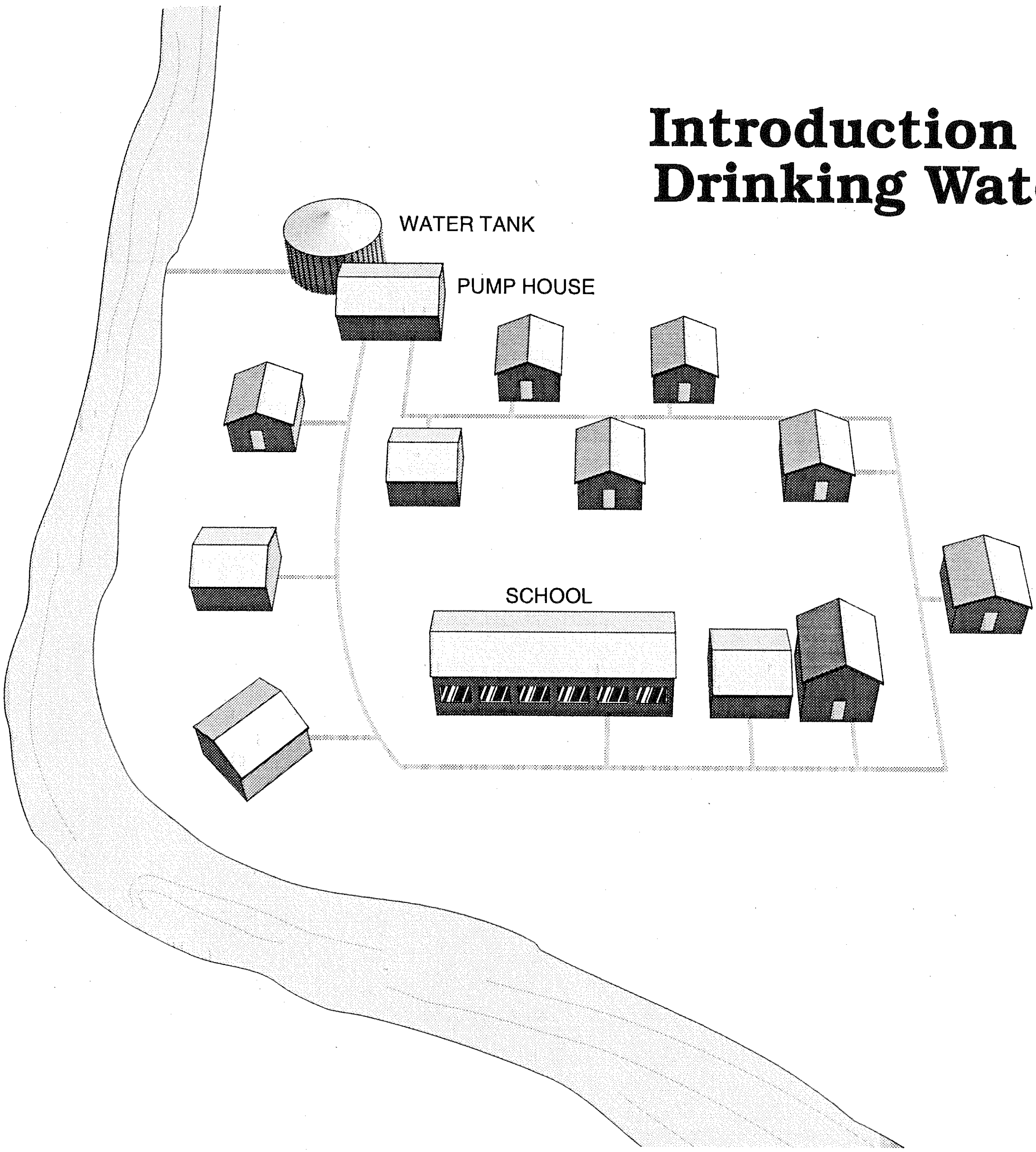
O & M of Small Water Systems

Introduction to Drinking Water



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O & M of Small Water Systems

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- Atmosphere
- Aquifer
- Aquatic life
- Bacteria
- Color
- Community water system
- Disinfection
- DCIP
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INTRODUCTION TO DRINKING WATER

INTRODUCTION

Who is this for?

The following materials were developed for the State of Alaska and are focused primarily on rural Alaska **public water systems**[1] serving less than 500 people.

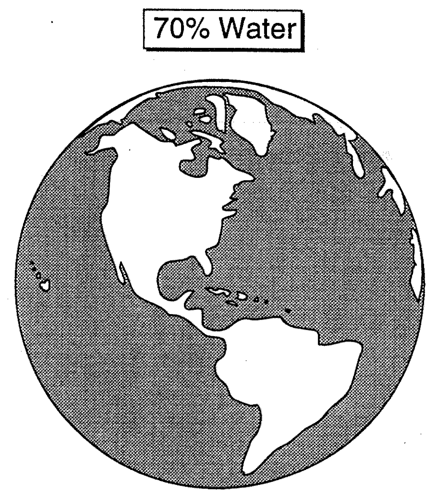
Content

This material is focused on identification of components and a discussion of their functions with an emphasis on operation and maintenance techniques.

WHAT IS WATER?

Abundance

Water is the most abundant and common material on earth. It covers 70% of the surface of the earth as water and ice.



Life Blood

Water is the life blood of the universe. If we are without water there could be no life. Our bodies are 65% water. Without drinking water for four to seven days our blood becomes thick and contains a high concentration of toxic waste materials. We become delirious and unable to function, death is not far behind.

Other Planets

As far as we know, earth is the only planet in the solar system to contain water. Others have ice, but only the earth has this miraculous life blood.

Universal Solvent

Water is often called the universal solvent; given enough time it will dissolve everything that it comes in contact with. Thus, it is effective in carrying food through our bodies to the individual cells and carrying away the cell waste.

Dissolves Minerals

As water flows through the gravel, fissures and sands in the earths crust and flows over the top of the ground it picks up minerals, **microorganisms**[2], dirt and bits of plants. Some of these materials are carried along by the water due to its speed. Others, such as minerals are dissolved in the water.

[1] **Public Water Systems** - Water systems designed to deliver water to more than one home or family.

[2] **Microorganisms** - Minute organisms, either plant or animal, invisible or barely visible to the naked eye.

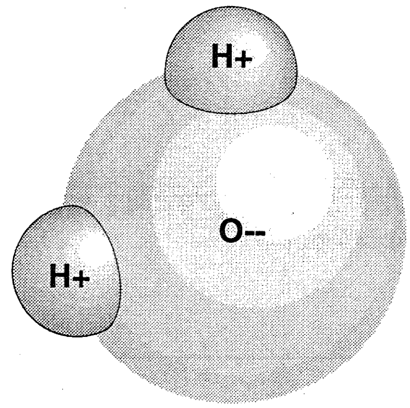
Gases

Water, like many other fluids, has the ability to also dissolve gases, such as oxygen (0_2) and carbon dioxide (CO_2). The oxygen in the water allows fish and other **aquatic life**[3] to live in the water. Without oxygen fish, like humans, would die. The gills of the fish allow it to filter this dissolved oxygen directly from the water.

WATER AS A CHEMICAL

The Water Molecule

The water **molecule**[4] is composed of one atom of oxygen and two atoms of hydrogen. This molecule is given the chemical symbol H_2O (H_2 for two hydrogen atoms and O for one oxygen atom). The chemical symbol is read as "H two O."



Like a Battery

Notice that the two hydrogen atoms are at one end of the molecule. The hydrogen atoms are positively charged. When they attach themselves to the oxygen molecule the whole molecule effectively becomes polarized with negative and positive poles, much like a battery. Because, it has both negative and positive charges it is much easier for it to attract other material. This is one of the reasons it is the universal solvent.

States of Water

Water has another unique property; it is the only material that is found on earth in the three basic states at standard temperatures. These states are solid (ice), liquid (water) and gas (water vapor).

Molecules in Motion

The water molecule, like other molecules is in constant motion. The rate of this motion is directly related to the temperature of the water. It moves slowest when the water is in the form of ice, and fastest when the water is a vapor.

Density of Water

As the temperature is reduced the rate of movement slows. As this happens the molecules get closer and closer together. At 4°C they are as close together as they are ever going to be. This increases water's **density**[5] to its maximum. The volume that a set amount of water occupies is at a minimum at this point. Below 4°C the molecules are moving so slow that their electrical charges begin to cause the molecules to line up in a pattern and form crystals.

[3] **Aquatic Life** - All forms of plant and animal life that live in water.

[4] **Molecule** - The smallest division that a substance can be broken down to without separating its individual atoms.

[5] **Density** - The weight per unit volume of a substance.

Expands When it Freezes

At 0°C the crystals are fully formed. This formation allows the molecules to line up in a way so that they occupy a greater space than they did before the temperature reached 0°C. This expansion is what causes water to break a bottle or pipe when it is frozen. Water is one of the few compounds that expands when it freezes. This causes ice to be lighter than the same volume of water and therefore it floats in water.

Water and Heat

The amount of heat it takes to cause the temperature of water to change is used as the basic measurement of heat. In the English system this heat is referred to as a BTU (British Thermal Unit). One BTU is defined as the amount of heat required to raise the temperature of one pound of water one degree **Fahrenheit**[6]. In the SI (System International - also called the metric system) the unit of heat is the calorie. One calorie is defined as the amount of heat required to raise one gram of water one degree **Celsius** [7].

DISTRIBUTION OF WATER ON EARTH

The Study of Water

The study of water, its location, use, quantity and occurrence is called **hydrology**[8]. This next section is a brief discussion of the types of water sources, the distribution of water in those sources and some of the uses of water. This is a small portion of hydrology.

DEFINITION BY SOURCES

The sources of water on the earth are divided into two categories; surface water and **groundwater**[9].

Surface Water

Surface water is water that is found in the oceans, lakes, streams, springs, and muskeg ponds. Surface water is exposed to the atmosphere and is affected by **ambient**[10] conditions. This is the source of drinking water for some of our largest communities.

Groundwater

Groundwater is all the water below the earth's surface. However, from a waterworks standpoint we only consider the water between the surface and 2500 feet down. Water below this depth is too hot and expensive to be usable. Groundwater may also include springs. Yes, springs were included in the surface water description, that is because they can be either.

70% of Earth Water

Seventy percent of the earth's surface is covered with water. The total volume of water on the earth is approximately 305.79 million cubic miles. Of this, 296 million cubic miles are in the oceans, leaving only 9.79 million cubic miles of fresh water.

6 **Fahrenheit** - Relating to an English thermometer scale with the boiling point at 212 degrees and the freezing point at 32 degrees.
7 **Celsius** - Relating to a thermometer scale used in the metric system on which the freezing point of water is 0 degrees and the boiling point is 100 degrees.
8 **Hydrology** - The applied science pertaining to properties, distribution, and behavior of water.
9 **Groundwater** - Subsurface water occupying a saturated geological formation from which wells and springs are fed.
10 **Ambient** - The surrounding atmosphere.

HYDROLOGIC CYCLE

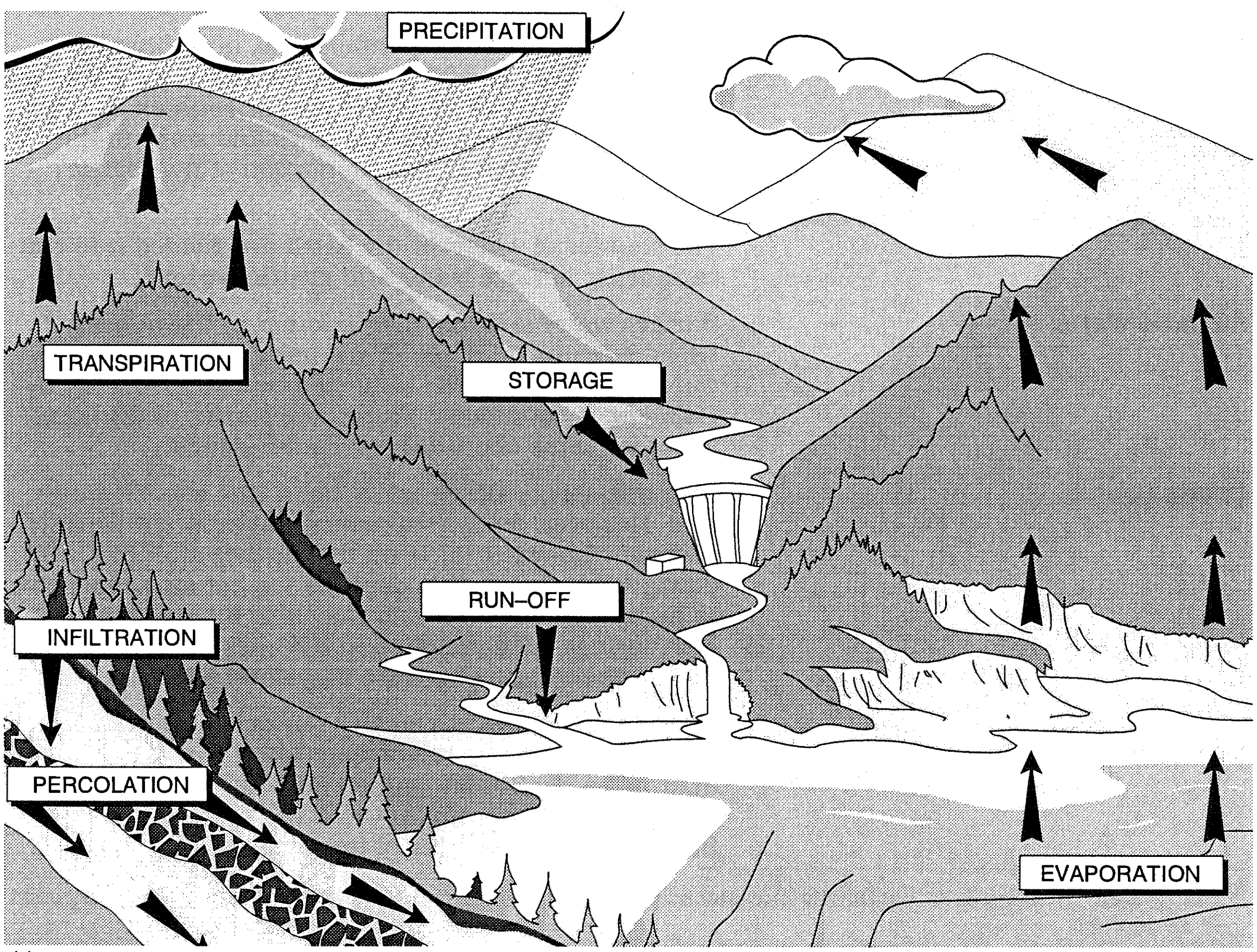
Introduction

The **hydrologic cycle**[11] is the key to our supply of fresh water. The cycle is made up of four key components.

- The atmosphere
- The **lithosphere**[12] - the crust of the earth
- The **hydrosphere**[13] - the water on the earth
- The sun - the energy source used to drive the hydrologic cycle

Available Water Supply

The amount of water available in the atmosphere, lithosphere and hydrosphere remains constant. It was formed during the creation of the earth. There will never be any more or any less than there is today. This water is continually recycled between the lithosphere and the atmosphere by the action of plants and the sun. In order to understand this process lets follow the cycle.



[11] **Hydrologic cycle** - Nature's method of continuously recycling the earth's unexpandable water supply, between the earth and atmosphere, making it possible to use this water over and over again.
[12] **Lithosphere** - The solid crust of the earth. It consists of the thin, loose layer known as soil and the mass of hard rock, several miles in thickness upon which soil lies.
[13] **Hydrosphere** - All of the water of the earth.

Precipitation

You could start the cycle anywhere because it is continuous and has no beginning or ending. So lets pick-up a droplet of precipitation and follow it through the cycle. **Precipitation**[14] in the form of rain, snow or sleet falls towards the earth.

Falls Toward Earth

As the precipitation falls toward the earth it can pick-up contamination in the form of minerals and toxics from industrial air pollution and natural pollution such as dust from a volcanic eruption. On its fall toward the earth some of the precipitation **evaporates**[15].

Evaporation

The amount of evaporation is dependent upon several factors, among them are the **humidity**[16], air temperature and the amount of wind. There is a significant amount of precipitation that is recycled back to the atmosphere before it ever strikes the ground.

Hits the Forest

Some of the precipitation hits the **forest canopy**[17], brush and grass. Some of the precipitation evaporates directly from the leaves of the canopy.

Hits the Ground

Some water flows down the outside of the trees onto the ground, and some strikes the ground directly. As water accumulates on the ground it runs downhill. This movement is referred to as **overland flow**[18].

Flow Along the Surface

As the water moves along the surface it picks up contamination in the form or **organic**[19] material such as, bits of leaves, and microorganisms such as **bacteria**[20], **viruses**[21], and **protozoa**[22], and **inorganic**[23] matter such as silt, clay, minerals and volcanic ash.

Surface Water

The overland flow accumulates in lakes, streams, muskeg ponds and rivers. Most rivers will eventually run into the ocean. These sources are referred to as surface water. A large quantity of the water that forms surface water will be evaporated back into the atmosphere. In fact in most of the world this is the largest single loss of surface water.

Groundwater

Some of the water that is running along the earth's surface seeps into the soil. This process is called **infiltration**[24]. As the water infiltrates the soil and moves downward some is taken up by the roots of trees and other plants. The water that is taken in by plants moves upward and is given off into the atmosphere

14 **Precipitation** - The process by which atmospheric moisture is discharged onto the earths crust. Precipitation takes the form of rain, snow, hail and sleet.
15 **Evaporate** - The process of conversion of water to water vapor by the sun.
16 **Humidity** - The amount of moisture in the air.
17 **Forest Canopy** - The enclosure made by the trees in a forest. The canopy can block all or most of the light from the forest floor.
18 **Overland flow** - The movement of water on and just under the earths surface.
19 **Organic** - Chemical substances of animal or vegetable origin, made basically of carbon structure.
20 **Bacteria** - Living organisms, microscopic in size, which consist of a single cell. Most bacteria utilize organic matter for their food and produce waste products as the result of their life processes.
21 **Viruses** - A submicroscopic organism which passes through filters which will strain out bacteria.
22 **Protozoa** - A small one-celled animal including, but not limited to, amoebae, ciliates, and flagellates.
23 **Inorganic** - Chemical substances of mineral origin.
24 **Infiltration** - The initial movement of water from the earth surface into the soil.

through the leaves of the plants in a process called **transpiration**[25].

Evaporation & Transpiration

This moisture mixes with the moisture that is evaporated from surface waters and from the plants. This combined process is referred to as **evapotranspiration**[26].

Groundwater Movement

The water not taken up by plants continues to move downward in a process called **percolation**[27]. This water continues to move downward until it collects in gravel and sands called **aquifers**[28]. There the water continues to slowly move towards adjacent lakes, streams and the ocean where it collects with the surface water and is evaporated back into the atmosphere.

Springs

Sometime in the past, changes in the earth's crust left the edge of an aquifer exposed to the surface. Where this happens the groundwater supply exits the hillside or mountain in what is referred to as a spring where it runs along the surface and mixes with surface water.

Back to the Atmosphere

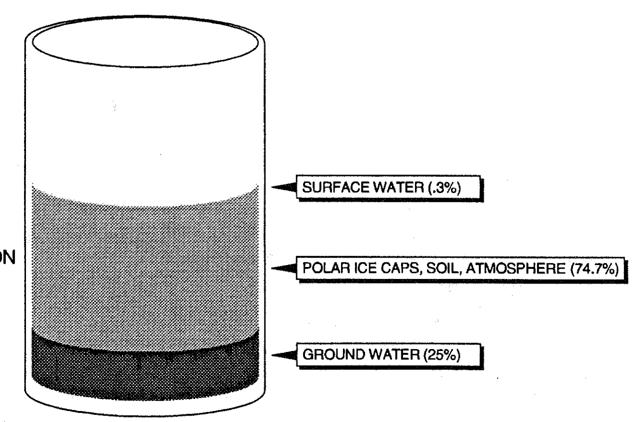
As you can see both the groundwater and the surface water eventually mix and are evaporated back into the atmosphere and form water vapor. This vapor is condensed by atmospheric conditions and form precipitation which falls to the ground and the cycle is continued, providing us with clean fresh water for our water systems.

DISTRIBUTION OF FRESH WATER

All Fresh Water

The 9.79 million cubic miles of fresh water represents only 3% of all of the water on the earth. 74.69% of the fresh water is tied up in the polar ice caps, soil moisture and the atmosphere and 25 percent is in the ground water supply. Of the 25% that is in the ground water supply only 44% is usable, that is less than twenty five hundred feet deep. This only leaves 0.31% of the fresh water on the earth as surface water.

FRESH WATER DISTRIBUTION

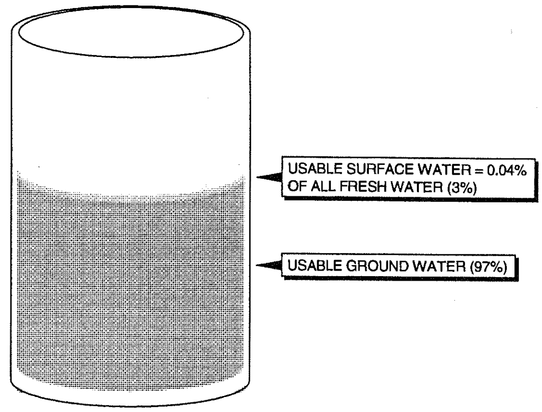


[25] **Transpiration** - The process by which water vapor is lost to the atmosphere from living plants.
[26] **Evapotranspiration** - The combined vaporization of water from water surfaces and plants.
[27] **Percolation** - Movement of water into and through the ground.
[28] **Aquifer** - A porous, water-bearing geologic formation.

Usable Fresh Water

There is approximately 1.09 million cubic miles of fresh water in the world. Ninety seven percent or 1.06 million cubic miles is in the ground water supply, above the 2500 foot level. Only three percent of the usable fresh water in the world is in surface water and only 0.04% of all fresh water in the world.

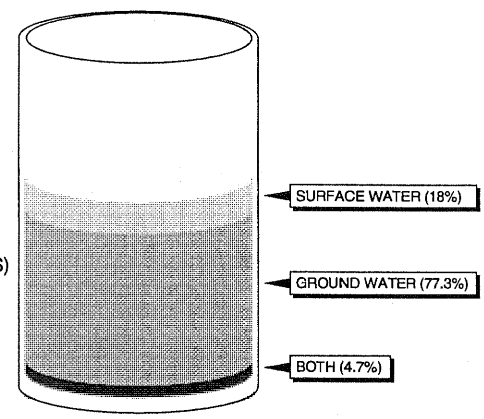
USABLE FRESH WATER



Distribution by System Type

Within the continental United States 77.3% of all public water systems use ground water, 18% use surface water and 4.7% use a combination of groundwater and surface water.

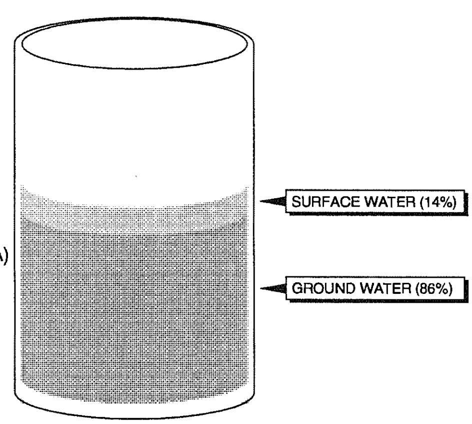
WATER DISTRIBUTION BY SYSTEM TYPE (US)



Distribution in Alaska

In the State of Alaska 86% of the Class A and B public water systems use groundwater and 14% use surface water. There are 1624 Class A and B systems in Alaska (1993).

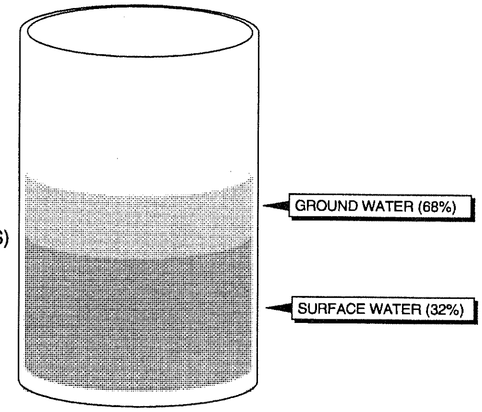
WATER DISTRIBUTION BY SYSTEM TYPE (ALASKA)



Distribution by Population

Within the continental United States 68% of the population is served by surface water suppliers while only 32% of the population relies on groundwater supplies.

WATER DISTRIBUTION BY POPULATION (US)



WHY THE DIFFERENCE?

In the Continental US

There are several reasons for the difference between the number of surface water suppliers and the number of people obtaining their drinking water from surface water suppliers. First, in the continental United States 37 of the 100 largest communities use surface water. This is because the majority of these communities are built next to surface water sources, including ten that are built next to the Great Lakes. In the West, communities such as Los Angeles, San Francisco, Portland and Seattle all utilize surface water.

Water Availability

Second, a large portion of this country is without any surface water source. Finally, there are few ground water supplies which can provide sufficient water for a large community.

Alaska Differences

Alaska has distribution conditions similar to the rest of the U.S.. First, there is very little usable ground water in most of the state (most need some kind of treatment). Second, Anchorage and Ketchikan use primarily surface water, Fairbanks uses a ground water supply and Juneau uses a combination of groundwater and surface water. This means that except in Southeast Alaska the majority of the smaller communities use groundwater supplies.

USES OF WATER

Categories

The consumption of water is often divided into categories depending on its intended use. Typical categories are; industrial use, agriculture use, domestic use and public water supply use.

Industrial Use

Industry in the United States uses an average of 150 billion gallons of water each day in order to produce the products that we all use. Typical uses include 270 tons of water to make one ton of steel, 250 tons of water to make one ton of paper and 10 gallons of water to produce each gallon of gasoline we use. The processing of sea food requires large volumes of high quality water. As you can see water plays an important role in industry. For instance the mining of gold in Alaska would have been near impossible without the use of water. Water is also used on the North Slope to force oil from the ground .

Agricultural Use

Even the food we eat requires water to grow and to produce. Each loaf of bread requires 115 gallons of water to produce and a ton of milk requires 4000 gallons for processing and clean-up. These figures do not include the water required to grow the wheat, feed and water the cow and clean-up the dairy.

Public Water Systems

Public water systems are designed to deliver **potable water**[29]. Public water systems in the U.S. deliver from 100 to 440 gallons of water per day per person. This consumption is a combination of domestic, public and light industrial use. While Alaska is the highest user with an average use of 440 gpdpc (gallons per day per capita) the use varies widely from a few gallons per day for self-haul systems to large volumes where water is allowed to run to prevent freezing. The average consumption in all of the U.S. is 170 gpdpc.

Uses

Within the U.S. this average of 170 gpdpc is used for laundry, 20 to 45 gallons per load, showers, 20 to 30 gallons each, baths 30 to 40 gallon each, flushing toilets 3.5 to 7 gallons per flush and most important **each of us drink one to two quarts of water a day**.

DEMANDS ARE SYSTEM SPECIFIC

Average day

As was pointed out above, in Alaska the average consumption of potable water is 440 gpdpc. The average day for your utility should be determined for each month and recorded as part of the routine records for the water system. Minimizing the average daily demand can reduce the cost of upgrading the system.

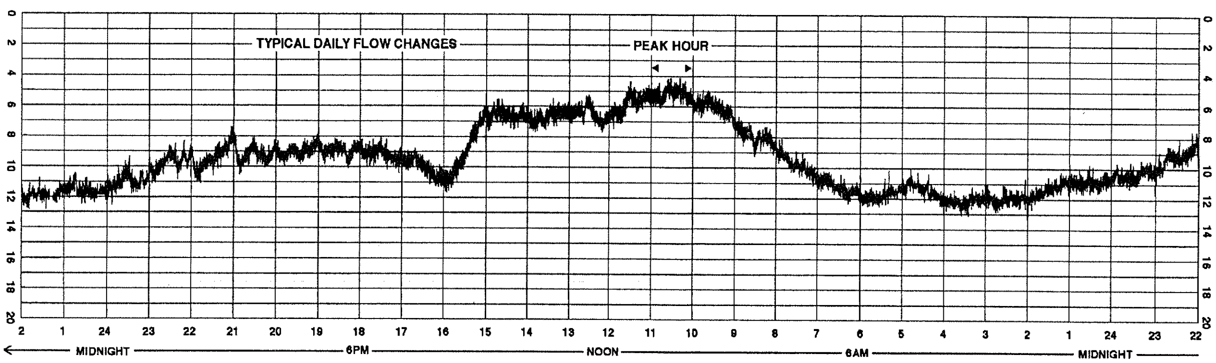
Peak Day

Normally a peak day ranges from 1.5 to 3 times the average day. The peak day for each month and the peak day for each year should be identified and recorded as part of normal operating procedure. The average and peak days for each year should be reviewed and changes explained.

[29] **Potable Water** - Water satisfactorily safe for drinking purposes from the standpoint of its chemical, physical, and biological characteristics.

Peak Hour

The peak hour of water use is often ten times the average hourly use. This peak hour is important to the operator and design engineer. The water system's pumps, storage and treatment must be designed so that the system can meet peak hour demands without stressing the system. The peak hourly demand is best determined from a chart recorder. If one is not available then this important piece of data will be missing and could cause difficulties in future design of the facility.



WHAT IS A WATER SYSTEM

Mechanically

Mechanically a water system is composed of components used to collect, treat and distribute water to individual customers.

Collection Components

The collection portion of the water system consists of methods of collecting surface water such as dams, rainwater catchments, roof catchments, intake structures, screens, pumps and piping. Groundwater is collected using a pump in a well.

Treatment Process

The treatment process varies from community to community. This process is designed and operated to perform a specific function. Typical treatment processes include the reduction of **color**[30] and **turbidity**[31] as well as removal of microorganisms and reduction and/or removal of harmful and nuisance chemicals that cause hardness and stains. These treatment processes are, in most cases accomplished through the addition of chemicals and the use of a filter.

Disinfection

Nearly all water systems **disinfect**[32] their water as a primary means of controlling disease-causing microorganisms. This disinfection process commonly is done with the addition of a small amount of chlorine. However, other chemicals and processes such as the addition of iodine, ozone and ultraviolet light are also used to disinfect drinking water.

30 **Color** - Primarily, organic colloidal particles in water.
31 **Turbidity** - A condition in water caused by the presence of suspended matter, resulting in the scattering and adsorption of light rays.
32 **Disinfection** - The process used to control pathogenic organisms.

Improve Health

Fluoride is added to many water supplies as a means of reducing tooth decay.

Heat Treatment

In many communities in the arctic heat is added to the water as a treatment process to keep it from freezing and/or to help in the chemical treatment process.

Distribution System Types

The distribution system like the treatment process varies widely based on community needs and environmental conditions. Typical distribution systems include piped systems, circulating loop systems, watering points and haul systems.

Distribution Components

Most distribution systems will include pipes, valves, fire hydrants, tanks, pumps, and house service connections.

HOLISTIC APPROACH TO - WHAT IS A WATER SYSTEM?

Definition

A water system is a dynamic process of collecting, treating, distributing, operating, maintaining and managing the mechanical components in such a way as to provide water to meet the customers' needs.

Adequate & Reliable

Meeting the needs means that the system must be adequate and reliable. The water must be safe to drink at all times and meet the quantity and quality requirements of the customer. This means that not only must the water be potable, but it must also be **palatable**[33] and aesthetically pleasing.

BRIEF HISTORY OF DRINKING WATER SYSTEMS

Ancient History

We have no record of when water systems as we know them were first used. However, we know that systems of bamboo pipes and channels were in use as long ago as 3000 BC.

Indus Valley

Somewhere between 1500 and 2000 BC in the Indus valley of Pakistan clay pipes were used to form a water distribution system in many of the communities.

Pumps

One of the first pumps ever developed was designed by Archimedes (287 - 212 BC) and is called the screw pump.

Romans

The Roman Empire existed from 100 BC to 212 AD. During their existence, they built many water collection and distribution systems. The most famous of these are the 300 miles of aqueducts that brought water from its sources into the city. The longest of these aqueducts was 20 miles in length. During the height of the empire these aqueducts moved as much of 84 million gallons a day to the city. The Romans

[33] **Palatable** - In relation to drinking water, it is that water which does not give off unpleasant taste and odors, is cool in temperature, has low color and low turbidity. Water which is pleasant to drink.

great concern over the quality of water caused them to enact penalties equivalent to $800 to $1000 of today's money for polluting a water source.

Wells

While there are recordings of hand dug wells from the beginning of recorded history it was not until 1126 AD that the first well was drilled. This occurred in Artois, France.

Public Water System

The first recorded public water system in the United States was established in Boston in 1652. By 1850 there were 83 such systems in the United States. These systems both reduced waterborne disease and caused it to spread, because once a system was polluted a large population could be infected.

Waterborne Disease

In 1880 in the United States cholera and typhoid, both waterborne diseases, were killing 75 to 100 people for each 100,000 population. At this time there were very few systems providing treatment of any type and there was no disinfection in any system.

Treatment

The first recorded use of a water filtration system was in Europe in the early 1700's. In 1835 the first slow sand filter was installed in the United States in Richmond, Virginia. The first rapid sand filter in the U. S. was installed in Summerville, New Jersey in 1885. While it is widely believed that chlorine was being used in some systems in the late 1800's, it was not until 1908 in Jersey City, New Jersey that we have the first recorded use of chlorine for disinfection in a water system in the United States.

Fire Hydrants

Fire hydrants similar to those we use today, called dry barrel hydrants, were first developed in Philadelphia in 1803. This style of fire hydrant allowed access to the water in the system without shutting down the system or losing excessive amounts of water. Also, the design allowed the hydrant to remain permanently installed with little possibility of freezing.

Piping

Significant strides in piping systems were not developed until the coke fired furnace was developed in the early 1700's and a method of welding was developed in the early 1800's. The first cast iron pipe was installed in Europe in 1785 and in the United States in 1816. Today there are over 200 utilities in the US with cast iron pipe over 100 years of age. Ductile cast iron pipe, a material stronger than cast iron was developed in 1948. Steel pipe was first introduced in 1825. **PVC**[34] was developed in the 1930's but not widely used until after the second world war.

[34] **PVC** - Poly Vinyl Chloride. A plastic pipe made by forcing heated plastic through a die.

REASONS FOR DRINKING WATER SYSTEMS

Public Health

The primary reason for the development and installation of a public water system is the protection of public health. The water system serves as a line of defense between disease and the public.

Process

Properly operated systems protect public health by:

- the removal and/or inactivation of **pathogenic**[35] microorganisms including bacteria viruses and protozoa,
- the reduction and/or removal of chemicals that can be detrimental to health such as arsenic, nitrates, lead and copper,
- providing quality water thus discouraging the customer from seeking unsafe but better tasting or looking water from a contaminated source.

Alternative Supplies

This last point is critical but often overlooked in the operation and management of a public water system. When the water produced by a system is objectionable because of odor, taste, or appearance, the customer will often seek another source for their drinking water. Ironically, these sources, while looking, tasting and smelling good, could contain microorganisms and/or chemicals that are harmful.

Waterborne Disease

Diseases that are carried by the water are called **waterborne**[36]. The organisms that cause these diseases do not normally live in the water, but are transported by the water. Examples of typical waterborne diseases are cholera, typhoid, dysentery, polio, hepatitis and Giardiasis. All of these diseases can be prevented from spreading through a water system with proper treatment and disinfection.

Effectiveness of Treatment

At the turn of the century there were 36 typhoid fever deaths for each 100,000 population. With the installation of water treatment plants and disinfection this was reduced to 0.1 deaths per 100,000 population. This reduction was enhanced by improvements in personal hygiene and had little to do with water treatment.

World Wide

In the United States we are indeed fortunate when it comes to waterborne disease. On a world wide scale, one child under the age of one year dies every 9 minutes from a waterborne disease.

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[35] **Pathogenic Organisms** - Bacteria, virus and protozoa which can cause disease.
[36] **Waterborne disease** - A disease caused by organisms or toxic substances which are carried by water. The most common waterborne diseases are typhoid fever, cholera, dysentery, giardiasis and other intestinal disturbances.

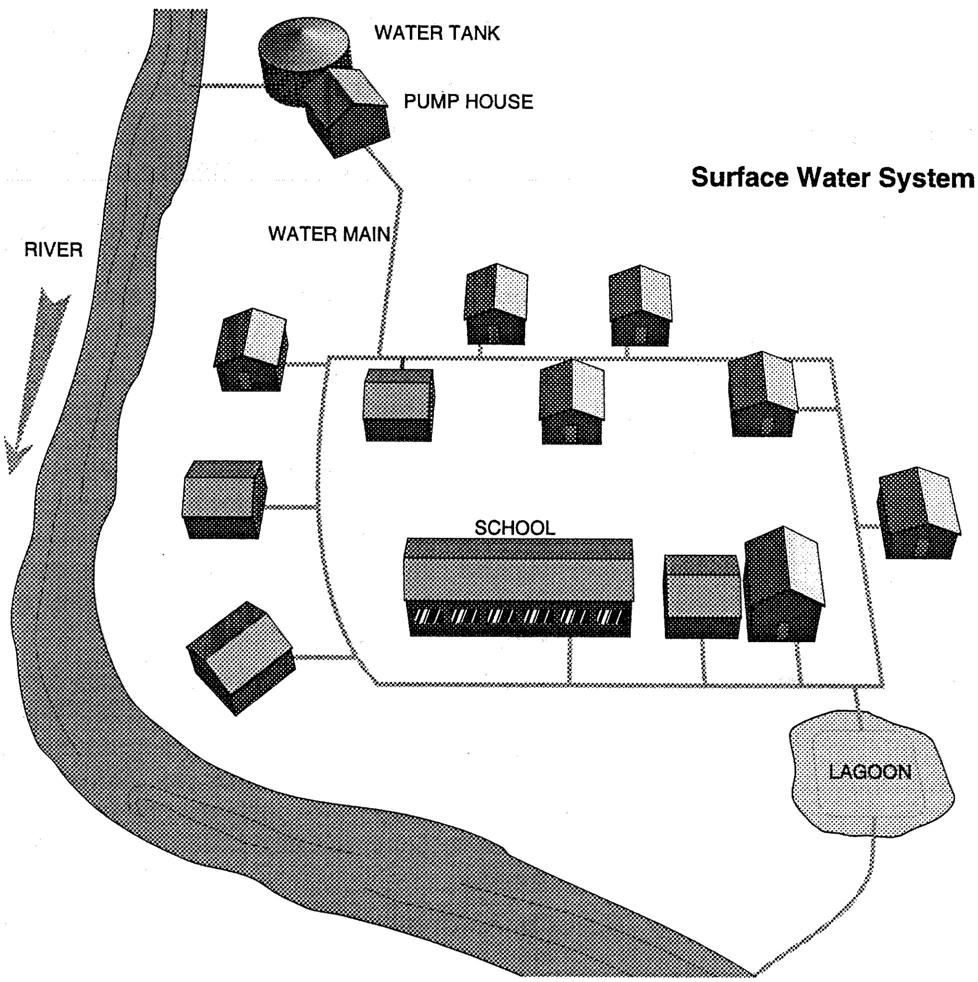
CLASSIFICATION OF SYSTEMS

Reason for Classification

Water systems are classified using various methods and criteria. The classification systems have, in each case been developed for a specific purpose. The most common methods are by type of source, by population, by size and population, and by complexity. The following discussion is a review of each of these systems.

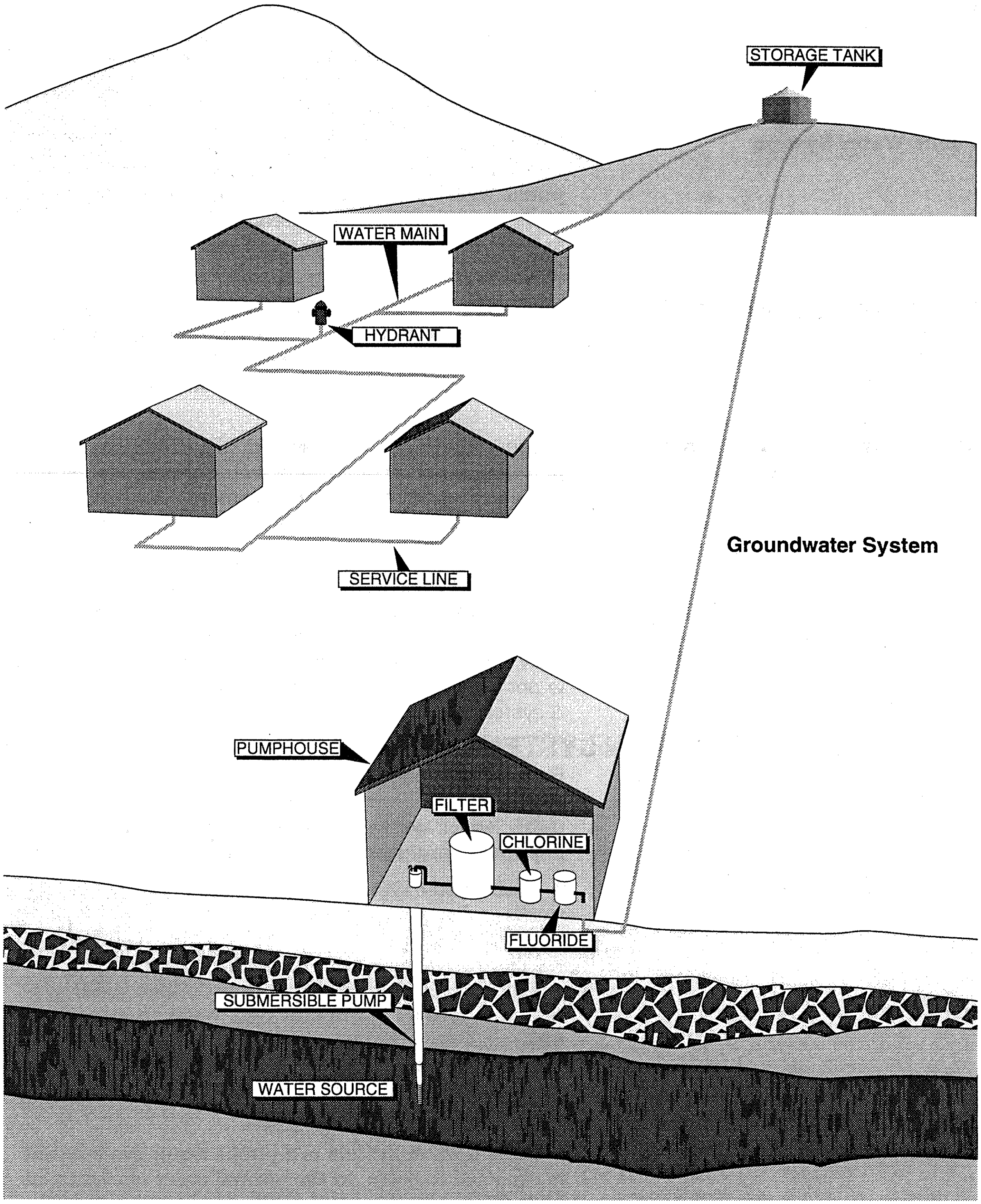
Classification by Source

One of the most common methods of classification is by source. The common classifications are surface water, groundwater and groundwater under the influence of surface water. This last type of system is discussed in detail in the module on sources.



Classification by Population

U.S. EPA has classified systems according to populations. These classifications are used to determine when a specific regulation must be applied. This classification was developed in order to allow the EPA to phase in regulations so that the largest segments of the population were addressed first. The typical classifications are; below 3300, 3300 to 10,000 and above 10,000.



Groundwater System

EPA CLASSIFICATION FOR REGULATIONS

Background

In order to apply drinking water regulations uniformly across the United States the EPA classified systems into three categories. All of these systems fall into the general category of a public water system.

Public Water System

For the purpose of the regulations a public water system is a system that supplies drinking water to the public where there are three or more service connections or is a commercial establishment which operates at least 60 days of the year and serves 10 or more people a day.

Community Water System

A community water system is a public water system that has 15 or more service connections and is used by year-round residents or serves 25 or more residents year-round. (In Alaska these are Class A systems.)

Non-Community Water System

A non-community water system is a public water system that is not a community water system. Generally these are systems with three or more connections but less than fifteen connections. (In Alaska these are Class B systems.)

NTNCWS

A special classification called a non-transient, non-community water system was established and refers to those public water systems that regularly serve at least 25 of the same people for six months or more but is not a community system. (In Alaska these are Class A systems).

ALASKA CLASSIFICATION SYSTEM

Background

Because of the uniqueness of Alaska a system that fits the State's need was devised. This system divides the public water systems into three categories based on population and number of connections.

Public Water System

A public water system is any source of water, intake works, collection system, treatment works, storage facility, or distribution system, including vehicle or vessel used to distribute water, from which water is available for human consumption; "public water system" includes a system providing water to more than **one** residential dwelling unit, including a duplex, or to a factory, office building, restaurant, school, or other similar facility, but does not include a system serving only a single-family residence.

Class A Water System

A Class A water system is a public water system that is expected to serve, in the normal order of events, at least 25 residents or 10 service connections used by residents, or 13 or more bedrooms used by residents, or that regularly serves the same 25 or more persons for at least six months of the year. Examples of a Class A system would include the City of Seldovia, City of Bethel, schools, and camps.

Class B Water System

A Class B water system is a public water system that is expected to serve, in the normal order of events, at least 25 persons each day or 10 service connections for at least 60 days of the year, and is not a Class A system. Examples of Class B systems would include seasonal lodges and restaurants.

Class C Water System

A Class C water system is a public water system that is neither a Class A nor a Class B public water system, nor a private water system. An example of a Class C system would be a duplex served by its own water system.

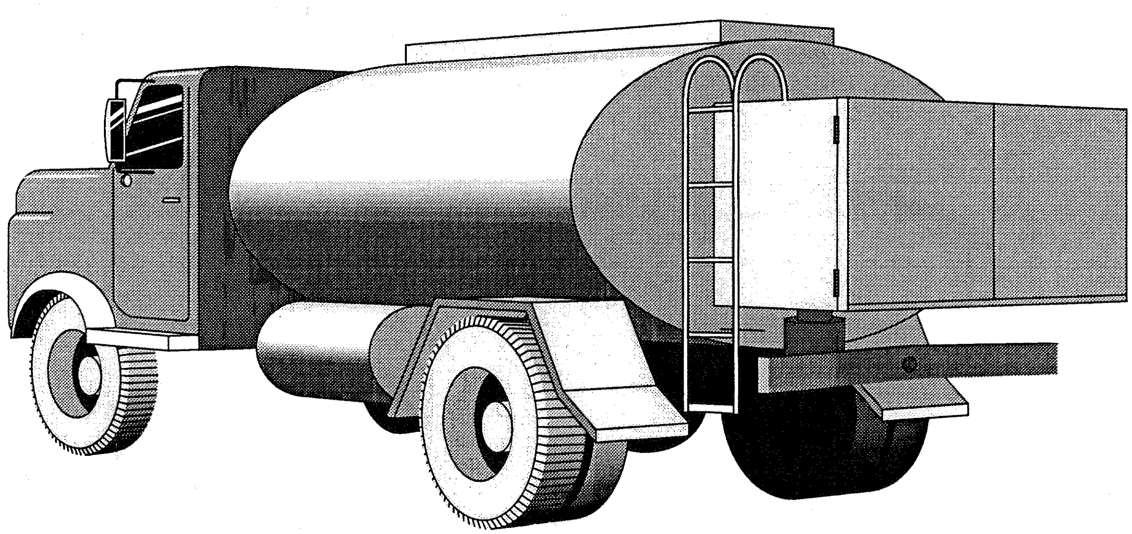
CLASSIFICATION BY SYSTEM COMPLEXITY

Background

For the purposes of application of treatment techniques, operator certification and training, technical assistance and engineering systems in Alaska are also classified by system type and/or complexity. The collection and treatment of water is not directly included in this system. Typical systems are:

HAUL SYSTEM

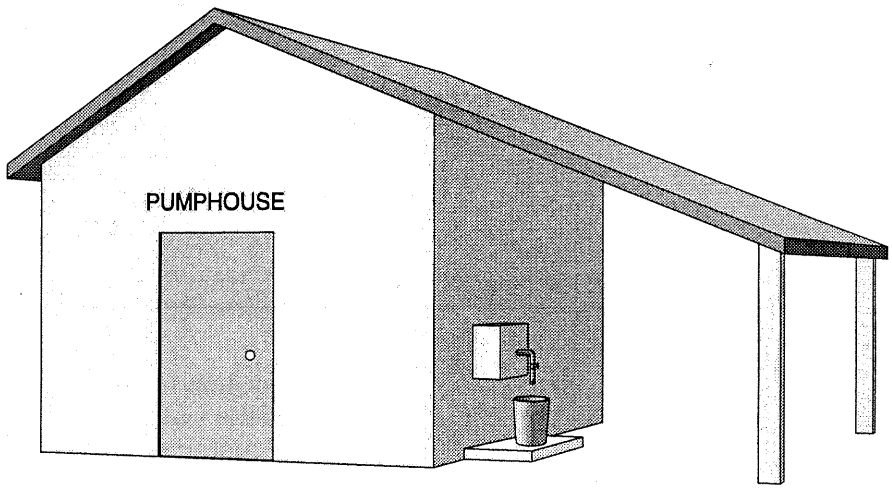
The haul system is a system where the **purveyor**[37] transports the water from the treatment plant or storage to the customer. This transportation is accomplished using a truck, trailer, or a track snow machine. Each customer has their own storage tank that is filled by the purveyor personnel. Water is delivered on an order basis in much the same way that furnace oil is delivered in much of the country.



[37] **Purveyor** - An agency or person that supplies potable water.

WATERING POINT

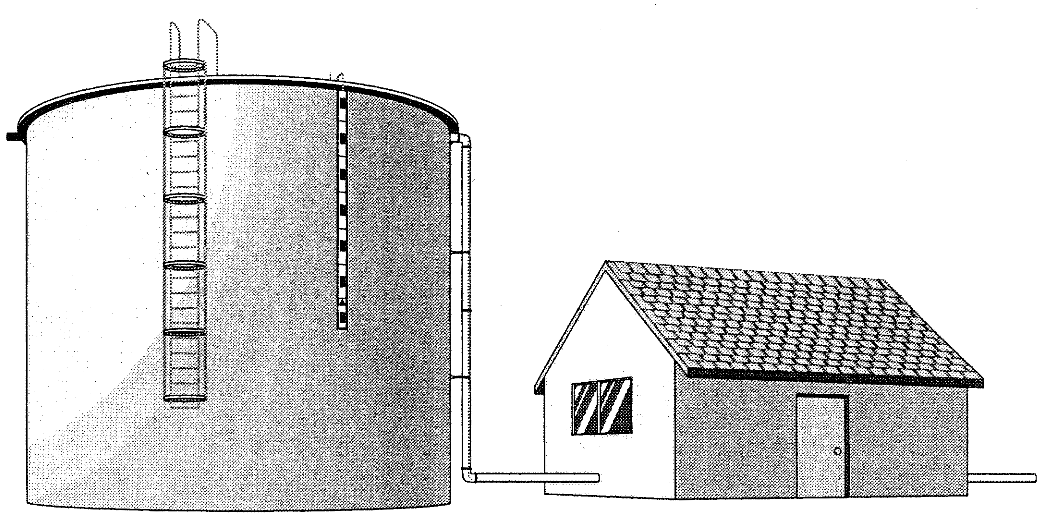
A common village distribution system is the watering point. This is a hosed connection to a storage or treatment facility. This connection may be inside or outside of the building. The building is commonly referred to as the pump house or washeteria. A typical process would be for the customer to bring their container to the watering point, place money in the form of coins in a coin box and receive a measured amount of water.



WATERING POINT

FILL AND DRAW

Another common village system is the fill and draw system. This terminology refers to the storage of the water rather than the distribution of the water. A typical fill and draw system consists of a large tank that is filled with treated water one or more times during the year. The village draws water from the tank during the rest of the year.



PIPED SYSTEMS

Several Configurations

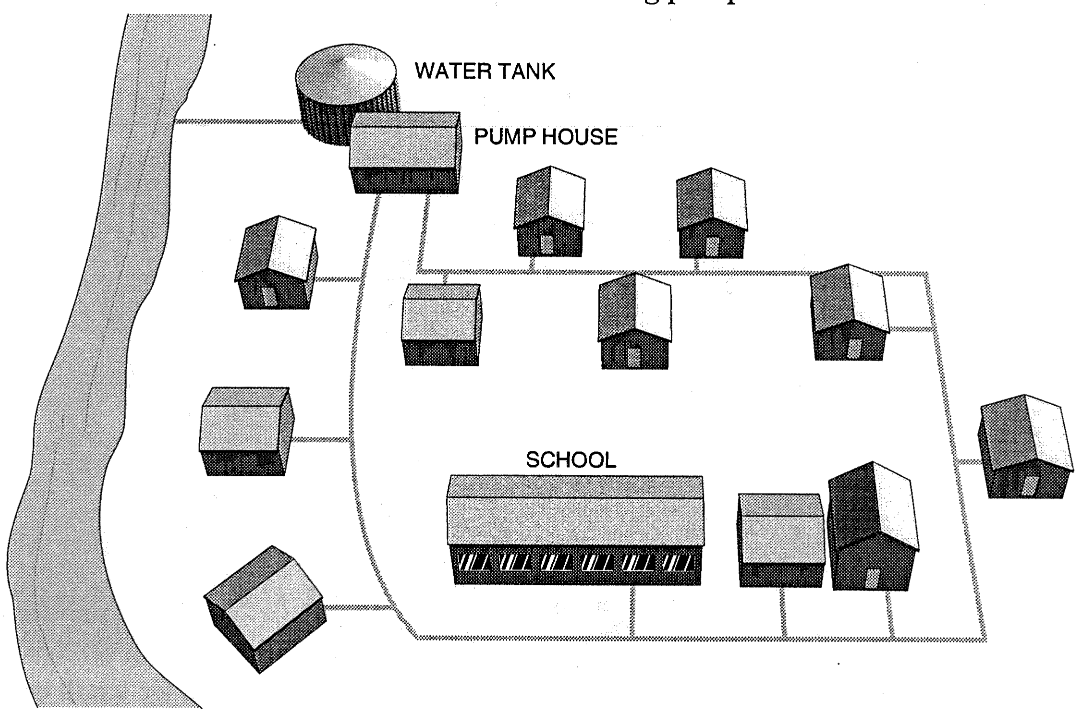
In Alaska there are several configurations of classic piped systems. A piped system refers to a system where the water is piped directly to the individual houses. There are variations on this type of system.

Standard System

The simplest is the standard system where a large pipeline leads from the storage to the housing area. Individual homes are connected directly to the piped system.

Circulating System

In order to prevent freezing it is necessary in some locations to heat the water and keep it moving all during the winter. These systems require a loop from the treatment facility or storage to the customers and back. The circulating system normally requires a boiler and a circulating pump.



Utilidors

To prevent water from freezing several special techniques are used in the arctic. One popular technique is the use of the utilidor. While expensive it provides a means of protecting the pipe from damage and allows the community to use a more traditional piped water system. Utilidors may be above or below ground. They are made of insulated wood or insulation covered with a special protective material such as corrugated steel or aluminum.

Class B Systems

It is very common for Class B systems (lodges, restaurants, etc.) not to have a classic distribution system that is found in the Class A system. In the Class B system the distribution system can be considered the internal building plumbing.

COMPONENTS OF A SYSTEM

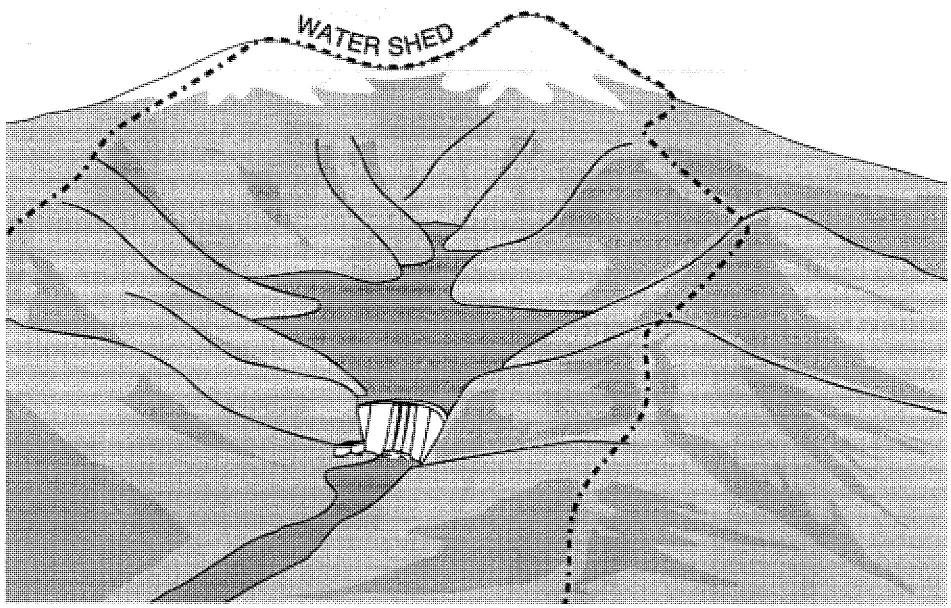
Introduction

The following is a brief description of the major components that would be found in a typical water system in a small community in Alaska. These components are divided into five distinct areas based on function. The areas are collection, treatment, distribution, management and operations and maintenance.

COLLECTION

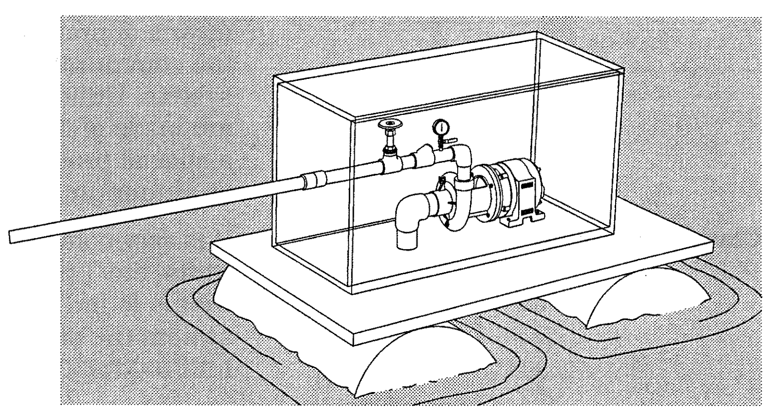
Watershed

When a system is utilizing surface water as a source, the protection of the quality and quantity of water starts by identifying and properly operating, maintaining and managing the source of water. In a surface water system the source is called the watershed or drainage basin. This is the area that collects and directs the water to your intake structure.



Intake Structures - Surface Water

Surface water intake structures for small communities can include dams or floats to collect the water, screens to prevent the entrance of large debris, pumps, and piping.

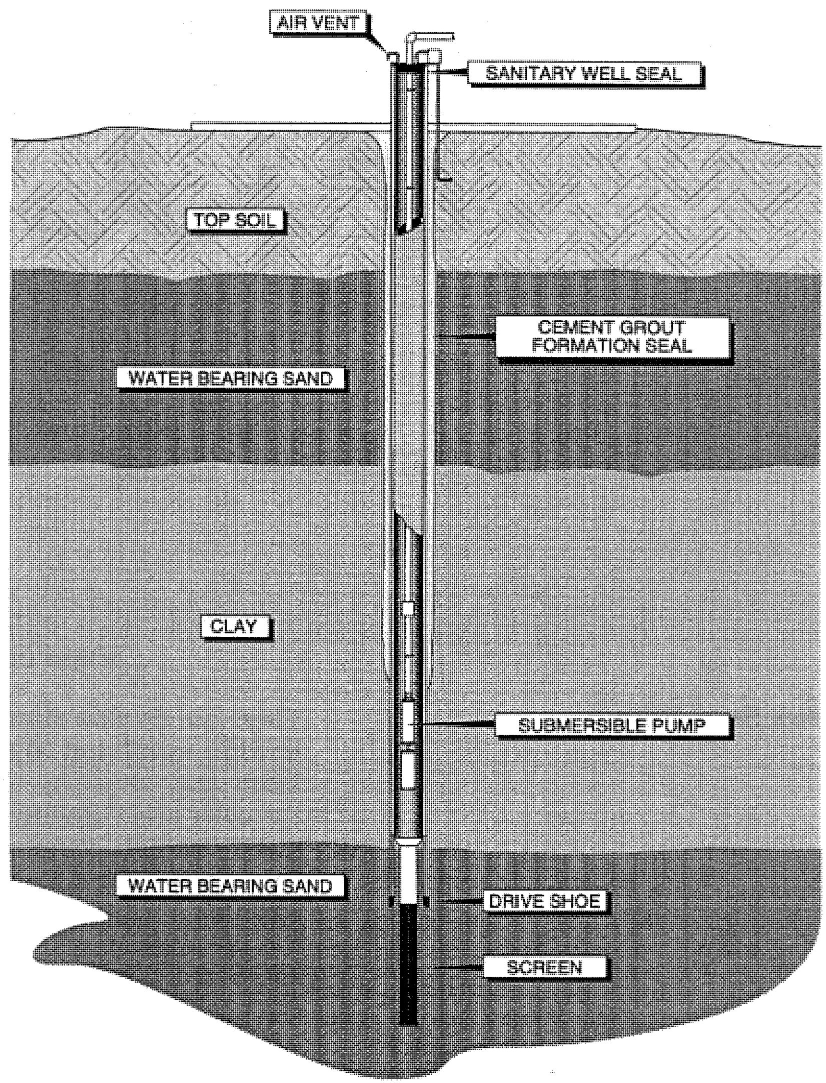


Groundwater

When a system utilizes groundwater, the protection of the source is just as important as the protection of the watershed in a surface water source. With a groundwater system this area is called the recharge area. It is where the groundwater supply is recharged by precipitation.

Groundwater Intakes

A groundwater supply must use a well and a pump in order to obtain the water. In Alaska, the most common pump used in small community wells is the submersible turbine. With this pump the pumping mechanism and the motor are placed below the water surface. The water is pumped either into a tank or directly to the treatment facility.



TREATMENT

Treatment Types

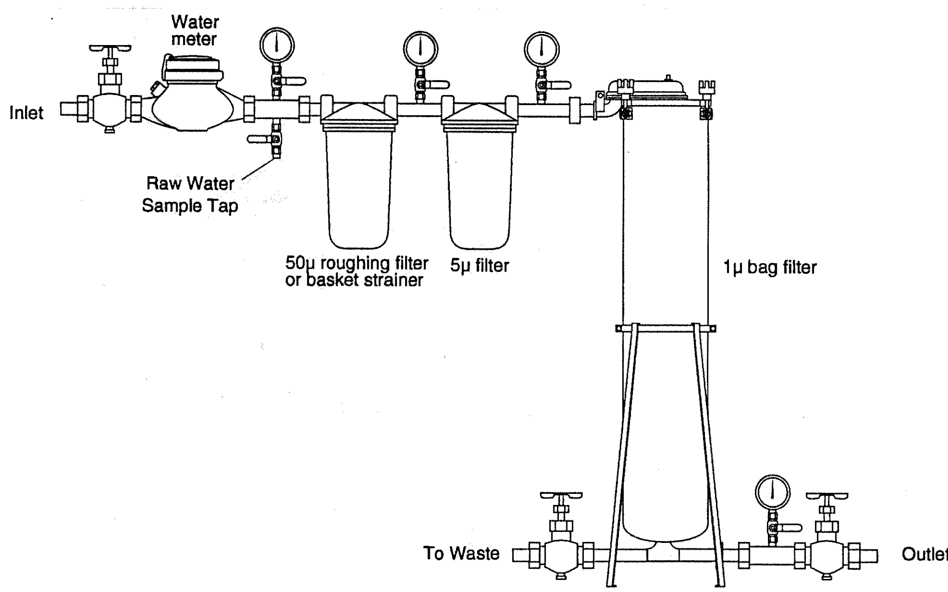
The type of treatment system employed by a water system is dependent on the system's needs. Typical treatment includes; filters for removing color, turbidity, microorganisms, and chemicals; disinfection, fluoridation, the addition of heat and corrosion control.

Filter Types

The type and size of the filtration system is dependent on the community size and the quality of the **raw water**[38]. Nearly all surface water supplies are required to have some form of filtration. Typical filter systems used in small communities include cartridge filters, slow sand filters, rapid gravity filters, pressure filters and treatment techniques for reduction or removal of chemicals.

Cartridge Filters

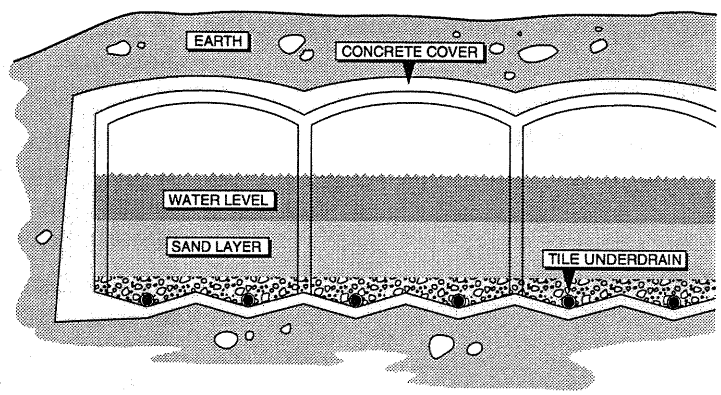
Cartridge filters are used where the demand and turbidity are low, such as roadhouses, logging camps, and very small villages. Specific cartridge filters can be effective in the removal of Giardia.



Slow Sand Filters

There are no slow sand filters in Alaska. They are used by small and large communities to remove turbidity and microorganisms. They are effective when the color and turbidity are low and the raw water quality is high. Their operational cost is much lower than conventional treatment. However, they require large areas of ground and are difficult to operate when the raw water quality deteriorates. A slow sand filter is composed of a filter bed of sand that is 24 to 42 inches deep. This bed is placed over an underdrain system. Water passes through the filter bed and material is strained from the water. The top one to two inches of material must be removed on a periodic basis in order to keep the filter operating.

38 **Raw water** - Water that has not been treated and is to be used, after treatment, for drinking water.

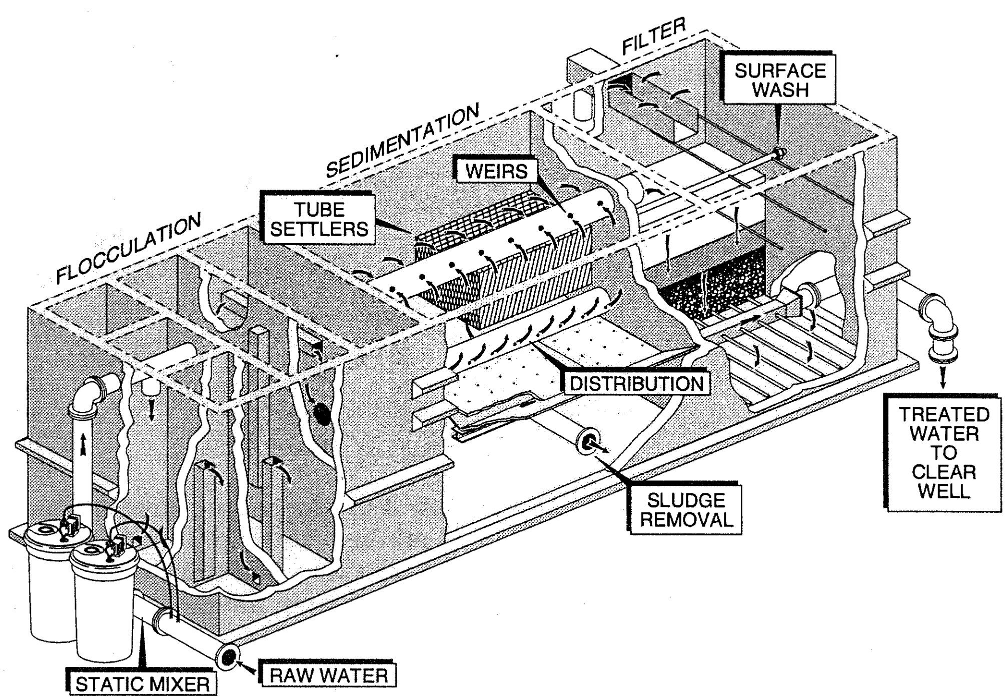


Rapid Gravity Filter

The most common filter system in the water works industry is the rapid gravity filter. There are two common variations of the system. The conventional treatment plant and a direct filtration plant.

Conventional Treatment

The conventional treatment plant utilizes chemicals such as alum to help remove turbidity, microorganisms and color. These chemicals are added in the rapid mix section of the plant. After the chemicals are mixed in the rapid mix, the water flows to a mixing chamber called a flocculation basin. Here, the treated water is slowly mixed and a feather like material called floc is formed. The floc is moved to the sedimentation basin where most of it settles out. From the settling basin the water is passed through a filter where



the remainder of the material is removed. Once the water leaves the filter it is chlorinated and delivered to the customers or stored for future distribution, as in the fill and draw systems.

Examples of Conventional Filtration

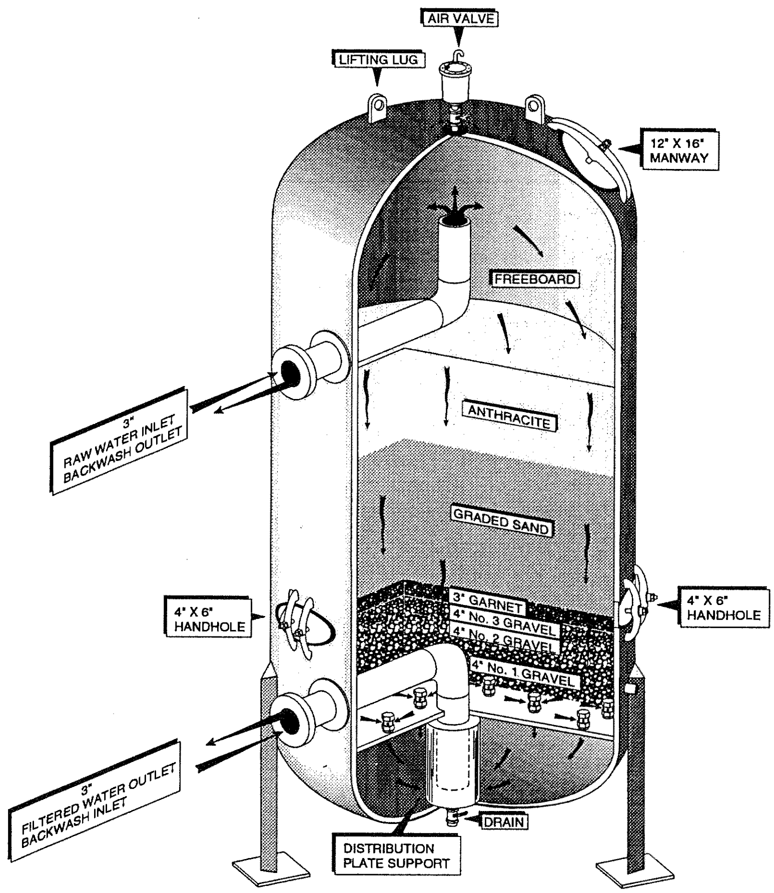
In Alaska conventional treatment plants exist in Kotzebue, Anchorage, Craig, Fairbanks, Petersburg and Prudhoe Bay.

Direct Filtration

A direct filtration facility is the same as the conventional treatment except there is no sedimentation basin. This reduces construction cost but increases operational requirements.

Pressure Filters

A pressure filter can be used in place of the gravity filter in a rapid gravity filter system. However, for optimum results they should be preceded by mixing and sedimentation components. The advantage of the pressure filter is the ability to use gravity head or



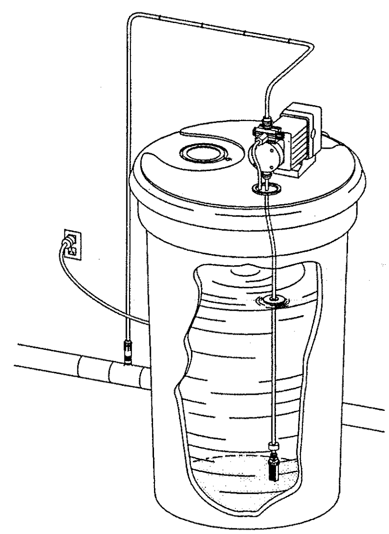
pump directly from the source straight through the filter and into storage. The rapid gravity filter often requires that the water be pumped twice, once into the plant and once from the plant to the distribution system.

Pressure Filters in Alaska

In the past the pressure filter system normally installed in many villages of Alaska consisted of only the filter. Some pressure filter systems feed chemicals that improve turbidity, color and microorganism removal just upstream of the filter. This process, while reducing the capital cost is only effective in low turbidity waters and may not reduce contaminants to acceptable levels, unless carefully controlled and operated. The very cold, highly colored waters of Alaska are very difficult to treat.

Chemical Removal

Many water supplies in Alaska have high concentrations of iron, manganese and total dissolved solids. These waters require special treatment. Fairbanks removes iron from its water through the use of chlorine and a conventional filtration facility. Nenana removes manganese through the use of a chemical called potassium permanganate and a special pressure filter called a greensand filter. Barrow removes total dissolved solids from the water through a process called reverse osmosis.



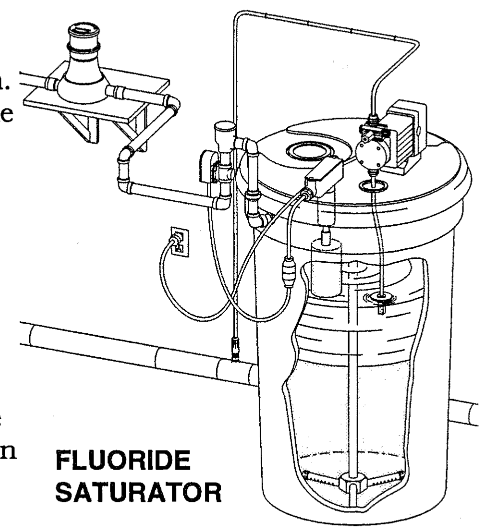
HYPOCHLORINATOR

Disinfection - Chlorine

Filtration is the first line of defense against contaminants that may enter the system. Disinfection is the second line of defense. In Alaska, as well as the other states, chlorine is the most common method used. Chlorine is supplied as a gas, solid or liquid. The solid and liquids are called hypochlorites. Other methods such as the use of iodine, ultraviolet and ozone are also effective in the disinfection of drinking water.

Contact Time

Regardless of the type of disinfection procedure used the ability of a chemical to disinfect is primarily based on the length of time the chemical is in contact with the microorganism. Proper contact time is provided by the storage tank. Temperature, pH and the types of organisms to be destroyed are also important.



FLUORIDE SATURATOR

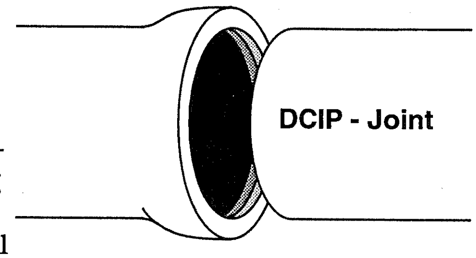
Chemical Addition

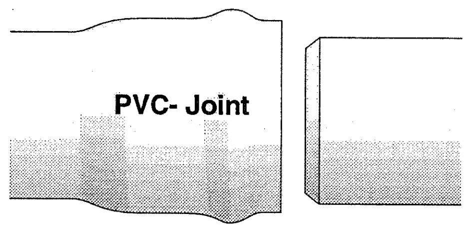
In some cases treatment is in the form of the addition of chemicals. Fluoride is added to drinking water to reduce tooth decay. Chemicals called sequestering agents are added to water to prevent stains by iron and manganese and chemicals such as soda ash and lime are added to the water to reduce corrosion.

DISTRIBUTION SYSTEM

Function

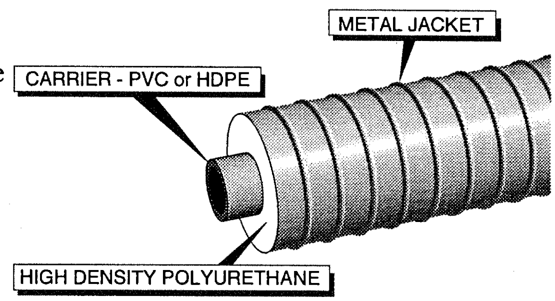
The distribution system is used to move the water from the treatment facility to the customer. As was mentioned above distribution systems come in a variety of designs from watering points to piped systems. The following discussion is focused on a typical piped system.





Piping

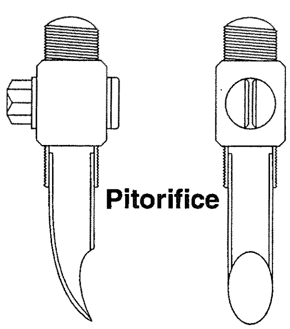
The piping used for distribution systems can be steel, ductile cast iron (**DCIP**[39]), asbestos cement, wood, PVC and high density polyethylene (HDPE). In southeast Alaska and the Anchorage area, PVC and DCIP are the most common materials. In the arctic region HDPE is the most common for new construction.



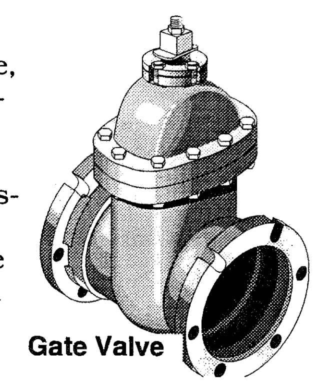
Arctic Pipe

In the arctic environment the HDPE pipe is commonly installed as arctic pipe. This is pipe with insulation covered with a protective layer.

Valves



In order to control flow, isolate lines and perform maintenance, valves are installed in distribution systems. There are many types of valves but the most common in the distribution system are gate and butterfly valves. Valves connected to the main lines to allow service to a house are a special plug valve called a corporation stop. In

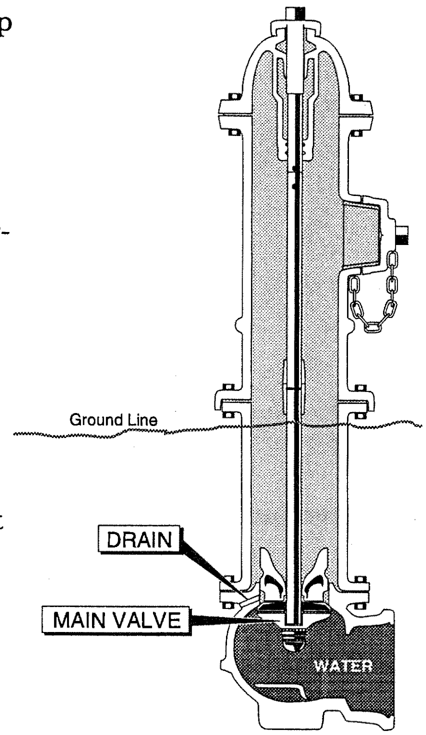


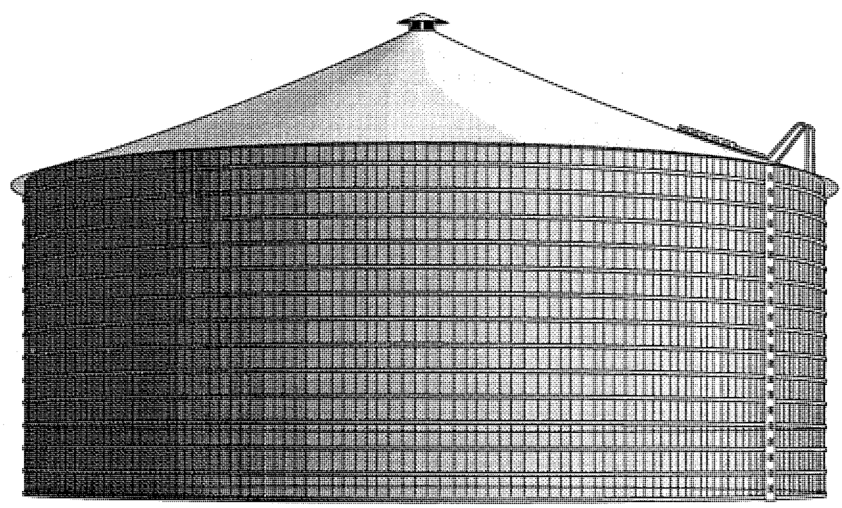
[39] **DCIP** - Ductile Cast Iron Pipe - Cast iron pipe, that is made by injecting magnesium into the molten cast iron developing a material of exceptional strength.

arctic piped systems a special corporation stop called a pitorifice is used to help circulate the water through the customers service line.

Fire Hydrants

In order to obtain the water needed to properly control a fire, fire hydrants are installed in the system. The hydrants used in Alaska are referred to as dry barrel hydrants. The operating valve is in the bottom of the hydrant below the frost line.



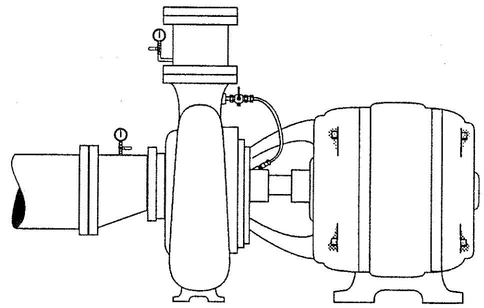


Reservoirs

Reservoirs or storage tanks are installed in a distribution system to allow it to handle peak flows. It reduces the needed peak capacity of the treatment plant. Reservoirs also are installed to provide adequate water for fire protection and to provide chlorine contact time.

Fill and Draw Reservoirs

In villages where the water supply freezes in the winter, reservoirs are filled in the late fall and the water used throughout the winter. This process is called a fill and draw system.

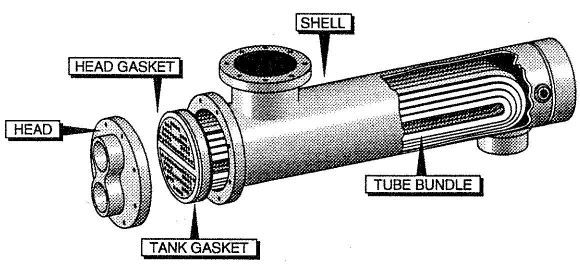


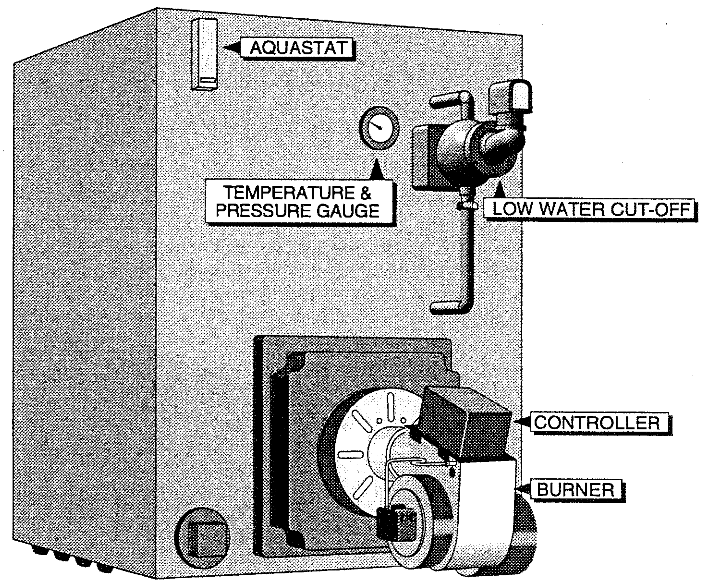
Pumps

Pumps are used in the distribution system to circulate water to prevent it from freezing, maintain pressure in the system and move water from one place to another.

Heat Exchangers

Boilers and heat exchangers are used to heat the water either in the distribution system or in the reservoir to prevent it from freezing. This same system is

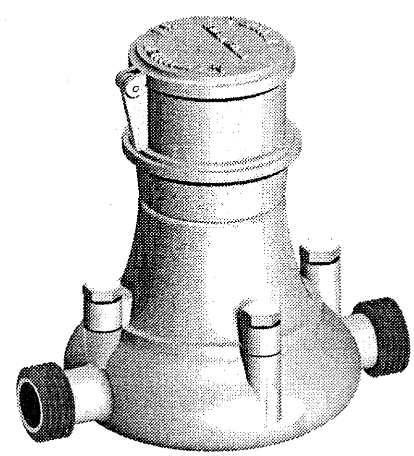




sometimes used to heat the water prior to other treatment processes in order to improve the efficiency of treatment.

Meters

Meters are installed in individual homes in order to determine use and allow the purveyor to equitably bill for the water used.



WATER SYSTEM ORGANIZATION

Components

A water system is composed of more than the physical facilities. Other major components of the system include the customers, the federal and state regulatory agencies, the governing body, the utility manager and field operations. Each of these groups has a unique and important role in providing safe water.

Customers

The customer is the end user of the product and is responsible for paying for the service provided and using the water in a wise manner.

Federal and State Agencies

Federal and state agencies are responsible for establishing regulations to assure that water provided by public water systems is safe to drink. A more detailed explanation of the various agencies involved in Alaskan drinking water systems is provided at the end of this section.

Governing Body

The governing body may be a city council or traditional council. The council sets policy and rates and is responsible for overseeing the entire water utility. The governing body as a group and sometimes as individuals is responsible and liable for the quality of the service the fair treatment of customers, employees and vendors, including contractors and for the financial solvency and physical well being of the water utility.

Manager

The utility manager is responsible for the day-to-day operation, preventive maintenance and emergency repairs. In small cities, the city manager, strong mayor or city administrator may fill the utility manager role.

Field Operations

Field operation workers maintain and operate the system. They are directly accountable to the utility manager.

Because this course is primarily focused on operation and maintenance of small water systems additional information on the responsibilities of management and the field staff are provided below.

MANAGEMENT

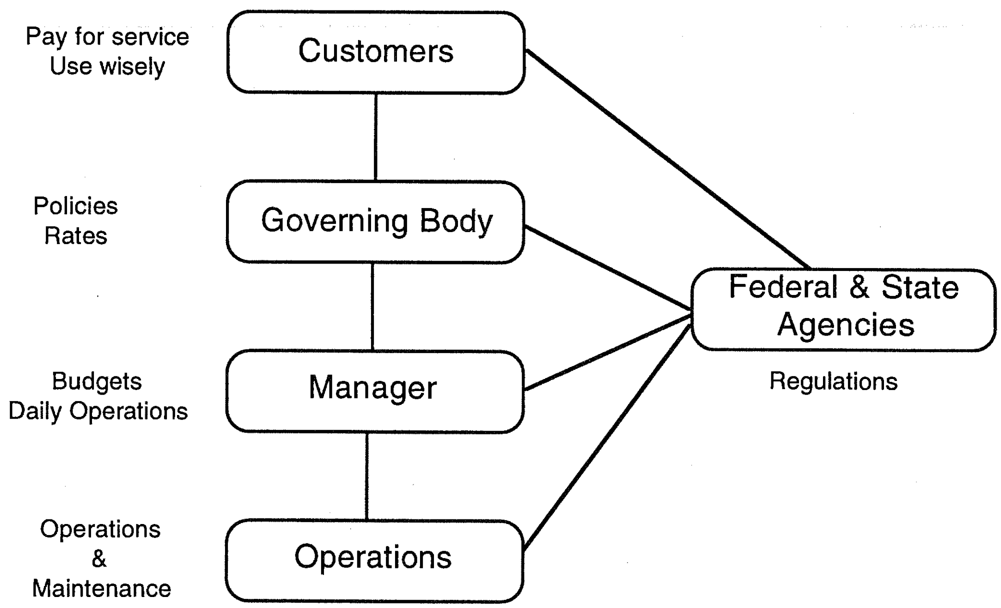
Who is Management

The identification of who or what level of the organization is management is a local decision and will not be addressed here. However, regardless of who is defined as management there are several management functions that must be performed in a properly operated water system. It makes no difference who performs these duties as long as they get done.

Management Task

Management is responsible for:

1. Establishing and printing rules for customers.
2. Setting proper, equitable rates for the use of water.
3. Developing plans so that future needs can be met.
4. Establishing long term (5 to 10 year) budgeting requirements.
5. Integrity of the financial situation, including budgeting, collecting utility bills and paying encumbered bills.
6. Establishing and supporting a worker safety program.
7. Seeing that operators are properly trained.
8. Establishing proper record keeping systems for water quality data, billing, budgets and operation data.



9. Communicating with state, customers and operators the needs of the system and the conditions of the system.
10. Developing and implementing a public relations/customer service program.

OPERATION AND MAINTENANCE

Overview

The operator of the water system is a major link in the protection of the health of the village. This is one of the most important responsibilities in the village. Without a properly trained operator a valuable water system can be damaged beyond repair in just a few days of cold weather.

Operator Tasks

A good operator must wear the hat of the mechanic, microbiologist, chemist, construction worker, janitor, public relations expert, data management expert and a host of others.

A good operator must:

1. Be properly trained
2. Establish an operating budget
3. Inspect equipment
4. Keep proper repair parts on hand
5. Collect adequate samples
6. Perform routine testing
7. Repair broken equipment
8. Prevent equipment breakdowns by performing preventive maintenance
9. Keep water temperature correct
10. Add proper chemicals in proper amounts
11. Prevent contamination of water sources
12. Prevent deterioration of the water system
13. Keep management aware of system problems
14. Communicate with state, customers and management

Maintenance Management

A good way for the operator to plan and perform all of these task is to develop a planned maintenance management system. This system includes a preventive maintenance system, data collection process, work order system and monthly reports to management. This process is useful in verifying budget requests and managing personnel requirements.

MONITORING WATER QUALITY

Health

In order assure the health of the customers that drink the water, each system is required by EPA and the State of Alaska to monitor the quality of the water on a routine schedule. The following two tables provide a brief overview of these monitoring requirements. For more details see tables B & D, pages 18 & 19 in the Alaska Drinking Water Regulations and pages 277 through 312 of the Introduction to Small Water Systems manual.

Intervals for Routine Sampling and Analysis for Class A Public Water Systems

Altered to reflect only those requirements for systems of less than 500 customers.

Inorganic Chemicals

(Arsenic, Barium, cadmium, chromium, fluoride, mercury, and selenium only)

Surface Water	Yearly
Groundwater	Every 3 Years

Nitrate

Surface Water	Quarterly
Groundwater	Yearly

Organic Chemicals

Pesticides

(Endrin, Lindane, Methoxychlor, Toxaphene, 2,4-D and 2,4,5-TP only)

Surface Water	Every 3 Years
Groundwater	Department's discretion

Volatile Organic Chemicals

See tables G, H, I, J and K or the Drinking Water Regulations

Total Trihalomethanes

Surface Water	Quarterly
Groundwater	Yearly

Radioactivity

(Gross Alpha and Combined Radium 226 and 228)

Surface Water	Every 4 years
Groundwater	Every 4 Years

Other Parameters

Disinfectant Residual	Daily
Fluoride	Daily
Turbidity	Daily
Coliform Bacteria	Monthly

Intervals for Routine Sampling and Analysis for Class B Public Water Systems

Altered to reflect only those requirements for systems of less than 500 customers.

Parameter	**Maximum Interval for Routine Sampling and Analysis**
Coliform Bacteria	
Groundwater	Quarterly
Surface Water	Monthly
Nitrate	Yearly
Disinfectant Residual	Daily
Fluoride	Daily
Turbidity	
Surface Water	Daily
Groundwater under the influence of surface water	Daily

AGENCIES ASSOCIATED WITH DRINKING WATER

Introduction

Drinking water like many other vital resources has a wide variety of organizations and agencies involved in its protection and proper use. In Alaska some of these agencies and organizations are:

ADEC

Alaska Department of Environmental Conservation - they are responsible for:

Drinking Water Program - ADEC's Drinking Water Program regulates the quality of drinking water provided by public water systems. They provide the following services: computer data base, State and Federal drinking water regulations, treatment technique information, regulation training and seminars.

Operations Assistance Program - This program provides the following services: certifies water and wastewater operators, provides or contracts to provide operator and utility management training, operations technical assistance, publishes newsletter, training calendar and resource directory, offers training material through the operator lending library and manages the Remote Maintenance Worker (RMW) Program.

Village Safe Water (VSW) - VSW engineers and maintenance specialists design and construct rural water, wastewater and solid waste facilities that have been funded through the legislature. VSW services are limited to second class or unincorporated communities or first class cities with populations less than 600. VSW works closely with the Public Health Service (PHS).

Municipal Grants - Administers the State's fifty percent grant and state loan programs for the design and construction of water, wastewater and solid waste facilities for first class cities.

PHS

The U.S. Public Health Service, Indian Health Service, is also know as the Alaska Area Native Health Service (AANHS). PHS has been given the responsibility by the Congress, under provisions of the Public Law 86-122, for the construction of sanitation facilities to serve American Indians and Alaskan Natives. These facilities are constructed in Alaska for those qualifying native Alaskan villages. They also provide operator training and technical assistance through their Planning and Training Branch.

Regional Health Corporations

The Regional Health Corporations are non-profit Native corporations which provide a wide-range of environmental and public health care services to Alaskan Natives. Villages within their boundaries are provided these services including, but not limited to, operator training and technical assistance. The Health Corporations employ sanitarians, engineers and Remote Maintenance Workers.

RMW's

Remote Maintenance Workers are employed by the Regional Health Corporations through a State grant. The RMW's provide on-site technical assistance and training to water and wastewater operators in particular rural communities that are within the boundaries of the Health Corporations. The RMW's provide help and assistance on all aspects of operation, maintenance, sampling and monitoring.

EPA

The Environmental Protection Agency develops and enforces national drinking water regulations that must be adopted by the State, if the State wishes to maintain primacy. EPA also develops policies, provides technical assistance and training on all aspects of drinking water regulations. They provide a toll-free Drinking Water Hotline.

DCRA

Department of Community and Regional Affairs provides assistance to local governments. The Municipal and Regional Assistance Division works with municipalities, village councils, non-profit corporations and unincorporated communities throughout Alaska. They can provide assistance in administration, site control, land management, planning and financial management and other training related to utility management.

DNR

Department of Natural Resources is responsible for water rights in Alaska.

AWMA

Alaska Water Management Association is the Alaska Chapter of the Water Environment Federation. AWMA operates jointly with the Alaska Section of the American Water Works Association (AKAWWA). A professional organization composed of operators, managers, engineers, state health personnel, consultants and equipment manufacturers. They provide an annual convention and training conference, regional training seminars, a quarterly newsletter, and bimonthly regional luncheon seminars in the southcentral region.

AWWA

American Water Works Association is a national professional organization composed of water operators, managers, engineers, state health personnel, consultants, and equipment manufacturers. They provide a variety of services including the exchange of information and ideas that help design, operate, manage and maintain water systems. They are located in Denver, Colorado.

INTRODUCTION TO DRINKING WATER WORKSHEET

1. Water is called the _____________ solvent.

2. What is the primary function of a water system?

3. What are the two sources of water?

   a. ________________________

   b. ________________________

4. Based on water source, what type of water systems are most common in Alaska?

5. In Alaska, the majority of the people (population number) receive their drinking water from what type of system? (Based on source)

6. What is the word used to identify water that is safe to drink?

7. What is the average water consumption in gallons per day per capita in the United States?

8. The peak day consumption in a water system is normally ______ to _____ times the average day.

9. Water cycles from the atmosphere to the earth and back to the atmosphere. What is this natural water cycle called?

10. As a part of the normal water cycle water is lost, or given up, to the atmosphere by trees and by evaporation from the surface of streams, lakes, and oceans. This combined loss is called ________________________.

11. The strata that is used to obtain ground water is called an ___________.

12. A ______________ disease, is a disease caused by a microorganism that is carried from one person or animal to another by water.

13. The three most common water treatment processes used in Alaska are used to remove or reduce, ____________, ______________ and _________________.

14. Name the three major components of a water system.

a. ________________________

b. ________________________

c. ________________________

15. Chlorine was first used in the United States as a disinfectant in the early ___________.

16. In Alaska a water system that is designed for more than 25 full-time residents for at least 6 months of the year is called a:

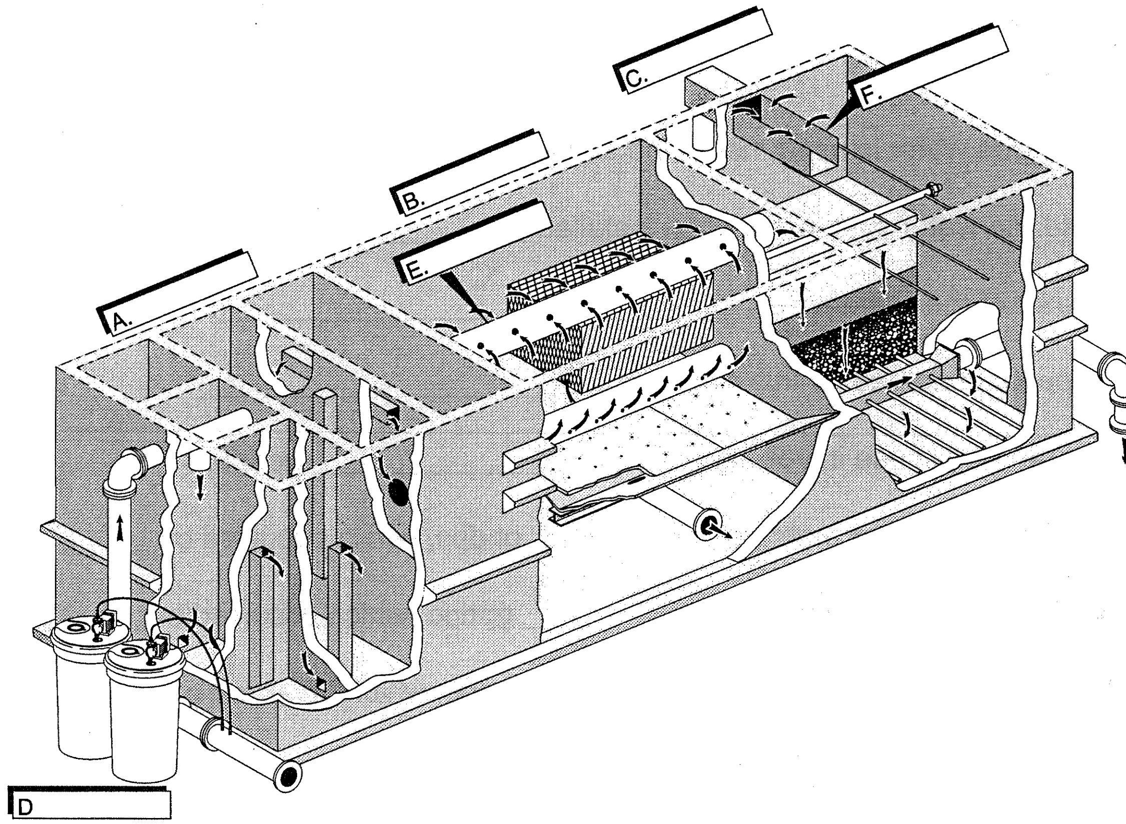
17. In Alaska a water system that is designed for 25 consumers that drink the water more than 60 days but are not full-time residents (not more than 6 months) is called a:

18. Describe briefly the major responsibilities of the management of a water system.

19. In a public water system, which person has the most important role in protecting public health?

20. The Alaskan agency responsible for managing the state's drinking water program is __________.

21. On the drawing below, identify the four major process units that make up a conventional water treatment plant.



STUDENT ACTIVITIES

1. Classify your system by source:
   - ❑ Groundwater
   - ❑ Surface water
   - ❑ Both

2. If surface water is used, name the sources ____________________.

3. Date the water system was first installed ______________.

4. Owner of the system ___________________________.

5. Population served by this system ___________________.

6. Average daily use in your system _______________ gpdpc.

7. Maximum day last month __________ gpdpc, which occurred on __________.

8. Minimum day last month ___________ gpdpc, which occurred on __________.

9. Maximum day last year ___________ gpdpc, which occurred on __________.

10. Minimum day last year ___________ gpdpc, which occurred on __________.

11. Classification of system - by federal regulations.

    - ❑ Community water system
    - ❑ Non-community water system
    - ❑ Non-transient, non-community water system

12. Classification in Alaska
    - ❑ Class A system
    - ❑ Class B system
    - ❑ Class C system

13. Classification by complexity of delivery (You may be more than one type)
    - ❑ Haul
    - ❑ Watering point
    - ❑ Fill and draw
    - ❑ Piped
    - ❑ Circulating
    - ❑ Utilidor

14. Major components in your system
    - ❑ Well
    - ❑ Surface water pump
    - ❑ Dam
    - ❑ Conventional treatment
    - ❑ Cartridge filters
    - ❑ Pressure filters
    - ❑ Chlorination
    - ❑ Fluoridation
    - ❑ Iron removal
    - ❑ Other - Describe

15. Mark those items that are presently being taken care of by management.

    - ❑ Establishing and printing rules for customers.
    - ❑ Proper, equitable rates for the use of water.
    - ❑ Plans so that future needs can be met.
    - ❑ Long term (5 to 10 year) budgeting requirements.
    - ❑ Finances, including budgeting, collecting utility bills and paying encumbered bills.
    - ❑ Worker safety program.
    - ❑ To see that operators are properly trained.
    - ❑ Proper record keeping system for water quality data, billing, budgets and operation data.
    - ❑ Communicate with state, customers and operators the needs of the system and the conditions of the system.
    - ❑ Developing and implementing a public relations / customer service program.

16. Mark those items that are presently being taken care of by operations.

- ❑ Properly trained
- ❑ Operating budget
- ❑ Inspect equipment
- ❑ Keep proper repair parts on hand
- ❑ Collect adequate samples
- ❑ Perform routine testing
- ❑ Repair broken equipment
- ❑ Prevent equipment breakdowns by performing preventive maintenance
- ❑ Keep water temperature correct
- ❑ Add proper chemicals in proper amounts
- ❑ Prevent contamination of water sources
- ❑ Prevent deterioration of water system
- ❑ Keep management aware of system problems
- ❑ Communicate with state, customers and management