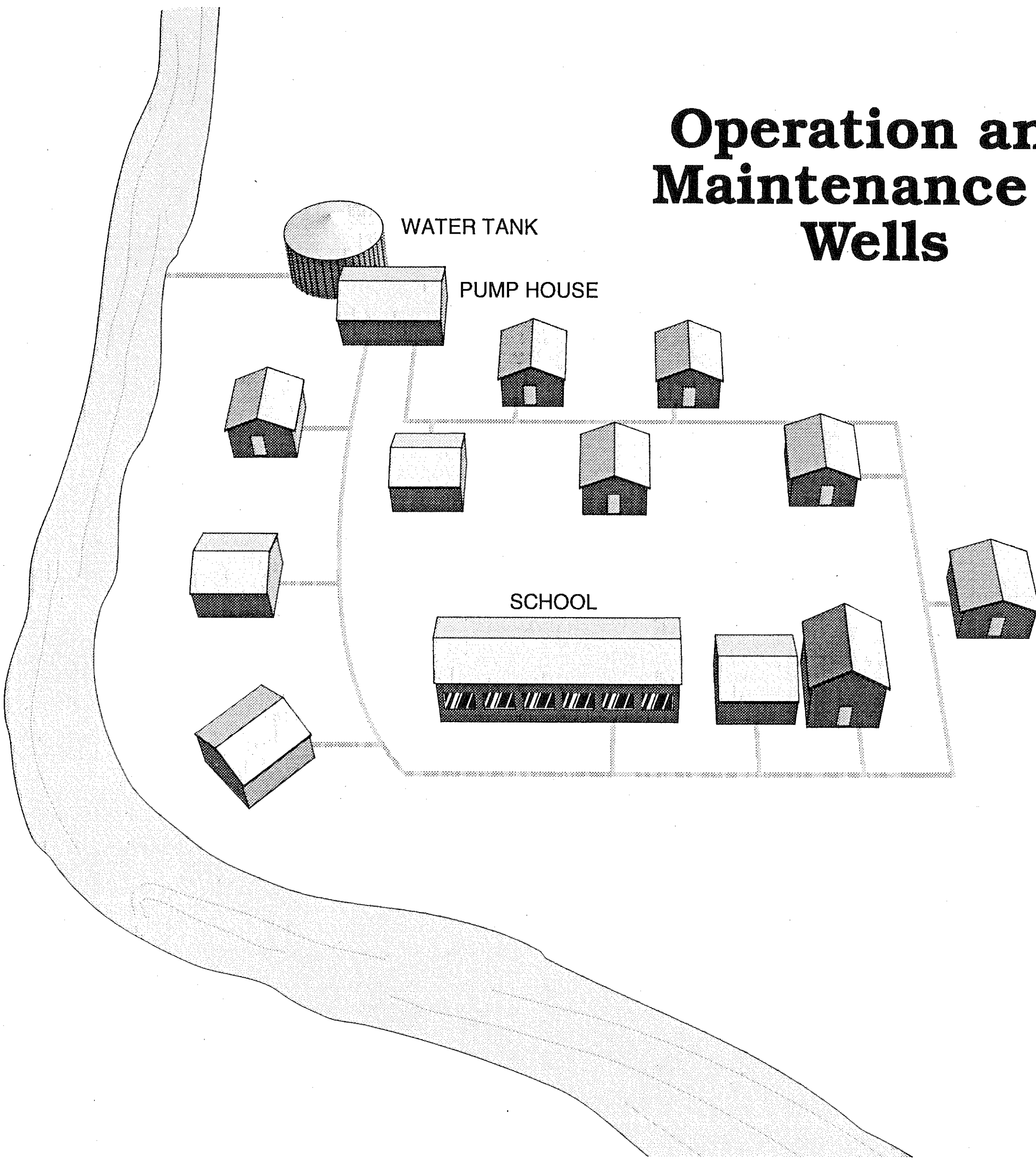
O & M of Small Water Systems



Operation and Maintenance of Wells

Alaska Department of Environmental Conservation
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O & M of Small Water Systems

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1298 Elm Street SW
Albany, Oregon
(503) 928-5211

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KEY WORDS

- Aquifer
- Confined aquifer
- Drawdown
- Igneous rock
- Metamorphic rock
- Porosity
- Riser
- Sedimentary rock
- Specific retention
- Static Water Level
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- Contactor
- Flow meter
- Sanitary seal
- Check valve

O & M OF WELLS

Introduction

The content of this module is dedicated to information needed by an operator at a certification level 1. This module is focused on the use of wells as a means of obtaining ground water or ground water under the direct influence of surface water (GUDISW). The content of the module will include small systems utilizing **submersible turbine**[1] pumps. **Lineshaft turbine**[2] installations will be discussed as a secondary role of the module. The discussion will provide some theory and background information, but the O & M of well systems is the primary concern. The hydrologic cycle (found in the OIT level material), the intake structures for springs, (found in the surface water module), pumps and related equipment (found in the module on pumping) and, hydropneumatic tanks that are commonly associated with small pumping installations (found in the reservoir module).

Use in Alaska

Wells are a major source of potable water in most of Alaska except in the southeast where their use is not as prevalent.

HYDRAULICS AND HYDROLOGY

GEOLOGY

Why?

While an understanding of geology is not a requirement of most operators, it is necessary to understand the information found in a well log. How the well driller logs the data about the different strata that are passed through is dependent upon their training. A example of a well log is found on page 5 and may be useful in following the discussion below.

Methods Used

There are various correct methods used. Our brief discussion here will provide information using one of the most common methods.

Simple Method

There are two types of strata that are found in the earths crust, consolidated and unconsolidated. The well driller may simply note that they are drilling in rock, clay, sand, gravel silt or boulders which are either consolidated or unconsolidated. Unconsolidated materials will normally provide the greatest sources of water.

Strata Component Size

One of the problems with reading information on the basic log identification is determining the difference

1 **Submersible Turbine Pumps** - A style of vertical turbine pump in which the entire pump assembly and motor are submersed below the water. The motor is commonly mounted below the pump.

2 **Lineshaft Turbine Pumps** - A type of vertical turbine. With this type of vertical turbine, the motor is mounted above the ground and the pump unit is mounted below the water surface. A column extends from the pump to a discharge head that is mounted above the ground just below the motor. A shaft extends on a straight line from the center of the motor to the pump. The pump may be mounted a few feet away from the motor or several hundred feet away.

between gravel, silt, sand and boulders. The table below gives typical size ranges for these common terms.

Boulders - 5 to 160 inches in diameter (128 - 4096 mm)

Coarse gravel 1.3 - 5 inches (32 - 128 mm)

Medium gravel 0.3 - 1.3 inches (8 - 32 mm)

Fine gravel 0.08 - 0.3 inches ((2 - 8 mm)

Coarse sand - 0.5 - 2 mm

Medium sand - 0.25 - 0.5 mm

Fine sand - 0.031 - 0.25 mm

Clay - 0.00024 - 0.031 mm

Rock Types

Some well drillers will become a little more sophisticated and identify the various rocks, (consolidated and unconsolidated) by geological rock types such as igneous, metamorphic and sedimentary.

Igneous Rock

Igneous rocks[3] are those rocks that are formed by heat. Igneous rocks include granite, rhyolite, basalt, syenite, diorlite and gabbro. Igneous rock formations provide very little water production and are commonly found is consolidated stratas.

Sedimentary Rocks

Sedimentary rocks[4] are those that were formed by flow and sedimentation. The flow could be water, air or land movement, such as a land slide or the movement of a glacier. Sedimentary rocks are typically shale, sandstone, limestone and dolomite. Sedimentary rocks can also be small fragments of igneous and **metamorphic rocks**[5]. Sedimentary rocks can be found as both consolidated and unconsolidated strata. In unconsolidated stratas the sedimentary rock is usually identified as clay, sand, silt, gravel or boulders. The best and largest of carriers of water are those stratas consisting primarily of unconsolidated sedimentary material.

Metamorphic Rock

The third category of rock is metamorphic rock. Metamorphic rock is made when another rock, igneous, sedimentary or metamorphic, is heated and placed under a great deal of pressure. This causes the rock to change - metamorphosis. Typical metamorphic rocks include slate, quartzite, marble and schist. Metamorphic rock stratas are commonly consolidated and provide very little water.

[3] **Igneous rocks** - Rocks which have solidified from a molten magma, and form one of the three main types of rocks which comprise the earth's crust.

[4] **Sedimentary rock** - Rocks which have been deposited as beds, often as sediments, forming one of the three main types of rocks which make up the earth's crust.

[5] **Metamorphic rock** - Rocks which were originally igneous or sedimentary rocks, but have been changed in character and appearance; they form one of the three main types of rocks which comprise the earth's crust.

Example

Looking at the well log below we can obtain the following information.

- The bore hole was 6 inches in diameter and 80 feet deep.
- The system used to describe the various strata uses material size and texture.
- 75 feet of 6 inch casing was used.
- Four feet of #30 screen was placed in the well. It is assumed that this is at the bottom of the well, but there is not specific information to confirm this.
- The well was not grouted.
- Was was first found at 46 feet. After construction the static level was at 35.5 feet.
- The water contained 2 mg/L (ppm) of iron.

Well Log
U.S. Public Health Service, Division of Indian Health

Location: New Stuyahok — Date Started: 8-26-75

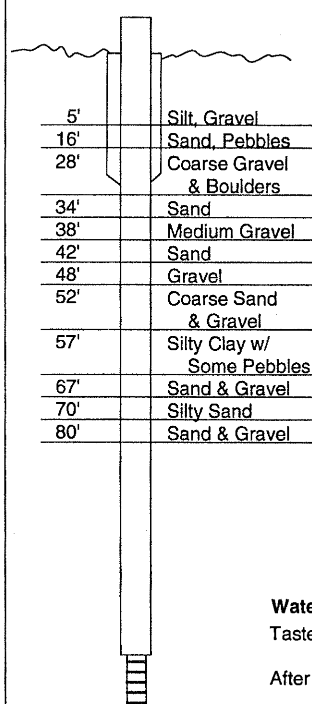
Date Completed: 9-20-75 — Crew: Estabrook - Elston

Total Depth of Well: 80 Ft. — Casing Installed: 75 — Diameter: 6"

Grout: ____ — Screen size: #30 — Mfg.: ____ — Length: 4'

Static Water Level: 35.5' — Hrs. Pumped: 24 @ 25 gpm — Drawdown: 6 ft.

Development Procedures: Surged hole for 9 hrs.



Date	Depth From - to	Formation
	0'-5'	Silt - Gravel
	5'-16'	Sand - Pebbles
	16'-28'	Coarse Gravel & Boulders
	28'-34'	Sand
	34'-38'	Medium Gravel
	38'-42'	Sand
	42'-48'	Gravel
	48'-52'	Coarse Sand & Gravel
	52'-57'	Silty Clay w/Some Pebbles
	57'-67'	Sand & Gravel
	67'-70'	Silty Sand
	70'-80'	Sand & Gravel

Water Data Field Test

Taste: Good — Appearance: Fresh ____

After 24 hours: ____ — Iron: 2 ppm — Chlorides: ____

TDS: ____ — Alkalinity: ____ — pH: ____

Special Notes:

Pick up water at 46 feet

TYPES OF AQUIFERS

Two types

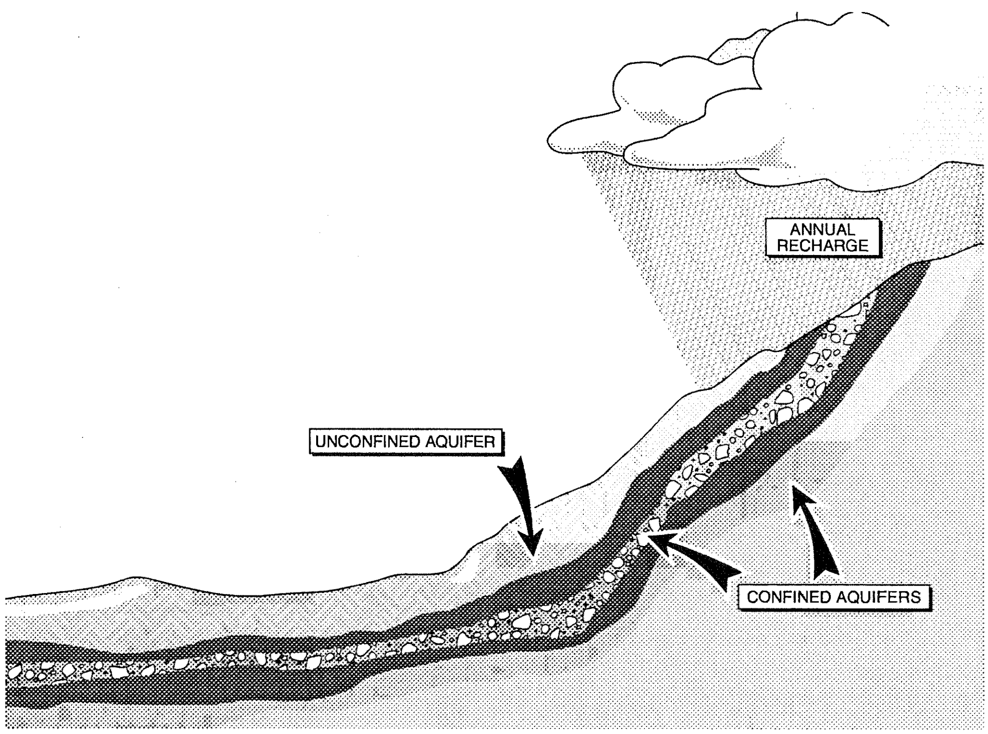
There are two types of **aquifers**[6], confined and unconfined. Remember an aquifer is a water bearing strata, commonly composed of unconsolidated sedimentary material.

Confined Aquifers

Confined aquifers[7] are also called **artesian aquifers**[8]. The aquifer is confined between two impervious layers of clay, rock or permafrost. The recharge for an **unconfined aquifer**[9] is typically in mountain ranges where they are exposed to rain and snow. The confined aquifers are the most desirable for use as community water supplies. These aquifers are least likely to become contaminated. However, once they are contaminated they make take decades to recover.

Unconfined Aquifer

An unconfined aquifer is also called a water table aquifer. The unconfined aquifer is commonly composed of a unconsolidated strata setting on top of a impervious (consolidated) material. The recharge for this type of aquifer is from rain and snow in the area adjacent to the well. This is the least desirable aquifer for a community water supply. The unconfined aquifer can be easily contaminated by a local spill of fuel oil or septic tanks in the vicinity.



[6] **Aquifer** - A porous, water-bearing geologic formation.
[7] **Confined Aquifer** - An aquifer which is surround by formations of less permeable or impermeable material.
[8] **Artesian Aquifer** - An aquifer that is under pressure. Water will rise in a well to a level above the saturated strata when the well is drilled in an artesian aquifer.
[9] **Unconfined aquifer** - An aquifer that is setting on an impervious layer but is open on the top to local infiltration. The recharge for a unconfined aquifer is local. Also called a water table aquifer.

GUDISW

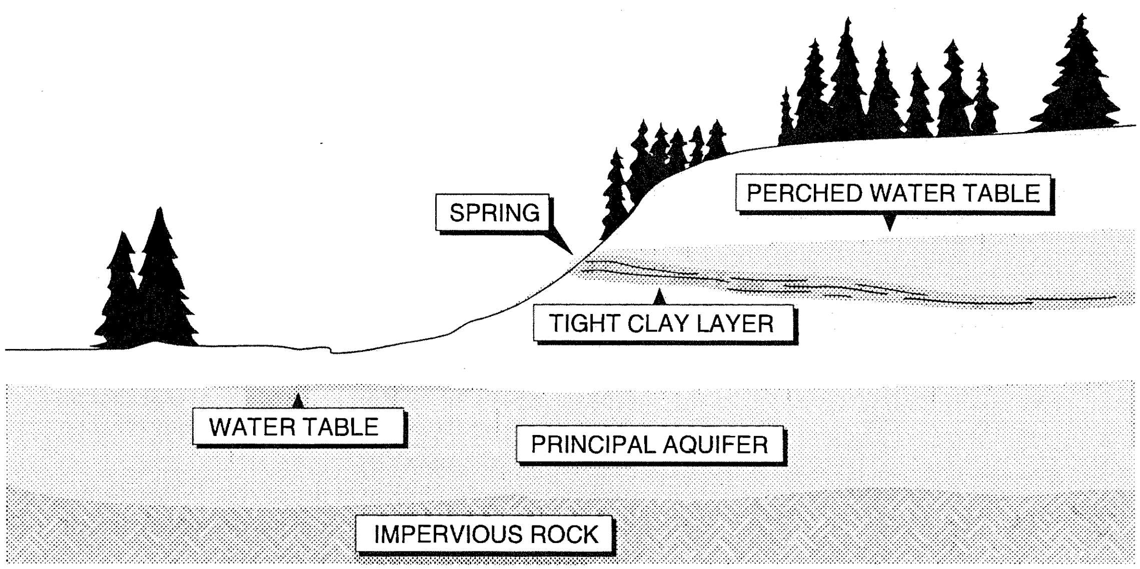
Water taken from a well in an unconfined aquifer has a better chance of being classified as groundwater under the direct influence of surface water (GUDISW) and therefore requires treatment under the surface water treatment rules (SWTR).

SPRINGS
From Confined Aquifer

There are two types of springs. One is caused from a geological shift in the earth's crust. This type commonly yields water from a confined aquifer and can produce large volumes of high quality water. The Bear Creek Springs in Medford, Oregon produces 17MGD. This type of spring will often meet the requirements to be classified as a groundwater supply.

Perched Water Table

In many parts of the country, one can observe a small hill set on the side of a larger hill or mountain. Between the two hills is a water bearing strata called a **perched water table**[10] (this water table is perched on the side of the mountain). At the toe of the down hill side of this small hill will often be a flow of water referred to as a spring. This type of aquifer yields low to medium flows of water whose quality and quantity are affected by local hydrological events an by events on or above the perched water table.



[10] **Perched water table** - A small water table set on the side of a hill or mountain that is covered by soil.

WATER MOVEMENT THROUGH AN AQUIFER

Composition of an Aquifer

An aquifer is made up of a combination of solid material such as rock and gravel and open spaces called pores. Regardless of the type of aquifer the water in the aquifer is in motion. This motion is caused by gravity or by pumping. The flow of water through the aquifer is influenced by the size, connectivity and number of pores.

Definitions

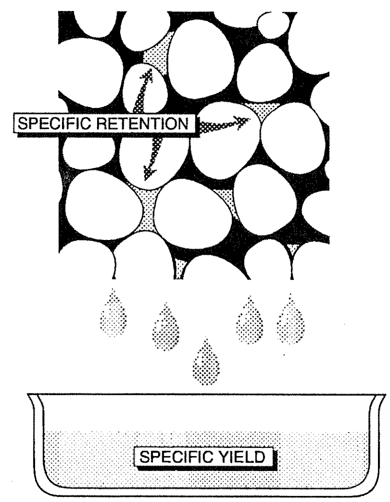
A special set of terms is used to describe and relate one aquifer to another and to relate possible water flow rates.

Porosity

Although all aquifers have pores between the solid material the volume of these pores varies depending upon the type of materials and their size range. The percentage relationship between the quantity of pore space to total space is called **porosity**[11]. For instance if a one cubic foot section of an aquifer were extracted, examined and found to contain 10% pores, the porosity would be 10%. Porosity ranges from 5 to 20% are normal for good aquifers.

Specific Yield

Not all of the water in a saturated strata will drain from the strata. Some water is attached to the rocks and grains and some is held in the strata due to capillary action in the pores. The amount of water that would drain from one cubic foot section of the aquifer is called **specific yield**[12]. The amount that stays behind is called **specific retention**[13]. These two numbers are used by hydrologist to evaluate aquifers. What is important here is that, while there may be water in an aquifer, we may not be able to retrieve it.



Permeability

The ability for water to pass through a aquifer is called **permeability**[14] and is determined by a number of factors including the quantity of pores, size of the pores

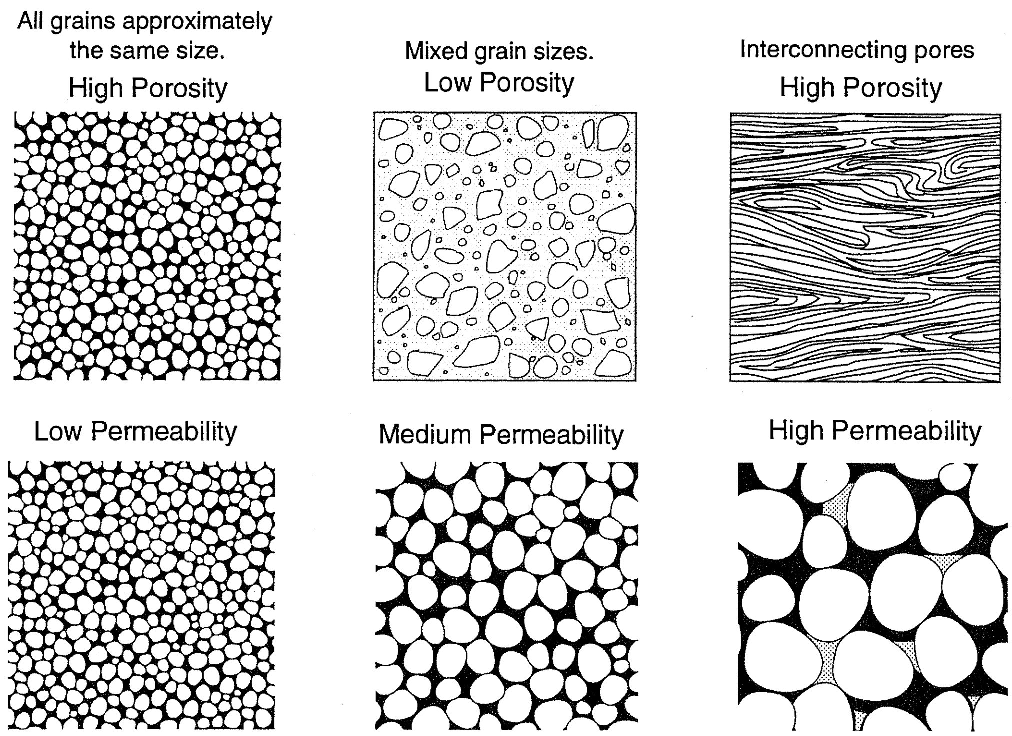
[11] **Porosity** - The ratio of pore space to total volume. That portion of a cubic foot of soil that is air space and therefore could contain moisture.

[12] **Specific Yield** - The quantity of water that a unit volume of permeable rock or soil, after being saturated, will yield when drained by gravity. It may be expressed as a ratio or as a percentage by volume.

[13] **Specific Retention** - The quantity of water retained against the pull of gravity by rock or earth after being saturated and allowed to drain completely.

[14] **Permeability** - The property of a material that permits appreciable movement of water through it when it is saturated and the movement is actuated by hydrostatic pressure of the magnitude normally encountered in natural subsurface water.

and the connectivity. It is possible to have an aquifer with high porosity but a low permeability. Such is the case with clay. It will hold a great deal of water but it is nearly impossible to pass water though clay. In general clay has a high porosity and low permeability, sands and gravels have high permeability. The best water production, quantity and quality, are from unconsolidated stratas that have a medium permeability and are composed of sands and gravels. In the example below the porosity of all three examples are the same but the permeabilities are different.



Transmissibility

The rate at which water will pass through an aquifer is called **transmissibility**[15]. This rate is influenced by permeability and the amount of head on the aquifer.

[15] **Transmissibility** - The rate that water travels toward a well. Commonly indicated as the coefficient of transmissibility and given in gpd/ft.

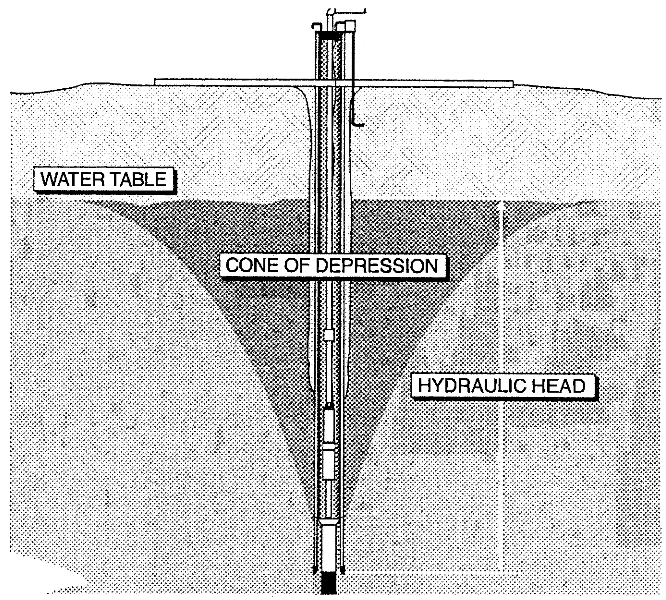
WATER MOVEMENT THEORY

Transmissibility

As was defined above the rate of movement of water through an aquifer is called transmissibility. Transmissibility is based on the hydraulic head on the aquifer, the permeability of the aquifer and on the specific yield.

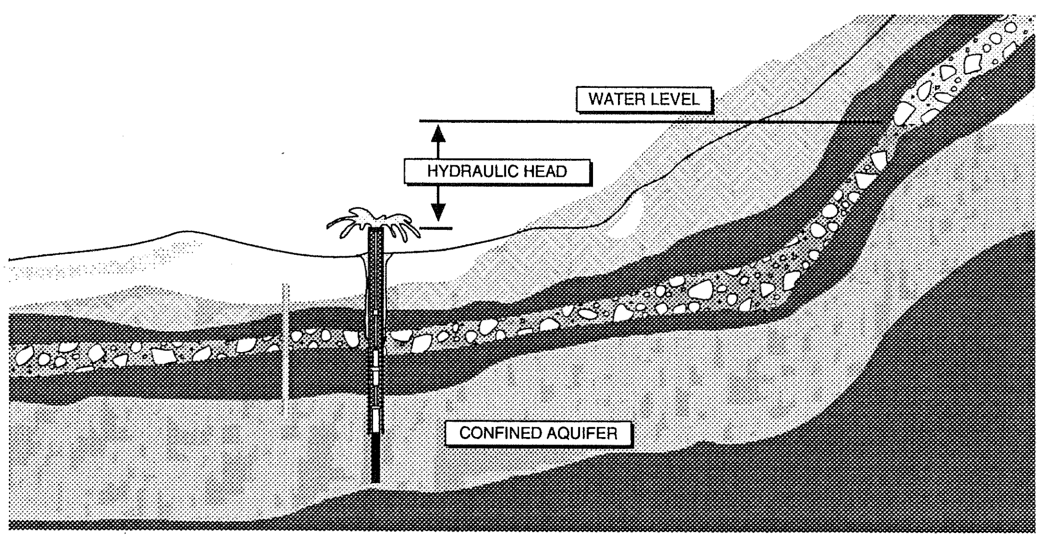
Water Table Aquifers

The hydraulic head on a water table aquifer is based on the height of the water table and the depth of the well. The deeper the well, in relationship to the height of the water table, the higher the head. This head is what pushes the water toward the well.



Confined Aquifers

In a confined aquifer the hydraulic head is based on how high the top of the saturated portion of the aquifer extends above the well.



Rate of Speed

The speed that water passes through an aquifer is commonly measured in inches per day. However, with sand and gravel aquifers it could be as high as feet per day.

Determining Transmissibility

Transmissibility rates are given in gallons per day per foot of aquifer and called the Coefficient of Transmissibility. This number is one of the key values used in comparing aquifers. The number cannot be determined by measuring or observing the aquifer. It must be determined from actual test well data.

Quantity of Water

Data collected from the tests that are needed to determine coefficient of transmissibility can also be used to determine the amount of water available in an aquifer. This calculation gives a value that is called the coefficient of storage.

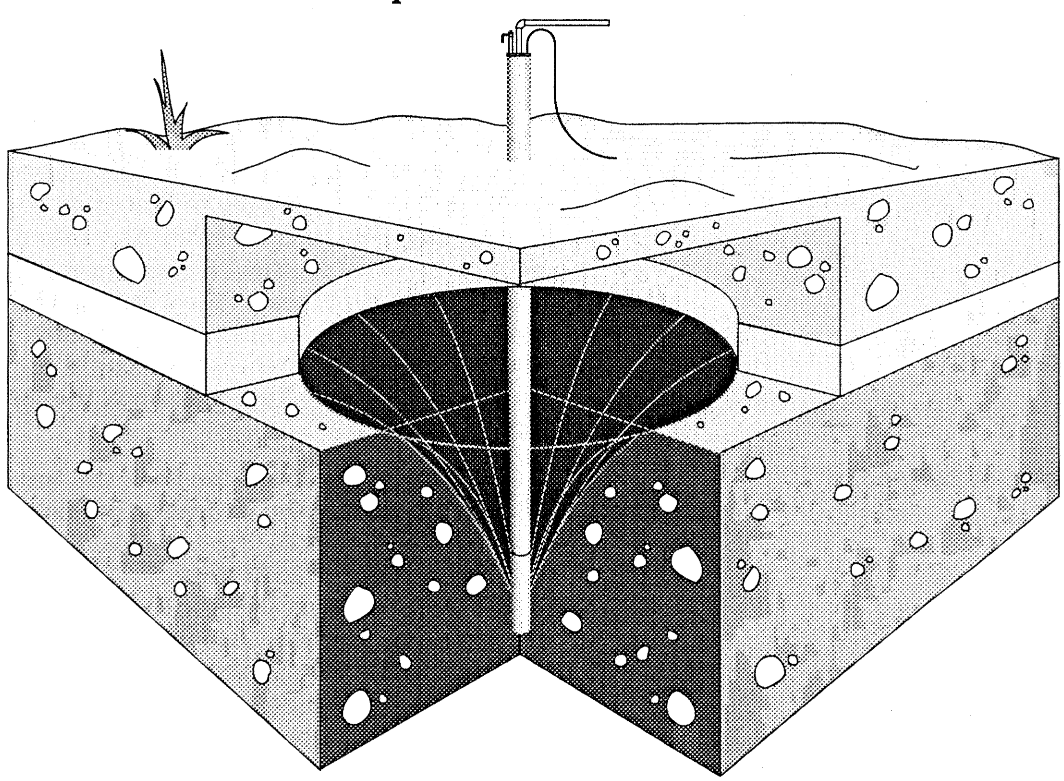
WATER MOVEMENT WITH A WELL

Natural Movement

In a confined aquifer the water naturally moves from the point of recharge downward to a river, stream or ocean where it evaporates returns to the atmosphere and continues its movement through the hydrologic cycle.

Pumping Process

As water is pumped from a well in a confined aquifer the water level in the well drops, this causes a difference in head between the water level in the well and the theoretical head of the aquifer. This head pushes water toward the well. The result is the **cone of depression**[16].



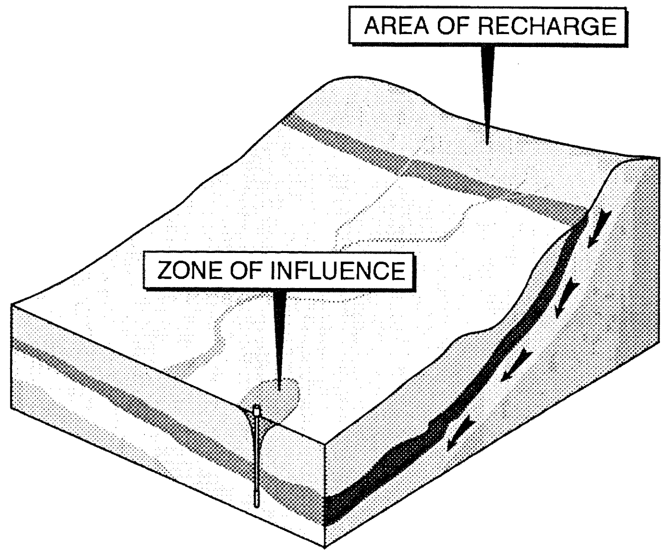
[16] **Cone of Depression** - The depression, roughly conical in shape, produced in a water table or other piezometer surface by the extraction of water from a well at a given rate.

Slope of Cone

The shape of the cone of depression depends on the coefficient of transmissibility. A high transmissibility will give a gentle slope to the cone and low transmissibility gives a cone with a steep slope.

Shape of Cone

Most text books show the cone of depression as a circular area, when viewed from the top. However, we know form the studies that have been done that the shape is dependent upon the transmissibility all around the well. The cone may in fact may be quite irregular in shape. The most common shape is oblong sloping upward to the **recharge area**[17].



Withdrawal

As water is withdrawn from the well the head will increase, increasing the flow toward the well. The rate of continuous withdrawal from a well is dependent upon the transmissibility and storage capabilities of the aquifer. The most desirable situation is for the design engineer to select a well pump of a size that allows the drop in water level in the well to stop before the pump breaks suction. Theoretically, it is possible to size a pump so that the well could pump continuously with out any further drop is the level of water in the well casing.

Zone of Influence

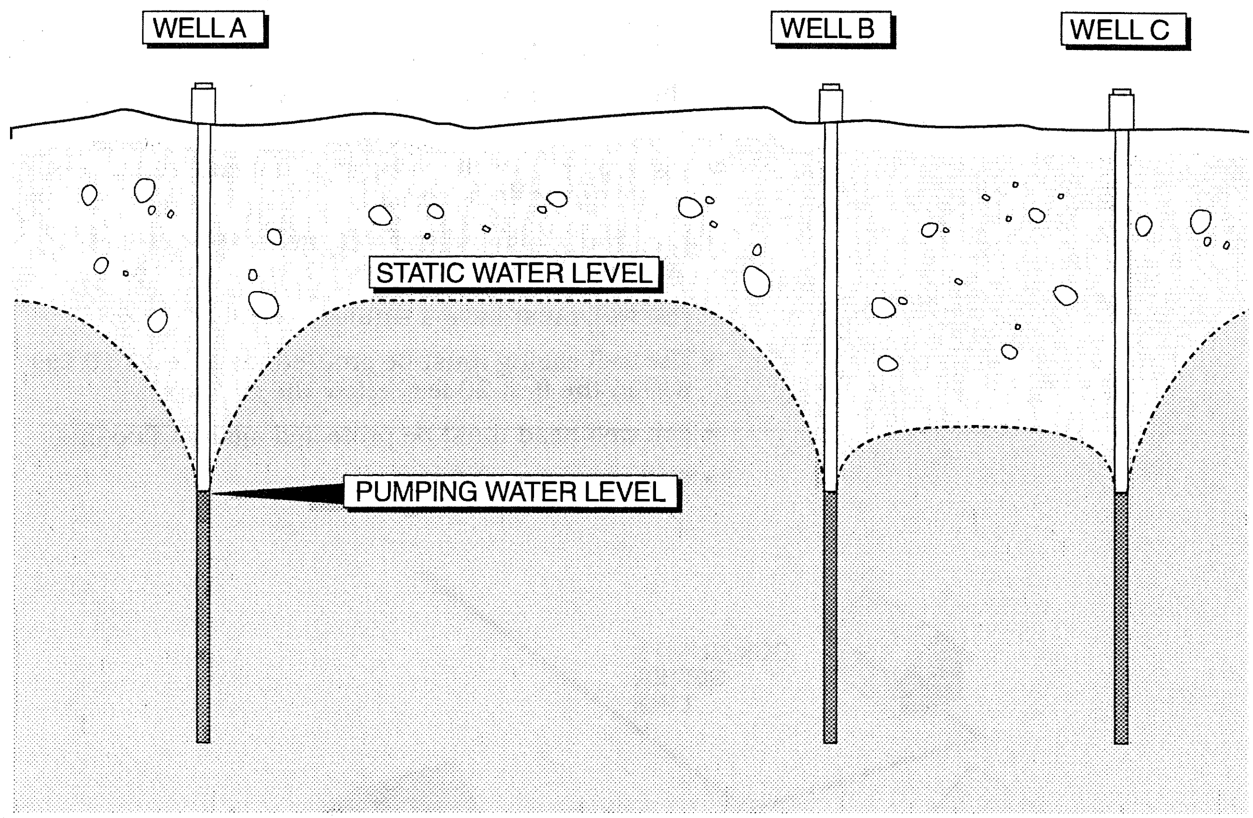
As water is drawn from the well, the water level in the well will drop and the hydraulic pressure inside the cone will be reduced. The area inside the cone is called the **zone of influence**[18]. Wells within the zone of influence of other wells will affect one another's production. For instance, two wells with overlapping zones of influence may be able to produce 100 gpm independently but only produce 60 gpm each when they are both in operation.

[17] **Recharge Area** - An area from which precipitation flow into the underground water sources.

[18] **Zone of influence** - The area inside and adjacent to the cone of depression.

EXAMPLE

Well "A" and "B" in the drawing below are properly spaced. The will both produce the desired quantity of water. However, well "C" is too close to well "B" and as a result the total production will be reduced anytime well "B" and "C" are both operating.



Potential Contamination

Sources of contamination or potential contamination within the zone of influence can be drawn into the aquifer. This can also happen with a confined aquifer. Contamination that is above the water table can be drawn into the confined aquifer through natural fissures in the confining layer between the two aquifers.

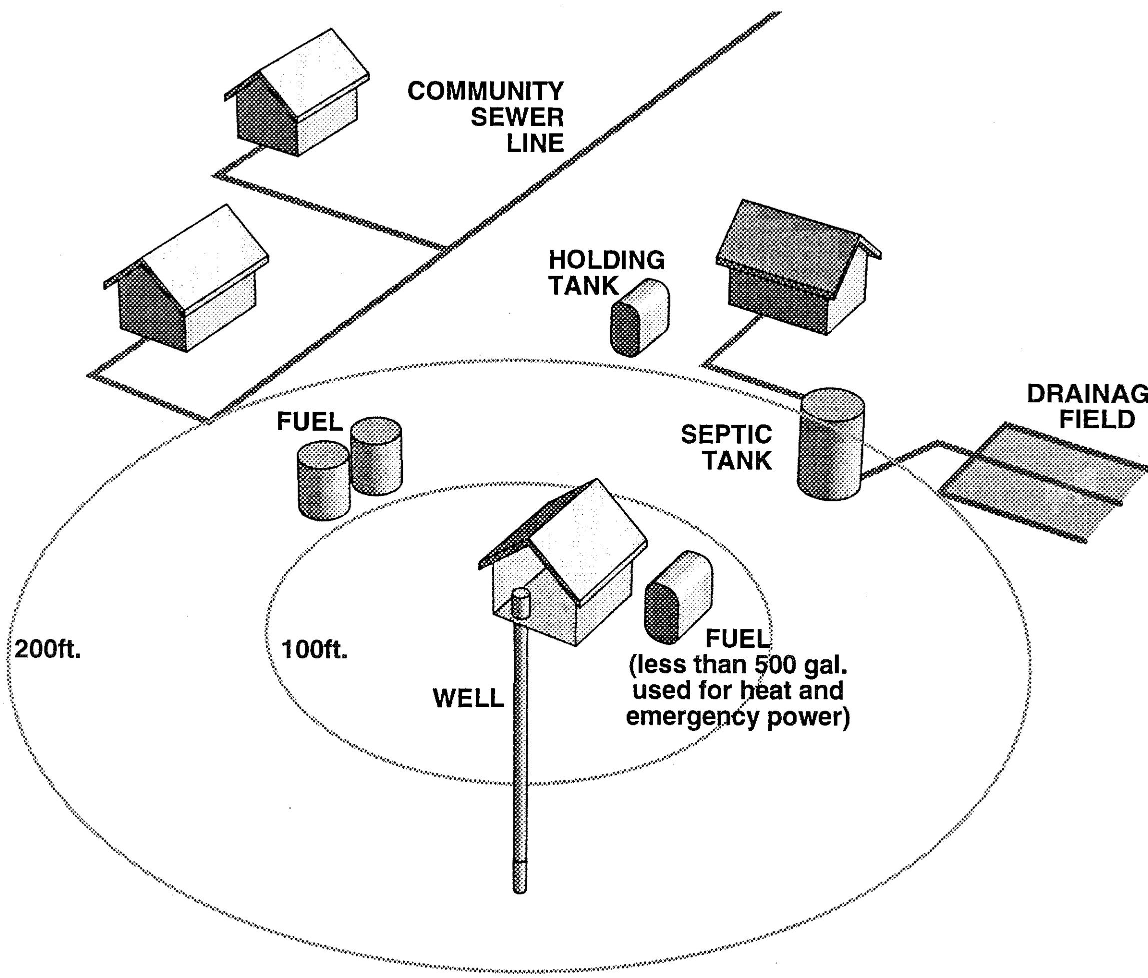
Regulations & Standards

In order to protect the groundwater source and provide high quality safe water, the water works industry has developed standards and specifications for wells. In addition the Alaska Department of Environmental Conservation has established minimum construction criteria for municipal wells. The following listing includes industry standard practices as well as those items included in the DEC regulations.

- There can be no wastewater disposal systems including septic tanks and drain fields within 200 feet of the well for Class A or B systems and 150 feet for Class C systems.
- There should be no community sewer line, holding tanks, or other potential sources of contamination within 200 feet of the well in a Class A or B system

or within 100 feet of the well in a Class C system.

- Fuel not used for on-site emergency pumping equipment or heating can not be stored within 100 feet of the well for a Class A or B system or within 75 feet of the well for a Class C system.
- Fuel for on-site emergency generators or building heating system can be stored on-site if the total volume is less than 500 gallons.
- The well casing must extend one-foot above the ground.
- The top of the well casing must extend 12 inches above the well house slab.
- The ground around the well must be sloped 10 feet away in all directions.
- The well must have a sanitary seal.
- The well casing must be grouted for at least 10 feet within the first 20 feet below the surface.
- The well head must be protected against flooding.
- Well pits are prohibited.



TYPES OF WELLS

Methods

There are various methods used to identify well types. The method used is chosen for the purpose of the individual or organization describing the well. The two most common types of identification are by construction method and by aquifer type.

CONSTRUCTION METHODS

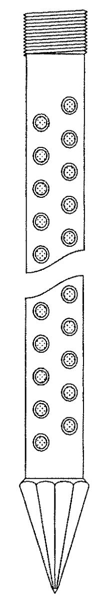
The most common construction methods are:

Dug

Dug wells are those that have been dug by hand. While this might seem unusual, there are some rather large hand dug wells in existence. The City of Spokane, WA uses hand dug wells that are over 200 feet deep. Hand dug wells are normally in water table aquifers and not considered to be desirable for community water supplies.

Driven wells

A second type of well is the driven well, referring to wells that utilize a sand point which is driven into a sand or small gravel water table aquifer. The sand point is a mechanical device made of a heavy sleeve with a hardened point. The sleeve is covered with a bronze or stainless steel screen. Sand point wells in water table aquifers are normally not considered to be desirable for community water supplies.



Bored Wells

A bored well is usually referring to a well that was dug using a post hole auger or other similar device. This well like the others discussed above is commonly placed in a water table aquifer and thus not considered desirable for a community water supply.

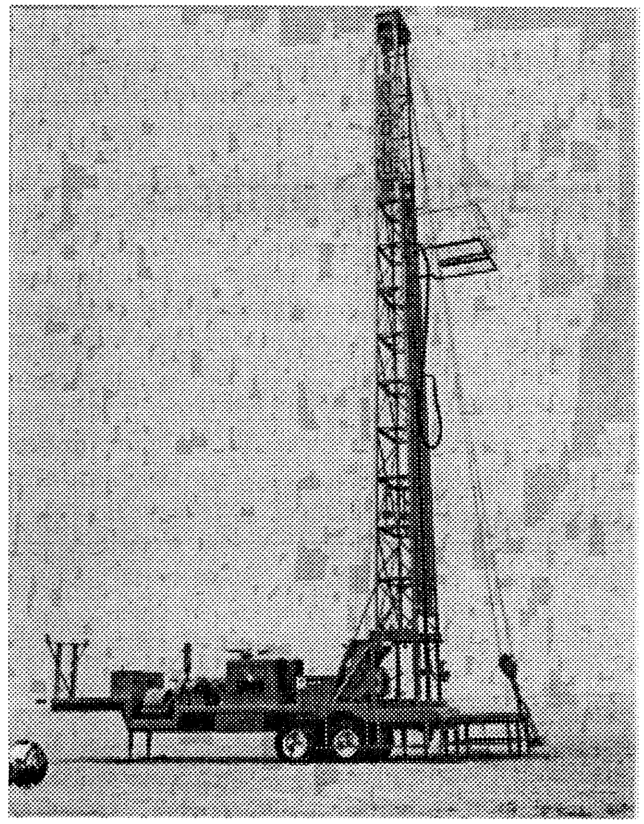
Percussion Drilled

A percussion or cable tool drilling rig uses a heavy drilling tool called a drilling string. This string is attached to a cable. The cable is used to raise and lower the tool allowing the impact of the tool to break up the material. The broken material is removed from the hole by mixing it with water and then using a special bail bucket to bail the material from the hole. The percussion drilling tool can be used to drill wells in water table and confined aquifers and is therefore one of the methods commonly used for the construction of a community well.

Rotary Bit

The rotary bit is a drilling machine similar to those used to drill for oil. A bit is placed at the end of a string of pipe. The pipe is rotated causing the bit to dig a hole in the ground. Material is removed from the hole by pumping drilling "mud" in and out of the hole.

The rotary bit, like the percussion tool can be used to construct wells in water table and confined aquifers.



CLASSIFICATION BY AQUIFERS

The most desirable method of classifying wells is by the type of aquifer they are placed in. There are two types of aquifers, unconfined and confined.

Unconfined Aquifers

Unconfined aquifers are also called water table aquifers and wells placed in them are called shallow wells. As described above this is the least desirable aquifer for a community well because of the high potential of local contamination.

Confined Aquifers

A well in a confined aquifer can also be called a artesian well or a deep well. There are two types of artesian wells, flowing and nonflowing. An artesian well is any well where the water level in the well casing raises above the saturated strata that the water comes from. When an artesian well is pumped the cone of depression causes a drop in either the water level in the casing or a drop in the pressure inside the casing. With a flowing artesian well, there would be a drop is pressure rather than a drop in water level.

WELL COMPONENTS

A well has components that are found in nearly all wells and components that are specific to the type of well construction and pumping unit used. In this section we will first discuss those components that are found in nearly all wells, and then the specifics of the more common pumping types, submersible pumps, pitless adapter wells and lineshaft turbine pumps.

COMMON COMPONENTS

Bore Hole

The hole in the ground produced by the drilling rig is called the bore hole. It is desirable that the hole be round, straight and plumb. A lineshaft turbine will not be able to be used if the hole is not plumb.

Casing

Each state has its own regulations concerning the type and length of the casing as well as how far the casing must extend above the ground. In Alaska, the casing on wells for public water systems must be made of steel must extend downward and into the bedrock or other confining layer above the aquifer at least three feet. If this is not possible, some other approved method of protection of the aquifer must be used. The casing must extend above the concrete at least one foot above the ground. In some states, such as Oregon the casing must extend two feet above the ground or above the 100 year flood plane which ever is greater. Where the casing exits the ground is called the well head.

Grout

The amount, type and depth of the **grout**[19] varies from state to state. In Alaska wells for public water systems must be grouted where the casing enters the confining layer. The casing must have continuous grouting of at least 10 feet within the first 20 feet below the ground surface.

Concrete Pad

In most states a concrete pad is required at the well head. In Alaska a six inch pad must be placed around the well head, extended at least 10 feet in all directions and sloped away from the well head .

Water Level

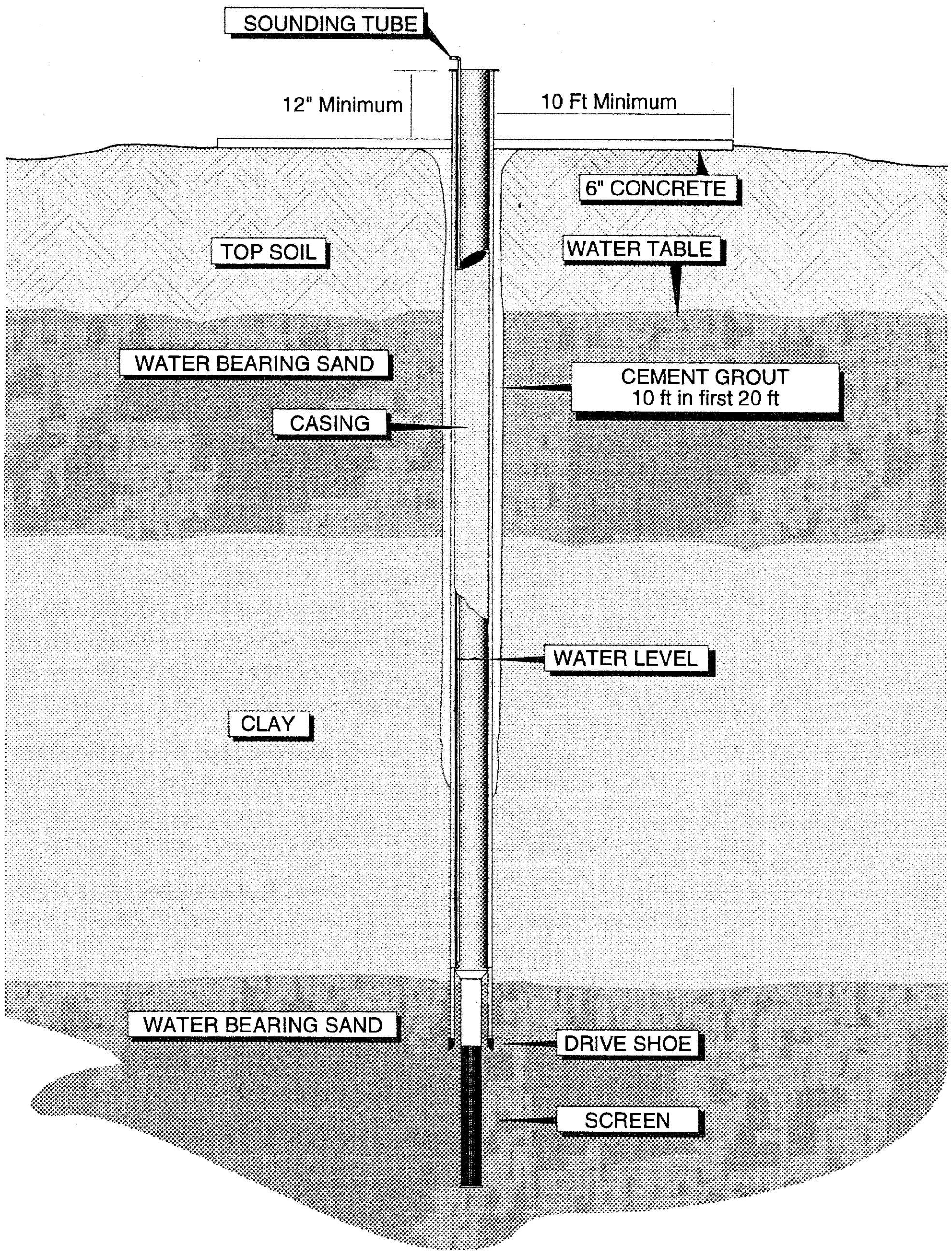
While not a requirement in most states, it is desirable from an operational stand point to have some means of determining the water level in the well. The most common techniques are;

- a sonic device that sends and receives a sound wave from the water surface in much the same way as a radar system works,
- electric tap, which is lowered into the well and the

[19] **Grout** - A fluid mixture of cement and water, sometimes including additives such as sand, bentonite and hydrated lime, which can be forced through a pipe, as in forming a seal in the annular space between a well casing and the bore hole.

distance traced by the a meter on the electric line real. When the end of the tap reaches the water a signal is received and the distance read,

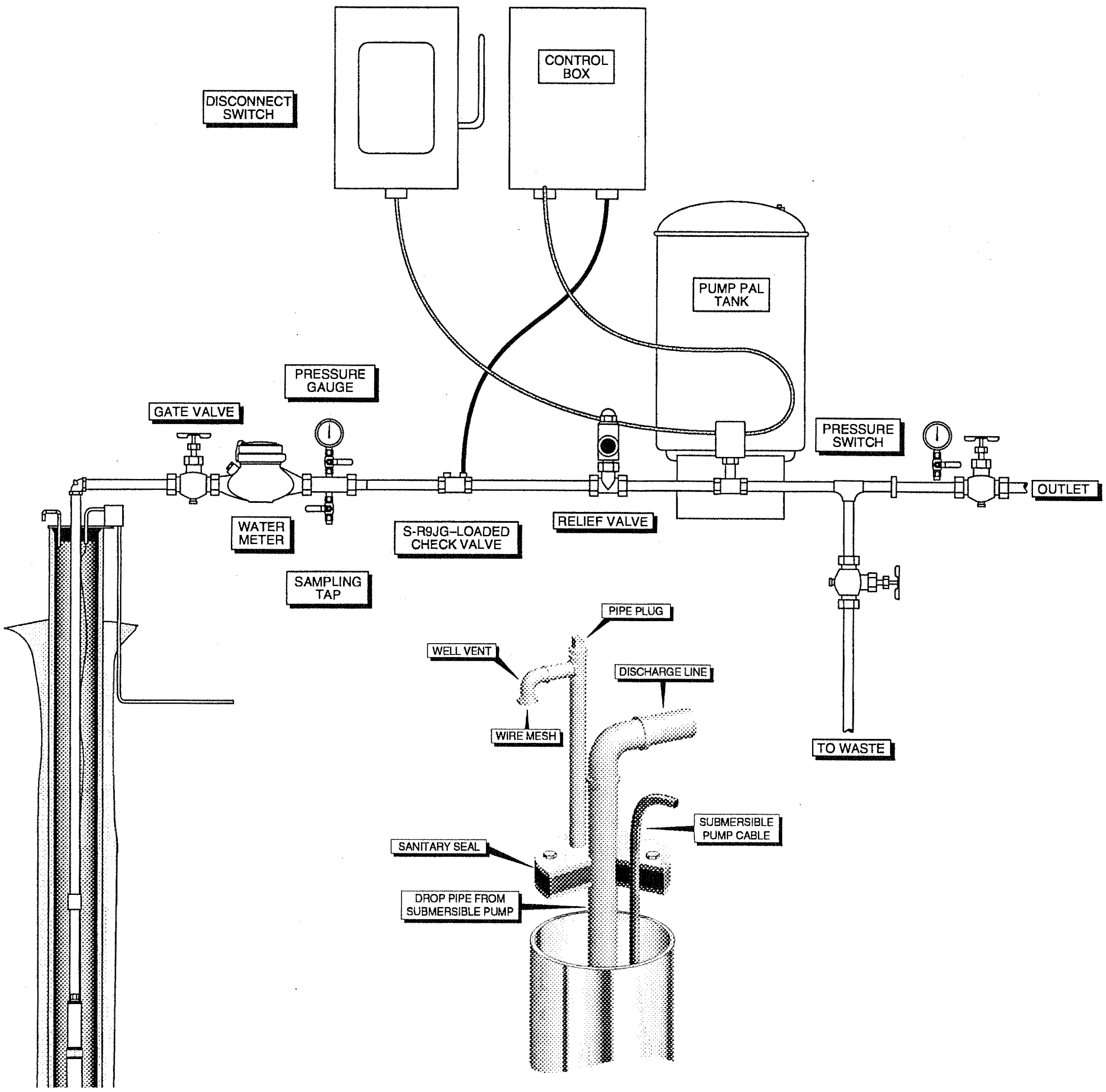
- bubbler tube, which is the oldest and one of the more reliable methods. With this method a plastic, copper or stainless steel tube is placed at the bottom of well along with the pump. Air is pumped down the tube and the pressure measured on a gauge. The pressure reading can be converted into the height of the water in of the well. Special gauges can be purchased that allow the distance to the water to be read directly.



SUBMERSIBLE PUMP INSTALLATION

Most Common

In small public water systems the submersible pump is the most popular well pumping system. The pump and motor must be installed at least five feet from the bottom of the well.



Riser

The line leading from the pump is called the **riser**[20]. This line is commonly steel but in some cases can be plastic. When it is made of plastic, special line straighteners must be installed to hold the pipe and special straighteners installed to prevent the pump from rotating during start-up. When the riser is plastic, a cable must be installed between the pump and the well head to allow removal of the pump assembly for repairs.

[20] **Riser** - The pipe between a submersible lineshaft turbine and the well head.

Check Valves

Most small submersible pumps have a check valve built into the top of the pump. This check valve prevents water from running back down the riser and through the pump, causing it to turn the opposite direction. Reversing the rotation of some brands of submersible pumps can cause damage to the unit.

Over 100 feet

When a submersible pump is installed in depths exceeding 100 feet a second check valve is placed at the top of the first joint in the riser. When the pump is placed at a depth exceeding 500 feet, a third check valve is placed two thirds (2/3) of the way up the riser.

Freezing Condition

In some freezing conditions water is allowed to flow all or part way down the casing. With no water in the upper portion of the casing, freezing possibility is reduced.

Heat Tape

It is common practice in arctic installations to include a heat tape on the upper portion of the riser. This is kept energized during the winter to prevent freezing of the water in the upper portion of the riser.

Sanitary Seal

To prevent the entrance of contaminants into the well a **sanitary seal**[21] is placed at the top of the well head. The most common sanitary seal used on a submersible pump installation uses two pieces of steel with a plate made of a rubber like material between them. Tightening the bolts on the seal causes the two pieces of steel to squeeze the rubber material to form a seal around the electrical conduit, discharge piping and against the well casing. The sanitary seal must be water and airtight.

Casing Vent

When water is pumped down in a well, the pressure in the casing is reduced. If there is no vent on the casing, this negative pressure could cause contaminants to be "pulled" into the well, collapse the casing or prevent the pump from performing properly. The casing vent should extend above the casing approximately one foot have a double 90° ell on the end and the end be covered with a #24 stainless steel screen.

Air Vent

Depending on the installation, water may be allowed to fall all or part way back down the riser. When this happens a vacuum is created inside the riser and discharge piping. This could cause damage to the piping or leaks at one or more fittings. Under these conditions an air vent is placed on the discharge piping. This vent allows air to be brought into the riser at pump shutdown. When the pump is restarted, the same vent is used to allow air to be discharged from the line. This reduces water hammer at the discharge check valve and air intrusion into the line.

[21] **Sanitary seal** - A watertight seal on top of the well casing or between a lineshaft turbine and the well casing, that prevents water or other liquid from entering the well under normal or flooding conditions.

Air Intrusion Problems

If air is allowed to enter into the distribution line it will cause numerous customer complaints. The complaints will take the form of "milky" water and air exiting the tap with such force as to blow a glass out of the customers hand.

Vent Valve

The valve commonly associated with an air vent on a pumping installation contains a stainless steel float. When air enters the float chamber the float drops and allows the air to exit. When the pressure in the system drops and there is no water to hold the float up, the valve is opened allowing air into the system.

Not on Hydropneumatic Tanks

An air vent valve is normally not installed when a submersible pump is installed in conjunction with a hydropneumatic tank. A discussion of the piping system associated with hydropneumatic tanks can be found in the module of reservoirs.

Discharge Pressure Gauge

Regardless of pump type it is an operational requirement to have a gauge on the discharge of the pump. Reading, recording and analyzing the data from this gauge, along with other operational data, can help the operator identify pump problems long before there is a pump failure.

Flow Meter

In order to determine how the pump is performing as well as determine the water demand, a flow meter should be installed on each and every well discharge. By reading, recording and analyzing the flow demand data and operator can, with the help of other data, determine pumping and consumption problems long before a failure or crisis has occurred.

Sampling Tap

In order to obtain samples of the raw water, a raw water sampling tap should be installed. This tap must be far enough away from the injection of any chemicals to prevent the chemicals from showing up in the sample.

Pump to Waste

While not a requirement in all states, a pump to waste line and valve make good operational sense. With this line placed after the flow meter, pumping tests can easily be conducted. The line can also be used to exercise the pump under stand-by conditions. It can also be used to pump water from the well when attempting to deal with a contamination problem or allowing the well to be pumped after a long shutdown without placing any accumulated debris into the system.

Isolation Valve

In order to work on the pump, it must be isolated from the system. A gate or butterfly valve is often installed on the discharge line as an isolation valve.

Spool

In order to reduce long term maintenance cost and make maintenance easier, a flange by flange spool is often placed in the discharge line before the isolation valve. The spool is easy to remove and install, reducing down time.

SUBMERSIBLE PUMP WITH PITLESS ADAPTER

Function

The pitless adapter allows water to be pumped from the well below the frost line and at the same time eliminates the need for a well pit.

Description

A pitless adapter is a mechanical device that connects onto the top of the riser, turns the water and piping ninety degrees and allows the riser to exit through the wall of the well casing through a water tight seal.

Types

There are various types of pitless adapters available on the market. The two most common are those that have a fitting welded to the case and those that use a rubber gasket on a threaded fitting. The gasket and the weld prevent contamination from entering the well casing.

Welded Type

The most common pitless adapter used in Alaska is the one that has a fitting welded to the outside of the well casing. The riser is connected to a fitting called the pitless adapter that attaches from the inside of the casing to the discharge fitting. The adapter is prevented from leaking by a wedge that is placed behind it. This wedge is also attached to the adapter and to the lift-out device.

Sanitary Seal

There are several sanitary seals used with pitless adapters. The two most common are the vented well cover and the cover with the center vent. The vent must extend 12 inches above the ground.

Gasket

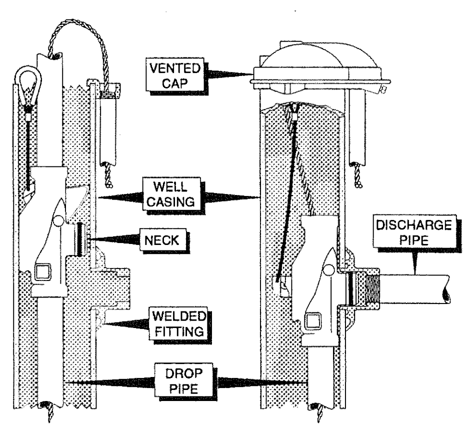
Both sanitary seals described above are sealed to the well casing with a rubber like gasket.

Electrical Connection

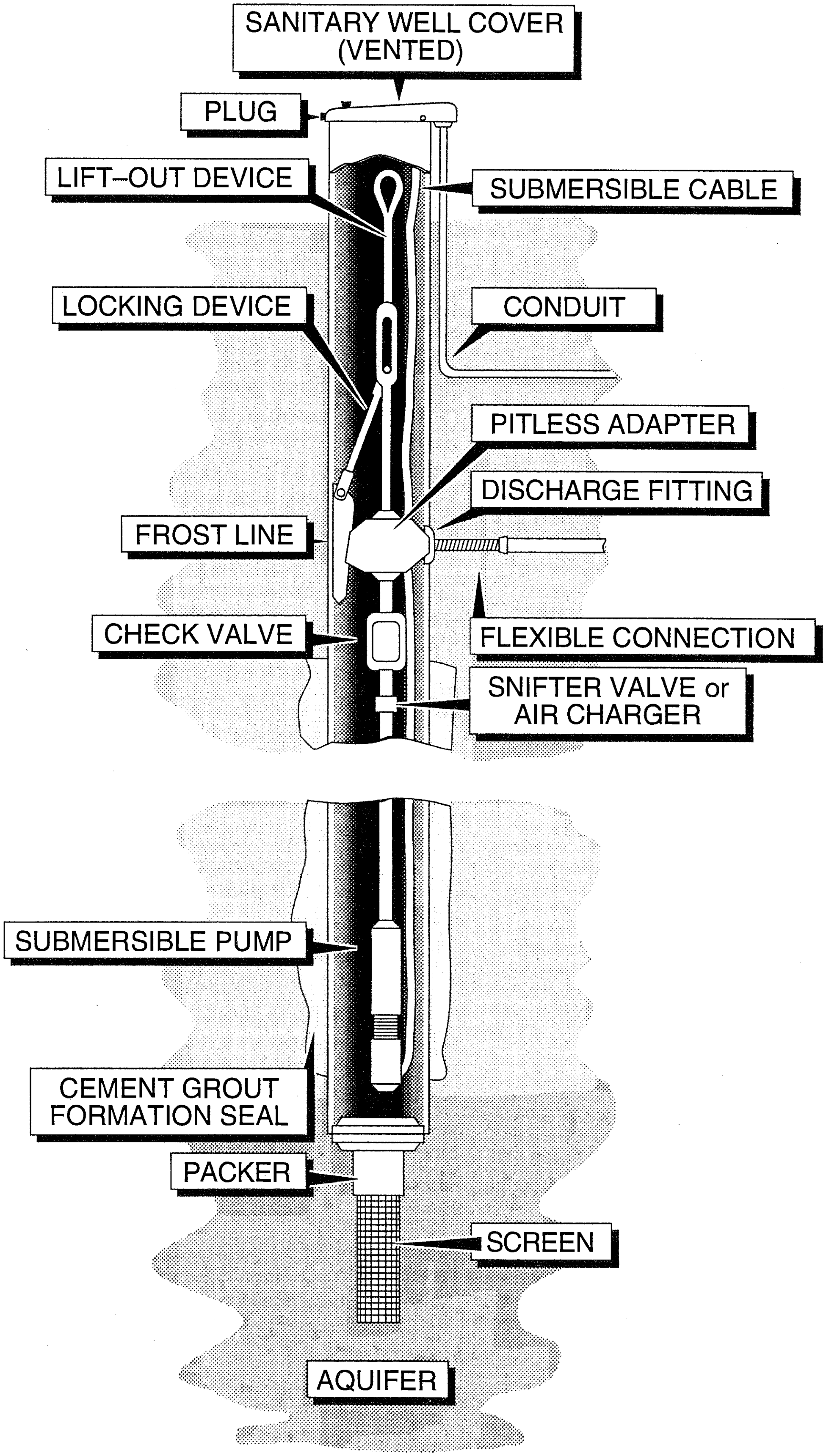
The two covers described above use similar electrical connections. The electrical conduit is either connected to an electrical box on top of the sanitary seal or directly to the sanitary seal. In either case the connection must be water tight.

Grouting

A properly installed "pitless adapter well" has grouting placed below the pitless adapter and extending down at least 10 feet.



Courtesy - Baker Manufacturing Co.


SANITARY WELL COVER (VENTED)
PLUG
LIFT–OUT DEVICE
SUBMERSIBLE CABLE
LOCKING DEVICE
CONDUIT
PITLESS ADAPTER
DISCHARGE FITTING
FROST LINE
CHECK VALVE
FLEXIBLE CONNECTION
SNIFTER VALVE or AIR CHARGER
SUBMERSIBLE PUMP
CEMENT GROUT FORMATION SEAL
PACKER
SCREEN
AQUIFER

LINESHAFT TURBINE INSTALLATIONS

Popularity

While the lineshaft turbine is not very popular in Alaska's small communities, it is very popular in large communities (Anchorage) and is very common in the lower 48 in both large and small communities.

Pump & Column

The pump in a lineshaft turbine installation is placed in the well casing, toward the bottom of the well. Water is pumped from the pump up through pipe called a column.

Shaft

Power is supplied to the pump by the motor, which is setting above ground. This shaft has radial support bearings every 5, 10 or 20 feet depending upon the design. The bearings and shaft may be housed inside of a second column. In this case, the bearings are normally made of bronze and are oil lubricated. When the bearings are exposed to the flow of water, they are said to be water lubricated. The water lubricated bearings are most often made of a rubber like material and are housed in a bronze bracket called a "spider."

Prelube

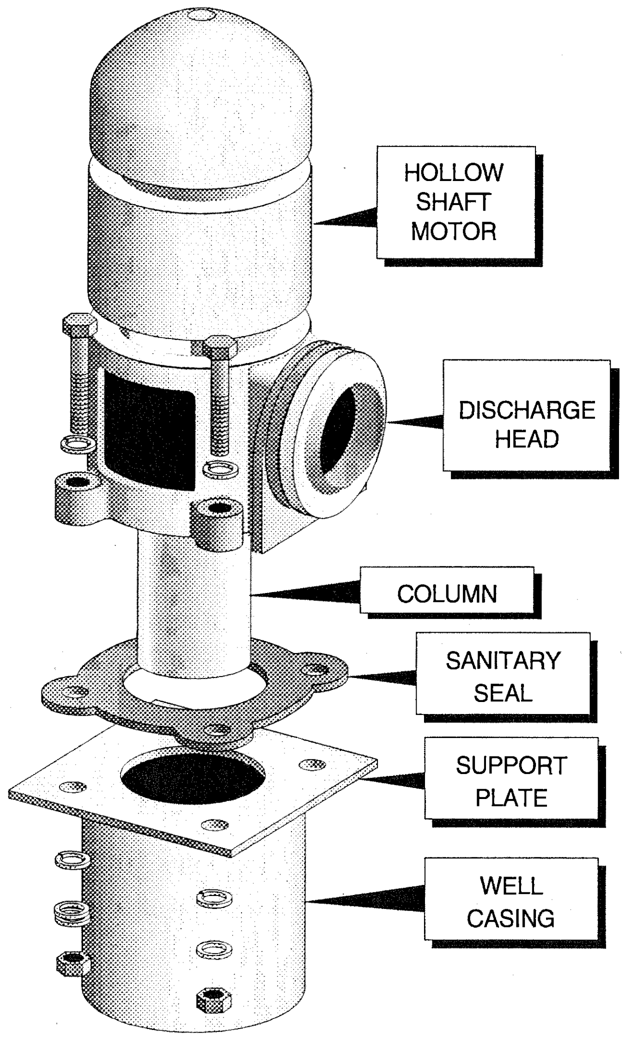
To prevent damage to the bearings when water lubricated bearings are used they must be wet before the shaft turns. The normal method of wetting the bearings is with a water line attached to the back of the discharge head. This water is called the prelube. The line is connected to a water source, sometimes just past the check valve, and controlled with a solenoid valve. When there is a demand for water the prelube line will open for a predetermined time before the pump starts. After the pump starts the valve will close. On very deep wells the prelube may run all of the time that the pump is off.

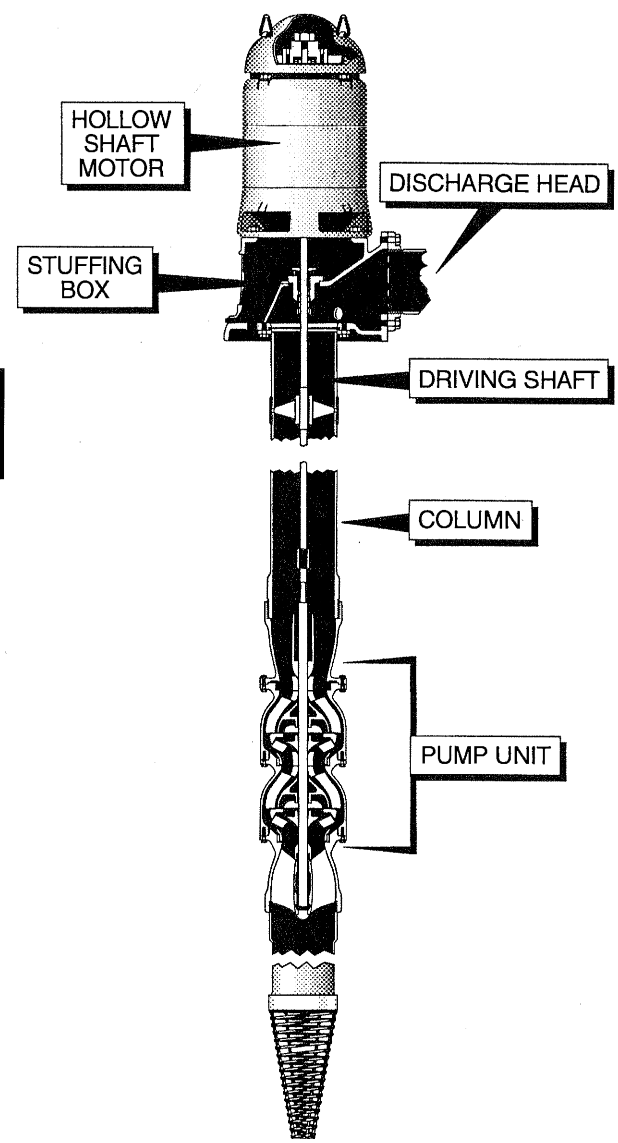
VHS Motor

There are two types of motors used with lineshaft turbines, VHS and VSS. The VHS motor is a vertical hollow shaft motor. With this motor the drive shaft of the pump extends up through the hollow shaft of the motor and connects to the top of the motor. This type of motor is often used with the pump, this utilizes semi-open impellers. The VHS allows for easy adjustment of impeller clearance in the pump bowls and thus allows the operator to adjust for impeller wear. This helps to maintain the proper performance of the pump.

VSS Motor

The second motor type used in lineshaft turbine installations is the VSS or vertical solid shaft motor. This motor is connected to the pump shaft using a traditional coupling and making the connection just below the motor. The VSS motor is primarily used on lineshaft turbines that utilize closed impellers. This type of installation does not require adjustment of the impeller clearance.





Support Plate

The well casing usually extends above the floor, as required by the regulations, and is encased in concrete, forming a concrete pedestal. Secured in the pedestal and welded to the well casing is a steal support plate.

Discharge Head

Fastened to the support plate with bolts is the pump discharge head. The discharge head holds the stuffing box and forms the 90 degree bend needed to get the water from the column into the discharge piping. The motor is mounted on top of the discharge head.

Sanitary Seal

A rubber like gasket is placed between the discharge head and the support plate and forms the sanitary seal for the well.

Well Vent

As with the submersible pump, the well casing must be vented to prevent collapse and "sucking back" of contaminated water from around the well head, or stuffing box. This vent can be through the casing or through the discharge head. The vent should be turned downward and be covered with a #24 mesh stainless steel screen.

Packing Water Discharge

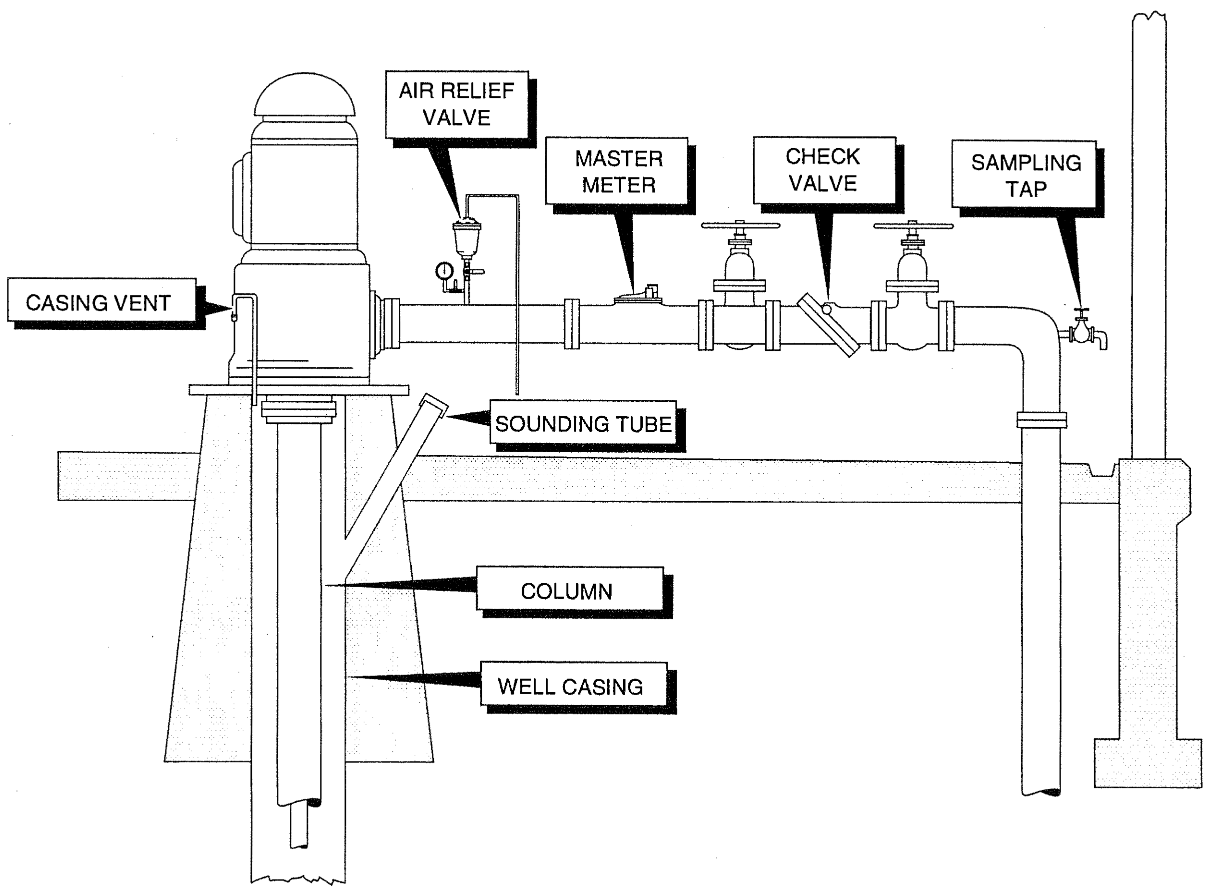
When a lineshaft turbine has packing in the stuffing box, there will be leakage through the packing. To prevent this water from running back down into the well, all holes in the discharge head should be plugged and the water piped away from the well head.

Discharge Piping

The discharge piping is connected directly to the discharge head and contains the related valves and fittings. To prevent vibration the weight of the discharge piping should not be on the pump discharge head but supported by pipe supports to the floor.

Discharge Pressure Gauge

Regardless of pump type it is an operational requirement to have a gauge on the discharge of the pump. Reading, recording and analyzing the data from this gauge, along with other operational data can help the operator identify pump problems long before there is a pump failure.



Air Vent

With most lineshaft turbines, when the pump is shut off water runs back down the column and into the well casing. When this happens, a vacuum is created inside the column pipe and discharge piping. This could cause damage to the piping, "suck" water back in around the packing or leaks at one or more fittings. To prevent damage, an air vent is placed on the discharge piping. This vent allows air to be brought into the column at pump shutdown. When the pump is restarted, the same vent is used to allow air to be discharged from the column. This reduces water hammer at the discharge check valve and air intrusion into the line.

Air Intrusion Problems

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In order to determine how the pump is performing as well as determine the water demand,a flow meter should be installed on each and every well discharge. By reading, recording and analyzing the flow demand data and operator can, with the help of other data, determine pumping and consumption problems long before a failure or crises has occurred.

Pump to Waste

While not a requirement in all states a pump to waste line and valve make good operational sense. With this line placed after the flow meter, pumping test can easily be conducted. The line can also be used to exercise the pump under stand-by conditions, as well as, to pump water from the well when attempting to deal with a contamination problem or allowing the well to be pumped after a long shutdown without placing any accumulated debris into the system.

Check Valve

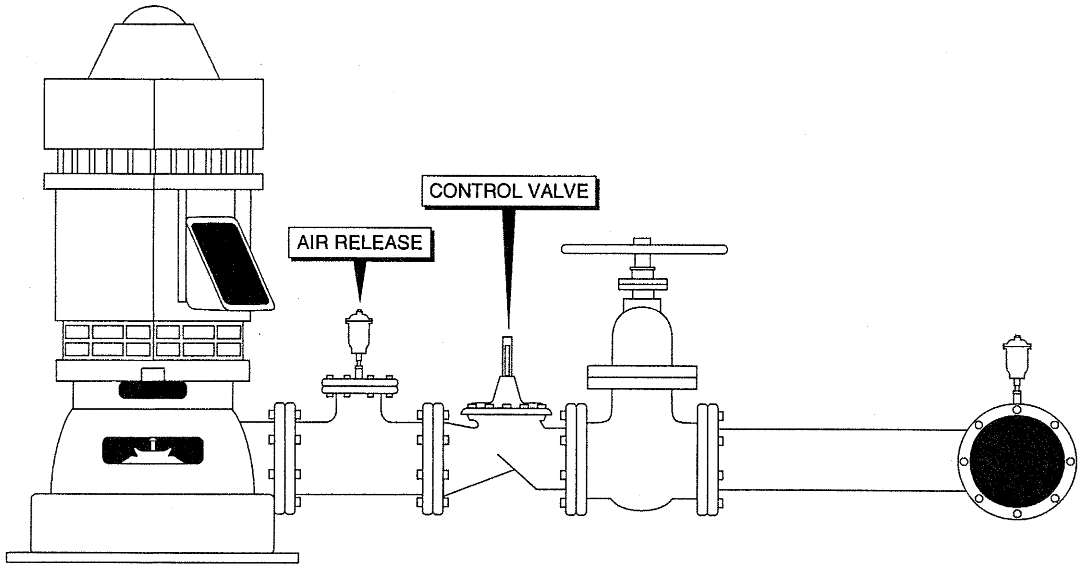
When a lineshaft turbine is being used to pump against a low head, a common swing check or silent check valve can be used to prevent the entire system from running back down through the pump and into the well.

Surge Control

When the pump is pumping against a high head the check valve would cause excessive water hammer at shutdown and could cause the piping to break. To prevent this there are two common techniques. The most common is the single surge control valve. The most common surge control valve is a wide body control valve like a Clay or Ross installed in the discharge line. This valve is closed at start-up. As the pressure on the pump side reaches the pressure on the down stream side of the valve, the valve slowly opens and allows the pump to deliver water into the system.

Shutdown with Control Valve

When there is no longer a demand for the pump, the control valve begins to slowly close. As the valve reaches the closed position, a micro switch is triggered by a rod extending from the top of the valve and a signal is sent to stop the pump.

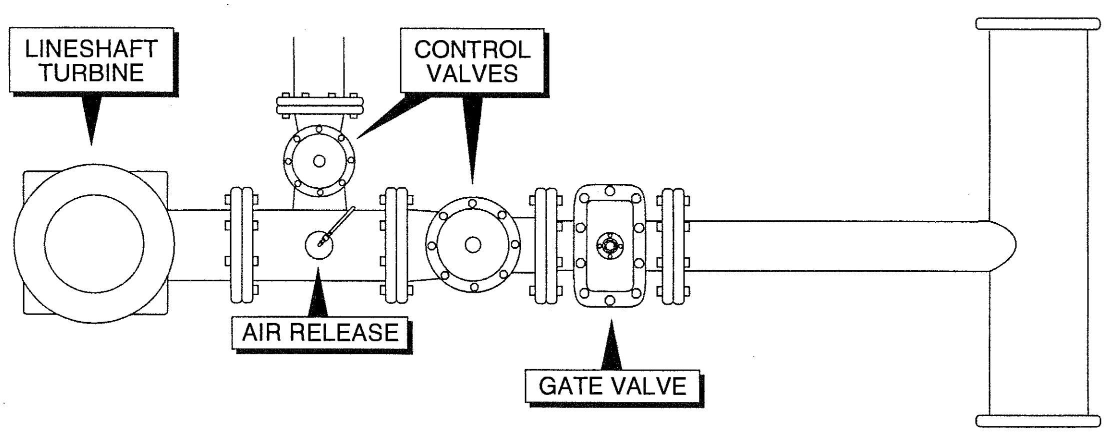


Double Control Valves

The second common method used to control water hammer works similar to the one just discussed, except two control valves are used. The second control valve is smaller than the first and placed on the discharge of a tee, which is placed upstream of the main control valve. When the pump is off, the large control valve is closed and the small valve is open. At start-up the small valve begins to close and the large valve opens. When the large valve is fully opened, the small valve is closed.

Shutdown - 2 Control Valves

At shutdown the large valve begins to close. As the pressure between the pump and the control valve increases to a predetermined level, the small valve begins to open. When the small valve is fully opened, the large valve is closed. At this point a micro switch that senses the valve position sends a signal to the motor to shutdown. This process produces very little water hammer as well as allowing the pump to reach operating RPM very quickly, thus reducing torque and stress on the pump shaft and reducing the amount of time that the motor is drawing high amperage.



Isolation Valve

In order to work on the pump, it must be isolated from the system. A gate or butterfly valve is often installed on the discharge line as an isolation valve.

Sampling Tap

In order to obtain samples of the raw water, a raw water sampling tap should be installed. This tap must be far enough away from the injection of any chemicals to prevent the chemicals from showing up in the sample.

Spool

In order to reduce long term maintenance cost and make maintenance easier, a flange by flange spool is often placed in the discharge line before the isolation valve. The spool is easy to remove and install, reducing down time.

ELECTRICAL SYSTEM

At the Pole

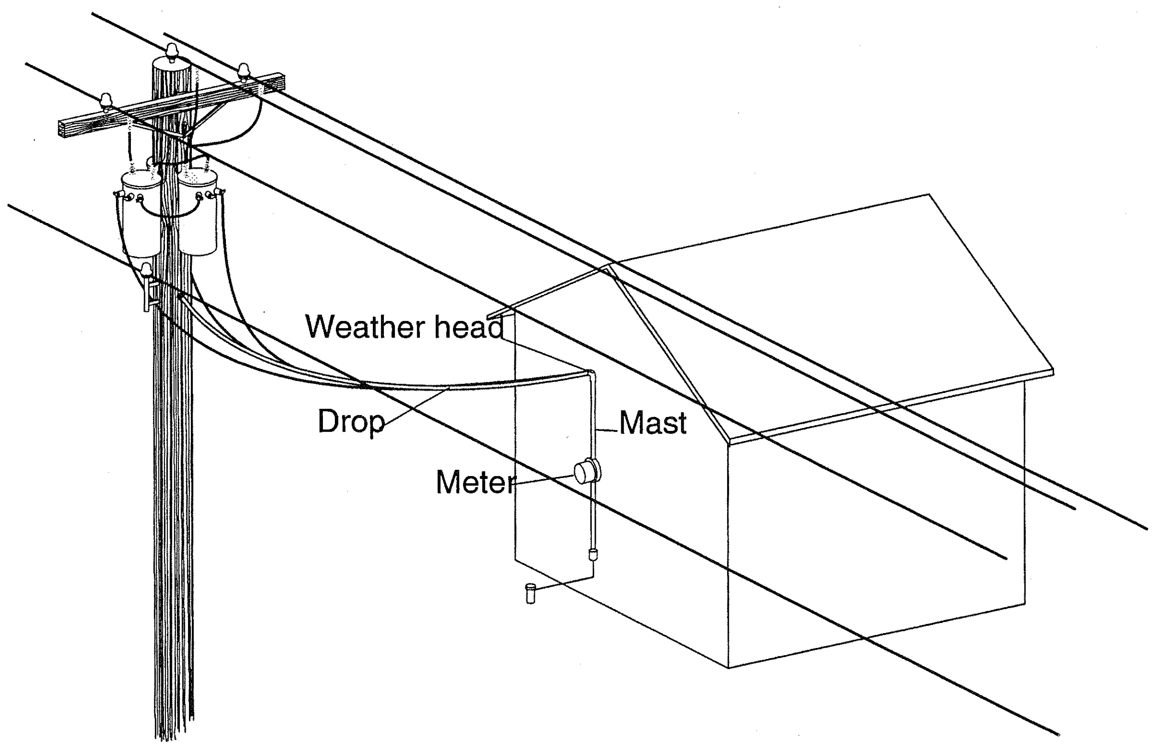
The electrical system starts at the electrical pole. The line leading from the electric company's transformers to the building is called the drop. The drop may contain three or four wires depending on whether the electrical supply is single phase or three phase system.

Mast

The drop is connected to the pump house electrical system at the connection extending from the weather head that sits on top of the mast. The mast is commonly made of two inch or larger galvanized pipe.

Meter

At the base of the mast is the electrical companies meter.



Disconnect

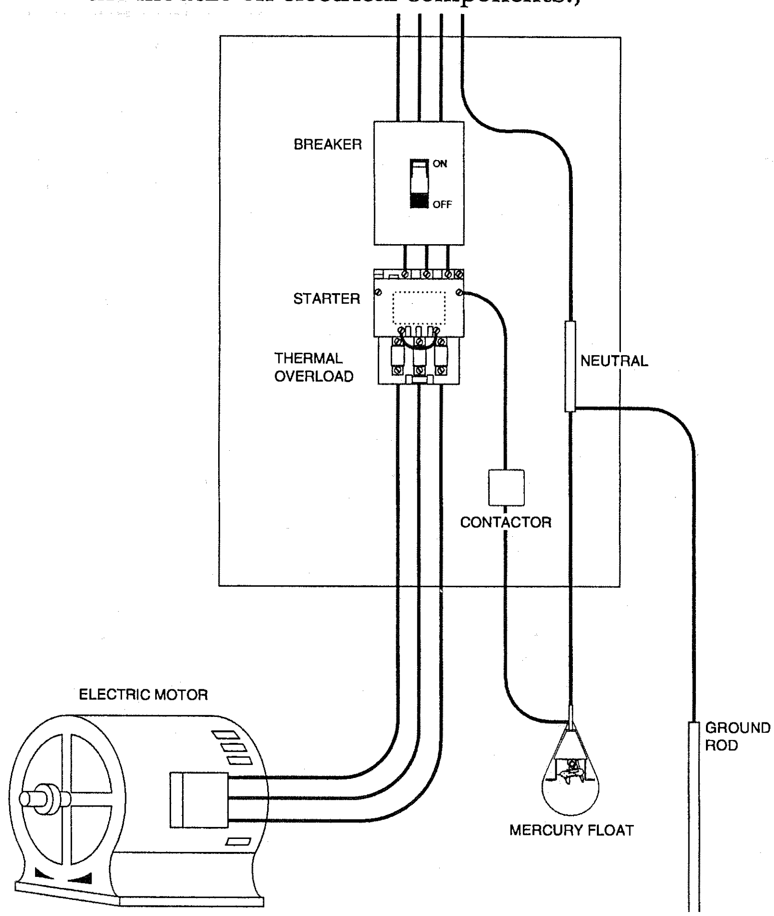
Power flows through lines leading from the base of the meter to the top of the electrical disconnect. The disconnect allows you to disconnect power to the entire pump house and safely make electrical repairs.

Breakers & Fuses

Electrically, just below the disconnect is the fuses or magnetic breaker. These devices serve the same purpose, they protect the building and the wiring from burning up as a result of a direct electrical short.

Magnetic Starter

Power flows from the fuses or breaker to the magnetic starter. The starter is an electromechanical device that is used to apply power to the electric motor on the pump. The magnetic starter is nothing more than a large electrical operated switch. The device is used because it can be opened and closed quickly by a remote signal. The remote signal can be a signal from a pressure switch or a level switch in the reservoir. (A more in depth explanation of these devices if found in the module on electrical components.)



Capacitors

Capacitors are used with single phase motors to help them start and in some cases to help them run. A discussion of how the single phase motors start and run can be found in the module on electric motors.

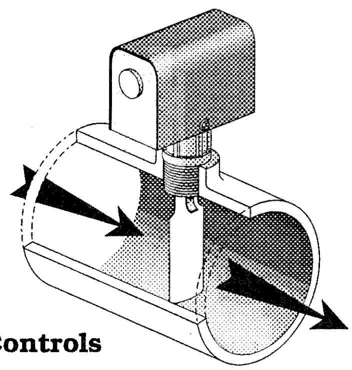
Control Relays

Connected electrically to the motor control circuit that operates the motor starter may be one or more control or contact relays. These can be used to run the fluoride feed pump, the chlorine feed pump, the potassium permanganate feed pump or other chemical feed pumps. These can be wired so that they will only come on when power is applied to the electric motor starter.

Meters

In the better installation the control panel holds a motor hour meter as well as amperage and voltage meters. Reading, recording and analyzing the data from these meters can help you determine the potential failure of an electric motor before it happens.

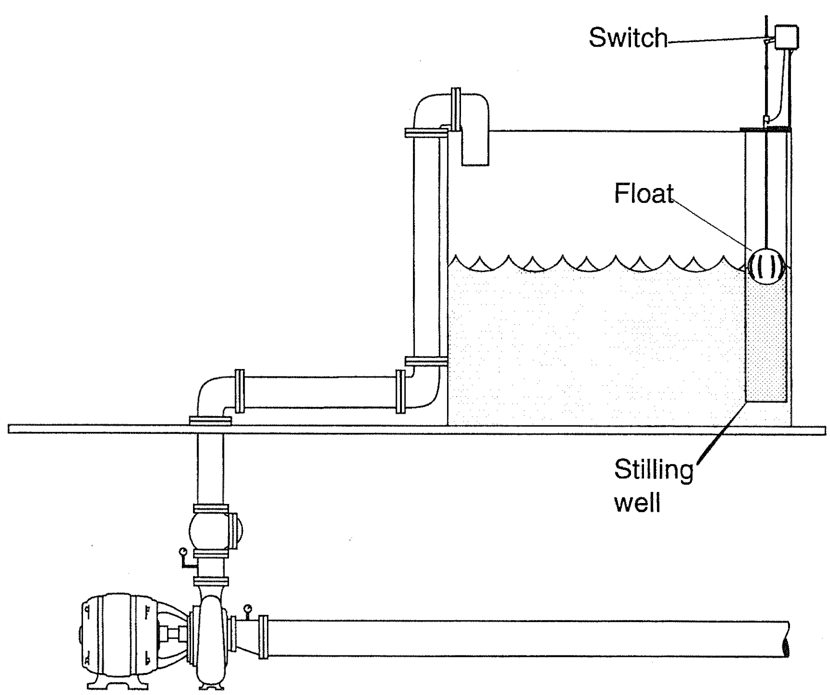
Flow Indicators



In systems where chemical feed pumps are required to come on when the well comes on, a fail safe flow indicator switch is often installed in the discharge piping. The flow switch utilizes a reed that is placed in the flow. When flow exists, the read moves and closes a set of contacts on top of the switch. By connecting chemical feed pumps to this set of contacts, they can be prevented from operating except when there is actually a flow through the discharge piping. This process can be very helpful in preventing an accidental overdose of a chemical.

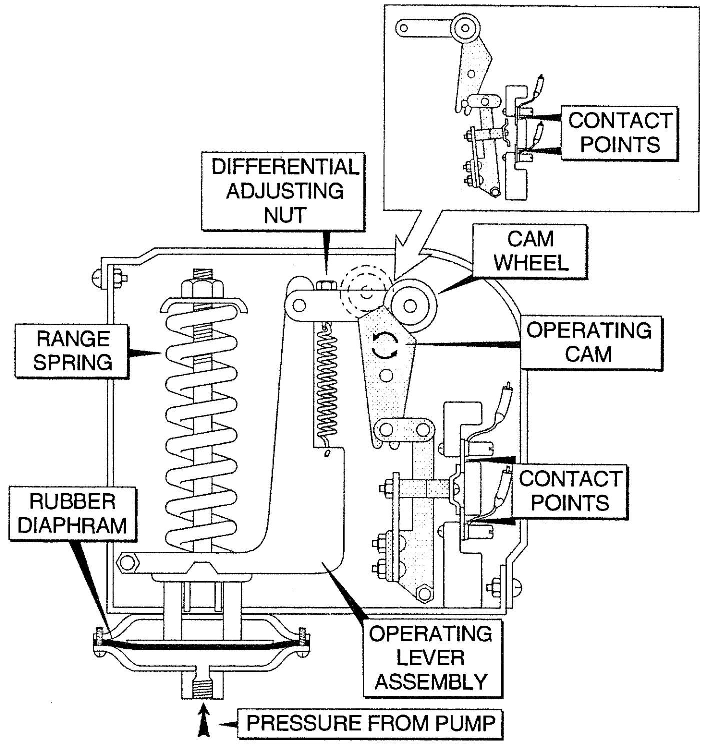
Level Controls

Each well installation must have some method of turning the pump on and off. Common methods are to use reservoir height or system pressure. With the reservoir height situation, the level of the water in the reservoir may be measured with an electrical probe, float or by using a pressure switch in the line below the reservoir. When the level drops to a predetermined point, the pump comes on and pumps until the water level reaches an upper point.



Pressure Controls

The pressure control system uses a pressure switch, which could be a bellows operated switch, mercury switch or electric transducer. This process requires a switch with a high and low setting or two switches. The two settings or switches are used to turn the pumps on and off.



Signal

The signal from the level or pressure switches is connected to the electrical control circuit that controls the electromagnet on the motor starter. By energizing the electromagnet on the motor starter the pump will start.

BUILDING

Design

The pump house building must be designed to protect the pump from the local weather conditions. There should be adequate heating in the winter and ventilation in the summer. The doors of the building should open out. The building should be vandal resistant and solid construction.

Why Open Out

Should a line break inside the building, it could fill with water until the level reached the electrical panel and shorted out the power to the motor. If the doors open in it will be difficult to enter the building. If they open out then access will be relatively easy.

Pump Removal

The building should be designed with a lift off roof or a section of the roof that can be lifted off to allow removal of the pump from the well.

PROTECTING THE SOURCE

National Program

EPA has established a national program called the Well Head Protection Program. This program requires the owner of the well to take certain actions and provides the owner with certain powers of land use in areas that could effect the quality of the water in the well.

Process

The process requires three actions:

- Identify, if possible, the actual recharge area of the well and identify the flow path that a contaminate might take from that area towards the well.
- Identify the zone of influence associated with the well. This is usually accomplished by mapping the cone of depression that is developed at different pumping rates.
- Identify and map all possible sources of contamination that are in the zone of influence, the recharge area or along the flow path between the recharge area and the well.

Contamination in Recharge Area

Contamination in the well recharge area can be natural or man made. Typical sources of contamination include:

- Fuel storage sites
- Waste oil collection and disposal sites
- Mining and/or logging in recharge area
- Any other activities in the area
- Permanent dwellings in recharge area
- Septic tanks
- Solid waste disposal - yours and any other communities within the area
- Old or existing military sites
- Abandoned wells
- Other existing wells
- Wastewater treatment plant
- Roads through recharge area
- Cemeteries

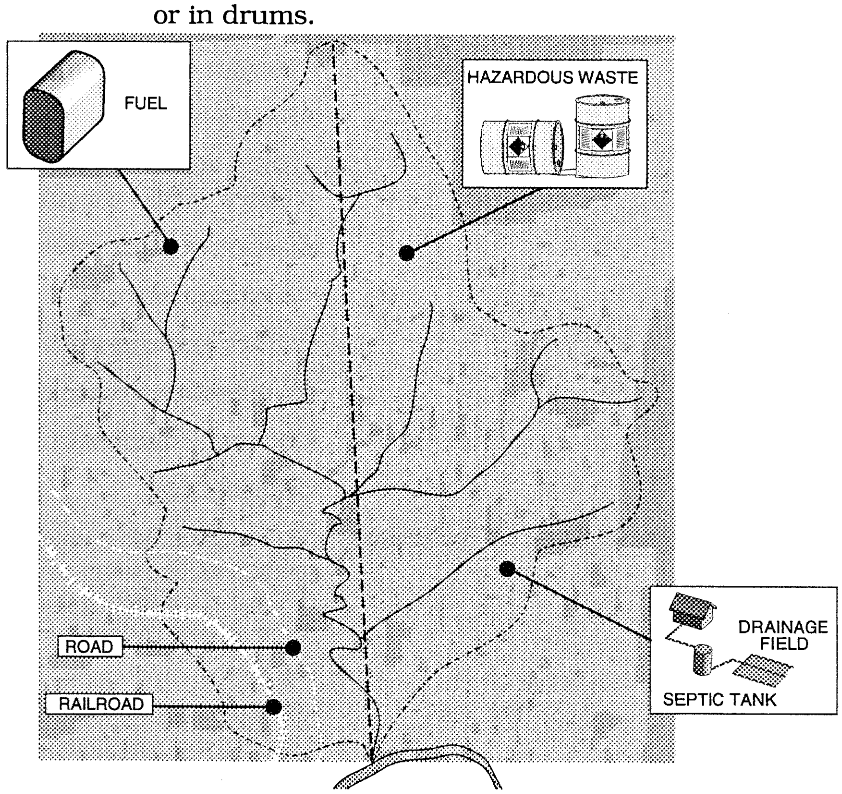
Contamination in Zone of Influence

Most states have specific regulations concerning protection of the zone of influence from contamination. In Alaska the following separation distances have been determined to be the minimum protection requirements.

- Septic tanks must be at lease 200 feet away from a well used for a Class for A or B water system and

150 feet away from a well used for a Class C water system.

- Buried fuel storage not used specifically for heating must be at least 200 feet away from a well used for a Class A or B water system and , 100 feet away from a well used for a Class C water system.
- No paint, oil or fuel should be stored in the pump house.
- Community sewer lines must be at least 200 feet away from a well used for Class A or B water systems and 100 feet away from a well used for a Class C water system.
- The area within 100 feet of the well must be owned by the water supplier.
- No roads can be within 100 feet the of well. If there are existing roads within 100 feet of the well then the well must be protected from runoff from the road.
- Above ground fuel used for on-site emergency pumping equipment or generators cannot be within 100 feet of a well used for a Class A or B water system or within 75 feet of a well used for a Class C water system.
- There are no restrictions on fuel oil used for boilers or other "noncommercial" uses, if the quantities are less than 500 gallons and are stored above ground or in drums.



GROUNDWATER UNDER DIRECT INFLUENCE OF SURFACE WATER

Background

When surface water can infiltrate a groundwater supply, there is a high possibility that the groundwater could be contaminated with Giardia, viruses, turbidity and organic material from surface water. As a result, the Surface Water Treatment Rule of the Safe Drinking Water Act requires that each state determine which groundwater supplies are influenced by surface water. When a groundwater supply is identified as being under the direct influence of surface water it is no longer considered a groundwater supply but is referred to as groundwater under the direct influence of surface water (GUDISW). When a supply is designated as GUDISW the states surface water rules apply to the system rather than the groundwater rules.

Involvement of DEC

It is the responsibility of DEC to identify and categorize all groundwater supplies into either groundwater or GUDISW. The process that will be used is shown below in a flow chart.

Five Steps

There are five steps that each system that has a shallow well, deep well, spring or infiltration gallery may need to go through to determine if the supply is groundwater or GUDISW. The steps are described below.

Step 1

DEC asks the question, "Is the supply open to the atmosphere and surface runoff?"

- If the answer is yes then the supply is classified as surface water.
- If the answer to the question, "is this a well?", is yes, then go to step #2.

Step 1 - Springs & etc.

If the intake is from a spring or infiltration gallery then proceed directly to step 4.

Step 2

Determine if the well meets the construction standards:

- Is there a sanitary seal?
- Does the well casing penetrate a confining layer?
- The only well screens or casing perforations are below the confining layer.

No on Standards

If the well does not meet the construction standards then go to step three.

Yes on Standards

If the well meets the construction standards, then DEC will review records for the following:

- No history of waterborne disease outbreaks attributed to the well.

- No history of total coliform or fecal coliform contamination during the previous three years.
- No history of turbidity problems in the well.

Yes on Standards and Records

If the answer is yes to both the construction standards and the records requirements, then the well is classified as a groundwater source.

No on Records

If the answer to the records requirement is no, then go to step three.

Step 3

At this point a determination has been made that the source is from a well and the well either did not meet the construction standards or did not meet the records requirements. In step three, there are two conditions. First an on-site inspection must reveal that there is a sanitary seal, the well is at least 100 feet from a surface water source and that the well screen is at least 30 feet from the surface. In addition, DEC may also consider hydrogelogical evidence submitted by the purveyor.

Yes to Step 3

If the well meets the above criteria and the hydrogelogical evidence indicates that the well is not vulnerable to Giardia the well is classified as a groundwater sources.

No to Step 3

If the answers to the questions in step 3 are no, then go to step 4.

Step 4

At this point you are considering a well, spring or infiltration gallery. The raw water must be sampled and tested each week for a period of one year. The sampling and testing are for turbidity, temperature, conductivity and pH.

Yes to Step 4

If these values are stable, then the supply is classified as a groundwater supply.

No to Step 4

If the results of the test are not stable, then go to step 5.

Step 5

Further samples are to be collected and analyzed. These samples are called MPA (Microscopic Particulate Analysis). The samples are analyzed for the presence of Giardia, Coccidia Helminthis, and Chlorophyll algae. The presence of any of these organisms is an indication of the influence of surface water.

Yes to Step 5

If all of these organisims are absence then the supply is classified as a groundwater supply.

No to Step 5

If any of these organisims are present the supply is said to be under the direct influence of surface water and is classified as GUDISW and the states surface water treatment regulations apply.

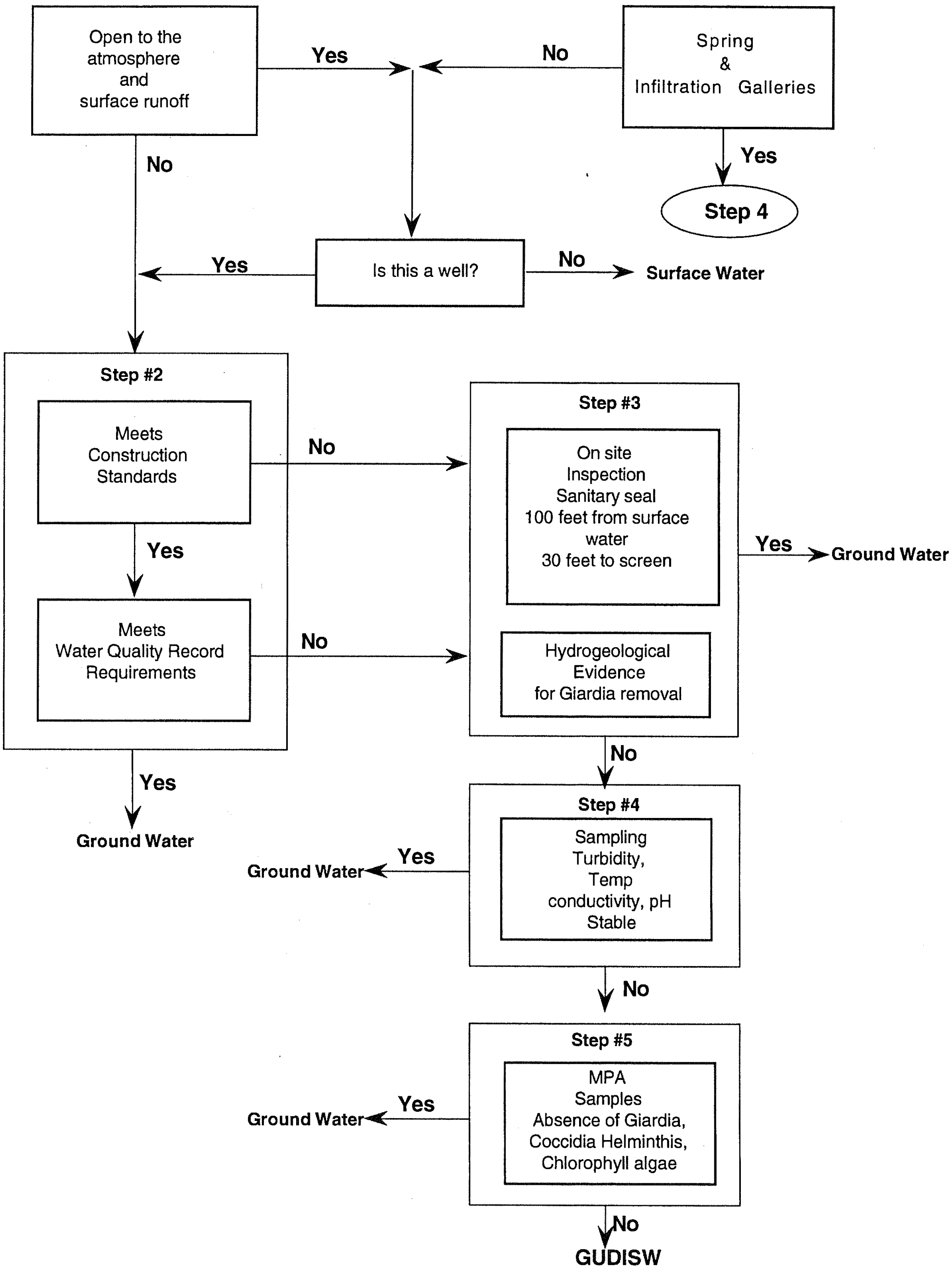
NEW CONSTRUCTION CONSIDERATIONS

When drilling a new well and it is desired to avoid the GUDISW designation, consider these conditions.

- Meet the construction regulations describe above.
- Make sure you are in an confined aquifer.
- Make sure the well is over 200 feet from a surface water source.

Determining if your water sources is Groundwater Under the Direct Influence of Surface Water. (GUDISW)

This evaluation is to be made on all shallow wells, deep wells, springs and infiltration galleries



START-UP

Assumptions

The following start-up procedure describes the sequence that is typical for starting up a well system that has been off line for an extended period of time due to maintenance or as a result of a seasonal operation. It is assumed that this system has previously been in operation, it is not a new system.

Steps

Start by making a careful observation of the facility and equipment. The details of this inspection will be different for each type of pump used. The information below includes the three well types described in this module. Select those activities that fit your facility.

- Visually check the power pole fuses - make sure they are all engaged.
- Place the disconnect in an off position & lock-out the system.
- Open the panel door and look for rodent nest.
- Vacuum dust from panel.
- Check voltage at top of breaker or disconnect - compare to previous data.
- Check to the water level in the well.
- With lineshaft turbines - change oil in motor, replace packing, check prelube for operation, if oil lubricated bearings - fill the oil reservoir and check drip rate (normal drip rate is 8 to 13 drops per minute) and make sure that the motor and pump shaft will rotate freely.
- Open pump to waste valve 1/2 open and close discharge isolation valve.
- Remove lock-out.
- Place H-O-A switch in Hand.
- As soon as is possible after the pump is running, check amperage, discharge pressure and flow. If amperage and flow are below normal, open the waste valve until normal flow is observed. Recheck amperage.
- With lineshaft turbines - check and adjust packing.
- Run pump for 15 to 20 minutes.
- Slowly open isolation valve and close pump to waste valve. Observe operation of any automatic surge control valves. Observe system pressure, flow and amperage.
- Turn H-O-A switch to off.
- Turn switch to Auto and observe operation sequence.

- Record data and any actions taken.
- Read and record, power meter, hour meter and flow totalizer.
- Collect any routine operational water quality data.

NORMAL OPERATIONS

Operation & Data Collection

Under normal operating conditions a well installation requires no special actions. The data collection, routine inspections and routine maintenance are described below. These are the procedures to follow for normal operations.

SHUTDOWN

Extended Shutdown

This procedure is to be used for extended shutdown of a well system for maintenance or as a normal seasonal operation.

To shutdown a well system; turn the H-O-A switch to off, place the disconnect in the off position, place appropriate lock-out device on the disconnect and tag the device.

Lineshaft

For lineshaft turbines, shutoff the prelube, if oil lubricated bearings. allow a small amount of oil to continue to drip (1 to 2 drops per minute).

Monthly

If possible all equipment should be operated for 15 to 20 minutes at least once a month. If it is not possible to run a lineshaft turbine each month, then the shaft should be rotated several turns by hand. This will prevent bearings from being damaged.

INSPECTION & DATA COLLECTION

Content of Section

The proper operation and maintenance of a groundwater supply requires that the operator routinely gather data, make observations and analyze the information gathered. While the state does have specific requirements for testing water quality the following discussion goes beyond those regulations and concentrates on the activities that have proven successful to well operated groundwater systems.

DEPTH OF WATER

Background

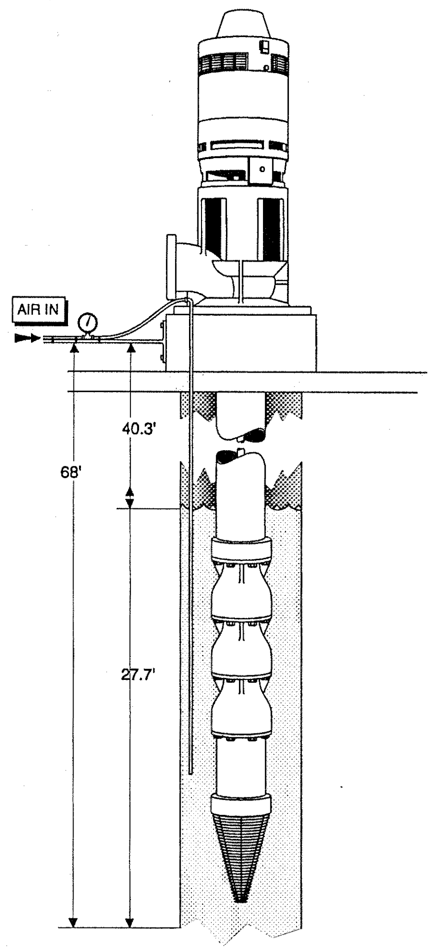
One item necessary to properly operate and analyze the wells ability to meet the use demand is the level of the water in the well. As discussed previously there are several methods of accomplishing this. The bubbler tube is one of the more popular techniques, but does require some interpolation and calculations to obtain the reading.

Equipment

A bubbler tube system consist, of a tube, usually 5/16" or 1/4" plastic, copper or stainless steel inserted down the well casing ending below the water level. Attached to the top of the tube is a pressure gauge and a connection for an air supply. The most common air supply is a bicycle pump.

Process

The process used is to pump air into the tube, forcing water out. Observe the gauge, when it stops rising the pressure is read. This pressure is then converted into feet. The value obtained is the depth of water above the end of the tube. In order to determine the distance from the top of the ground to the water level, the length of the tube must be known and the calculated distance is then subtracted from the length of the tube.



Calculation

$$\text{Height of water} = \frac{(\_\_\_\_\_\_)\text{ psi on gauge}}{0.433\text{ psi/ft}} = \text{feet}$$

Example

Find the distance from the top of the well to the water when the tube is 68 feet long and the pressure is 12 psi.

$$\text{feet} = \frac{12\text{ psi}}{0.433\text{ psi/ft}} = 27.7\text{ feet}$$

68 feet - 27.7 feet = 40.3 feet to water

DETERMINING SPECIFIC CAPACITY

Background

Specific capacity[21] of a well should be determined quarterly if at all possible, but at a minimum of once a year. The specific capacity can be very helpful in determining if the well screens of the strata next to the well are plugging with debris or chemicals such as iron, manganese or calcium carbonate. In wells where iron bacteria is a problem, the accumulation of iron bacterial slime can also cause a plugging of the well screens. In order to determine specific capacity the flow from the well and the drawdown must be determined. There are numerous methods available to determine the level of the water in a well, the most common have been discussed above. The procedure described below assumes that a sounding or bubbler tube is to be used.

Units

Specific capacity is a measure of the number of gallons of water that are produced by a well for each foot of drawdown(gpm/foot).

Equipment

In order to perform this test the following equipment is required:

- Flow meter with rate in gpm and a totalizer
- A means of determining the level of water in the well
- Stop watch
- Pad and pencil

SPECIFIC CAPACITY PROCESS

General

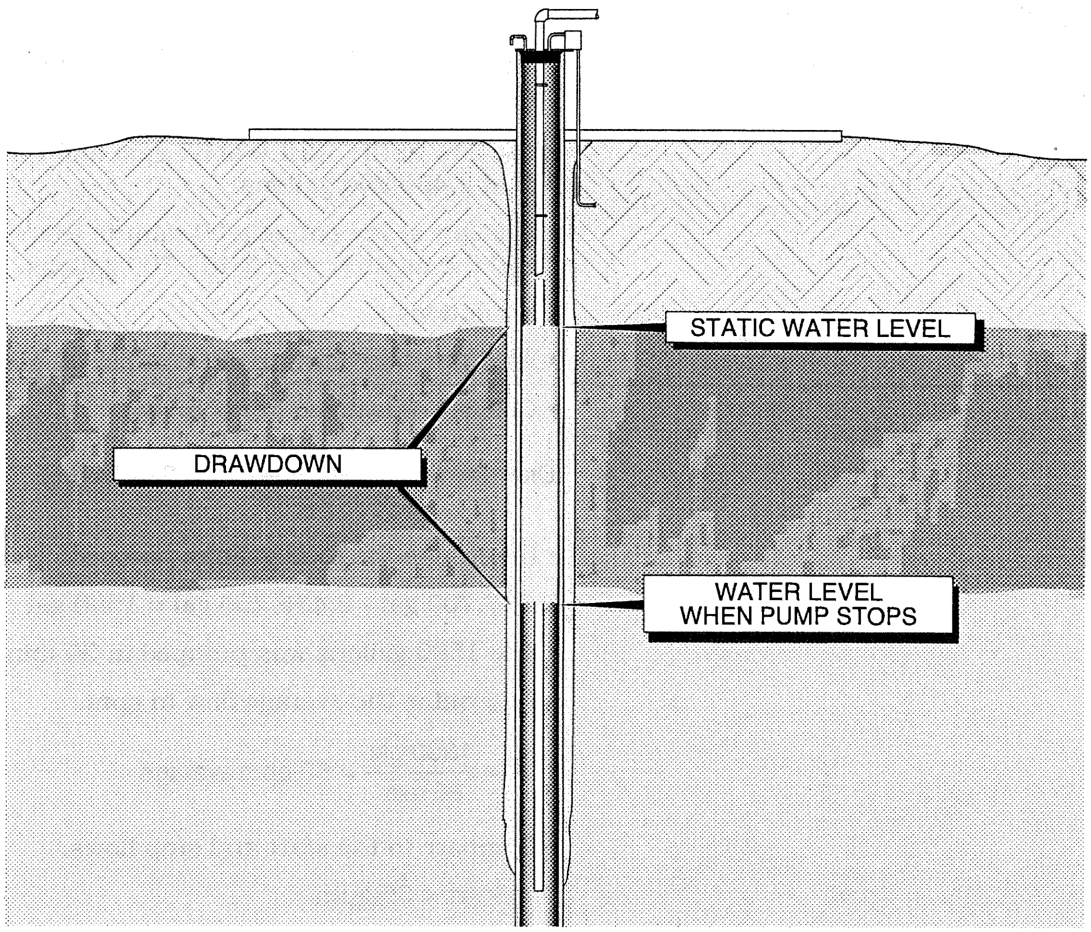
The basic process requires allowing the well to recover, pumping at a specific rate and measuring **drawdown**[22] during the pumping cycle.

SPECIFIC STEPS

- Keep pump off line for as many hours as possible. This will allow the well to recover and give a much more accurate account of the condition of the well. A typical off time is 24 hours. If being off line for 24 hours is not possible then use what ever time is available.
- Determine pressure on bubbler tube. This pressure is a reflection of **static water level**[23] in the well.
- Turn the well pump on and allow it to operate for length of time equal to a normal run cycle. In most cases it is not necessary or desirable to have the pump operate for more than one hour.
- Read flow meter just after the well pump is started - record rate and totalizer and start your stop watch.

[21] **Specific Capacity** - The rate of delivery of a well expressed in gpm/ft of drawdown.
[22] **Drawdown** - The distance between the starting level and the pumping level.
[23] **Static Water Level** - The level of water in a well which is not being pumped.

Remember as the well pumps down, the TDH associated with the pump will increase and thus reduce the pump flow. Therefore, it is necessary to determine the pumping rate and the total volume pumped. The total volume will be used to determine an average pumping rate.



- Just before pump shuts off, record pumping rate and totalizer and stop the stop watch.
- At shut off, determine pressure on bubbler tube. This is the drawdown level.
- Subtract drawdown level from static level to determine the total drawdown. This figure will most likely be expressed in psi.
- Convert the drawdown in psi to feet (divide the psi by 0.433 psi/ft).
- Determine average flow in gpm for the length of the test. This is done by subtracting the starting totalizer reading from the ending reading and dividing by the time laps in minutes between the two readings.
- Verify the reading. The value in gpm should be less than the beginning reading and greater than the

ending reading. If it falls outside of this range, check data. If the data and calculations are accurate then the problem is with the accurately of the meter or totalizer.

- Determine specific capacity by dividing the average flow rate in gpm by the drawdown in feet.

Specific Capacity Example

Data

- The pressure at the start of the test was 8 psi.
- The pressure at the end of the test was 14 psi.
- The flow at the start was 65 gpm and the totalizer read 2,456,200 gallons.
- The flow at the end of a 30 minute test was 40 gpm and the totalizer was 2,457,700 gallons.

Calculations

- Find the drawdown in psi - 14 psi - 8 psi = 6 psi.
- Convert drawdown in psi to feet.

$$\text{Drawdown} = \frac{6\text{ psi}}{0.433\text{ psi/ft}} = 13.9\text{ or }14\text{ feet}$$

- Determine the total gallons pumped.

2,457,700 gal - 2,456,200 gal = 1500 gal

- The 1500 gallons was pumped in 30 minutes.
- Determine the average flow in gpm.

$$\text{gpm} = \frac{1500\text{ gal}}{30\text{ min}} = 50\text{ gpm average}$$

- Compare to the start and stop flows.

  Start = 65 gpm

  Stop = 40 gpm

The flow is within this range and is considered to have a high level of accuracy.

- Determine the specific capacity.

$$\text{Specific Capicity} = \frac{50\text{ gpm}}{14\text{ ft}} = 3.6\text{ gpm/ft of drawdown}$$

INSPECTION

Proper operation of any facility requires routine inspection of the facility and the equipment. The following is a generic listing of what should be inspected during these visits and at what frequency. This list should be altered to meet local conditions.

- Check the appearance of building, inside and out for damage, deterioration and overall appearance. - weekly.
- Clean the grounds and interior of the building - weekly.
- Check all pipes, pumps, and valves for leaks - weekly.
- Observe the appearance of the equipment - weekly.
- Check the position of the H-O-A switch - daily.
- Check the oil level in lineshaft turbine motors or right angle gear drives - daily.
- The condition of the sanitary seal, air vent and well head - twice a year.

RECORDS

In order to evaluate the condition of the well facility and to reduce time and cost associated with maintenance and repair, certain records should be maintained. The following is a generic list of the minimum records:

- Water quality - While not required by most state regulations, raw water quality data is collected by those facilities that are properly operated. Most operators agree, that this data should be maintained for at least 10 years.

Typical raw water quality data that is collected includes; bacteriological data, (Bac-t samples of the raw water should be collected and tested at least once a quarter), inorganics, organics and VOC.

- A copy of the well log should be available, with copies stored at various locations.
- There should be as-built drawings of the well house and pump station. It is best if there are at least two copies available. One should be at the well house the second should be stored at city hall.
- Copies of manufacturers data and O & M manuals for the pumps, motors and related equipment should be on hand.

MONITORING - WATER QUALITY

Relative to the Regulations

The following listing of suggested water quality monitoring and testing is not totally associated with the State Drinking Water Regulations. This suggested list is based on what is considered by the water works industry to be "good practice." This data is collected to allow the operator to evaluate the water quality and thus make changes in treatment when necessary. The process can also alert the operator to pending problems and thus avoid costly emergencies. This listing is associated with the well system only and does not reflect testing that should be done in conjunction with treatment.

- Fluoride - Daily
- Raw water temp - daily
- Raw water pH - weekly
- Raw water - if treating for iron or manganese -weekly
- Finished water - Bac-t - monthly
- Raw water - Bac-t - quarterly
- Raw water fluoride - quarterly
- Raw water - specific conductance - quarterly
- Nitrates - State requirement - 1 year
- Inorganics - State requirement - 3 years
- Radioactivity - 4 years
- Organics - At state discretion

ROUTINE MAINTENANCE

Other than the building and piping system, there is very little maintenance that must be done to a well system. Most of the maintenance is associated with the collection and analysis of data. However, depending on the type of pumping installation, the following activities should be completed:

- Lineshaft turbine - change oil in the motor - annually
- Lineshaft turbines - change packing - annually
- Vacuum dust from control panel - annually (Remember to use proper lock-out tag-out procedures)
- If a wide body control valve is used - replace pilot valve, valve face, seat, spring and diaphragm. Inspect main valve movable closure, valve seat face and diaphragm

MONITORING - OPERATIONS

Besides the data associated with water quality, it is desirable to collect and analyze data associated with the operation of the well and its pumping equipment. The following is a simple view of generic data that should be considered when determining the monitoring data requirements.

- Motor hours - daily
- Flow meter - daily
- Power consumption - weekly
- Water depth in the well - quarterly
- Calculate specific capacity - quarterly
- Motor amperage and voltage - quarterly
- Megger motor - 1 year

Data Collection Form

On the following page is a generic data collection form for an imaginary water utility. It is presented here as an example of how a data collection form might look and to give information on what data should be collected.

City of ____________ Month of ____________

1. Date	2. Meter Reading	3. Gallons pumped X 100	4. Distance to water ft	5. Discharge pressure psi	6. TDH - feet	7. Water horsepower	8. Hour meter reading	9. Hours pumped	10. Power meter reading	11. KW Used	12. KW per 100 gal	13. Avg. Amps	14. Avg. Volts	15. Electric horsepower	16. Efficiency
1															
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HOW TO USE THIS FORM

Data Collection Frequency

If the amperage and voltage readings must be obtained by opening the panel door and physically making the readings then the data in columns 13 & 14 should only be completed once each month. If on the other hand, the well pump control panel has amperage and voltage meters built into the panels then these readings should be made at least once a week. Some operators prefer to make these readings daily. Other than the columns indicated all other data should be collected daily.

COLUMNS

1. Date - The days are numbered from the bottom up to make subtraction easier.
2. Meter Reading - This is the flow meter reading from the well pump.
3. Gallons pumped X 100 - This value should be expressed in hundreds of gallons pumped.
4. Distance to water - This is the distance from the center of the discharge line to the top of the water in the well at the time of the pressure reading. If this distance is not easily obtained, use the last known number.
5. Discharge pressure - This is the discharge pressure from the well.
6. TDH - Total Dynamic Head is calculated as follows:

$$\text{TDH} = \frac{\_\_\_ \text{ psi (discharge pressure)}}{0.433 \text{ psi/ft}} + \_\_\_\_ \text{ ft, (column 4)}$$

7. Water horsepower. Water horsepower is calculated as follows:

$$\text{WHP} = \frac{\text{TDH, ft(column 6)} \times \text{Q, gpm} \times 8.34 \text{ lbs/gal}}{33{,}000 \text{ ft-lbs/min/hp}}$$

The flow (Q) is the flow at the time of the readings in gallons per minute. Or, an average flow can be determined by multiplying column 9 X 60 min/hr and dividing this value into the results in column 3. The results will have to multiplied times 100.

8. Hour meter reading.
9. Hours pumped - The difference between any two days readings.
10. Power meter reading.

11. KW Used - This is obtained by subtracting one day from the previous days readings.

12. KW per 100 gallons. This is obtained by dividing column 11 by column 3.

13. Average Amps - If this is a three phase motor, the three readings will need to be added and divided by 3.

14. Average Volts - If this is a three phase motor, the three readings will need to be added and divided by 3.

15. Electric Horsepower is obtained by the following:

$$1\ \text{phase} = \frac{\text{\_\_\_\_ column 13 X \_\_\_\_ column 14}}{746\ \text{watt/hp}} = \text{EHP}$$

$$3\ \text{phase} = \frac{\text{\_\_\_\_ column 13 X \_\_\_\_ column 14 X 1.73 X P.F.}}{746\ \text{watt/hp}} = \text{EHP}$$

P.F. is the power factor. This value must be measured using special instruments. The local power supplier may be helpful in making this reading. Because the value changes very little with time, the reading need only be made once a year. If a reading cannot be obtained use 0.9. The value can be adjusted when a reading is actually taken. In the mean time the calculated value for horsepower can be obtained and used to see if there is a change from month to month. The amount of the change will not be altered by the value of the power factor.

16. Efficiency - The efficiency of the well can be obtained by dividing water horsepower, column 7 by the electrical horsepower, column 15 and multiplying by 100.

$$\text{Eff}\ \% = \frac{\text{WHP}}{\text{EHP}} \text{X}\ 100$$

TYPICAL PROBLEMS

Motor running in wrong direction

With a three phase motor, switch any two of the three legs. The motor will change directions

HEATERS TRIPPED

Common Problems

One of the most common pumping problems is the tripping of the heaters or thermal overloads. This can happen for a variety of reasons, but is most commonly associated with an excessive amperage draw. If the problem is one that only happens once every few years then the heaters should be reset and proceed as normal. However, if the problem reoccurs, then the amperage should be checked and compared with the name plate amperage. If the draw is above the name plate then help will be require.

Procedure for Setting Heaters

One of the most common operational errors is the resetting of the heaters by pressing the "reset" button when power is applied to the motor. **Always turn the H-O-A switch to off before pressing the reset.** This will prevent premature failure of the motor starter. After pressing the reset, place the H-O-A switch in Hand or manual to see if the pump runs. If all conditions are normal, then switch to the auto position.

Trouble Shooting Submersible Pumps

Motor Does Not Start

Cause of Trouble	What to Check	Corrective Action
No power or incorrect voltage	Check voltage. Voltage must be within ± 10% of rated voltage	Contact power company if voltage is incorrect
Fuses blown or circuit breakers tripped.	Check fuses for recommended size and check for loose, dirty or corroded connections in fuse block. Check for tripped circuit breaker	Replace with proper fuse or reset circuit breaker
Defective Pressure switch	Check voltage at contact points. Improper contact of switch points can cause voltage less than line voltage	Replace pressure switch or clean points
Defective wiring	Check for loose or corroded connections. Check motor lead terminals with voltmeter for power	Correct faulty wiring or connections
Bound Pump	Locked rotor conditions can result from misalignment between pump and motor or sand bound in the pump Amperage readings 3 to 6 times higher than normal will be indicated	If pump will not start after several tries, it must be pulled and the cause corrected
Defective cable and motor	See Electrical section for testing motor and insulation	

Motor Starts Too Often

Cause of Trouble	What to Check	Corrective Action
Pressure switch	Check setting on pressure switch and examine for defects	Reset limit or replace switch.
Check valve, stuck open	Damaged or defective check valve will not hold pressure	Replace if defective
Leak in system	Check system for leaks	Replace damaged pipes or repair leaks

Motor Runs Continuously

Cause of Trouble	What to Check	Corrective Action
Pressure switch	Switch points may be "welded" in closed position. Pressure switch may be set too high	Clean points or replace switch, or readjust setting
Low level of water in well	Pump may exceed well capacity. Shut off pump, wait for well to recover. Check static and drawdown level from well head.	Throttle pump output or reset pump to lower level
Leak in System	Check system for leaks	Replace damaged pipes or repair leaks
Worn Pump	Symptoms of worn pump are similar to those of drop pipe leak or low water level in well. Reduce pressure switch setting, if pump shuts off worn parts may be the cause. This would be associated with a reduction in gpm and amperage	Pull pump and replace worn impellers, casing or other fitting parts
Loose or broken motor shaft	No or little water will be delivered if coupling between motor and pump shaft is loose or if jammed pump has caused the motor shaft to shear off	Check for damaged shafts if coupling is loose and replace worn or defective parts
Pump screen blocked	Restricted flow may indicated a clogged intake screen on pump. Pump may be installed in mud or sand	Clean screen and reset at less depth. It may be necessary to clean the well
Check valve stuck	No water will be delivered if check valve is in the closed position	Replace check valve.

Motor Runs But Overload Protector Trips

Cause of Trouble	What to Check	Corrective Action
Incorrect voltage	Using voltmeter, check the line terminals. Voltage must be within ± 10% of rated voltage. Low voltage is more of a problem than high voltage	Contact power company if voltage is incorrect.
Overheated protectors Defective Cable or Motor	Direct sunlight or other heat source can make the control box temperature high enough to cause the protectors to trip. See electrical section for how to test for pump or motor problems	Shade box, provide ventilation or move box away from heat source.
Worn pump or motor	See data above	

Pumps Operates but Delivers Little or No Water

Cause of Trouble	What to Check	Corrective Action
Pump may be airlocked	Start and stop pump several times, wait about one minute between cycles. If pump resumes normal deliver, air lock was the trouble.	If this test fails to correct the problem then proceed below
Water level in well too low	Restrict flow of pump output, wait for well to recover and restart pump	If partial restriction corrects the trouble, level discharge valve in restricted setting. Otherwise, lower pump in well if depth is sufficient.
Discharge line check valve installed backwards	Examine check valve. Make sure that arrow indication direction of flow points in correct direction	Reverse valve
Leak in riser (drop) pipe	Raise pipe and examine for leaks	Replace damaged section of drop pipe.
Pump check, valve jammed by riser (drop) pipe.	Lift riser pipe and examine connection at outlet of pump. If the riser pipe has been screwed in too far it may be jamming the pump's check valve in the closed position	Unscrew drop pipe and cut off portion of threads
Pump intake screen blocked.	The intake screen may be blocked by sand, mud or iron bacteria slime	Clean screen and install pump with 10 feet of clearance to bottom of well. If iron bacteria, chlorine addition may be required
Pump parts worn	Sand and mud are abrasive and may cause excessive wear to the pump impeller and bowl. Before pulling pump, reduce settings on pressure switch to see if pump shuts off. If it does, worn parts are probable at fault. This condition would also so a reduction in flow in gpm as well as a drop in motor amperage and an increase in pump running time	Pull pump and replace parts
Motor shaft loose	Coupling between motor and pump shaft may have worked loose	Tighten all connections and set screws

VERTICAL PUMP TROUBLE SHOOTING

Common Problems and possible solutions

INSUFFICIENT PRESSURE

1. Speed too slow (check voltage)
2. Impeller trimmed incorrectly
3. Impeller loose
4. Impeller plugged
5. Wear rings worn
6. Entrained air in pump
7. Leaking column joints or bowl castings
8. Wrong rotation

INSUFFICIENT CAPACITY

1. Speed too slow
2. Impeller trimmed incorrectly
3. Impeller loose
4. Impeller or bowl partially plugged
5. Leaking joints
6. Strainer partially clogged
7. Suction valve throttled
8. Low water level
9. Wrong rotation

NO LIQUID DELIVERED **USING TOO**

MUCH POWER

1. Pump suction broken
   (water level below bell inlet)
2. Suction valve closed
3. Impeller plugged
4. Strainer clogged
5. Wrong rotation
6. Shaft broken or unscrewed
7. Impeller loose

1. Speed too high
2. Improper impeller adjustment
3. Improper impeller trim
4. Pump out of alignment or shaft bent
5. Lubricating oil too heavy
6. Pumping sand, silt or foreign material

VIBRATION

1. Motor imbalance - electrical
2. Motor bearings not properly seated
3. Motor drive coupling out of balance
4. Misalignment of pump, castings, discharge head, column or bowls
5. Discharge head misaligned by improper mounting or pipe strain
6. Bent shafting
7. Worn pump bearings
8. Clogged impeller or foreign material in pump
9. Improper impeller adjustment
10. Vortex problems in sump
11. Resonance - System frequency at or near pump speed

ABNORMAL NOISE

1. Motor noise
2. Pump bearings running dry
3. Broken column bearing retainers
4. Broken shaft or shaft enclosing tube
5. Impellers dragging on bowl case
6. Cavitation due to low submergence or operation beyond maximum capacity rating
7. Foreign material in pump

O & M OF WELLS

WORKSHEET

1. Which strata would be the most likely to produce high quantities of water?

    _______ a. Clay

    _______ b. Consolidated

    _______ c. Confined

    _______ d. Unconsolidated

    _______ e. Basalt

2. The following is a list of material found in a bore hole. Identify which is a description of the largest particle.

    _______ a. Clay

    _______ b. Gravel

    _______ c. Sand

    _______ d. Silt

    _______ e. Fine Sand

3. Rocks that are formed from heat and pressure are called:

    _______ a. Sedimentary

    _______ b. Igneous

    _______ c. Metamorphic

4. Artesian well is primarily found in a ____________ aquifer.

    _______ a. Sedimentary

    _______ b. Artesian

    _______ c. Unconfined

    _______ d. Confined

    _______ e. Any

5. The most desirable type of aquifer for a community water supply is the ____________ aquifer.

    _______ a. Sedimentary

    _______ b. Artesian

    _______ c. Unconfined

    _______ d. Confined

    _______ e. Any

6. A well placed in a water table aquifer would most likely be classified as ______________.

_______ a. GUDISW

_______ b. Confined aquifer

_______ c. Flowing artesian aquifer

_______ d. Groundwater

_______ e. Surface water

7. The ratio of pores to total volume of a section of an aquifer is called ______________.

_______ a. Permeability

_______ b. Specific Yield

_______ c. Specific Retention

_______ d. Porosity

_______ e. Transmissibility

8. The ability of an aquifer to pass water is called_____________________.

_______ a. Permeability

_______ b. Specific Yield

_______ c. Specific Retention

_______ d. Porosity

_______ e. Transmissibility

9. The slope of the cone of depression is primarily influenced by ____________________.

_______ a. Porosity

_______ b. Motor size

_______ c. Diameter of the well

_______ d. Transmissibility

_______ e. Distance to the recharge area

10. The area inside the cone of depression is called, _________________________.

_______ a. Cone area

_______ b. Recharge area

_______ c. Zone of influence

_______ d. Transmissibility area

_______ e. Specific Yield zone

11. The ________________ , the water level in the well prior to the start of the pump.

_______ a. Static level

_______ b. Drawdown level

_______ c. Standing level

_______ d. Specific Capacity

_______ e. Pre-pumping level

12. The the two most common methods of constructing municipal wells are?

_______ a. Driven

_______ b. Dug

_______ c. Rotary bit

_______ d. Bored

_______ e. Percussion

13. Wells that are called deep wells are basically drilled in what type of aquifer?

_______ a. Confined

_______ b. Unconfined

_______ c. Water table

_______ d. Community

_______ e. Deep

14. In Alaska the casing on a public water system well must extend _______ above the ground.

_______ a. 2 feet

_______ b. 18 inches

_______ c. 1 foot

_______ d. 28 inches

_______ e. 6 inches

15. In Alaska, how many feet of grout must there be between the casing and the bore hole on a public water system.

_______ a. 4 feet

_______ b. there is no requirement, the well must be grouted only enough to assure the casing is held in place.

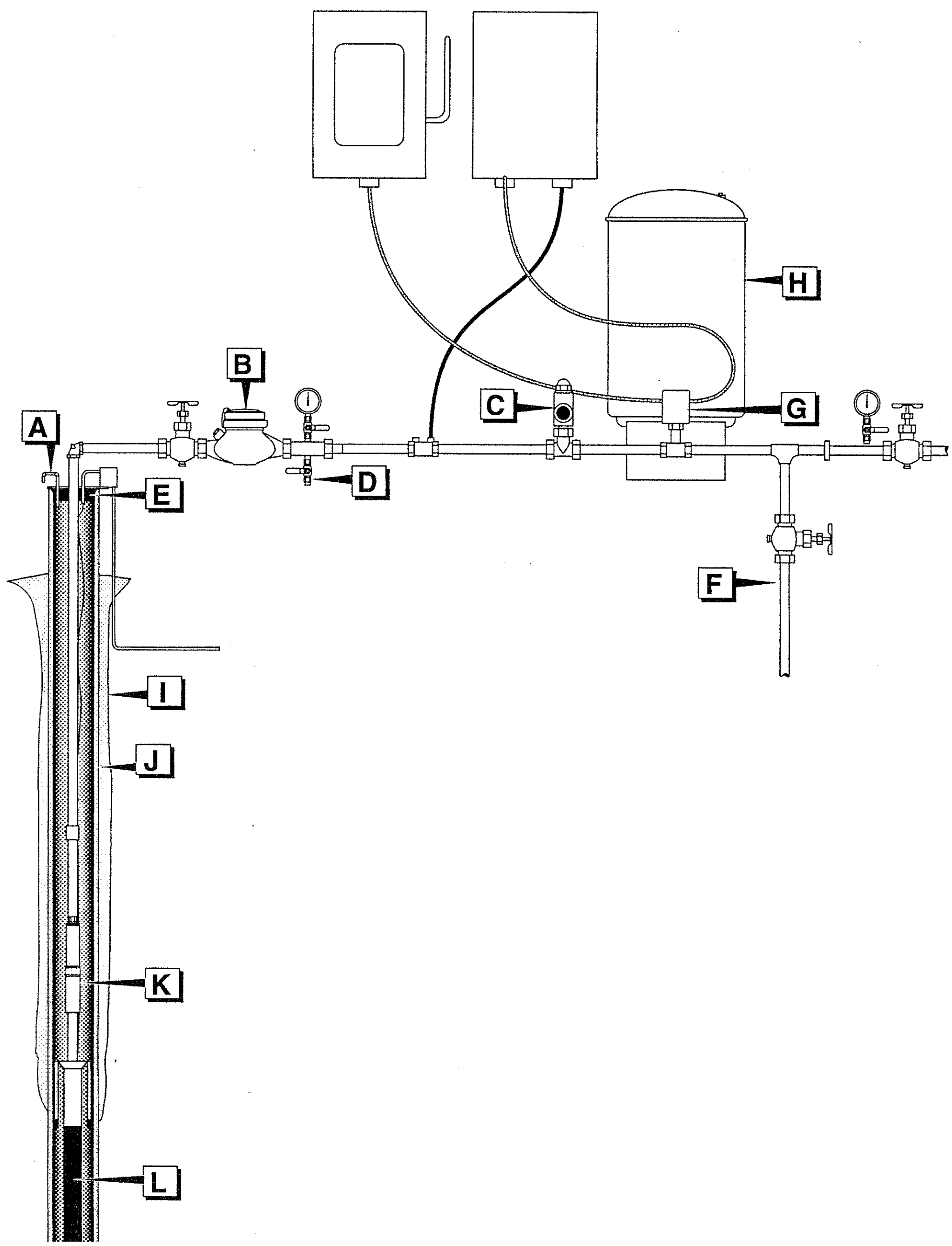
_______ c. 10 feet

_______ d. 25 feet

_______ e. To the end of the first joint of the casing

16. The drawing below is composed of three wells. Identify the components indicated by matching them with the list provided.

I ______ Grout	A ______ Vent
J ______ Casing	D ______ Sample tape
E ______ Sanitary seal	B ______ Flow meter
K ______ Submersible pump	H ______ Pressure tank
G ______ Pressure Switch	F ______ Pump to waste line
L ______ Well screen	C ______ Pressure relief valve



17. Public water systems in Alaska must have a concrete pad poured around the well head. How far must this pad extend from the well head?

_______ a. 5 feet

_______ b. 2 feet

_______ c. 10 feet

_______ d. 20 feet

_______ e. 12 feet

18. How far down must the casing in a well used by a public water system in Alaska must extend?

_______ a. 20 feet

_______ b. 10 feet

_______c. 3 feet into the confining aquifer

_______d. 5 feet

_______ e.3 feet into bedrock

19. Why should the there be a air vent in the casing of a well?

_______ a. Prevent water hammer

_______ b. Prevent air from entering the system

_______ c. Allow excessive air that is released from the water to exit the casing

_______ d. Prevent collapse of the well casing

_______ e. Reduce the possibility of premature failure of the pump

20. A sanitary seal is placed on a well to ______________________________.

_______ a. prevent contamination

_______ b. prevent excess air from entering the well

_______ c. protect the electrical connections

_______ d. protect the motor from sudden drawdown

_______ e. reduce the run time of the electric motor

21. A wide body globe valve is often installed on the discharge of a lineshaft turbine pump. What is the function of the valve?

_______ a. Prevent air intrusion

_______ b. Protect the well from contamination

_______ c. Prevent water from running back down the casing

_______ d. Reduce water hammer

_______ e. Prevent the pump motor from reversing direction

22. The gauge on the discharge of a well pump serves what purpose?

_______ a. Used to calculate specific capacity

_______ b. Used to calculate transmissibility

_______ c. Evaluate the pump operating condition

_______ d. Give the operator something useful to do

_______ e. Tell when it is to replace the packing in the pump

23. A "Spider" bearing is found on what type of pumping installation?

_______ a. Pitless adapter

_______ b. Water lubricated lineshaft turbine

_______ c. Submersible pump

_______ d. Suction lift pumping conditions

_______ e. Spider pumps

24. When referring to the motor used on a lineshaft turbine the terms VHS and VSS are often used. What component are these terms referring to?

_______ a. Pitless adapter

_______ b. Different impeller types

_______ c. Different types of pumping units

_______ d. The motors

_______ e. The type of bearings used on the column shaft of a lineshaft turbine

25. The electric device used to protect the building and its wiring in case of an electrical short is the ____________.

_______ a. Magnetic breaker

_______ b. Transformers

_______ c. Contactors

_______ d. Magnetic starter

_______ e. Motor heaters

26. With a groundwater supply, the process of identifying potential sources of contamination and developing a plan of action on how to deal with these sources of contamination is called....

_______ a. Contamination survey

_______ b. Sanitary survey

_______ c. Well head protection program

_______ d. Recharge survey

_______ e. Federal well recharge area protection program

27. For a Class A water system in Alaska, septic tanks must be at least ________ feet from the well.

_______ a. 50 feet

_______ b. 20 feet

_______ c. 200 feet

_______ d. 100 feet

_______ e. 150 feet

28. 27. For a Class A water system in Alaska, buried fuel not specifically used for heating, must be at least ________ feet from the well.

_______ a. 50 feet

_______ b. 20 feet

_______ c. 200 feet

_______ d. 100 feet

_______ e. 150 feet

29. For a Class A water system in Alaska, community sewer lines must be at least ________ feet from the well.

_______ a. 50 feet

_______ b. 20 feet

_______ c. 200 feet

_______ d. 100 feet

_______ e. 150 feet

30. For a Class A water system in Alaska, roads should be ________ feet from the well.

_______ a. 50 feet

_______ b. 20 feet

_______ c. 200 feet

_______ d. 100 feet

_______ e. 150 feet

31. For a Class A water system in Alaska, above ground fuel used for on-site emergency pumping equipment must be _________ feet from the well.

_______ a. 50 feet

_______ b. 20 feet

_______ c. 200 feet

_______ d. 100 feet

_______ e. 150 feet

32. The presence of algae in a well supply would most likely classify the water sources as......

_____ a. Groundwater supply

_____ b. A Class B groundwater supply

_____ c. A Class C groundwater supply

_____ d. GUDISW

_____ e. Groundwater supply at step 4 with special provisions

33. Use the following data to calculate specific capacity of a well.

- The pressure at the start of the test was 10 psi
- The pressure at the end of the test was 18 psi
- The flow at the start was 145 gpm and the totalizer read 2456200 gallons
- The flow at the end of a 30 minute test was 95 gpm and the totalizer was 2459700 gallons

_____ a. 1.4 gpm/ft

_____ b. 0.25 gpm/ft

_____ c. 0.6 gpm/ft

_____ d. 2.67 gpm/ft

_____ e. 33.7 gpm/ft

34. Why is it operationally sound to collect raw water quality data from a groundwater sources?

_____ a. If the regulations change you can be ahead of the game

_____ b. The engineer may need the data

_____ c. Reduce the possibility of costly emergencies

_____ d. Allows the operator to know just how much water is available

_____ e. There is no reason, it is just a good idea

35. The oil in the motor of a lineshaft turbine should be changed every __________.

_____ a. Year

_____ b. Month

_____ c. Quarter

_____ d. Week

_____ e. Two months

36. How often should the Specific Capacity of a well be checked. (The desirable frequency not the absolute minimum).

_______ a. Yearly

_______ b. Monthly

_______ c. Quarterly

_______ d. Weekly

_______ e. Every two months