- **Is there a set of construction standards used by the PWS?**

  Failure to use construction standards can complicate the installation of piping, valves, and hydrants that are of different brands, types, and materials. This contributes to increased materials inventory costs and maintenance worker training. In addition, lack of construction standards may contribute to poor quality construction, which results in premature failure of materials.

- **Does the PWS have its own construction standards or has it adopted some from another agency?**

  Many small utilities borrow construction standards from a larger local community. While this can work, the standards often do not fit the needs of the community. This can cause contractors and staff to ignore the standards. The result can be the same as not having a standard.

- **Do the construction standards meet primacy agency requirements?**

  Because some primacy agencies do not review construction standards, the PWS may have adopted standards that violate existing standards. Assuming the primacy agency developed standards to provide the minimum degree of reliability to the system, the PWS's standards should be consistent with, and at least as protective as, the primacy agency requirements.

- **Are in-house staff and contractors required to use the same standards?**

  In many locations, staff construction methods may vary from those used by contractors. The lack of consistency in construction methods and in the standardization of materials, could lead to maintenance problems and slow repairs during emergencies.

- **Does the water system follow their own standards?**

  The surveyor should ask for a copy of written standard operating practices and construction standards. The surveyor should ask whether system operations and maintenance staff have access to the SOPs and construction standards, and if in-house staff uses these standards for all construction projects.

11.7 Water Quality

Water quality can deteriorate in the distribution system. A loss of pressure can allow contaminants to enter the distribution system as a result of back pressure, and very high pressures can cause back siphonage. High water pressures can also cause water lines and fixtures to break allowing contaminants to enter the distribution system.

As distribution systems are built or expanded, dead-end lines are sometimes inevitable. Dead-ends in distribution systems can lead to water becoming stagnant in portions of the distribution system, which could lead to loss of disinfectant residual and bacterial regrowth.

11.7.1 Disinfection Procedures

The installation of new pipes or the repair of existing pipes can introduce contaminants into the distribution system. Repair crews must follow proper procedures for disinfecting a water line after installation or repair. The surveyor should determine if PWS supervisors ensure these crews follow the disinfection procedures, including bacteriological sampling.

11.7.2 Sanitary Deficiency Questions and Considerations – Water Quality

- **What disinfection procedure does the water system use for new or repaired water mains?**

  The primacy agency standard should be followed. Otherwise, AWWA Standard C651 Disinfecting Water Mains is generally considered the industry standard. The surveyor should ask the operator what procedures they follow and if they have developed their own written SOP based on the primacy agency or AWWA standard. Any procedure should include the requirement that all bacteriological sample results are negative before the water main is returned to service. The AWWA standard describes three methods and includes using calcium hypochlorite tablets, continuously feeding sodium or calcium hypochlorite solution, or introducing a slug of high-concentration chlorine solution.

- **Are distribution mains looped to the greatest extent possible?**

  Dead-end lines can lead to stagnant water which increases water age and may lead to a reduction in disinfectant residual and cause other water quality issues. When possible, the water system should install water mains in a grid pattern to improve water circulation. Where a pipe is dead-ended for future expansion or to serve a dead-end street, a hydrant or blow-off valve should be installed near the end of the main so that it can be flushed as needed to remove stagnant water and restore the disinfectant residual.

- **Has the addition of service connections created dead-end lines?**

  Areas of stagnant water in a distribution system may result in bacteriological regrowth, increased DBP formation, red water, or customer complaints. Operators should routinely flush these areas, and the water system should put into place long-range plans for new connections and looping, if they are feasible. The surveyor should inquire about records of complaints and corrective actions taken.

- **Are there any bottlenecks in the piping system (a small diameter pipe connected on both ends by larger diameter pipe)?**

  Bottlenecks in the physical piping can cause high velocities, which can cause a Venturi effect, drawing contaminated water into the system through leaks in the bottleneck.

- **Are there any isolation valves in the distribution system that are inadvertently closed?**

  When maintenance work is needed in the distribution system, some valves may be closed to isolate the work area. After completing the work, the contractor or PWS worker may forget to re-open one or more valves, causing changes in flow direction, velocity, water age, and water quality. Adding this valve-opening step to a written SOP for maintenance work or other documentation or communication protocol can help to prevent this type of error.

- **Are blow-offs connected to sanitary or storm sewers, or do they exit below ground, below flood level in ditches or streams?**

  Blow-offs are gate, butterfly, or globe valves installed at the end of dead-end lines and in other locations to flush water from the distribution system. The surveyor should document how the flushed water is disposed of. The blow-off valve may be connected to a storm drain or sewer for disposal of the flushed water, or the outlet point may drain to a ditch or stream. Any piped connection should contain an air gap to prevent untreated water from the storm drain or sewer from backflowing into the water main. Direct connections between the blow-off valve and the storm drain or sewer are considered to be a direct cross-connection which can be a public health risk. The surveyor should find out whether blow-offs are operated automatically or manually, and if the flushing is based on time or water quality (e.g., chlorine residual, customer complaint).

- **Is there any point in the PWS where pressure drops below primacy agency pressure standards during peak demand or fire response?**

  The surveyor should consider pressures below primacy agency requirement a deficiency. Low or negative pressures can cause untreated water to enter the distribution system through leakage points or faulty seals. Also, a backflow condition could occur due to back-pressure. The system's design and operation must supply adequate quantities of water under ample pressure to prevent, as much as possible, conditions leading to the occurrence of negative pressure.

  Steps to prevent negative pressure include minimizing unplanned shutdowns, training operators and fire department personnel on proper valve opening procedures, providing adequate supply capacity, correcting undersized conditions, and properly selecting and locating booster pumps. Continuity of service and maintenance of adequate pressure throughout a PWS are essential for preventing back-siphonage.

The surveyor should determine if the water system has registered complaints about inadequate pressure and if there is a program to periodically monitor pressures throughout the system.

- **If the valves are in a vault, is the operator trained in confined space procedures?**

  The operator should understand the difference between permit-required and non-permit-required confined spaces. If the operator is trained to enter confined spaces, the operator should have the proper equipment and follow a written confined-space entry procedure. Vaults should be marked with signs identifying them as confined spaces.

- **If there are pressure zones controlled by automatic PRVs, do the PRVs work properly?**

  The surveyor should ask the operator how often upstream and downstream pressures are checked at each PRV. There should be operating pressure gauges above and below the PRV so the operator is able to determine if the PRV is working properly. If the upstream and downstream pressures are the same, does the operator open a fire hydrant downstream and observe the reaction of the pressure across the valve?

- **If there are PRVs, can the operator describe how they work and what they do?**

  The surveyor should check that the operator understands the key components of his or her water system. Knowledge gaps make it unlikely that the operator will resolve in a timely manner any problems that arise. Failure of a PRV can cause high downstream pressures that can lead to the failure of main lines and services.

- **What are the possible impacts of a PRV failure?**

  The failure of the PRV to reduce pressure can cause a main or service line to break. Low pressures can result in backflow from back-pressure or back-siphonage. The longer a PRV failure goes undetected, and the longer the delay in fixing it, the greater the possibility of contaminating the system.

- **Are there any low areas in the distribution system?**

  Low areas in the distribution system can accumulate silt and organic material that can reduce chlorine residual, and cause bacteria growth and taste and odor problems. Spot flushing can be used to remove the accumulated sediment and maintain the finished water quality. The flushing frequency depends on system-specific water quality and operating conditions.

- **If there is a hydraulic model, has it been compared to actual conditions? When was the model last updated? Does the operator or system manager know how to use the hydraulic model to evaluate normal and emergency conditions (e.g., areas with low-pressure)?**

  Hydraulic models help the manager identify low-pressure points and areas of inadequate supply. While many water systems lack hydraulic models, water systems that have not addressed low-pressure problems can benefit from a model or other specific method. A model is of little value, however, if the water system has not calibrated it against actual system data.

- **Are backflow prevention assemblies installed and tested at each commercial site where backflow could cause a reduction in water quality?**

  Chapter 12 discusses cross-connection issues in depth. These testable assemblies are important features for preventing contamination of the system.

- **Does the discharge piping on all automatically operated air valves extend a proper distance above ground and flood level?**

  One source of contamination is untreated water that enters the distribution system through air valves.

- **Has management or the operator identified distribution system problem areas on a PWS map?**

  A map or other record-keeping method for system problems is a good indicator of management support for solving system problems. If the PWS is not using a map or other method to record system problems, are they aware of current problems? The surveyor should identify any management or operations issues (e.g., training, budget) that may delay or prevent implementation of corrective actions.

- **Does the PWS provide bulk water stations? How are they monitored and controlled?**

  If the system provides stations for bulk water distribution, how does the PWS monitor and protect the facilities? Is there an actual facility or is it just a metered hose on a fire hydrant? How do they prevent cross-connections (e.g., preventing customers from dangling the supply line into their tank)? How do they track and charge for the quantity consumed?

11.8 Maps, Drawings and Planning

Almost all distribution system components are underground and, therefore, not visible during a survey. As water systems expand distribution systems, it becomes more important for operators to understand the configuration of the distribution system and maintain adequate maps, as-built plans and drawings that show the current configuration of the distribution system.

These maps should also have color coding or other types of legends that indicate, valve locations, pipe diameters, and types of pipes. Without this information, water systems may not have the proper replacement materials on-hand or available when breaks or other emergencies occur.

11.8.1 Sanitary Deficiency Questions and Considerations – Maps, Drawings and Planning

- **Are as-built drawings available?**

  As-built drawings are scaled drawings that show the actual locations of all constructed facilities. The lack of as-built drawings makes it difficult for the staff to perform proper repairs in a timely manner.

- **How often are maps updated?**

  Annual updates to drawings and as-builts help reflect current conditions. Inaccurate data can cause the staff to obtain the wrong materials and thus delay a repair. If this happens too many times, the staff may stop using the drawings. Eventually, staff with historical knowledge move on, leaving new staff with outdated or no information.

- **Do maps and as-builts contain the proper information?**

  Maps and as-builts should contain the following information, or the information must be available in some form of asset data base: pipe size, date of installation, pipe material, line valve and blow-off locations, hydrant locations, storage tank locations, and interconnections to other systems.

- **Is there a master plan showing proposed construction and replacement lines?**

  To provide adequate and reliable service now and in the future, management should base system changes and additions on a master plan. If this plan does not exist, the PWS commonly responds to developers' needs. This can cause the system to expand lines to areas that it cannot serve with adequate pressure.

11.9 Distribution System Monitoring

The majority of the regulatory monitoring requirements are at the entry point to the distribution system or at the treatment plant. There are, however, several regulations that require monitoring be conducted in the distribution system or at the residential taps. These regulations require water systems to develop monitoring plans and make them available to the surveyor upon request.

11.9.1 Sanitary Deficiency Questions and Considerations – Distribution System Monitoring

- **Have there been changes in the distribution system since the last sanitary survey?**

  Changes in the distribution system such as population and demand shifts, additions to the distribution system, looping of dead-ends, new dead ends, and storage additions can affect where representative samples for total coliform, lead & copper, and disinfectants and DBPs are taken.

- **Does the operator have goals for and monitor for chlorine residuals throughout the distribution system?**

  The SWTR requires water systems to measure residuals at the same time and place as coliform samples are collected. Many states require daily monitoring of disinfectant residuals in the distribution system. The maintenance of a chlorine residual regardless of source type, is the last line of defense against waterborne disease. This is one of the key quality control items in the operation of a water system, and setting measurable goals is a good method for evaluating treatment objectives.

- **What is the operator using to measure disinfectant residuals?**

  The surveyor should determine what the operator uses for measuring disinfectant residuals. The surveyor should also review the operator's standard operating practice for calibrating the field instrument, performing field measurements, and recording field data.

- **If required, is the disinfectant residual at least 0.2 mg/L prior to the first customer?**

  This is a requirement for all surface water and Ground Water under Direct Influence of Surface Water (GWUDI) systems. It assumes that this residual is available after the water system has met disinfection CT requirements.

- **If required, does the operator maintain a measurable disinfectant residual at coliform sampling points?**

  This is a requirement for all surface water and GWUDI systems. It is good operational practice to keep a measurable residual at all points in the distribution system. If any point in the system does not have a chlorine residual, the water quality is suspect. Surveyors should also review state standards regarding minimum residual levels.

- **Are there an adequate number of disinfectant residual sampling sites, and do they provide a representative sample of PWS conditions?**

  The PWS should establish sufficient disinfectant residual sampling points, representative of the entire system. Small systems may be able to rotate through a number of sample sites to get an overall picture of disinfectant residuals.

- **Does the operator use the correct, unexpired, reagent for testing free and total disinfectant residuals?**

  Check the reagents. Operators may accidentally use reagents for total chlorine residual when using free chlorine as a secondary disinfectant.

- **Is the operator waiting the correct length of time before reading the disinfectant residual?**

  Some kits require completion of the test for DPD (N,N Diethyl-1,4 phenylenediamine sulfate) within 1 minute of adding the reagent, for free chlorine and within 3 to 5 minutes for total chlorine. Manufacturers of photometers specify the steps and time required to take readings. In general, the operator needs to follow the manufacturer's instructions when using field test kits.

- **When has the operator last calibrated or replaced the testing instrument?**

  The operator should routinely check chorine test kits against standards or other test kits regardless of the type of test kit (e.g., spectrophotometers or color wheels). A color wheel stored in a closed box (protected from light) should last years while one left exposed to sunlight on a pickup dashboard very well may fade out in a year or two.

  When did they last calibrate the instrument? Have the operator compare a fresh sample result to those from the surveyor's photometer. If the measurements are significantly different, have the operator calibrate his instrument and repeat the comparison.

- **Does the operator measure and record PWS pressures at high and low elevations?**

  To obtain representative data, system pressure should be measured at high and low elevations. In addition, data should be recorded using blue ink to make it easier to determine originals.

- **Does management record and analyze customer water quality complaints?**

  Many states require utilities to record the nature and response to all water quality complaints. With the 1996 Amendments to the SDWA, water systems are now required to provide customers with water quality information in the Consumer Confidence Report, and communication with customers is no longer just good operations and customer relations. By recording and analyzing customer complaints, a manager can prevent problems, or address them before they get out of hand. Many customers are very sensitive to changes in water quality, and a positive response to customer problems is a good management practice.

- **If the PWS is fully metered, what is the percentage of total water produced that is considered to be non-revenue water?**

  Water systems are adversely impacted because millions of gallons of water are lost to leakage, meter error, and water theft each year (AWWA, 2016b). Accounting for water and minimizing water loss can help a water system be more sustainable. Surveyors should discuss with the operator whether metering data are being used to characterize the amount of non-revenue water being produced. Water systems should address such water loss in its planning and engineering documents.

- **Does the PWS meet state standards for water loss/leakage?**

  Some states have standards for distribution system water losses or requirements for water audits. The surveyor should confirm that the water system is complying with its state's water loss or audit requirements.

- **Is the PWS managing water loss and supply efficiency?**

  A water loss control program helps to identify real or physical losses of water from the water system and apparent losses (water that is consumed but not accounted for). Real losses, also referred to as physical losses, are actual losses of water from the system and consist of leakage from transmission and distribution mains, leakage and overflows from the water system's storage tanks and leakage from service connections up to and including the meter. Real losses represent costs to a water system through the additional energy and chemical usage required to treat the lost water. Apparent losses represent a loss of revenue because the water is consumed but not accounted for and thus not billed. Once a water system identifies its real and apparent losses, it can implement controls to reduce them.

- **Has the system implemented a leak detection program, including data collection and analysis?**

  Not only do detecting and repairing leaks reduce the amount of water loss, doing so generates additional data that can help characterize a system's water losses. Some leak detection devices use acoustic technology to identify leaks in need of repair. Once a leak has been detected and located, the pipe can be repaired or replaced. Repairing and replacing pipes requires trained personnel and the proper inventory of parts and materials.

- **Has the water system completed any water loss studies? If so, what is the water system doing in response to the findings?**

  A water audit is an accounting of all of the water in a water system resulting in a quantified understanding of the integrity of the water system and its operation. It is usually the first step toward developing a plan to address water losses. Once a water audit has been completed and water losses have been characterized for the water system, the system can take measures to address the water losses identified in the audit. Such measures include more effective maintenance; meter installation, testing and replacement; and leakage management (USEPA, 2013a).

- **Does the PWS meter all service connections?**

  A water system may meter all of its service connections or a subset of them. Some water systems do not meter their municipal buildings or schools. During the sanitary survey, the surveyor should gather information about how many of the service connections are metered and which service connections are not metered, if applicable.

- **Does the PWS have a meter calibration and repair/replacement program?**

  At the system level or supply-side, improvements in water efficiency in the distribution system begin with metering, water audits, and water loss control programs. Leak detection and repair can minimize the potentials for intrusion into distribution systems and has important public health benefits. An evaluation of water loss and control could be part of sanitary surveys or other state oversight programs.

  A high quantity of non-revenue water is an indication of either inaccurate meters or excessive leakage. Inaccurate meters result in a PWS losing revenue for all the water consumed by customers, reducing income and making it more difficult to maintain the system. Holes in pipelines and bad pipe joints are potential entry points for contaminated ground water.

11.10 Operation and Maintenance

Water system management and operators should not only record distribution system data about issues that occur, but also display it in a manner that is functional. Maps and overlays with different color pushpins that indicate line break locations, low disinfectant residuals, positive total coliform samples, customer complaints, etc., are especially effective.

The design of the distribution system should include a sufficient number of strategically located valves to isolate breaks and other construction areas, to facilitate rerouting of water flow to potentially affected customers, minimizing interruption of services. Operators should have maps readily available that include the locations of these valves.

The geological conditions of soils can cause piping materials to deteriorate or shift during drought and other conditions. Construction design standards require proper installation of bedding and support at elbows, tees and dead-ends in the distribution system. These measures, when taken, assure the water system minimizes breaks and damage to the distribution system.

11.10.1 Sanitary Deficiency Questions and Considerations – Operation and Maintenance

- **What is the frequency of main breaks?**

  Main breaks are normal common problem in a water system. If the breaks are frequent, there may be a problem with the integrity of the piping material (frequency depends on area and type of piping material). Each main break opens the system to contamination, and frequent breaks increase the potential for introducing waterborne pathogens into the system.

  Most breaks are generally due to leaks, not age. The leaks undermine the pipe, causing it to fail under the weight of the overburden. To prevent main breaks, the operator should conduct a routine leak detection program and keep a record of distribution system repairs. This record should identify the location and type of repair, repair device or length of replacement pipe, and general condition of the line.

  Water systems in drought-stricken or other areas where conditions are significantly affecting water quantity especially need a robust leak detection/prevention and repair program.

- **Are the breaks primarily in one area? What type of pipe is involved?**

  If management has this type of information, it is an indication they are attempting to address problems before they become critical. They should be comparing this information with the master plan to ensure they are in agreement. The lack of this information may indicate a failure by management to respond to the system's deteriorating conditions.

- **Is there a line flushing program? Is a systematic unidirectional process used? Are records maintained of frequency, location, and amount of time required?**

  The distribution system should be flushed regularly as part of routine distribution system maintenance. The flushing should be well planned and carried out, preferably beginning at points near the water plant and storage facility and moving to the outer ends of the system.

- **Is there a fire hydrant flushing program separate from the line flushing program?**

  Fire hydrant leaks can be a source of water quality deterioration. The water can become stagnant, consuming chlorine, causing odor and taste problems, and increasing bacteriological counts. Annual flushing can prevent this problem.

- **Is there a valve inspection and exercising program? Does the operator maintain the records?**

  Maintenance crews should inspect and exercise every valve in the distribution system according to a routine schedule. This should include completely and repeatedly opening and closing, until the valve seats properly. The operator should schedule repairs for any leaking or damaged valves and maintain a record of valve maintenance and operation, including the number and direction of turns to closure.

- **Does the PWS have a backhoe? If not, how long would it take a contractor or rental company to provide one if needed? Can the PWS obtain this equipment late at night?**

  The lack of equipment, such as a backhoe, can prevent the staff from making repairs in a timely manner. The longer a portion of the system is shut down at a reduced pressure, the greater the opportunity for contamination.

- **How often does the operator take pressure readings in the distribution system? Are they representative of the system? What kind of readings result in action? What actions does the operator take?**

  Operators may conduct a program to read pressures in conjunction with the fire department to determine adequacy of fire flow. A record of pressures and flows throughout the system may help to identify problems. Recording these pressures during the day and at night will indicate hydraulic efficiency under common conditions.

- **Are adequate repair materials on hand?**

  If repair materials are not available, how many hours would it take to obtain these materials at 2:00 a.m.? The repair materials should include repair clamps, couplings, and one section of pipe for each size and type of piping, plus size and type of fitting and isolation valves used including parts for the water system-side portion of service lines such as corporation stops.

- **Are there written procedures for isolating portions of the system and repairing mains?**

  Written emergency response procedures improve the water system's reliability. In a small system, they provide a way to handle unexpected problems when the regular operator is not available. They also give the operator a means of dealing more effectively with non- routine tasks.

- **Does the PWS maintain an updated list of critical customers?**

  Reducing water pressure, shutting off service, or reducing water quality can severely affect some customers, including hospitals, clinics, photo developers, and users of special medical equipment. It is important for customer support and for the reduction of liability to maintain a list of these customers and to notify them of changes in the system that could adversely affect them.

- **Does the PWS have a corrosion control program?**

  The PWS should have a program to evaluate internal corrosion (i.e., within the piping system), its effectiveness in controlling contaminants, such as lead and to minimize red water complaints. Management should maintain records of complaints and the corrective actions.

- **Does the PWS have an interconnection with any other water systems?**

  An interconnection to an adjacent water system may provide an alternative source of finished water, in cases of drought, contamination of the primary source, or similar emergency. The surveyor should ask if the water system has a written agreement regarding the interconnection and whether the valve separating the two systems is in an operable condition.

- **Does the PWS have adequate AND operable valves?**

  The PWS should have enough isolation and blow-off valves to make necessary repairs without undue interruption of service. Maintenance crews should exercise and maintain these valves, regularly.

- **Are all elbows, tees, and dead ends supported by concrete thrust blocks or restraining fittings?**

  Concrete thrust blocks, or other devices, must restrain or support all fittings, elbows, tees, and dead ends.

- **Is proper bedding used, and do contractors or maintenance staff follow proper backfill procedures during the installation of new or repaired pipes?**

  Bedding and backfill protect pipes from external damage. Proper bedding and backfill are especially important when installing PVC pipe to support pipe walls and protect them from deflecting, and thus breaking longitudinally.

- **Does the PWS or their contractors perform pressure or leak tests on all new pipe construction?**

  Pressure tests check the integrity of the piping material. Leak tests check the integrity of the pipe joints.

- **If corrosive soils are present in the distribution system area, are cast-iron, ductile iron, and steel pipe protected from external corrosion?**

  There are several methods to protect pipe from external corrosion including coatings, polyethylene sleeves, and cathodic protection systems. Alternatively, the water system could choose to use PVC or HDPE pipe in corrosive soils.

- **Are cast-iron and steel pipe protected from external corrosion?**

  There are several methods to protect pipe from external corrosion including coatings, polyethylene sleeves, and cathodic protection systems. Alternatively, the water system could choose to replace these pipelines with PVC or HDPE pipe in corrosive soils.

- **How does the surveyor's sanitary survey findings affect the RTCR sampling requirements?**

  The RTCR requires a special monitoring evaluation for all ground water systems serving 1,000 or fewer people. The surveyor must assess the appropriateness of the sampling frequency, number of samples, sample locations and collection dates based on new data from the sanitary survey.

  The surveyor should determine how effective the source, treatment and distribution barriers are regarding protection from contamination, and then modify the sampling as needed for public health protection. In addition, the surveyor may need to change the sampling sites and frequency for any of the following reasons as determined during the sanitary survey:

  - Increase in population served.
  - New distribution system areas served.

- New storage tanks.
- Deterioration of water system infrastructure.

The surveyor should coordinate with the RTCR manager to re-evaluate the RTCR monitoring frequency for any PWS (not monitoring monthly) when sanitary survey findings show*:

- Significant deficiencies/sanitary defects, including in distribution system.
- Cross-connection problems.
- Noncompliance with State certified operator provisions.

*See 40 CFR 141.854(g)(1), 40 CFR 141.854(e)(2), 40 CFR 141.855(d)(1)(ii), 40 CFR 141.855(d)(1)(iii)(B).

11.11 Possible Significant Deficiencies for Distribution Systems

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The primacy agency determines both significant deficiencies and the corresponding corrective actions.

- Cross-connection(s).
- Negative or low pressures in the distribution system.
- Unapproved construction materials and methods.
- Lack of proper valving.
- Air release valves not plumbed to daylight.
- Inadequate pipe size for distribution needs.
- Not maintaining disinfectant residuals as required by either federal or state standards.

12 Cross-Connections

A cross-connection is an actual or potential physical connection or arrangement between otherwise separate potable water piping systems and any contaminant that allows water to flow between the two systems. Cross-connections in water systems are significant sanitary risks that threaten drinking water quality and public health. During a sanitary survey, the surveyor must first evaluate the adequacy of the system's cross-connection control program. Second, the surveyor should identify unprotected cross-connections owned or controlled by the water system in the treatment facility and in the distribution system. To perform these evaluations, the surveyor should be able to meet the following objectives.

12.1 Learning Objectives

By the end of this chapter, students should be able to:

- Define the term cross-connection and recognize common cross-connections.
- Differentiate between the two types of backflow that can occur due to cross-connections: back-pressure and back-siphonage.
- Identify backflow prevention devices and assemblies to prevent backflow and backsiphonage, explain their operation, and determine if the water system installed them properly.
- Evaluate the water system's cross-connection control program and its implementation.
- Identify unprotected cross-connections within the water system, including those in a treatment facility, pumping station, or distribution system.
- Determine if the water system uses, properly tests and maintains appropriate backflow prevention devices and assemblies according to the degree of hazard.

12.2 Data Collection

To evaluate the system's compliance status, the surveyor should review the following information:

- System's written cross-connection control program.
- Number and type of backflow preventers in the system.
- Frequency of testing of backflow preventers.
- Qualifications of persons authorized to test devices.
- Procedure for reviewing new building construction plans.

12.3 Regulations and Standards to Consider

The surveyor should consider or review the following information prior to the survey:

- State regulatory requirements for cross-connections.

- Local plumbing code.
- Cross-Connection Control Manual, EPA Publication No. 816-R-03-002.
- Recommended Practice for Backflow Prevention and Cross-Connection Control, AWWA M14.
- Manual of Cross-Connection Control, University of Southern California – Foundation for Cross-Connection Control.

12.4 Basic Information

12.4.1 Cross-Connection Defined

To prevent contamination of its water, a system needs to ensure proper installation of service connections and continually monitor them for cross-connection hazards. Hazards occur when a contaminant flows toward the potable supply. Unless controlled, cross-connections can result in contaminated water replacing potable water at various sites within a water system. There is a potential for the contamination to spread throughout the distribution system, endangering the health of the entire community.

12.4.2 Plumbing Defects

Plumbing defects can occur in any part of a water system, and cross-connection hazards can occur where outside water pressure can exceed potable water pressure. Cross-connections must be prevented or controlled at all service sites. The water treatment plant is often the site of a number of cross-connections.

12.4.3 Types of Cross-Connections

A cross-connection link can be either a pipe-to-pipe connection, in which a potable water pipe connects to an untreated water pipe without proper control valves, or a pipe-to-water connection, in which the outlet from a potable water supply (e.g., a chemical feed line) is below the surface of or the top of the vessel containing untreated water. Cross-connections are usually made unintentionally or because their hazards are not recognized or are underestimated.

12.4.4 Back-Pressure and Back-Siphonage

There are distinguishing characteristics, based on their origins for the two major types of cross-connection hazards, back-pressure backflow and back-siphonage backflow. Back-pressure backflow refers to the flow of contaminated water toward a potable supply when the contaminated water's pressure is greater than the potable water's pressure. Back-siphonage backflow results from negative pressure (a vacuum) in the distribution pipes of a potable water supply, drawing contaminated water toward the potable supply.

12.4.5 Control of Cross-Connections

Successful control of cross-connection hazards depends not only on inspecting for cross-connections by a water system and by water users, but also on an enforceable cross-connection control program. Some states require water systems to have a cross-connection control program that meets minimum requirements and includes authority to conduct the program. If a community subscribes to a modern plumbing code, such as the Uniform Plumbing Code or International Plumbing Code, the provisions in those codes include requirements for backflow protection. In either case, the water system needs authority to conduct a community survey program and require backflow protection through an ordinance or other means and to carry out a comprehensive cross-connection control program.

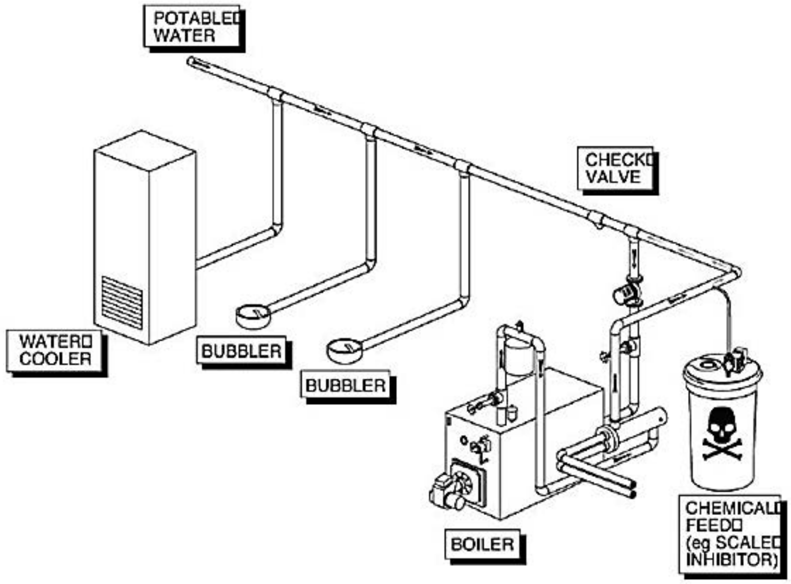

Figure 12-1: Backflow as a result of back-pressure

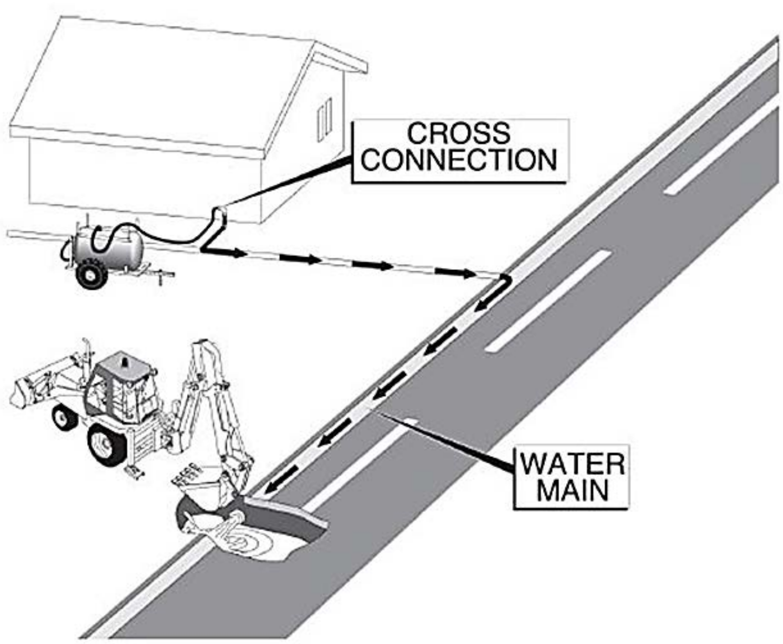

Figure 12-2: Backflow as a result of back-siphonage

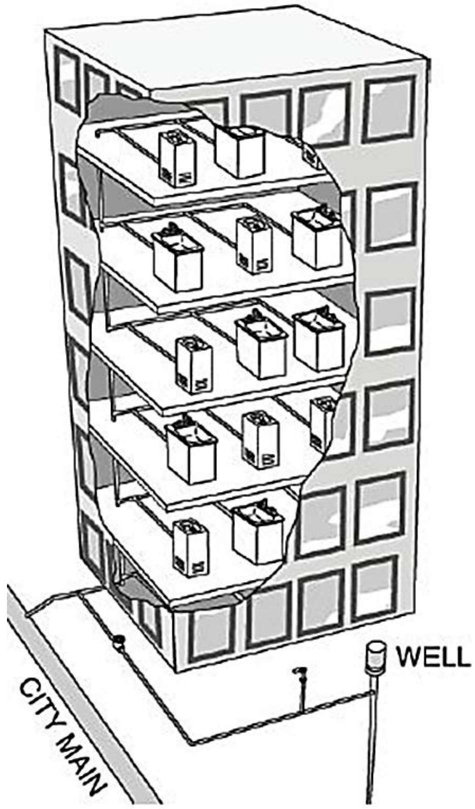

Figure 12-3: Backflow as a result of hydraulic head

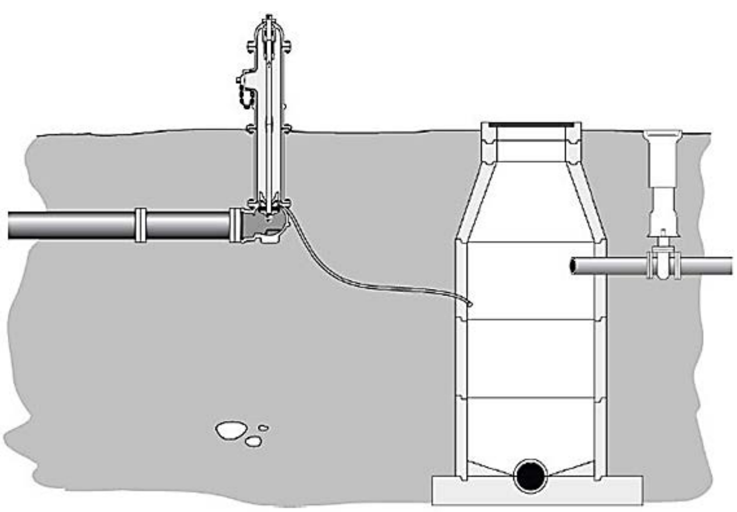

Figure 12-4: Direct cross-connection

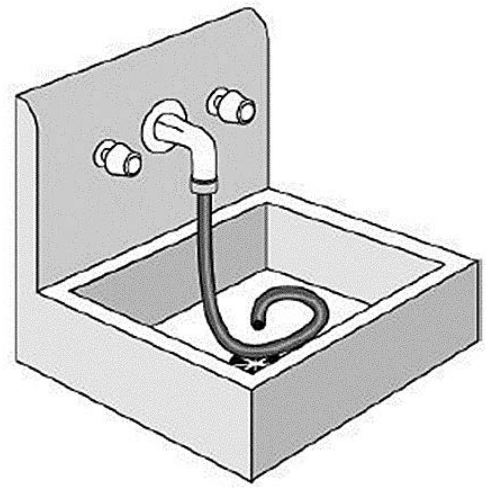

Figure 12-5: Indirect cross-connection

12.4.6 Components of a Water System's Cross-connection Control Program

A cross-connection control program should have these basic components:

- Ordinance or other authority to establish a program.
- Technical provisions to eliminate cross-connection hazards.
- Right of entry and survey of existing facilities served by the system.
- Backflow prevention assembly testing, repair and recordkeeping.
- Certification of backflow prevention assembly testing personnel.
- Review of new construction plans and new services for potential cross-connection hazards.
- Penalty provisions for violations.

A cross-connection program can protect the potable water supply through a service protection or containment process, where water systems install backflow prevention, if needed, before the meter or point of service. Customers can also provide backflow prevention at individual plumbing fixtures within their plumbing system – commonly referred to as internal protection or fixture protection. Ideally, customers should install atmospheric vacuum breakers (AVBs) on all threaded hose bibs. Some local plumbing codes require hose bibs that have threads be of the kind that only accept AVBs. The AVB has the appropriate threads to which customers may then attach a hose.

The plan and new service review components of a cross-connection control program may require coordination with other agencies such as building permits, plumbing code enforcement, or local health agencies to establish responsibilities and communication.

12.5 Protection Against Sanitary Deficiencies from Cross-Connections

Plan review, plumbing code enforcement, and cross-connection site surveys can provide some control of cross-connections at sites serviced by a water system. However, where the potential for cross-connections and backflow exists, a potential risk to the potable water supply and public health also exists, and the water system needs additional methods or mechanical means of protecting the potable water supply. For example, a temporarily submerged water outlet fixture in an apartment building could result in contamination of the water for the entire building (as well as threaten the public water supply), if conditions resulted in back-pressure or back-siphonage.

12.5.1 Pressure

An important aspect of reducing the threat from cross-connections and backflow is maintaining adequate pressure in the distribution system. Some states have a minimum pressure requirement of at least 20 psi, under all conditions of flow in all portions of the system. The surveyor needs to review pressures throughout the system as part of the distribution system element of a sanitary survey.

12.5.2 Methods and Mechanical Assemblies

A number of methods and mechanical assemblies are available to protect the potable water system from contamination from cross-connections, including the following:

12.5.2.1 Air Gap

Air gaps are non-mechanical methods that are very effective at preventing backflow and back-siphonage. To prevent a cross-connection hazard in the apartment fixture example described previously, the fixture in the building should have a vertical air gap of twice the diameter of the pipe or fixture, between its outlet and its flow level rim. This eliminates the physical cross-connection link and protects the building (and the municipal supply) water against backflow. An air gap for water service entering a building only protects the municipal supply, however, and not the building system. Although very effective, an air gap does interrupt flow and results in a loss of pressure and, therefore, operators install them at the ends of plumbing lines or to fill reservoirs or storage tanks where pressure loss is not an issue.

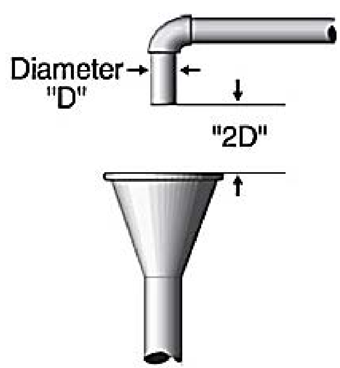

Figure 12-6: Air gap

12.5.2.2 Backflow Prevention Devices and Assemblies

Water systems can install non-testable backflow prevention devices or testable backflow prevention assemblies when an air gap is not appropriate or possible.

Although state requirements may vary, there is general agreement that back-siphonage can be prevented by installing vacuum breakers at water outlets, where contaminated water is present (for example, at toilets and urinals equipped with flush meters). Use of vacuum breakers at hose bibs is acceptable; however, they are not effective against back pressure. In-ground irrigation systems require better backflow prevention devices such as double-check valves, inspected annually or as required by local plumbing codes.

12.5.2.3 Atmospheric Vacuum Breaker

Atmospheric pressure activates an atmospheric vacuum breaker (AVB) to block the water supply line when negative or no pressure develops in the line. This action admits air to the line and prevents back-siphonage. Vacuum breakers must be installed a minimum of 6 inches above the highest outlet. A vacuum breaker does not provide protection against backflow resulting from backpressure and are not suitable for installations where they may be under constant pressure, because they may stick open. Therefore, operators should not install them where backpressure may occur or with a valve (or nozzle) on the downstream side that can shut water off. Operators will not be able to test AVBs after installation.

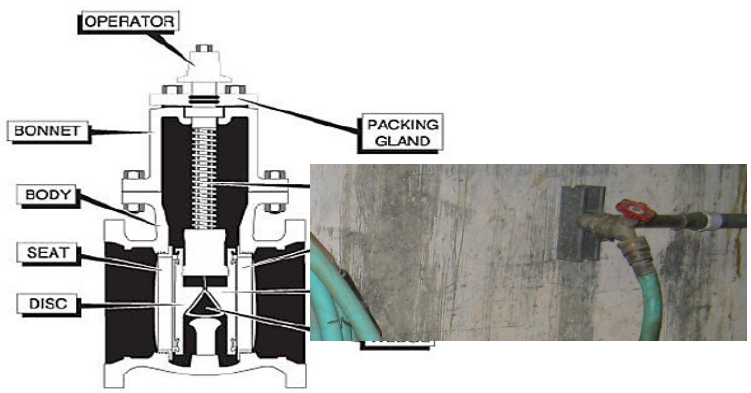

Figure 12-7: Atmospheric vacuum breaker

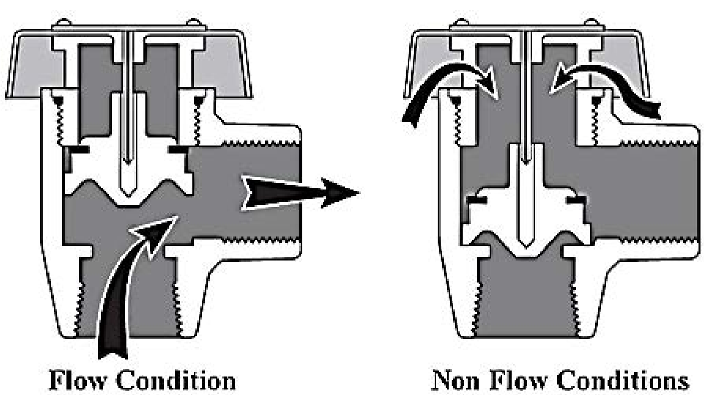

Figure 12-8: Gravity atmospheric vacuum breaker

12.5.2.4 Pressure Vacuum Breaker

Water systems install PVB assemblies in pressurized systems, and the assemblies only operate when a vacuum occurs. It is usually spring loaded and should be specially designed to perform adequately after extended periods under pressure. This device is suitable for use when a high degree of hazard is present, but only under back-siphonage conditions, for example, on irrigation systems. Pressure vacuum breakers (PVB) must be installed a minimum of 12 inches above the highest outlet. Unlike the AVB, operators can inspect and test these assemblies, which they should do at least annually.

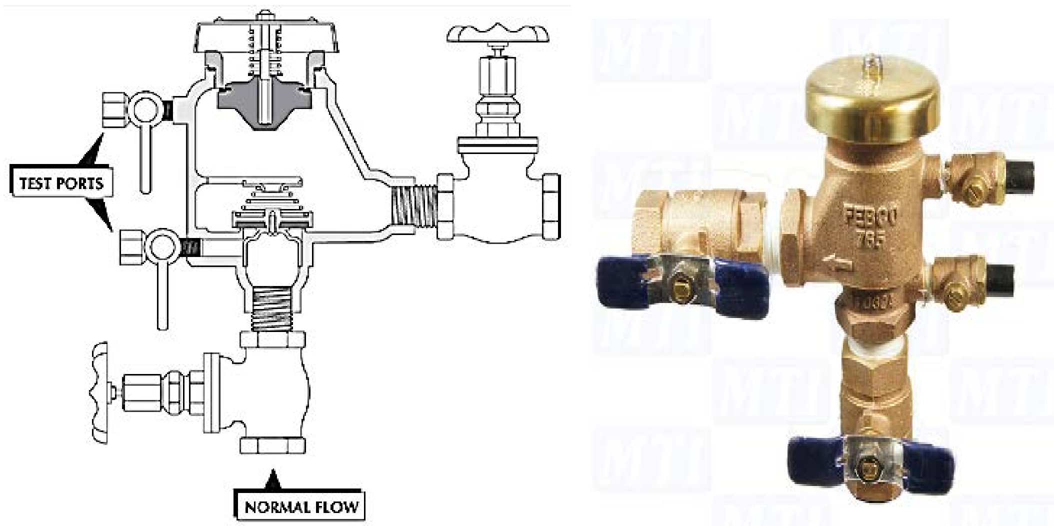

Figure 12-9: Pressure vacuum breaker

12.5.2.5 Double-Check Valve Assembly

The double-check valve assembly protects against both backflow and back-siphonage and is a reliable means of backflow protection in non-health hazard applications. For example, water systems can install these for protection against contaminants that would cause only aesthetic changes to water quality. The double-check valve assembly can be tested and should be inspected and tested annually. The double-check system has the advantage of a low head loss (maximum 10 psi). With the shut-off valves wide open, the two checks, when in an open position, offer little resistance to flow.

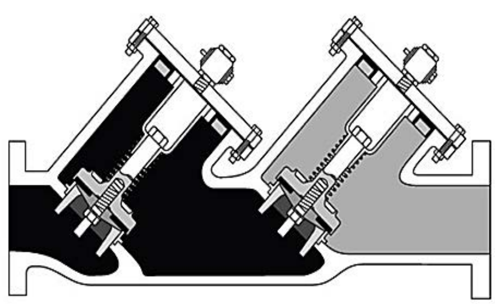

Figure 12-10: Double check valve assembly

12.5.2.6 Reduced Pressure Principle Backflow Preventer (RPP) Assembly

The RPP (also called a reduced pressure zone or RPZ backflow preventer) assembly is the most reliable of the mechanical assemblies used to prevent backflow for both backpressure and back-siphonage and for health or non-health related hazards. Water systems often use RPP s to provide internal protection such as make-up water to boilers or other pressurized systems, as well as at the meter or service connection (containment) to high-hazard customers, such as manufacturing facilities or customers with auxiliary water supplies on the premises. This device consists of two independently loaded pressure-reducing check valves and a pressure-regulated relief valve located between them.

Because all valves may leak as a result of wear or obstruction, check valves alone do not provide adequate protection. If some obstruction prevents a check valve from closing tightly, the leakage back into the central chamber would increase the pressure in this zone and the relief valve would open and discharge flow to the atmosphere. Operators or properly trained personnel can inspect and test the RPP which they should do at least annually.

A continuous discharge of water from the relief port indicates a malfunction of one or both of the check valves or the relief valve; however, the relief port may periodically discharge small amounts of water during normal operation. Under no circumstances should anyone plug the relief port, because the assembly depends on an open port for safe operation.

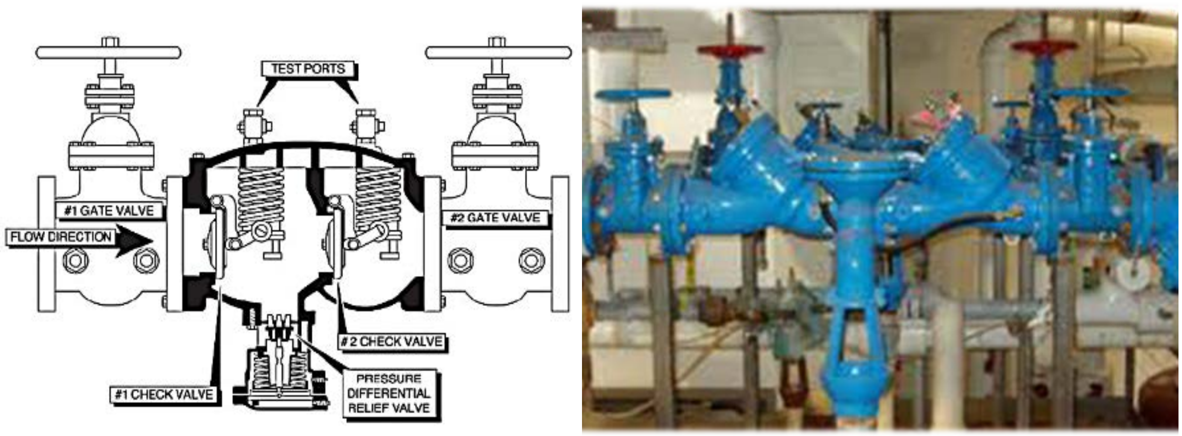

Figure 12-11: Reduced pressure principle backflow prevention assembly

12.5.3 Device Use and Maintenance

All the devices and assemblies described previously, as well as the air gap, can be used for internal or fixture protection within the premises (isolation). The device or method needed for protection is determined by the level of hazard present and the pressure conditions. Protection of the public water supply at the meter or service connection (containment) usually requires an air gap, RPP, or double check valve assembly, depending on the level of hazard present. In some cases, water systems or local plumbing codes may allow PVBs at connections that only serve landscape irrigation systems.

Note: Manufacturers require installation of some devices in a certain orientation (horizontal or vertical). Operators must also install them according to direction of flow. The surveyor should check for proper installation.

12.5.3.1 Testing Required

Operators should have applicable backflow preventer assemblies inspected and tested at least annually to assure their proper function. The surveyor should verify air gaps to ensure they have not been defeated or modified.

12.5.3.2 Certified Testers

Many states now require the certification of individuals who test backflow preventers. This is an important component of a system's cross-connection control program. Water systems may have their own employees certified, or allow private contractors to test assemblies.

12.5.4 Cross-Connections Owned or Controlled by the Water System

12.5.4.1 Requirements

In addition to the many cross-connections that may exist on the premises of a water system's customers, there can also be potential cross-connections owned or controlled by the system itself. These potential cross-connections should be subject to the same scrutiny as those on private property.

12.5.4.2 Location of Cross-Connections

There can be cross-connections in water treatment plants, pumping stations, or in the distribution system that can pose a risk to water quality and public health. During a sanitary survey, the surveyor should identify all cross-connections that are under the water system's control. The water system must manage all potential cross-connections through a documented cross-connection control program.

12.5.4.3 Water Treatment Plants

Water treatment plants can have a variety of potential cross-connections. If they do exist, the water system should eliminate them with an air gap or, if that is not possible, the appropriate backflow-prevention device or assembly. The surveyor should determine whether the following cross-connections exist:

- Submerged inlets or water piped directly to chemical feed tanks.
- No anti-siphon valves on chemical feeders.
- Hose bibs without vacuum breakers.
- Laboratory aspirators.
- Split chemical feeds to raw or partially treated water and finished water. Examples are pre- and post-chlorination or pre- and post-caustic addition for pH control.
- Surface wash on filters.
- Filter-to-waste piped directly to a drain.
- Drain line from online analyzer directly connected to a drain.
- Drain or sewer traps with direct water injection.

- Floor drains that allow the return of water to the process stream.
- Bypasses around backflow preventers.
- Feed water to boilers with chemical injection.
- Water loading stations for bulk water sales.

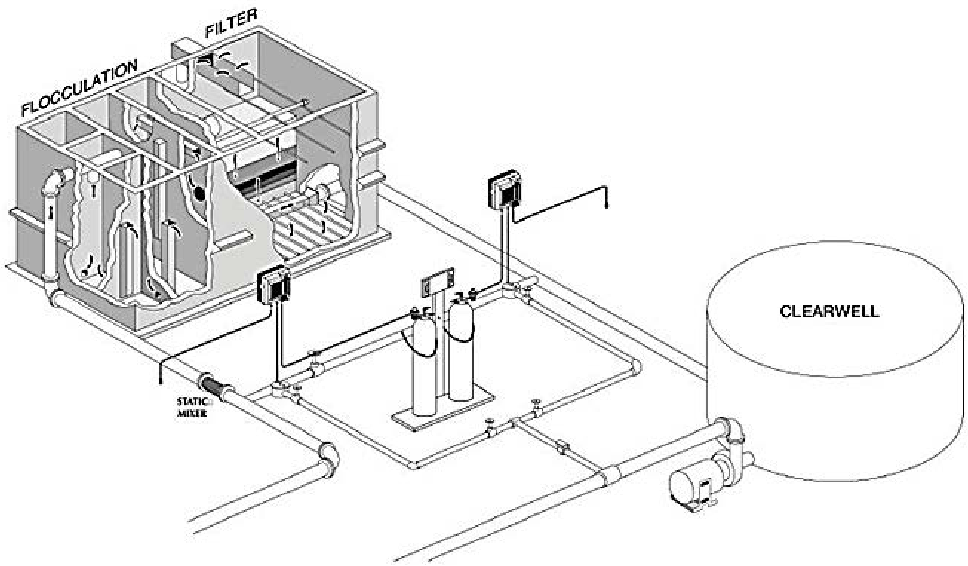

Figure 12-12: Split feed cross-connection diagram

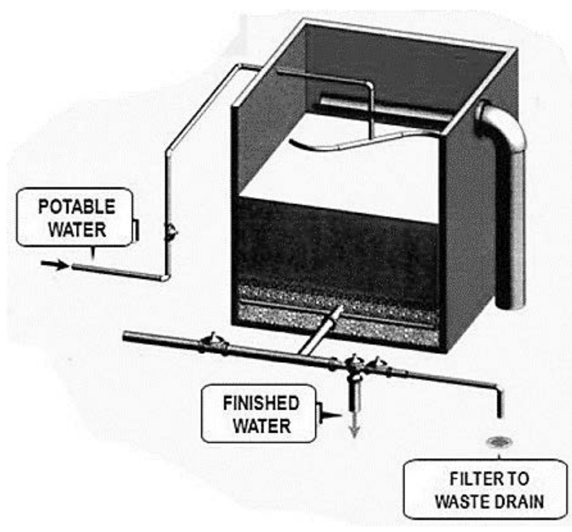

Figure 12-13: Surface wash cross-connection (potable surface wash water and unfiltered water)

12.5.4.4 Pumping Stations

The surveyor should also evaluate pumping stations for cross-connections. Potential cross-connections include:

- Priming of raw water pumps with finished water.
- Air release valves piped directly to a drain.
- Cooling water for an emergency generator submerged in a drain or returned to the potable supply.

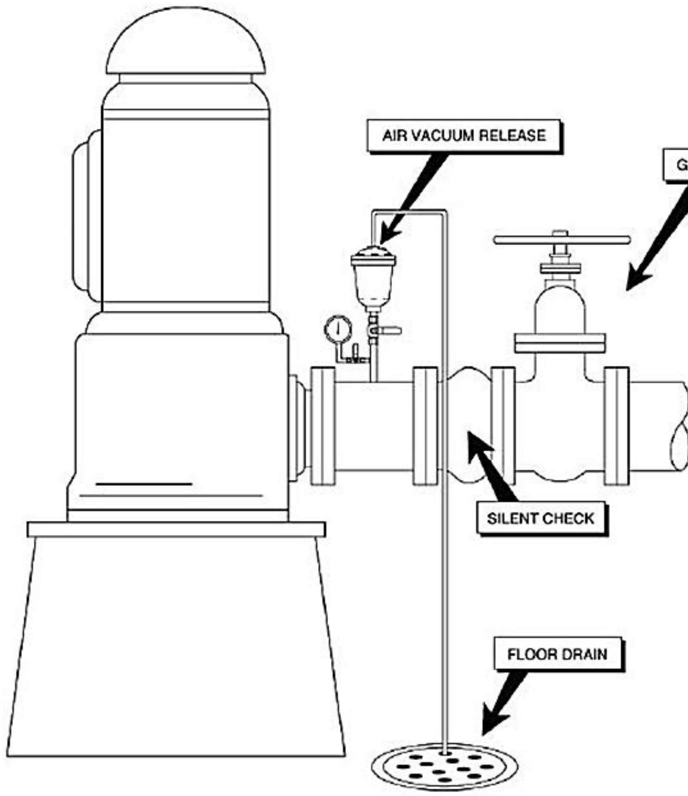

Figure 12-14: Air release valve piped to drain

12.5.4.5 Distribution System

The surveyor, as well as the operators, cannot see many of the potential cross-connections in a distribution system. Therefore, the personnel responsible for the operation of the distribution system must be able to provide the appropriate answers relating to these cross-connections:

- Submerged blow-off in streams.
- Water mains passing through sewers or below sewers.
- Connections to unapproved water systems or sources (i.e., fire systems or private wells).
- Submerged inlets in the water system's own meter testing equipment.
- Air release valves in pits where their open ends may be submerged.
- Submerged relief ports from pressure-reducing valves.

- Overflows and drains from storage tanks connected directly to or not ending at least two pipe diameters above storm drains, sewers or other catchment.
- Direct connections to sewers for flushing either the water main or sewer.
- Hydrants with drain lines directly connected to sewers.
- Uncontrolled use of fire hydrants. (Water systems should only allow contractors and others who use fire hydrants to do so through metered flow including protection against backflow with an RPP).
- Filling newly installed mains from fire hydrants for flushing and disinfection.

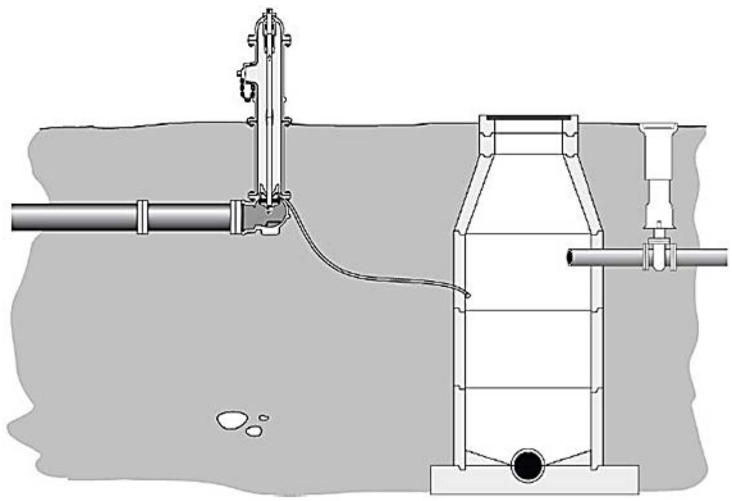

Figure 12-15: Hydrant drain to manhole

12.6 Sanitary Deficiency Questions and Considerations – Cross-Connections

During a sanitary survey, the surveyor should undertake two major activities related to cross-connections. The first is to evaluate the adequacy of the water system's cross-connection control program. The second is to look for unprotected cross-connections that the water system may own or control. These cross-connections may be in the water treatment plant, at pumping stations, or in the distribution system. To perform these major activities, the surveyor should determine the answers to a number of questions.

- **Does the PWS have a written cross-connection control program?**

  The surveyor should determine if the system has a formal written program for controlling cross-connections. If so, he or she should review the program to determine if it has the following basic components:

  - Authority to establish a program.
  - Technical provisions.
  - Right of entry and surveys.

- Assembly testing and repair.
- Certified testers.
- Plan review and survey of new construction.
- Penalties.

▪ **Is the cross-connection control program active and effective in protecting against cross-connections and backflow conditions?**

To determine if the water system implements the program effectively, the surveyor can review its staffing and the certification status of each staff member that tests or repairs backflow prevention assemblies. Further, the surveyor should check the records of the number of surveys conducted; the number of various non-testable devices and testable assemblies installed in the system; and the number, and frequency of assembly tests performed. The surveyor should specifically look for test records on large buildings that have fire sprinkler systems, funeral homes that do embalming, medical facilities, and manufacturing facilities.

▪ **Does the cross-connection control program address areas of specific concern for cross-connection and backflow in the water system's service area?**

Areas of specific concern include auxiliary water supplies, including private wells, internal water recycling or reuse, graywater systems, and dual plumbed distribution systems distributing recycled water.

▪ **Are there any unprotected cross-connections at the water treatment plant?**

The surveyor should look for cross-connections at the water treatment plant that are not protected with an air gap or a backflow prevention assembly. Some examples of potential cross-connections at the water treatment plant include:

- Raw water piping that is directly connected to finished water piping.
- A water supply line submerged in a chemical storage tank (i.e., a day tank).
- An air release valve piped directly to a drain; water discharged from water quality monitoring station that is piped directly to a drain.
- Cooling water for an emergency generator with a submerged outlet.
- Direct connection of finished water piping and the filter backwash system.

The surveyor can find such cross-connections by identifying any uses of water in the treatment facility, and following the piping from the source of water to each water use and to the point of disposal. Also during the sanitary survey, the surveyor should discuss with the plant operator the importance of eliminating cross-connections.

▪ **Does the PWS test backflow preventers at treatment plants and other facilities it owns?**

The surveyor should determine whether the water system tests all assemblies at least yearly by reviewing the records book and equipment tags. Even a system that does not have an active cross-connection control program should ensure the continued proper operation of its backflow preventers. A tag should be placed on each assembly to document test and repair dates.

- **How are backflow prevention assemblies in the distribution system tested and maintained?**

  The water system should test all backflow prevention assemblies at least annually and more often if required by the primacy agency or local plumbing code. If an assembly fails this test, the water system should either repair it or replace it with a new assembly. The surveyor should be familiar with primacy agency and plumbing code requirements for testing frequency and the time allowed for completing repairs. The surveyor should check that the water system meets these requirements for all backflow prevention assemblies.

- **Are there any unprotected cross-connections in pumping stations?**

  While inspecting pumps and pumping stations, the surveyor should identify any potential cross-connections that are not protected with an air gap or a backflow prevention assembly. Some examples of potential cross-connections include:

  - Raw water pumps that are primed with finished water.
  - Air release valves piped directly to a drain.
  - Water discharged from water quality monitoring stations that is piped directly to a drain.
  - Cooling water for emergency generators with submerged outlets.
  - Cooling water returned to the potable system.

  The surveyor can find such cross-connections by identifying any uses of water in the pumping station, and following the piping from the source of water to each water use and to the point of disposal.

- **Are there unprotected cross-connections in the distribution system that the PWS owns or controls?**

  The surveyor should evaluate the presence of unprotected cross-connections in the distribution system in a similar manner as the pumping station. The surveyor should ask the distribution system operations manager or an operator to identify water uses in the distribution system. Examples of water uses may include: contractor use of fire hydrants; water system maintenance staff use of hydrants for flushing; and overflow and drain lines from finished water storage facilities directly connected to a storm drain or sewer.

- **Are new services reviewed for cross-connection hazard?**

  Construction of new customer service lines and related water system components are subject to engineering plan review according to primacy agency requirements and water system's standard practices. Water system components such as backflow prevention assemblies installed in building plumbing systems also must meet requirements of the local plumbing code. The surveyor should ask the operator how new service lines are reviewed and what specific requirements address cross-connection control.

- **Does the PWS have a program to control the use of fire hydrants?**

  The use of fire hydrants by non-water system personnel for filling tanks, cleaning sewers, or providing water for construction projects has the potential to create serious cross-connection hazards. If customers or contractors use fire hydrants for these purposes, the surveyor should determine if the water system has a program to ensure such customers/contractors follow appropriate procedures to prevent backflow. These procedures can include a permit system that requires the use of meters, air gaps, and backflow preventers.

12.7 Possible Significant Deficiencies for Cross-Connections

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The primacy agency determines both significant deficiencies and the corresponding corrective actions.

- Customers with private wells interconnected with premise plumbing.
- Hospitals, extermination businesses, industrial customers, etc., with no testable backflow prevention assemblies.
- Uncontrolled or unattended attachments to hydrants for use by water haulers.
- Backflow prevention assemblies are not tested, or no surveillance/enforcement program exists for usage and testing requirements (e.g., for home irrigation systems in addition to the usual businesses).
- High leakage rates that pose risks of backsiphonage during pressure drops (response to fires, main breaks, power outage, etc.).
- Pressure/air relief valves located below grade in vaults or not separated from drains.
- No cross-connection program.
- Testable backflow prevention assemblies are not tested on an annual basis.
- Assemblies that fail the annual test are not repaired.
- New services not reviewed for cross-connection hazards.
- Cross-connections between treated and untreated water.

13 Process Control and Compliance Monitoring

Monitoring is an important activity for water systems and should be reviewed and assessed during a sanitary survey. Compliance monitoring is required at several locations throughout the water system. Chapter 2, Drinking Water Regulations, discusses compliance monitoring considerations during a sanitary survey. Evaluating the adequacy of laboratory practices and the system's data integrity is also an important task for the surveyor during the survey.

Many water systems take measurements that are above and beyond their compliance requirements in order to track water quality and help them treat and manage their water. Knowledgeable operators make decisions based on such process control monitoring results. While these measurements may not be regulated, their results guide operational decisions and should therefore be carried out in a responsible manner that produces reliable results.

13.1 Learning Objectives

By the end of this chapter, students should be able to evaluate process control monitoring programs, associated data collection and management systems, and laboratory practices. Specifically, they should be able to:

- Determine if in-house testing facilities, procedures, and equipment are adequate.
- Determine if operators or laboratory staff calibrate and properly maintain testing equipment as specified by the manufacturer.
- Determine if instrument configuration settings are resulting in data output that is not representative of actual performance (i.e., signal averaging, minimum/maximum recording values – capping).
- Determine if reagents are fresh (i.e., not past the expiration date), and if staff properly discards them after the expiration date.
- Determine if the operator is performing tests properly by following approved SOPs.
- Determine if operators make treatment modifications based on laboratory results.
- Determine if the water system uses certified laboratories when required.
- Determine if monitoring includes the correct parameters.

13.2 Data Collection

To evaluate the system's compliance status and data integrity, the surveyor should review the following information:

- Current treatment processes in use at the water system.
- Instrument configuration settings, and maintenance and calibration records.

- SOPs used by plant staff.
- Quality assurance audits performed by the water system.
- SCADA upgrades, verification checks, and calibration records.
- Daily operations log books.

13.3 Regulations and Standards to Consider

The surveyor should review the following information prior to the survey:

- Water treatment operating guidelines.
- Primacy agency monitoring guidelines and recommendations.
- Applicable EPA approved analytical methods (see 40 CFR 141 subpart C). Review any list of known laboratories that have recently lost their drinking water certification.

13.4 Basic Information

All monitoring, whether performed in-house or at an outside lab, should produce reliable results that are being used by the water system to operate the system. The surveyor should investigate what parameters are being analyzed, their results, and how those results are used by the operators.

13.5 Approved Laboratory

Chapter 2, Drinking Water Regulations, covers monitoring requirements related to specific provisions of the NPDWRs. With the exception of a few parameters, such as turbidity, pH, temperature, alkalinity and hardness, and disinfectant residuals, a certified laboratory should be performing the required analyses; this may be either the system's own laboratory or a contract laboratory. Either a state accrediting agency or the National Environmental Laboratory Accreditation Program (NELAP), also referred to as The NELAC Institute, certifies a drinking water laboratory.

13.5.1 Sanitary Deficiency Questions and Considerations – Approved Laboratories

- **Is the laboratory certified for all the analytes being monitored?**

  Laboratory certifications are for the specific analyte or methodology that they perform. Certification varies from laboratory to laboratory.

- **Is the laboratory certification current?**

  During the sanitary survey, the surveyor should ask which laboratory is used for each regulatory monitoring parameter. While a surveyor can review the laboratory's certification to check that it is current, this task is usually performed by other primacy agency staff.

13.6 In-House Monitoring

The operator should establish adequate in-house monitoring to properly evaluate the operation of the treatment system and develop an on-going process control monitoring program. The tests performed and the number of sample points used depends on the type of treatment plant and related primacy agency requirements. The frequency of sampling depends on the purpose of the sampling (regulatory versus process control) and other parameters that might affect the treatment process or water quality. All monitoring conducted for the purpose of process control should be performed using equipment and methodologies approved by the primacy agency.

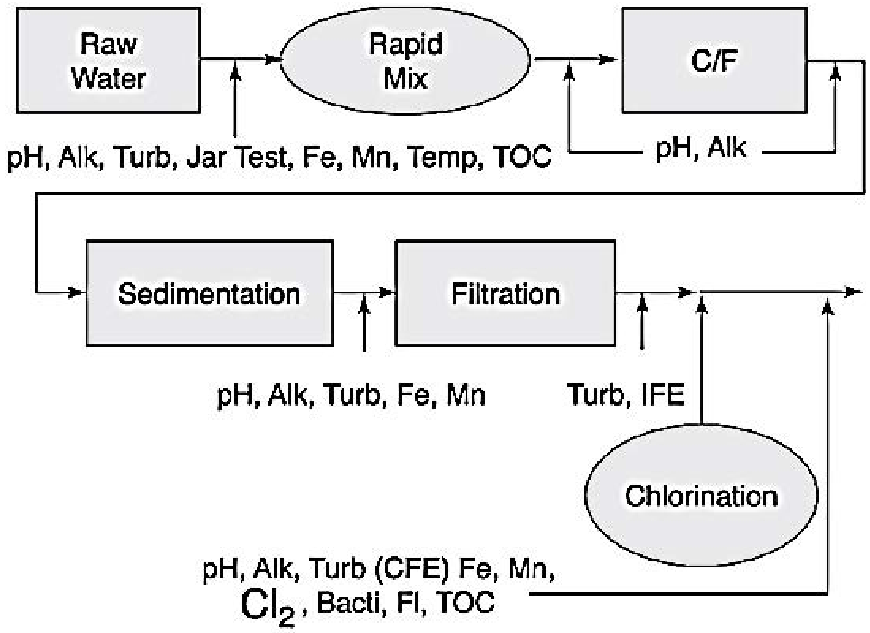

Figure 13-1: Comprehensive monitoring program: conventional treatment plant

13.6.1 Instrument Calibrations and Standard Testing

If instruments are not reporting accurately, any process control decision is less reliable. Testing with standards can assist the operator with troubleshooting the problem by confirming if the reagents, procedure, instrument, or the analyst is the cause of an inaccurate value. Ensure operators routinely calibrate instruments, both for precision (repeatedly the same) and accuracy (matching a known, correct value). The surveyor should ensure that flow-through continuous monitors are within the prescribed levels for the instruments, per manufacturer's requirements.

13.6.2 Sanitary Deficiency Questions and Considerations – In-House Monitoring

- **Is adequate monitoring in place?**

  The operator should have an in-house monitoring program in place and, at a minimum, should be performing the monitoring required to comply with all provisions of the SDWA.

- **Is the operator following proper sample collection and analysis procedures?**

  The surveyor should observe the operator's technique in collecting samples and performing analyses. The operator should follow correct procedures for collecting laboratory samples in appropriate sample containers, calibrating the test equipment and for performing the test itself.

For example, the operator should periodically check secondary turbidity standards against primary standards.

- **Are testing facilities and equipment adequate?**

  Management should provide the operator with adequate test equipment to implement a comprehensive monitoring program. The surveyor should verify that all test equipment used by the operators is working properly. The on-site laboratory itself, in terms of space and testing environment, should be adequate for the test equipment in use. Operators should check and regularly calibrate on-line monitoring equipment, such as turbidimeters, pH meters and chlorine residual analyzers, to ensure accurate performance.

  Items to consider for online chlorine analyzers include:

  - Location of instrument manual.
  - Documentation of last calibration record.
  - Frequency of calibration.
  - Expiration dates of reagents.
  - Condition of analyzer, sample vials, standards, and associated equipment.

  In the case of turbidimeters, operators should calibrate the instrument in accordance with the manufacturer's instructions – usually monthly or quarterly for a primary calibration and daily, weekly or monthly, for a secondary calibration. Many primacy agencies allow a comparison check between a continuous turbidimeter and a bench top turbidimeter to substitute for the secondary calibration. Items to consider for turbidimeters include:

  - Location of instrument manual.
  - Last calibration check and documentation of action.
  - Proper function of photocells.
  - Availability of supplies for primary calibration.
  - Flow rate into the turbidimeter.

  For pH meters, the meter itself is generally robust, while the probes are more subject to failure. Items to consider are:

  - Use of appropriate 3 point calibration curve for pH.
  - Last time pH probe was cleaned or replaced.
  - Use of non-expired pH buffer standards.

  For instruments that operators cannot calibrate (such as pocket colorimeters for chlorine residual measurements), the operator should verify accuracy of the instrument by performing the test against a set of secondary standards. The surveyor should ask how the operator tests these instruments and if he or she removes the instrument from service, if the test is not within manufacturer's tolerances. Items to consider for pocket colorimeters include:

- Routine performance of secondary standard verifications.
- Condition and cleanliness of sample vials.
- Setting of the instrument to the proper range, according to the manufacturer requirements (whether high or low disinfectant concentrations are expected).
- Use of the correct reagents (free versus total).
- Expiration dates of reagents.

The surveyor should ensure operators use the correct chemical reagents, applicable to the test method currently in use on the equipment. The reagent containers should be clearly marked with the name of the reagent and the date of its preparation. Operators should be discarding manufacturer-prepared reagents when they exceed the expiration date. The surveyor should also verify that the method or instrument used for the analysis is approved and appropriate. In some cases, the water system may use a method (such as amperometric chlorine analysis) where the primacy agency must approve the verification studies. In those cases, the surveyor should verify the existence of an approval letter from the primacy agency for such methods.

- **Does the manufacturer recommend testing a "reagent blank" for each lot of reagent used in their colorimetric methods (including chlorine)?**

A "reagent blank" is determined by following the method procedure in the protocol. The operator analyzes water that does not contain the analyte of interest (e.g., analyzes a sample by adding the reagent to deionized or distilled water to determine a reagent blank value for chlorine). The operator then subtracts the "reagent blank" value from all other samples using that lot of reagent.

- **Does the operator properly maintain records of the monitoring program?**

The water system management, operators and laboratory staff are all responsible for maintaining results of the monitoring program in an organized recordkeeping system. Most systems have handwritten logs and data reporting systems. A more sophisticated automated data handling system may also be present, whose records the surveyor must verify. The surveyor should perform data verification by identifying a time period, for example, midnight, a week before the survey, and verifying that the analytical result in the handwritten log sheet matches the value in the monthly operating report and the official record keeping system at the PWS.

For water systems with SCADA, the surveyor should perform a quick verification of the SCADA data quality. In situations where these types of systems are in place, the surveyor verifies that the value for an analytical result is the same in the records for the handwritten log, the instrument, the controller, signal output monitor, the Human Machine Interface, and the SCADA reports.

For systems using these types of automated systems, the surveyor should determine how the system protects their data. Do they have routine backup procedures in place to recover from system failures?

- **Does the operator use the results?**

  The operator should plot trends or analyze the data in some way to control his/her processes and to evaluate compliance status. This enables the operator to see the relationship in treatment changes. For example, how iron levels decrease when chlorine levels increase, or how pH increases or decreases when the addition of lime increases or decreases.

- **Does the operator adjust treatment based on laboratory results?**

  The surveyor should determine what actions the operator takes based on the test results. The operator should understand the importance of the test results as they relate to the performance of the treatment plant, water quality at the individual treatment units, and for the water system in general.

13.6.3 Instrument Location

The surveyor should determine if operators have automated sampling devices installed on the correct pipe, at the correct location in the pipe for sample collection, and have calibrated the flow rate through the instrument, within the manufacturer's specifications. The surveyor should also evaluate where the instrument resides in the plant and how far it is from the sampling point. In addition, it is important to check that there are air gaps between any water discharge lines from online instruments and drains receiving the discharges, in order to prevent backflow.

If the sample tap is too far from the analyzer, the volume of the draw may not completely clear the tube or pipe supplying the analyzer. Results are not representative of actual conditions, but are of water quality at an indeterminate time in the past. Changes made to chemical feeds may not be readily available at the analyzer. Sample tap locations on pipes may also have a bearing on readings. For example, samples taken from bottoms or tops of pipes are, in general, not as representative as those taken in the lower ½ to 1/3 of a pipe.

Equally important to note is that sample taps too close to an analyzer may also not be representative of feed dosages, as there will not have been sufficient time for complete mixing.

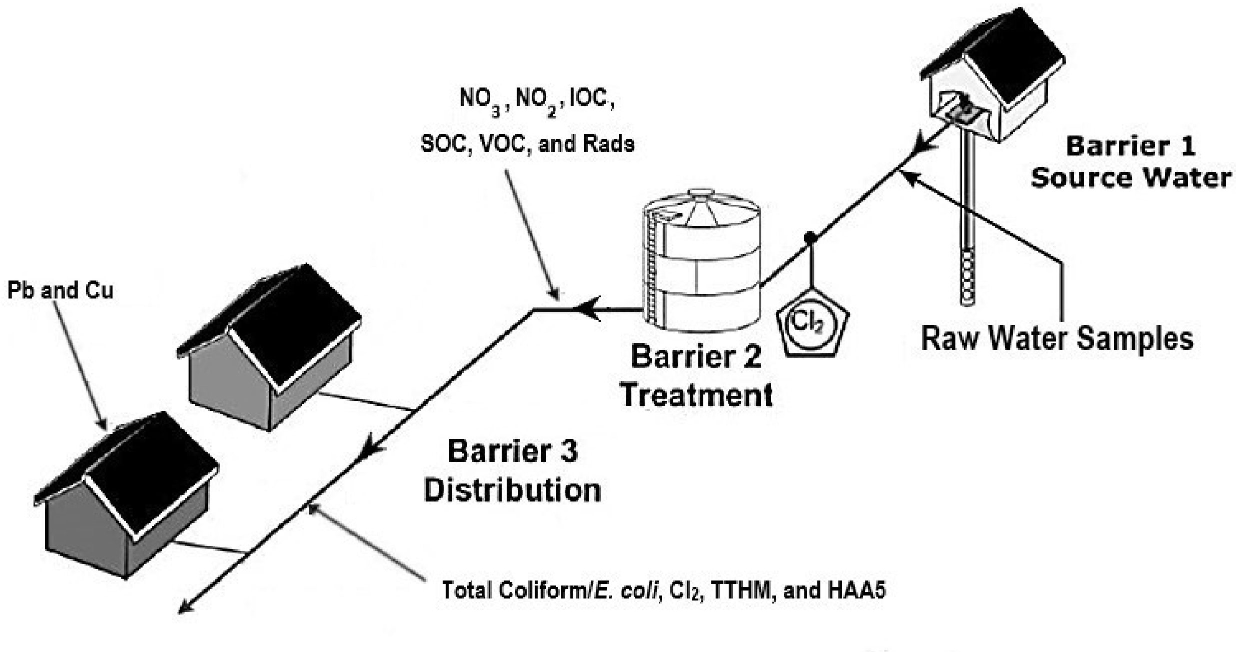

Figure 13-2: Ground water systems sampling locations

13.7 Electronic Data Recording, Monitoring, and Testing: SCADA

Supervisory Control and Data Acquisition (SCADA) refers to centralized systems which monitor and control entire sites, or complexes of systems spread out over large areas. These systems generally perform two main functions:

- Control plant functions (turn on pumps, open or close valves, etc.).
- Data acquisition (data transferred from instrument to plant operations center).

The types of data technology usually used in a SCADA system are analog and digital. Digital signals are best for discrete values (e.g., pump status is on or off). Analog signals are continuously variable and often used in SCADA systems for data that change over time (flow, turbidity, chlorine residual). A 4 to 20 milliamp (mA) signal always transmits analog data, where the 4 mA signal represents zero values and the 20 mA signal represents the maximum value of the readings. It must be noted that the lower the span of values (e.g., 0 to 5 units versus 0 to 10 or higher), the better the data resolution and more accurate the data.

The accuracy of the SCADA system depends on the following:

- Signal consistency from the instrument to the Programmable Logic Controller (PLC).
- The scale of the monitored parameter – the surveyor should ensure that the operator, manufacturer or the person who installed the instrument did not cap or truncate readings at an inappropriate level.
- The resolution of the PLC.

In Figure 13-3, the signal from the instrument to the transmitter is almost always analog. The transmitter converts the signal to digital to show on a signal output monitor, and then forwards the analog signal to the PLC. The PLC once again converts the signal to digital and sends that value to the personal computer. From there forward, the signal remains digital.

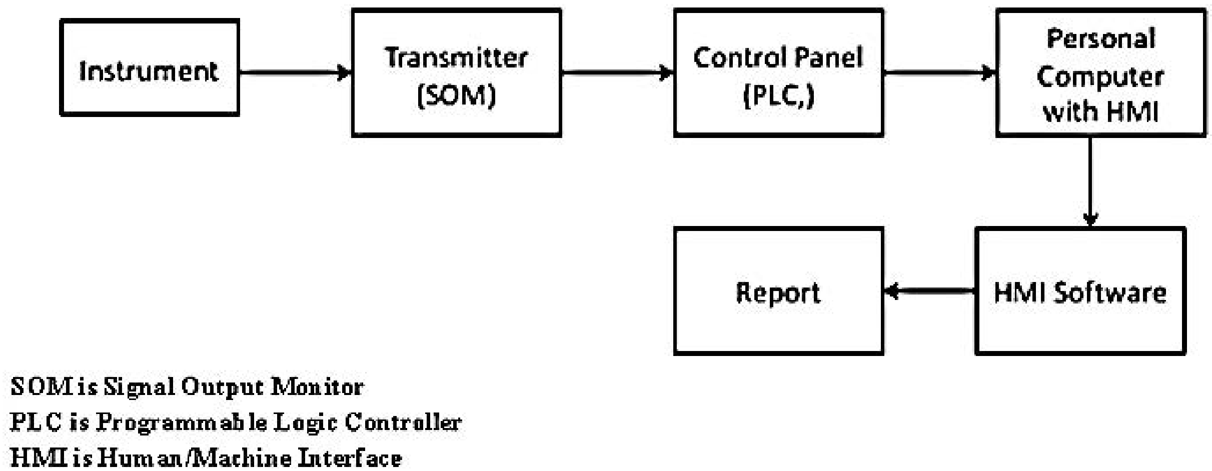

Figure 13-3: Data flow from instrument to report

Water systems typically contract with vendors who specialize in the installation and maintenance of SCADA systems. Operators should perform quality control checks on the entire data flow process. If the SCADA system is recording data every 15 minutes, the surveyor should ask how the system compiles the data – through discrete readings or averages – and if it is capped or truncated.

If an operator initiates a calibration process, the SCADA system may stop recording some of the data until the calibration is complete. Does the operator have backup methods of continuing to collect readings during calibration processes? These systems produce substantial sets of data, so the surveyor should ask if there are any storage capacity issues and if the system can maintain historical data, necessary to meet data retention requirements. If not, does the water system minimize storage capacity needs through the archival of final "paper report" documents?

Water treatment plants should follow the manufacturer's recommendations for data recording purposes, since there are no data recording standards and recording practices vary among the various SCADA vendors. Operators need to calibrate their SCADA systems regularly (e.g., annually), since the 4 to 20 mA signal varies with age and time, and is subject to signal drifts. If the precision of data readings is unusually high, the operators may have the upper limit capped with a data value below a required compliance level. For example, setting the 20 mA signal to correspond to a turbidity reading of 1 NTU instead of something greater than 5 NTU.

Over time, SCADA systems may compensate for "zero drift" where there is a shift in the zero point of the sensors. In addition, every time a water system performs electrical upgrades to their systems, these changes could impact the SCADA system.

13.7.1 Sanitary Deficiency Questions and Considerations – Evaluating SCADA systems

- **When was the current SCADA system installed?**

  The surveyor should ask the operator when the SCADA system was initially installed and if there have been any upgrades since that time.

- **Did the operator receive adequate training and written guidance to operate and maintain the SCADA system?**

  During the sanitary survey, the surveyor should identify any training or resource needs for proper O&M of the SCADA system.

- **Can the operators contact the SCADA vendor when they cannot resolve an issue?**

  Water systems typically contract with vendors who specialize in the installation and maintenance of SCADA systems. The surveyor should ask the operator if the vendor is available as needed to answer technical questions.

13.8 Possible Significant Deficiencies for Process Control Monitoring

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The primacy agency determines both significant deficiencies, and the corresponding corrective actions.

- Using a laboratory or analyst for compliance samples who is not certified for drinking water analyses.
- Use of expired reagents.
- Use of incorrect sample containers to collect compliance samples (glass versus plastic, preserved versus unpreserved).
- Use of unapproved sampling site for compliance monitoring.
- Compositing of compliance samples instead of taking individual samples (unless allowed).
- Instrumentation not calibrated and verified according to manufacturer’s operational manuals or state requirements.
- Failure to maintain a disinfectant residual log book.
- If required, failure to continuously monitor and record turbidity from individual filters at least every 15 minutes.
- If required, failure to continuously monitor or collect grab samples every 4 hours for combined filter effluent turbidity.

14 Water System Management

Competent management provides the funding and support (administrative, personnel, and purchasing) needed to ensure continued and reliable operation through adequate staffing, operating supplies, and equipment repair and replacement.

14.1 Learning Objectives

Upon successfully completing this chapter, students should be able to evaluate the management of a water supply system. Specifically, they should be able to:

- Identify and evaluate key components of a water system's management organization.
- Identify the plans necessary for regulatory compliance and long-term sustainability.
- Evaluate staffing: numbers, skills, certification, training, and safety.
- Identify the key components necessary for reliable system operations.
- Evaluate, in general terms, the system's managerial and financial capacity for long-term reliability.

14.2 Data Collection

The surveyor should obtain information about the water system before the sanitary survey. If unable to do so, the surveyor will need to obtain the following information and data during the survey.

- Previous sanitary survey reports.
- Correspondence between the water system and the primacy agency regarding the corrective action plan or important changes or directives that affect O&M of the water system.
- Compliance monitoring results.
- Regulatory compliance record as documented in the Safe Drinking Water Information System (SDWIS).
- Plans on file (e.g., source protection, sampling, emergency and contingency, cross-connection control, and repair, replacement, future expansion).

14.3 Regulations and Standards to Consider

The surveyor should consider and review the following information, prior to a survey:

- NPDWRs.
- AWWA Standards.
- 10 States Standards if adopted by the state regulatory code.

- Pertinent monitoring requirements.
- Capacity development guidance.
- Consumer Confidence Reports.
- Minimum operator certification requirements.

14.4 Roles and Responsibilities

The management of a system may be as small as a single individual serving as the operator and manager, or it may be a hierarchy of multiple elected officials and municipal employees who approve budget requests, make purchases, and plan for infrastructure repairs and replacements, to ensure the long-term adequate, reliable and safe production, storage, and distribution of potable water. Determine who has responsibilities for making financial decisions and ensuring that regulatory compliance requirements are met. Make sure you are working with the most effective and responsible level of management.

14.5 Organization

Management of a small water system often involves only one or two key individuals: the operator and the owner or elected official, who is ultimately responsible for the system's O&M. One advantage of a small management team is the ability to identify the individual in charge and to provide information to that person. However, the workload may far exceed the staffing capabilities. More complicated management hierarchies improve individual workloads, but also increase the opportunity for miscommunication and inadequate information collection and dissemination.

Whatever its form, management can have a profound effect on the reliability of a system. Managers must have a working knowledge of the compliance requirements that apply to their system. Certified or qualified staff must be empowered to make operating decisions, and have management support and understanding of their resource needs.

Information collection and management is also important. Activities range from tracking operating expenses and locating valves on a distribution map, to maintaining a record of breaks and repairs and a log of customer complaints. Information of this nature is critical for planning and budgeting for the next year, as well as the next decade.

14.5.1 Sanitary Deficiency Questions and Considerations – Organization

- **Who owns the PWS?**

  The system representative should be able to tell you who owns the PWS and should be able to provide documentation of ownership.

- **Is there a formal organizational chart?**

  This chart can give the surveyor a clearer view of how the PWS is organized and who is responsible for each portion of the PWS. When there is no, or an outdated, organizational chart, operators often may be unsure of whom to consult for decisions, what the normal lines of communications are, and what their job responsibilities are.

- **Does the operating staff have authority to make required operation, maintenance, or administrative decisions affecting the performance and reliability of the plant or PWS?**

  Determine any established administrative policies that limit the decision-making authority of the operations staff and adversely affect plant performance. Examples include the lack of authority to adjust the chemical feed, hire an electrician, or purchase a critical piece of equipment, as well as a lack of support for training and insufficient plant funding. Document policies that are in conflict with state requirements.

- **Are administrators familiar with SDWA requirements and PWS needs?**

  Key managers should be familiar with the SDWA requirements that apply to their system. They should learn about system needs through plant visits and frequent discussions with their water operators. Lack of first-hand knowledge may result in poor plant performance, poor staff morale, and poor budget decisions, as well as limited support for system modifications.

- **Is there a formal and adequate planning process?**

  The lack of long-range plans for facility replacement, alternative sources of water, and emergency response can adversely affect the system's long-term performance.

- **Does the PWS manage its information?**

  This type of information justifies decisions and promotes compliance with SDWA and industry suggested practices for water conservation and quality.

  Information management includes formal systems and written procedures, including:

  - Cataloging, sorting, and storing maps and as-built plans.
  - Updating maps.
  - Handling and tracking customer complaints.
  - Handling and tracking line breaks, repairs, and replacements.
  - Identifying, collecting, and analyzing key operational (process control) and required monitoring data.
  - Developing and maintaining standard operating policies and procedures.
  - Developing and maintaining maintenance records.
  - Developing and maintaining financial records.

  The information listed above is important for addressing existing problems and planning for future needs.

- **Does the PWS track and identify typical operating parameters such as non-revenue water and cost per unit of production of finished water?**

  When utilities track and share this type of information among operations personnel and the governing body, it is a good indication that the PWS focuses on obtaining results and meeting customer needs.

- **Does the PWS use a computer system to track finances, operational data, and maintenance practices?**

  While a computer is not a requirement, it facilitates storage and presentation of data to support management decisions.

- **Is there effective communication between key management staff, operations staff, and the primacy agency?**

  Difficulties here can account for problems with the budget and personnel policy. They also can account for poor relations between management and staff and between the organization and the primacy enforcement agency. Surveyors should review previous correspondence to determine the responsiveness of the system and should ask questions to confirm observations.

- **What is the level of cooperation between the system and other agencies and organizations?**

  To be successful, a PWS needs to cooperate with associated utilities and enforcement agencies. Examples include cooperation with water conservation agencies, with one-call (Call Before You Dig) groups such as the American Public Works Association (APWA) underground utility coordinating committee, and with county and state agencies involved in land-use planning and long-term water use, conservation, and water needs. This cooperation also involves active membership in professional groups such as AWWA and APWA.

- **What is the level of cooperation between the PWS and the local fire department?**

  This is often difficult to determine directly. However, you may ask questions such as:

  - What role does the fire department play in inspecting and flushing fire hydrants, and determining the type and location of new fire hydrants?
  - What role does the fire department play in the PWS's emergency plan as a first responder for chemical spills or accidental releases?
  - What is the policy and procedure for notifying the fire department when a hydrant is out of service?
  - What is the notification procedure when the fire department uses a fire hydrant?
  - What is the role of the fire department in determining construction needs?

- **Is there a customer complaint system and an ongoing public information program?**

  Lacking a system to keep track of and respond to customer complaints may indicate ineffective communication with customers. Not having an ongoing public information program, including a Consumer Confidence Report, may indicate that the PWS does not provide adequate information to its customers. Plotting customer complaints and other information (e.g., dead ends, line breaks, low residuals, positive total coliform samples, high DBP results, etc.) on a map helps the water system target problem areas.

- **Does the PWS have a budget and an adequate source of capital for operations, maintenance, and capital projects? Is the PWS eligible for, and has the PWS received, state or federal funding?**

  It is important for a PWS to have adequate returns or access to capital (from public or private sources) to repair or replace infrastructure and to address emergencies. Lack of access to or exhaustion of available funding, may indicate problems with the PWS's managerial and financial capabilities. However, PWSs should not borrow funds for normal O&M functions, except in emergencies.

  Federal and state funding programs generally provide lower interest rate loans to PWSs, in particular, smaller water systems. Limited federal and state grant funding is also available, particularly for small, more rural water systems. However, many of the programs have eligibility requirements and fund only certain types of PWSs and certain types or categories of projects. For example, some states have limited Drinking Water State Revolving Fund loans to publicly owned water systems. In addition, water systems cannot use these funds for routine monitoring, operation, and maintenance.

  All PWSs, particularly small water systems, should establish a credit rating, allowing them access to funds if an emergency occurs or an unexpected cost arises. Financial institutions look at the health of the PWS as measured through indicators, ratios, ratings, previous credit records, and proof of assurance of repayment, when determining whether a PWS is a good credit risk.

- **Does the PWS have a budget and an adequate source of capital to fund staff wages?**

  Staffing costs often comprise a significant portion of a water system's budget. The surveyor should consider whether the PWS has undergone a high rate of operator turnover and whether operators' salaries are contributing to the problem.

14.6 Planning

Planning is the process of developing written programs and practices, and identifying the internal and external resources needed to implement them. The following plans are important to many PWSs:

- Source protection.
- Monitoring. In particular sampling sites for:
  - Lead and Copper.
  - Total Coliform.
  - Stage 2 DBPR.
- Emergency or contingency.
- Customer relations program.
- Distribution maintenance including flushing, valve surveys and repairs, hydrant surveys and repairs, and water main repair, rehabilitation.
- Storage tank survey, cleaning, and maintenance program.
- Capital improvement plan.
- Cross-connection control program.

- Safety program.
- Water security program.

There are also safety programs and requirements with which the PWS must comply. Other equally critical plans include an annual budget, asset management plans and a 10-year capital improvement plan to address repair, replacement, and future expansion.

14.6.1 Sanitary Deficiency Questions and Considerations – Planning

- **Is an emergency or contingency plan available, workable, and exercised?**

  The PWS should have an emergency or contingency plan that outlines what actions will be taken and by whom. The emergency plan should meet the needs of the facility, account for the geographical area, and specify the nature of the likely emergencies. Does the plan consider conditions, such as storms, floods, and major mechanical failures? Management should update the emergency plan annually, educate the operators and other staff about the plan, and larger facilities should practice implementation of the plan annually.

- **Are written, workable plans available for the areas listed below?**
  - Source protection.
  - Sampling and monitoring.
  - Emergency or contingency.
  - Hazard communication plan (if required).
  - Cross-connection control.
  - Repair, replacement, and future expansion (capital improvement).
  - Distribution system flushing program.

14.7 Personnel

Personnel issues include adequate numbers of skilled operations staff, compliance with state certification requirements, training, and safety.

14.7.1 Sanitary Deficiency Questions and Considerations – Personnel

- **Are there sufficient personnel?**

  There should be enough personnel to provide for operation during evenings, weekends, vacations, and illness. The number of operators depends on the type and size of the treatment process and distribution system, and the population served.

- **Is there anticipated staff separation within the next five years?**

  Are any operators preparing to retire within the next five years? Are there operators currently in an apprenticeship role who are likely to seek increased employment at another PWS? PWS managers should have a plan for replacing enough operators to ensure a smooth transition in staffing. Management should also minimize the loss of collective knowledge about the PWS when operators retire or leave. Seasoned operators should be helping ensure that written SOPs are complete and up-to-date before they leave the PWS.

- **Is there a contingency plan for replacing retiring or separating PWS personnel?**

  Labor statistics indicate that roughly one-third of the water sector workforce will be eligible for retirement within the next ten years. There should be a succession plan in place to recruit new operators or to enter into a partnership with a contract operator in the event of staff separation.

- **Is the staff qualified?**

  The staff should have the appropriate aptitude, education, and level of certification to perform the job correctly.

  PWSs must comply with state requirements for certification. Water systems should prominently display proof of certification or otherwise make such certification available to the surveyor. Certification at the correct level is one major measurement of management commitment and staff qualifications.

- **Does management ensure personnel are adequately and appropriately trained?**

  To operate a PWS properly, management must provide the time and budget for operator training, including continuing education and licensing requirements. Do managers have sufficient staff to provide operational coverage where other operators may take full advantage of training time without interruptions?

  There should also be an ongoing training program. There are various ways to train personnel. Training can include in-house training conducted by more experienced personnel, as well as state-sponsored training.

  Correspondence courses, such as Water Treatment Plant Operation, Water Distribution system Operation and Maintenance, and Small Water system Operation and Maintenance from California State University, Sacramento School of Engineering, and AWWA courses are also available. The surveyor can solicit information from the operator about process controls, maintenance requirements, and safety, to help determine the adequacy of their training.

- **Is complacency an issue?**

  Are certified operators not applying the skills they should have, based on their certification? Management could be limiting what they can do or how much time they have to do it. Investigate process control testing and maintenance. Is the operator complacent and not performing maintenance or process control testing, or do management practices keep operators from performing daily control practices and routine maintenance?

- **Does management adequately train the operators in safety procedures and equipment?**

  The safety of the operators and other staff is of paramount importance. Injuries can adversely affect the PWS. Although surveyors are not safety experts, conversations with the operator and manager of the PWS enable the surveyor to determine if a safety program is in place. Adequate safety training and safety equipment are essential. Management should be able to give the surveyor a list of training activities and training attendance records. Proper safety equipment should be on-site, adequately maintained and readily accessible. Examples of necessary equipment include, but are not limited to, signs posted on confined spaces, self-contained breathing apparatus, cylinder repair kits, eyewash stations, and fire extinguishers.

14.8 Operations

Management must first provide the facilities and equipment required to operate reliably and in compliance with all applicable regulations. Written SOPs that all operators follow the same practices, and help with knowledge transfer from experienced staff to new hires.

14.8.1 Sanitary Deficiency Questions and Considerations – Operations

- **Is there an overall O&M manual for the facility?**

  In addition to the standard O&M manual, manufacturers' literature should be available for all pieces of equipment. All of this information, and the as-built plans of the facility, should be on-site or readily available. The operators cannot properly maintain equipment without adequate manuals and manufacturers' literature.

- **Has management established SOPs at the facility?**

  Ask operations and management personnel about the availability of O&M manuals, manufacturers' literature, and SOPs. SOPs are essential to ensure consistent plant operations from one operator to the next, as well as from current operators to the next generation of operators. Operators and management are responsible for keeping all SOPs current, and they should review and revise them when changes at the plant occur. Are the SOPs adequate to maintain the highest quality of finished water? Are SOPs accessible to operations staff?

- **Is there sufficient storage for spare parts, equipment, vehicles, traffic control devices, and supplies?**

  The surveyor should assess storage spaces for adequacy, housekeeping, and general appearance. The appearance of the facilities is often a reflection of the importance that management places on the people who work at the PWS.

- **Are the facilities and equipment of the PWS adequate?**

  Inadequate facilities and equipment, such as undersized pumps, lack of redundancy, and poor maintenance, can interfere with the production of potable water. Buildings and structures should be sound and provide appropriate security. The operator should maintain equipment according to manufacturers' specifications and intended use.

14.9 Finance

Financing addresses the water system's day-to-day operating budget, future repair and replacement, and future expansion.

Reviewing these five areas helps to evaluate the three elements of managerial capacity and the three elements of financial capacity.

Table 14-1: Managerial and Financial Capacity

Elements of Managerial Capacity	Elements of Financial Capacity
Ownership accountability. Staffing and organization. Effective external linkages.	Revenue sufficiency. Fiscal controls. Credit worthiness

Although much of the information to address these issues can be collected during the sanitary survey, some aspects of managerial and financial capacity may not be evident from a survey and a conversation with the operator. Fully assessing capacity in these areas may require a meeting with the water system's manager or governing authority, as well as additional review of financial documents. The questions in this chapter should enable you to make at least a preliminary assessment of managerial and financial capacity.

In addition to looking specifically at a water system's finances, the surveyor should be aware that other aspects of the sanitary survey indicate the state of the PWS's finances and its financial capacity. For example, infrastructure deficiencies may be due not only to a lack of technical and managerial capacity, but also to a lack of financial capacity. Without sufficient revenue, the PWS will not be able to cover the costs of source water protection, treatment, storage facility maintenance, and PWS upgrades.

14.9.1 Sanitary Deficiency Questions and Considerations – Finance

- **Does the PWS have the technical, managerial, and financial capacity to deliver safe water to its customers on a continuing basis? Are the financing and budget satisfactory? What is the estimated income? What are the estimated expenses?**

  Water system management should have organizational and annual reports regarding the water system's technical, managerial and financial capacity to achieve the objectives of delivering safe water.

  The PWS should have sufficient revenue for operation, maintenance, and future replacements. Water system management should maintain these funds and not commingle them with other accounts. The PWS should operate on its own revenues and should have a sinking fund for major equipment replacement.

  An inability to answer the questions above indicates a lack of financial planning necessary for financial capacity. If answers are available, but they indicate that PWS revenues do not cover costs, the PWS lacks financial capacity. This lack may pose risks, if insufficient funding results in an inability to maintain and upgrade the facility, pay appropriate salaries, or maintain sufficient stocks of spare parts, chemicals, or equipment.

- **Does management properly prioritize funding?**

  Determine if the manner in which available funds are used causes problems in obtaining needed equipment or staff. In addition, determine if management expends funds on lower priority items, while higher priority items are unfunded.

- **Are there sufficient funds for staff training?**

  Management should identify staff training needs and allocate resources (time and funding) to allow staff to attend training sessions as needed to meet their job responsibilities. If the state primacy agency requires operator certification, water system management should also consider budgeting for the number of hours required for an operator to maintain his or her license.

- **Are projected revenues consistent with projected growth?**

  If a PWS's revenue projections are not consistent with its projected growth, or if rates do not reflect actual costs, including amortization of capital, eventually there will be insufficient revenue to operate the PWS.

- **Does the PWS have formal accounting systems and written procedures for financial records?**

  If the PWS does not have formal systems and procedures for financial recordkeeping, management is likely not following appropriate accounting and financial planning methods.

- **Does the PWS have budget and expenditure control procedures?**

  Although it is important that water system staff have the authority to purchase supplies and equipment as needed, it is equally important that there be standard procedures for budget and expenditure control. A follow-up question might be to ask the operator what they do when they need to purchase something for the PWS. By discussing a real example, you might discover that the operator was unsure of the terms used in the first question where the PWS does in fact have purchase order procedures and authorization requirements, and, therefore, has budget and expenditure control procedures.

- **What are the PWS's debt service expenses?**

  If a PWS's debt service expenses are exceptionally high, the PWS either has a large level of debt or pays a high interest rate on its debt. This situation could mean the PWS has exhausted its access to capital or has a poor credit rating forcing the water system to pay higher interest when it borrows. In either case, high debt service expenses indicate a lack of financial capacity.

- **Does the PWS have a water conservation policy or program?**

  Water rates that promote conservation can yield savings. Conservation reduces the demand on the source, reduces chemical and electrical costs, and minimizes wear and tear on equipment such as pumps. In many cases, a PWS can avoid the need for plant expansions by implementing an effective water conservation program.

14.10 Possible Significant Deficiencies for Water System Management

All significant deficiencies listed below are examples only. Each primacy agency may have identified a different set of significant deficiencies than those listed. The primacy agency determines both significant deficiencies and the corresponding corrective actions:

- Ongoing, unaddressed violations.

- Non-compliance with corrective action plan for significant deficiency identified in the last sanitary survey.
- No or inadequate SOPs.
- Insufficient staffing or coverage.
- Key managers unfamiliar with the SDWA requirements.
- No tracking of assets.
- No equipment use logs.
- No annual budget.
- No asset management or capital improvement plans.

15 Other Considerations

15.1 Introduction

The evaluation of the eight elements of a sanitary survey is essential to the protection of public water supplies and the protection of public health. The surveyor may consider additional water system characteristics such as sustainability and water system security that further contribute to the long-term success of a PWS in continuing to provide safe drinking water to the population served.

15.2 Learning Objectives

By the end of this chapter, students should be able to:

- Recognize a range of steps that the water system can take for sustainability.
- Understand capacity development (e.g., technical, managerial and financial capacity) of a well-functioning PWS.
- Identify steps to improve water availability.
- Consider water efficiency and conservation as a factor in supplying water.
- Understand the effects of extreme weather conditions or events (drought, flooding, tornadoes, hurricanes, etc.).
- Identify key points for security.

15.3 Sustainability

Employing the concept of sustainability in the management of a water system has implications across many aspects of a water plant and its operation. Water system management may think of sustainability as applying practices and techniques to obtain the greatest long-term benefit. This may include setting long-term goals and objectives for water delivery to the community, identifying and analyzing a range of alternatives to achieve those objectives, utilizing water management approaches, relying on the nature of the water cycle and changing weather patterns, evaluating life-cycle costs of equipment and water treatment processes, and developing a financial strategy to ensure long-term funding for the water system.

15.3.1 Technical, Managerial, and Financial Capacity

Having and maintaining the capability to operate a water system to continuously provide safe water to customers is a significant responsibility and contributes to meeting sustainability objectives. Several key capabilities are essential:

- **Compliance:** Is the PWS meeting current regulatory requirements? Do managers and operators understand all regulations applicable to their water system?

- **Education:** Is the PWS providing information to increase customer understanding of the value of water services, as well as expanding its own staff's knowledge of water and energy efficiency measures to improve operations? Does management support and provide the time and budget necessary for operators to meet continuing education and licensing requirements? Do managers have sufficient staff to provide operational coverage, where other operators may take full advantage of training time without interruptions?

- **Finance:** Is the PWS ensuring long-term financial stability to maintain the necessary infrastructure for providing safe drinking water on a continuing basis? Are the PWS's water rates set based on customers' ability to pay for delivery of safe drinking water or the actual costs of producing and delivering water, including amortizing capital assets?

- **Management:** Does the management of the water system understand the implications of decisions made at the operating level (and vice versa) and have knowledge of their responsibilities to deliver safe water to their customers? Are the water system's assets effectively managed and taking advantage of technology to improve safe water delivery to customers?

- **Optimization:** Does management support the operators in optimizing the various treatment unit processes to produce the best quality water possible? Improving on treatment efficiencies can reduce costs by using chemicals only in the quantities actually needed. Optimizing current processes may also postpone or eliminate the need for capital improvements. Making customers aware of these practices also helps justify the water system's rate structure.

15.3.2 Water Availability

At the core of sustainability for a water system is water availability and its management. Ensuring that water is continuously available to a community is key to the community's public health and economic vitality. From a sustainability perspective, the water system's viability relies on determining the various alternative sources of water supply and using the supply that is most practical. A water system should periodically evaluate alternative water sources available to the PWS; this may include consideration of the amount of water in an aquifer, stream or reservoir and its fluctuation over time, other users' water withdrawals, local climate, and water quality and its protection.

15.3.3 Extreme Weather Conditions

These conditions can affect water availability. Short- and long-term conditions may result in variability in the supply available to a PWS to meet demands. These varying durations, as well as emerging contaminants (e.g., pathogens, algal toxins), may result in variability in the quality of the supply used by a PWS. Variability in quantity or quality may affect the ability of a PWS to provide a reliable supply of drinking water that meets federal and state standards.

The water cycle is a delicate balance of precipitation, evaporation, and all of the steps in between. Warmer temperatures increase the rate of evaporation of water into the atmosphere, in effect increasing the atmosphere's capacity to "hold" water. Increased evaporation may dry out some areas and fall as excess precipitation on other areas. As heavy precipitation events become more frequent, flooding is likely to increase in some areas of the country. At the same time, droughts are likely to become more common, especially in arid regions. Both flooding and droughts can degrade water quality, in addition to impacting water availability.

Managers can minimize these effects and make their PWS more resilient by taking the following steps:

- Conserving water and minimizing runoff.
- Protecting valuable resources and infrastructure from flood damage.
- Managing rainfall on-site to limit contamination and protect water quality.
- Limiting development within vulnerable watersheds.
- Consider water reuse (direct or indirect) to reduce demands on stressed surface and ground water sources.

Water systems can address variability in the available supply because of extreme weather events, with additional supplies or with storage. A review and assessment of the capacity of available water supplies and system storage should be part of sanitary surveys, plan reviews, and other state processes (e.g., permits). Additionally, PWSs should refer to the following tools and guides in preparing for extreme weather events:

- Climate Resilience Evaluation and Awareness Tool
- Water Availability and Variability Strategies for Public Water Systems
- Storm Surge Inundation Map and Hurricane Strike Frequency Map
- Adaptation Strategies Guide
- Flood Resilience: A Basic Guide to Water & Wastewater Utilities

15.3.4 Asset Management

The water system has natural features, including its aquifer, stream or reservoir, and its engineered components, such as the treatment plant and pipes that are its assets for providing water. Asset management involves maintaining a desired level of service for what you want your assets to provide at the lowest life-cycle cost. Lowest life-cycle cost refers to the best appropriate cost for rehabilitating, repairing or replacing an asset. A good asset management program typically includes a written plan. The implementation of this plan affects the long-term availability and cost of water to the community.

Knowing what, how many, and what condition the water system's assets are in (including accounting for ground and surface water as natural assets) is the first step towards improved management of the components of the PWS. An asset management plan also considers the useful life of the asset to allow for replacement and determine how to budget and finance asset replacement.

15.3.5 Emergency Planning

Emergencies affecting water systems may arise from flooding, drought, power loss, chemical spills, or other causes. Each situation may have different impacts on the water system. In each case, water availability or quality may be a factor in the water system's ability to deliver safe water to its customers.

Advanced identification of alternate water supplies assists in addressing public health concerns in an emergency, including loss of water availability.

15.3.6 Sanitary Deficiency Questions and Considerations – Sustainability

Previous chapters already cover some of the components related to sustainability. Chapters 3 and 4 (Ground Water and Surface Water sources, respectively) cover quantity issues, while Chapter 11 – Distribution covers determining and managing/reducing water loss. The questions below discuss additional sustainability considerations.

- **Has the water system identified and implemented techniques and practices for its sustainability?**

  Determine if the water system has planning documents that include long-term goals and objectives, analysis of alternatives, use of natural services of the water cycle, evaluation of life-cycle costs and a long-term financial strategy, as well as other steps supporting sustainability.

- **Are water conservation and efficiency of water-using products key factors in ensuring water availability?**

  Water conservation, steps taken to reduce water demand, can serve as an alternative water source, making water available for other uses. The efficient use of water can also help reduce demand on water supplies, as well as demands on water system infrastructure, and help PWSs deal with both short- and long-term changes in water availability and quality. Improvements in water efficiency can provide important sustainability benefits, including reducing or delaying the need for capital projects and reduced energy use. Water efficiency improvements can also provide environmental sustainability benefits such as reduced pressure on water resources.

  In states without regulatory requirements, water efficiency improvements could be part of state or technical assistance provider outreach, education, and assistance efforts. Water efficiency efforts at the consumer level to reduce demand would also be a part of these efforts.

- **Do customers have information on efficient water-using appliances?**

  The EPA's WaterSense program seeks to protect the future of our nation's water supply by promoting water efficiency and enhancing the market for water-efficient products, programs, and practices. Some utilities offer rebates for WaterSense labeled products. Water systems can also apply to become a WaterSense program partner and receive tools they can use to promote their own water efficiency programs.

- **Has the water system conducted an energy audit?**

  Unaccounted for energy usage and energy expenses could leave the water system in an undesirable financial situation. Asset management plans should include power ratings and capacities for all electrical equipment, especially pumps.

- **Can the water system separate its energy costs from other operating costs?**

  As energy costs rise, operating costs rise. EPA has developed an energy assessment tool to assist water systems in understanding their energy use. This tool can be accessed on EPA's website at: https://www.epa.gov/sustainable-water-infrastructure/energy-use-assessment-water-and-wastewater-systems.

- **Has a water supply analysis and water supply plan with demand projections been done?**

  The water system should have a plan for capital improvements once average daily production approaches or exceeds a certain percentage of the design capacity of major PWS components (e.g., the safe yields of the sources of supply or the raw water pumping and transmission, treatment, finished water pumping, storage, and additional sources). Many primacy agencies have regulations that define the percentage of design capacity for which PWSs have to begin planning for expansion.

- **Are the sources of supply adequate to meet current and expected demand?**

  The surveyor should ask the operator if the withdrawal rate from each source of supply has remained constant over the long-term. If less water is available during drought periods, the surveyor should ask what operational changes are made during these periods.

- **Are there long-term changes in source water quantity or quality expected and plans to address any changes?**

  Changes in source water pH, alkalinity, temperature, turbidity, and color can affect water treatment operations. For example, some chemical reactions proceed at a slower rate when the water is colder. When the source water has higher turbidity, sediment will accumulate in sedimentation basins at a faster rate, and the filters may need to be backwashed more frequently.

- **Is there a drought response plan?**

  The surveyor should ask if the water system has written practices for emergency operations such as operating during drought conditions.

15.4 Water System Security

Under the Bioterrorism Act of 2002, CWSs serving more than 3,300 persons were required to conduct vulnerability assessments to help water systems evaluate susceptibility to potential threats and identify corrective actions that can reduce or mitigate the risk of serious consequences from adversarial actions (e.g., vandalism, insider sabotage, terrorist attack, etc.). Sanitary surveys offer an opportunity to review a water system's emergency response plan and check that the emergency contacts list is up-to-date.

Water systems can take simple steps to provide basic water system security, such as locking the pump house and treatment plant, installing fencing around the treatment plant, storage facilities and pumping stations; and installing lighting, security cameras and, automated intrusion alarms.

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Appendix B Incompatible Chemicals

Purpose: The purpose of this appendix is to assist with the identification of chemicals in use at water treatment plants that should be stored separately. Several chemicals commonly used in water treatment are considered "incompatible" with one another. **The term "incompatible" applies to chemicals that could create a hazardous reaction (such as production of toxic gas, accelerated corrosion, or generation of excessive heat through an exothermic reaction, which could result in an explosion and fire) if mixed together in their concentrated form.** Depending on the type, form, concentration, and amount of chemical, this reaction could be catastrophic, resulting in a loss of life and rendering the water plant inoperable. It is therefore important to store chemicals in a manner that will prevent incompatible substances from coming into contact with one another.

Chemicals commonly used at water treatment plants can be divided into six broad groups of "incompatible" chemicals. These groups are listed in the table below:

Group 1:	Acids
Group 2:	Bases
Group 3:	Salts & Polymers
Group 4:	Adsorption Powders
Group 5:	Oxidizing Powders
Group 6:	Compressed Gasses

To ensure the safety of PWS personnel and the PWS itself, each of these groups of chemicals is considered incompatible with the other and therefore should be stored separately. Examples of chemicals that should not be stored near each other, and the resulting consequence of improper storage include the following:

Examples of Incompatible Chemicals	Hazardous Reactions
Powdered Activated Carbon (PAC), an adsorption powder, mixed with Potassium Permanganate, an oxidizing powder.	Excessive heat generation, with the possibility of explosion and fire. Note: PAC alone is extremely combustible.
Calcium Hypochlorite, a combination base/oxidizer, exposed to moisture or mixed with a viscous fluid such as oil	Excessive heat, fire, or explosion possible. Can provide an ignition source for combustible materials.
Concentrated Sulfuric Acid, a strong acid, mixed with Concentrated Sodium Hydroxide, a strong base.	Excessive heat and liquid explosion. Note: Highly concentrated acids and bases, when mixed together, will have a much more hazardous reaction than weak acids and bases.
Calcium Oxide, a strong base available only as a powder, exposed to moisture.	Excessive heat, fire. Can provide an ignition source for combustible materials.

Liquid chemicals should be stored separately from dry chemicals, regardless of which compatibility group they fall into. Certain concentrated dry chemicals will produce an exothermic reaction when exposed to liquid or even small amounts of moisture. All chemicals should be stored in secure, well-ventilated areas that are free of moisture (especially dry chemicals), freezing conditions (especially liquid chemicals), excessive heat, ignition sources, and flammable/ combustible materials. Products such as paint, antifreeze, detergent, oil, grease, fuel, solvent, and beverages should never be stored in the same area as water treatment chemicals.

Following is a list of a number of chemicals commonly used in water treatment, listed by their compatibility group. Because there is a wide range of chemicals available and in use today, surveyors may encounter chemicals not included in the tables below. OSHA Regulation 29.CFR.19101. 200 (Hazard Communication) requires that all organizations that handle hazardous chemicals, including water systems, maintain a SDS in their files for each chemic al s tore d on-site. If there is a question regarding the properties or incompatibility of any chemical encountered at a plant, the appropriate MSDS should be reviewed.

Common Water Treatment Chemicals - Compatibility Groups**

Group I: Acids

Name	Common Name	Available Forms
Acetic Acid	Ethanoic Acid	Liquid
Hydrofluosilicic Acid	Fluosilic Acid	Liquid
Hydrogen Fluoride Acid	Hydrofluoric Acid	Liquid
Hydrochloric Acid	Muratic Acid	Liquid
Nitric Acid	Nitric Acid	Liquid
Sulfuric Acid	Sulfuric Acid	Liquid

Group II: Bases

Name	Common Name	Available Forms[1]
Calcium Hydroxide	Hydrated Lime	Dry
Calcium Oxide	Quicklime	Dry
Calcium Hypochlorite	HTH	Dry
Sodium Bicarbonate	Sodium Bicarbonate	Dry
Sodium Carbonate	Soda Ash	Dry
Sodium Hydroxide	Caustic Soda, Lye	Liquid, Dry
Sodium Hypochlorite	Bleach	Liquid
Sodium Silicate	Water Glass	Liquid

[1] Liquid and dry chemicals should be stored separately, even if they are in the same compatibility group. Certain concentrated dry chemicals, like calcium hypochlorite and calcium oxide (quicklime) will produce an exothermic reaction when exposed to liquid or even small amounts of moisture.

Group III: Salts & Polymers

Name	Common Name	Available Forms[1]
Aluminum Sulfate	Alum	Liquid, Dry
Copper Sulfate	Blue Stone	Liquid, Dry
Ferric Chloride	Ferrichlor	Liquid, Dry
Ferric Sulfate	Ferrifloc	Dry
Ferrous Sulfate	Coppras	Liquid, Dry
Polyaluminum Chloride	PACL	Liquid
Polyelectrolytes (Cationic, Anionic, Non-ionic)	Polymer	Liquid, Dry
Sodium Aluminate	Soda Alum	Liquid, Dry
Sodium Fluoride	Sodium Fluoride	Liquid, Dry
Sodium Hexametaphosphate	Glassy Phosphate	Dry
Sodium Phosphate	Sodium Phosphate	Liquid, Dry
Zinc Orthophosphate	Zinc Ortho	Liquid

[1] Liquid and dry chemicals should be stored separately, even if they are in the same compatibility group.

Group IV: Adsorption Powders

Name	Common Name	Available Forms
Powdered Activated Carbon	PAC	Dry
Granular Activated Carbon	GAC	Dry

Group V: Oxidizing Powders

Name	Common Name	Available Forms
Potassium Permanganate	Permanganate	Dry

Group VI: Compressed Gases[1]

Name	Common Name	Available Forms	Incompatible Chemicals Within this Category[2]
Ammonia	Ammonia	Liquid, Gas	Chlorine
Chlorine	Gas Chlorine	Liquid, Gas	Ammonia
Carbon Dioxide	Dry Ice	Liquid, Gas	-
Sulfur Dioxide	S0 2	Liquid, Gas	-

[1] Each compressed gas should have its own separate storage/feed area.

[2] Chlorine and ammonia are incompatible. They should be stored separately from each other, as well as from all other chemical groups.

Appendix C Best Available Technologies

Summary of Best Available Technologies (BATs) for Inorganic and Radiological Contaminants

	Activated Alumina	Coagulation and Filtration	Direct and Diatomite Filtration	Granular Activated Carbon	Ion Exchange	Lime Softening	Reverse Osmosis	Corrosion Control	Electrodialysis	Chlorine	Ultraviolet Light	Oxidation and Filtration
Antimony		x					x					
Arsenic	x	x			x	x	x		x			x
Asbestos		x	x					x				
Barium					x	x	x		x			
Beryllium	x	x			x	x	x					
Cadmium		x			x	x	x					
Chromium		x			x	x	x					
Cyanide					x		x			x		
Mercury		x		x		x						
Nickel					x	x	x					
Nitrate					x		x		x			
Nitrite					x		x					
Selenium	x	x				x	x		x			
Thallium	x				x							
Combined Radium (226 &228)					x	x	x					
Gross Alpha							x					
Beta Particles					x		x					
Uranium		x			x	x	x					

BEST AVAILABLE TECHNOLOGIES (BAT) FOR DISINFECTION BYPRODUCTS (DBPs)	
TTHM	PWSs that disinfect their source water: Enhanced coagulation or enhanced softening, plus GAC10; or nanofiltration with a molecular weight cutoff ≤1000 Daltons; or GAC20. See 40 CFR 141.64(b)(2)(ii) for details.
	Consecutive Water Systems: *Water systems serving ≥10,000*: Improved distribution system and storage tank management to reduce residence time, plus the use of chloramines for disinfectant residual maintenance. *Water systems serving <10,000*: Improved distribution system and storage tank management to reduce residence time. See 40 CFR 141.64(b)(2)(iii) for details.
HAA5	PWSs that disinfect their source water: Enhanced coagulation or enhanced softening, plus GAC10; or nanofiltration with a molecular weight cutoff ≤1000 Daltons; or GAC20. See 40 CFR 141.64(b)(2)(ii) for details.
	Consecutive Water Systems: *Water systems serving ≥10,000*: Improved distribution system and storage tank management to reduce residence time, plus the use of chloramines for disinfectant residual maintenance. *Water systems serving <10,000*: Improved distribution system and storage tank management to reduce residence time. See 40 CFR 141.64(b)(2)(iii) for details.
Bromate	Control of ozone treatment process to reduce production of bromate. See 40 CFR 141.64(a)(2) for details.
Chlorite	Control of treatment processes to reduce disinfectant demand and control of disinfection treatment processes to reduce disinfectant levels. See 40 CFR 141.64(a)(2) for details.
BEST AVAILABLE TECHNOLOGIES (BAT) FOR VOLATILE ORGANIC CHEMICALS (VOCs) AND SYNTHETIC ORGANIC CHEMICALS (SOCs)	
VOCs	Granular Activated Carbon (GAC) and Packed Tower Aeration (PTA) for all VOCs except Dichloromethane and Vinyl Chloride for which only PTA applies. See 40 CFR 141.61(b) for details.
SOCs	GAC for all SOCs except for Glyphosate for which only Oxidation applies. In addition, Packed Tower Aeration also applies to Di (2-ethylhexl) adipate, Ethylene Dibromide and Hexachlorocyclopentadiene. BAT for Acrylamide and Epichlorohydrin are treatment technics and require use as specified by manufacture but no more than: Acrylamide=0.05% dosed at 1 ppm and Epichlorohydrin=0.01% dosed at 20 ppm (or equivalent). See 40 CFR 141.61(b) for details.

This table is intended to serve as a summary of the BATs for inorganic and radiological contaminants. Details about treatment limitations and appropriate applications are provided in 40 CFR 141.62(c) and (d) for inorganic contaminants and 40 CFR 141.66(g) for radionuclides.