Training Guide

An Introduction to Water Loss and Leak Detection
Rural and Small Water Systems
Training Guide

An Introduction to Water Loss and Leak Detection

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Introduction

This guide is *An Introduction to Water Loss and Leak Detection*. In it you will learn about the types of water loss and the steps in isolating and pinpointing leaks.

NOTE: This guide is intended only as an *introduction* to the complex task of performing a leak detection survey. It will help you recognize those parts of a leak detection survey that you and your staff can do yourselves, and those steps that will require more expert help. **Before beginning a leak detection survey, please read this training guide completely.**

Remember that leak detection is not an exact science, and that no two water systems are alike! Each system presents its own special challenge. If you are familiar with the entire leak detection process before you begin, you can design a program that is best for your system.
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Chapter 1

Water loss and leak detection an overview

Almost every water system has a problem with water loss. When water is under pressure in miles of buried pipes, you can be sure that water will be lost somewhere!

Sometimes it is easy to find the reasons for water loss, and other times it is very difficult. This training guide will review the benefits of finding lost water and the different types of water loss. It will also give you some tips for finding missing water.

What are the benefits of finding lost water?

There are many good reasons to search for missing water. By lowering your system's water loss, you can reduce wear on equipment. You can also lower electricity bills and other operating costs for treating, pumping, and storing water.

Solving water loss problems can even improve public relations by helping you lower rates and improve service. If your system is operating more efficiently, you may eliminate the need for costly capital improvements. You may also be able to expand service.

Also, reducing water loss helps protect the public health. For example, if water loss is caused by leaks, repairing them lowers the risk of a cross-connection. By fixing leaks you may also lower insurance costs and reduce system liability.
Perhaps the most important benefit of finding lost water is to save a precious resource. Because of pollution and increasing demands, saving water is becoming more important each year.

**What are the types of water loss?**

Water loss is unmetered water that leaves a water system. In some cases, water only *seems* to be missing because of human errors or other errors such as broken meters. Genuine water loss is generally caused by three things: authorized unmetered accounts, theft, and leaks.

---

**Authorized unmetered accounts**

An authorized unmetered account refers to any legal connection to the water system that is not metered.

Some water systems supply water at no charge to special users without installing a meter. This practice is not recommended. Install meters for all users including those who are not billed.

---

An authorized unmetered account (such as the golf course at left) is any legal connection to the system that is not metered.
Authorized, unmetered accounts may include:

- free accounts (elderly, low-income, special arrangements)

- city facilities
  - water and wastewater plants
  - fairgrounds
  - parks
  - golf courses
  - cemeteries
  - playgrounds
  - landscapes
  - swimming pools
  - city shops, offices
  - water fountains

- community facilities
  - state and county offices
  - schools
  - churches
  - hospitals
  - rest homes

- fire fighting

- special events (fairs, construction)

- maintenance equipment and procedures
  - water line flushing
  - hydrant flushing
  - sewer cleaning
  - street cleaning
  - storage tank drainage
  - pump and turbine cooling
  - filter backwashing

(For filtered systems, water is used for filter backflushing. Treated water used for backwashing can account for 2% to 10% or more of the total treated water.)

Install meters to unmetered connections as soon as you discover them. Estimate the amount of water that has been used for the past year. You can use this figure to adjust any estimates you may have made about the amount of water your system is losing.

For help in making estimates, see the Appendix
Theft

Another cause of water loss is unauthorized connections (theft). Unauthorized connections include:

- disconnected sources illegally re-connected
- closed accounts that have been illegally reopened (billing has been stopped but the service has not been disconnected)
- illegal taps on distribution lines
- connections to fire hydrants for non-emergency use
- meters that have been turned around
- meters with registers removed
- illegal taps that bypass meters

When reading meters or performing any other work on the distribution system, look for signs of theft. Stop unauthorized use as soon as you discover it. (Be sure to check the legal rights of water systems in your area.)

Estimate the amount of loss because of unauthorized connections. You can use this amount if you adjust any estimates you may have made about the amount of water your system is losing.

Leaks

For most systems, leaks are the hardest form of water loss to control. A leak is any hole, crack, or flaw in the system that permits the uncontrolled flow of water. A leak can occur at any point in a water system.

For example, a leak may be a hole in a pipe. A leak may be an overflowing storage tank. A leak can occur around worn pump packing or a damaged fire hydrant seat. A check valve that lets water drain back into a well is a type of leak, too.
Underground leaks often go undetected for long periods. This is because NOT ALL LEAKS SURFACE!

What is the first step in finding leaks?

The best way to find leaks is with a leak detection survey. This is a step-by-step way of locating a leak wherever it may occur.

The first step in a leak detection survey is to collect the maps of your system. This is discussed in Chapter 2.
Chapter 2

Maps

A leak detection survey begins with good maps. These will help you create an efficient leak detection plan for your distribution system. Maps also help to find lines, valves, and other buried parts of the distribution system where leaks might occur.
Map selection

Select a map that shows the principle mains of the entire distribution system. The map should show water sources, treatment plants, mains, line sizes, valves, service lines, curb stops, hydrants, and elevations.

As a tip, keep maps that show previously repaired leaks and the locations of customer complaints. These may provide clues to locating leaks.

Making maps

Some systems do not have complete or up-to-date maps. In this case, it may be necessary to make new maps. You may not, however, need to create a map from a blank sheet of paper. There are several possible sources of help.

Contractors or engineers who installed the original system generally keep a file for each system they design. You might also obtain maps from inspectors, lending agencies, and other people and offices associated with your system's construction.

Many state regulatory agencies require that a set of plans and maps be submitted for any original construction or upgrade. These maps are kept on file.

Maps of your system may be on file with your state regulatory agency.
If you must draw new maps, use aerial photos or regional or county maps to start. When drawing new maps, include:

- water sources
  - spring location and development
  - well location
  - reservoirs
- treatment plant
- storage facilities
- mains
- service connections
- valves
- fire hydrants
- elevations
- other utilities

All pipes should be identified according to type, size, and depth. Also, the exact distance from a reference point is useful.

Information about valves and hydrants are sometimes kept on separate maps. This information includes the model type, installation date, plus the direction and number of turns for opening valves.

Mapping for the future

If your system does not have maps now and chooses not to make maps at this time, record the location of repairs and new lines on city or county maps. In this way, you can begin to create a set of maps.
Chapter 3

The preliminary survey

Some parts of a water system leak more than others. At the beginning of your leak detection work, perform a preliminary survey. Look for signs of leaks and check the most common places for leaks to occur.

Inspect the system by sight

Leaks are found by sight or sound. The simplest way to find leaks is to look for wet spots. A wet spot does not tell you exactly where a leak is, though. Some leaks may flow many feet before surfacing. Also, some wet spots are not leaks at all! A wet spot is just an indication that a leak may be in the area.

The following is a list of some of the places where you may find leaks by visual inspection:

- storage tank overflows
- stuck air relief valves
- excessive leaks because of old or worn pump packing
- new or recently repaired lines
- cracked meter bottoms
As you inspect the area, look for illegal taps or connections. For example, check fire hydrants on private property for illegal hose attachments.

**Damaged fire hydrants**

One of the most common sources of leaks is fire hydrants. Valve seats can be damaged or improperly seated. Water can leak past these and out through drain holes inside the hydrant barrel.

Some operators check fire hydrants for leaks by listening to each hydrant. Listen for leaks by using one of the listening devices or techniques described in Chapter 5.

If the hydrant is a dry barrel type, you may be able to listen for leaking water without special listening devices. To listen for leaks, first make sure the hydrant valve is completely closed. Stand to one side of the hydrant (in case it isn't working properly) and remove one of the nozzle caps. If you do not see any signs of a leak, listen from the open nozzle. You may be able to hear leaking water.

**Customer complaints**

Finally, do not forget customer complaints. Review recent customer contacts. Comments about pressure changes or flow interruption may provide clues about which parts of the system need repair.

**The next step**

If you still cannot account for a significant part of your water after checking the common sources of leaks, the chances are good that your system has leaks underground. The procedure for isolating leaks is described next.
Chapter 4

Zones and zone measurements

Finding leaks that do not surface can require dividing a water system into "zones" and taking "zone measurements."

A zone is an area that can be isolated from the rest of the system by closing key valves. A zone measurement is an estimate of all water use within a zone, including leaks.

Unusually high use in a zone can mean there is a leak. Low use can identify areas that do NOT have serious leaks. By comparing measurements of each zone, you can determine where the worst leaks are.

Zone measurements are normally taken late at night when customer use is expected to be low. Usually, the best hours are between 2:00 AM and 4:00 AM. If there is no customer use, any running water you detect is probably caused by a leak.

Zone measurements can save time and money by eliminating large portions of a water system from additional leak detection work.

Caution: When you isolate a zone, you may be interrupting service to hospitals, fire fighters, and other emergency users. Develop a plan for quickly returning service if any emergency should develop during leak detection.

Taking zone measurements may also temporarily interrupt normal service to customers. Before beginning work, tell your customers what you are doing.
Some systems notify customers by newsletter, newspaper, television, radio, or bill stuffer. These notices give the location of the zone and when zone measurements will be taken.

Selecting zones

To select zones, examine the maps for your system. Some zones may be obvious.

For example, a community may naturally divide into three zones. These zones could include a business area, and two residential areas.
Some community water systems are "looped." These will require valves on the loop that can be closed to create zones.

Rural water systems often branch into several clearly distinct zones. If possible, look for zones that have approximately the same amount of pipe or number of connections. This makes comparing zone measurements easier.

Note: For some very small systems it may not be necessary to divide the system into zones. It may be possible to begin leak detection with a listening program as described in the next chapter.

**Zone measurements**

The next step is to take zone measurements. Zone measurements can give you an idea of how much water is being lost in each section of your system. In this way you begin to narrow down the exact location of leaks.

**Detecting leaks in a zone**

In some cases you may want to begin your examination of a zone by simply checking for any use at all. For example, a zone may contain only businesses and offices that are closed during the zone measurement period. If the zone is isolated and water use is detected, the use is probably caused by a leak. If no flow is detected you can eliminate that zone and move on to another.

There are two quick ways to check for possible leaks in a zone. You can listen for leaks, or check for leaks with a pressure gauge.

One way to find leaks in a zone is to listen for water use.
Listening for water use

1. Select a zone measurement time (such as 2:00 AM to 4:00 AM).
2. Close all valves that control flow into and out of the zone.
3. Listen to each valve. If you hear water seeping past, you may want to repair the valve before going on.
4. Open the valve that controls water flow into the zone.
5. Listen to the valve. If the zone is completely isolated and there is no customer use, there should be no sound of water flowing past the valve.

Testing pressures for possible leaks

Another way to find a zone with leaks is to observe water line pressures:

1. Select a zone measurement time (such as 2:00 AM to 4:00 AM).
2. Install a pressure gauge at any point in the zone.
3. Close all valves that control flow into and out of the zone.
4. After all valves are closed, listen to each one. If you hear water seeping past one, you may want to repair it before going on.
5. Observe the gauge during the measurement period.

If there is little or no use during this time, there should be little change in the water pressure.
If there is a significant drop in pressure, (greater than 5-10 psi per minute) there may be a leak. Notice how the pressure changes. Customer use will make pressure changes irregular. A water leak is steady. The drop in pressure caused by a leak will also be steady.

**Measuring water loss in a zone**

If leaks are suspected, storage tank levels or meters can measure use within a zone.

**Storage tank levels**

One of the easiest ways to measure water use in a zone is to use storage tank levels. If a zone can be isolated to include a tank, water use can be measured by the drop in water level.
1. Select a measurement period (such as 2:00 AM to 4:00 AM).

2. Close all valves that control flow into and out of the zone.

3. After all valves are closed, listen to each one. If you hear water seeping past any valve, you may want to repair it before going on.

4. Record the tank levels at the beginning of the period.

5. Open the valve that controls water flow into the zone.

6. Record the tank levels at the end of the period.

   Calculate the number of gallons used during the zone measurement time. See the Appendix for a review of the formula for calculating the volume of a storage tank.

**Meters**

Another way to measure flow into a zone is by placing a meter at the entrance to the zone. Meters may be in-line or you may bypass the valve with a meter jumper.
1. Select a measurement period (such as 2:00 AM to 4:00 AM).

2. Close all valves that control flow into and out of the zone.

3. After all valves are closed, listen to each one. If you hear water seeping past any valve, you may want to repair it before going on.

4. Record the meter reading at the beginning of the period.

5. Open the valve that controls water flow into the zone.

6. Record the meter reading at the end of the period.

   The size of the meter depends on the flow. Generally, you can use a 2" meter. Be sure, however, that the meter you use is matched to the flow of water being tested.

   Meters can give you accurate information, but using them can be difficult. Installing a meter can be expensive and time-consuming.

   **Note:** Be sure to open all valves that were closed for the zone measurement!

### Evaluating the measurements

Before going on to any more leak detection work, analyze the data you have collected. Compare the measurements for one zone with the others. Ask questions about your findings:

- Does one zone seem to be using more water than the others?
- Is there a reason for excessive use other than leaks?
- Can some zones be eliminated from additional leak detection work?

### Sub-dividing zones

If one zone seems to have unusually high water use, you may want to look at your map again. If possible, divide a zone into smaller sections. Examine each section as described in this chapter. Work one section of the zone completely before moving to the next.

Continue like this throughout the area. Check smaller lines leaving the main line and continue listening from valve to valve. Narrow down the location of a leak as much as possible.

### The next step

The next step is to proceed with a listening survey to pinpoint the location of the leak.
Chapter 5

Pinpointing leaks

In the last chapter you learned how to narrow down the location of a leak to a part of a zone. This chapter will review the steps in pinpointing leaks. These include:

- selecting equipment
- looking at and listening to all valves, hydrants, pumps, etc. for signs of leaks
- listening to water lines

Leak detection equipment

A variety of equipment is available for leak detection. Equipment can range in cost from a few dollars to thousands. Most leak detection devices have one thing in common, though. Each depends on the sound (vibrations) leaks make.

Simple devices

The simplest listening device is something that can carry the vibrations caused by a leak. For instance, some operators "listen" to a hydrant by placing the tip of a screwdriver or wrench against the valve stem and the handle next to their ear. The vibrations
created by water passing a damaged valve seat may be detected in this way.

*A hydrophone* is an inexpensive device that works the same way, but is designed for more comfortable and convenient listening.

*Geophones* are another inexpensive listening device. Geophones are similar to the stethoscope a doctor uses.

### Electronic leak detectors

Electronic leak detectors are much more sophisticated and complex than geophones. These electronic devices amplify sound caused by the vibrations of leaking water.

### Using electronic leak detectors

Operating electronic leak detection equipment requires some skill and practice. Experiment with leak detection equipment before using it for leak detection.

For assistance, contact an authorized factory representative or a professional water association in your area.
Leak correlators

The most elaborate leak detection device is the leak correlator. Leak correlators are not affected by depths or soil type. A leak correlator is a microprocessor device that measures the time it takes for sound to travel between two points along a pipe.

Leak correlators are very expensive and complex. Leak correlation services are normally provided by private contractors.

To use a leak correlator successfully, you must know the location and length of the pipe you are checking. This is why you need detailed maps of your system. When accurate data is fed into a leak correlator, the chances of pinpointing leaks are extremely good.

Other equipment

Other equipment that may be useful in leak detection include valve box locators, line tracers, and various tools.
Valve box locators

Valve box locators help locate valve boxes, curb stops, or manhole covers. Water systems in cold weather states with excessive snow or ice cover may find these especially useful.

Line Tracers

A line tracer is useful when maps are not available to show the location of metal pipe. A line tracer will not locate plastic lines unless a metal wire was installed with the water line.

Tools

Tools that are useful for leak detection include:

- a meter valve wrench for opening and closing curb stops
- a valve wrench for opening and closing main line gate valves
- pipe wrenches
- a 50' to 100' tape measure
- shovels
- a pressure gauge and various fittings

You will need a variety of tools for leak detection work.
Listening for leaks

The next step is to begin listening for leaks in the area you have isolated.

Leak sounds

Leak detection by listening is possible because of two sounds. One is the sound water makes as it leaves a restricted opening. The sound is sent through the pipe wall and along the length of the pipe. The other sound is made by escaping water hitting the surrounding soil.

Leaks can make different sounds. The sound of a leak depends on:

- pipe material
- depth of the pipe
- composition of the soil
- size of the leak
- depth of the water table

Smaller leaks under high pressure usually make more noise than larger leaks under low pressure. In some cases, large leaks under low pressure make almost no sound. If these do not surface, locating them can be very difficult.

When you hear a leak, try to determine if it is near or far. For example, if you hear water passing through a valve, continue listening from valve to valve throughout the area. Usually, the louder the noise, the closer the leak.
Sounds can be misleading, however. Sometimes the sounds of a leak are confused with traffic noise or wind. Always double check an area before digging.

**Listening to devices**

The best place to listen is on the distribution pipe itself. Unfortunately, it is not always easy to get to the pipe. If you can't listen on the pipe, listen on any contact point on the system. These include meters, pumps, hydrants, and valves. Pay special attention to fire hydrants (see Chapter 3) and valves.

**Valves**

There are several different types of valves you can use on a water system. These can include valves used for:

- shut-off and flow regulation
- pressure regulation
- pressure reducing and pressure sustaining
- air and vacuum relief
- pressure relief
- valve protection
- tank level regulation
- blow-off and drain access
- backflow prevention

Regardless of the type of valve, inspect for signs of damage or leaks. Look at the area around the valve for damp spots. Listen to valves for sounds of jetting water when the valve should be closed.
For example, many leaks have been discovered around isolation valves. These are often used for flow shut-off and regulation. Inspect the stem and nut of isolation valves. Inspect the valve for proper operation. Close the valve completely and count the number of turns. Compare this number with other maintenance records if they are available. If the number of turns has changed since the last inspection, the isolation valve may be damaged.

If you hear leak sounds on these devices, the next step is to pinpoint the leak by listening to lines.

Listening to lines

For many water systems, the distribution pipe is nonmetallic and the contact points are far apart. In this case it may be necessary to use a geophone or an electronic ground leak detector to pinpoint underground leaks.

Begin by locating distribution system pipe with a line tracer if the pipes are metallic. Otherwise, use system maps to find the exact location of pipe. You may want to mark the ground that is directly over the buried pipe.

Listen along the line of the pipe every 5 to 10 feet. Mark the spots where the sounds are the loudest.
Note: When you think you have located the leak, review your steps and repeat the listening! If you do not hear the sound again, you have not discovered a leak.

Sounds can be misleading. The vibrations from leaks can travel along the pipe and be heard some distance from the leak. Vibrations may also be caused by other things, such as customer use or leaks on other lines.

Inspect the area above the leak sound again. Look for damp spots or any other thing that may cause a noise.

If there is clearly no other reason for water use, and you still hear a noise when you listen again, you have probably discovered a leak.

Service lines

Some leaks occur on customer service lines. Check records for customer complaints of low pressure or water in a basement.

For a quick check, close the curb stop. Make sure the customer does not have a tap open. Slowly open the curb stop and listen. If you hear water passing through the valve, the customer may have a leak.

Caution: If you must do some digging, practice good trench safety. Be sure you know where underground utilities are before you start. Beware of buried gas lines, power cables, cable TV and telephone lines. Before digging, contact these companies for location and marking.

Recording Leaks

When you repair a leak, measure or estimate the amount of water that is leaking and record your findings. Include the:

- size of leak
- amount of water recovered
- cause and type of leak
- location
- date located and repaired
- repairs made

Estimating water loss

In some cases you may want to estimate the amount of water that was lost because of a leak. For help, see the Appendix.
Appendix
Making estimates

In this section you will learn how to find the volume of a tank, and how to estimate the amount of water lost because of leaks, theft, or other authorized unmetered connections.

Estimating volume

The formula for estimating volume is:

\[
\text{Volume in cubic feet} = 3.14 \times \left(\frac{1}{2} \times \text{Diameter}\right)^2 \times \text{Height}
\]

To convert cubic feet to gallons multiply by 7.48:

\[
1 \text{ cubic foot} = 7.48 \text{ gallons}
\]

EXAMPLE: A storage tank has a diameter of 20 feet and has a height of 40 feet. The volume is:

\[
3.14 \times \left(\frac{1}{2} \times 20\right)^2 \times 40 = 12,560 \text{ cubic feet}
\]

\[
12,560 \text{ cubic feet} \times 7.48 = 93,948.8 \text{ gallons.}
\]
Estimating water loss

Authorized and unauthorized use

Bulk use is the easiest unmetered use of water to estimate. This is because water taken from the system enters a truck or tank of known size. If you know the number of times the container was filled, your estimates will be accurate.

For other unmetered connections, compare the unmetered use with a similar metered use. For example, an illegal connection on a stock tank may be very much like another field connection that is metered.

If there is no similar metered use, estimate using one of the methods described in the next section for leaks.

Leaks

If the leak is in a place that is easy to reach, try to find the amount of time it takes the leak to fill a bucket of known size. From this figure, you can estimate the amount of water loss in gallons for the record review period.

EXAMPLE: A leak filled a five gallon bucket in 20 seconds:

<table>
<thead>
<tr>
<th>5 gal.</th>
<th>15 gal.</th>
<th>900 gal.</th>
<th>21,600 gal.</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 sec.</td>
<td>1 min.</td>
<td>1 hr.</td>
<td>1 day</td>
</tr>
</tbody>
</table>

If the leak is hard to reach, try calculating the loss. The formula is:

\[ \text{Loss in gallons per minute} = 30.394 \times \text{Area of hole or crack in square inches} \times \sqrt{\text{pressure in pounds per square inch}}. \]

To find the area of a circle:

Radius = \( \frac{1}{2} \) diameter

\[ \text{Area} = 3.14 \times \text{radius}^2 \]

EXAMPLE:

A leak is coming from a hole approximately 1/4 inch in diameter. The pressure on the line is 60 pounds per square inch.

First, find the area of the hole:

\[ 1/4 \text{ inch} = .250" \]

\[ \text{Radius} = 1/2 \text{ of } .250" = .125" \]

\[ \text{Area} = 3.14 \times (.125)^2 = .049 \text{ sq. in.} \]

Next, put the area into the formula:

\[ 30.394 \times .049 \text{ sq. in.} \times 7.75 \text{ psi} = 11.54 \text{ gal. per min.} \]
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