NATURAL RESOURCES CONSERVATION SERVICE

Virginia Engineering Design Note 614 (DN-614) Watering Facility

September 2010

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WATERING FACILITY
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This document presents a guide for Natural Resources Conservation Service field staff and conservation partners for the planning, design, construction, and maintenance of watering facilities and associated livestock watering system components. It is only a guide – NRCS conservation practice standards and construction specifications must be followed. In addition, environmental evaluations need to be conducted and other requirements, as directed by law and agency policy, need to be met.

This document is divided into two parts. Part I presents an overview to introduce watering system terminology, concepts, safety, and the overall process from planning to design, installation, and maintenance. Part II presents a computer spreadsheet tool. The tool is applied to eight examples to demonstrate design calculations.

The information presented in this Design Note is a compilation of the wealth of livestock watering system design knowledge from the most experienced NRCS and conservation partner staff in the state of Virginia. In addition, this document also draws from the USDA-NRCS Engineering Field Handbook, USDA-NRCS Montana Stockwater Pipeline Manual, information provided by the East National Technology Support Center, and materials presented at NRCS-sponsored training sessions in Virginia, such as *Introduction to Conservation Engineering* and Joint Employee Development seminars.

Photograph courtesy of Wayne Turley, Holston River SWCD.

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Part I: Overview

Watering facilities enable a producer to provide a reliable source of water for livestock while protecting the quality of surface waters, reducing erosion, and allowing for improved use of pasture lands. Benefits to the natural resource base include:

- Soil: Erosion due to traffic and overgrazing near streams and ponds is reduced.
- Water: When used in combination with fencing of open waters, water contamination from livestock feces and stream bank erosion is reduced.
- Air: Animal wastes may be more evenly distributed in a grazing situation with watering facilities. This will reduce localized odor problems.
- Plants: Trampling of riparian vegetation is reduced. A well-planned grazing/watering system provides better distribution of nutrients from livestock feces.
- Animals: Livestock benefit from a reliable, clean source of water. Aquatic wildlife benefits from improved surface water quality and reduction in stream bed disturbance.
- Humans: Livelihoods of humans benefit from improved livestock health and improved water quality of streams.

The engineering principles governing watering system design are relatively simple and the associated calculations can be performed with the spreadsheet design tool featured in Part II. Nevertheless, the majority of the watering system is located beneath the ground, making it difficult to identify and correct mistakes once the system is in place. Attention to detail in every phase is critical because the consequences of failure can be severe to the livestock operation.

This portion of the Design Note reviews basic terminology and concepts and then outlines a procedure based on the NRCS Three-Phase Planning Process. Its purpose is to provide the inexperienced conservationist with a big-picture understanding of what is needed to design a livestock watering system. Part II provides calculation details using the Virginia Livestock Watering Systems spreadsheet tool.

Chapter 1. Concepts and Terms

Figure I-1 illustrates components of a typical watering system. Water moves from a **source** (such as a well, spring, pond, or stream) through a **pipeline**, possibly to a **reservoir**, and then to **troughs** where the animals drink. There are three major types of troughs commonly used in Virginia:

- Freeze-proof or frost-free trough: These troughs are commercially available and made of durable plastic. Animals push down on a plastic ball to drink. An insulating tube inserted into the ground about four feet deep helps to keep the supply line from freezing. The trough itself is insulated and the water is covered except when an animal drinks.

- Heavy equipment tire trough (HETT): Used tires from heavy construction equipment can be salvaged for use as troughs. They generally hold more water than frost-free troughs and are often used in situations where storage is used to compensate for a low supply rate. Make sure the tire's liquid ballast was not a toxic substance.

- Concrete troughs: Concrete troughs can be pre-cast or formed in place. They generally hold more water than frost-free troughs.

Examples of watering troughs are shown below. Standard design drawings for troughs can be found at the Virginia NRCS SharePoint site:
https://nrcs.sc.egov.usda.gov/east/va/engineering/Standard%20Drawings/Forms/WebFldr.aspx

Frost-Free Trough *Heavy Equipment Tire Trough (HETT)* *Concrete Trough*
Photographs courtesy of Chris Barbour, Skyline SWCD

Associated with the trough and pipeline are plumbing **fittings** and **valves** for connecting the pipe sections and controlling flow. The trough is surrounded by a **heavy use area**, an apron of gravel or concrete designed to withstand livestock traffic. Moving the water from the source to the troughs requires energy, which may lead to consideration of a **pump**, **power source**, and **control devices**. Each of these components requires decisions on the part of the landowner and the overall design must be within the context of the farm management system, water budget, energy budget, and delivery system.

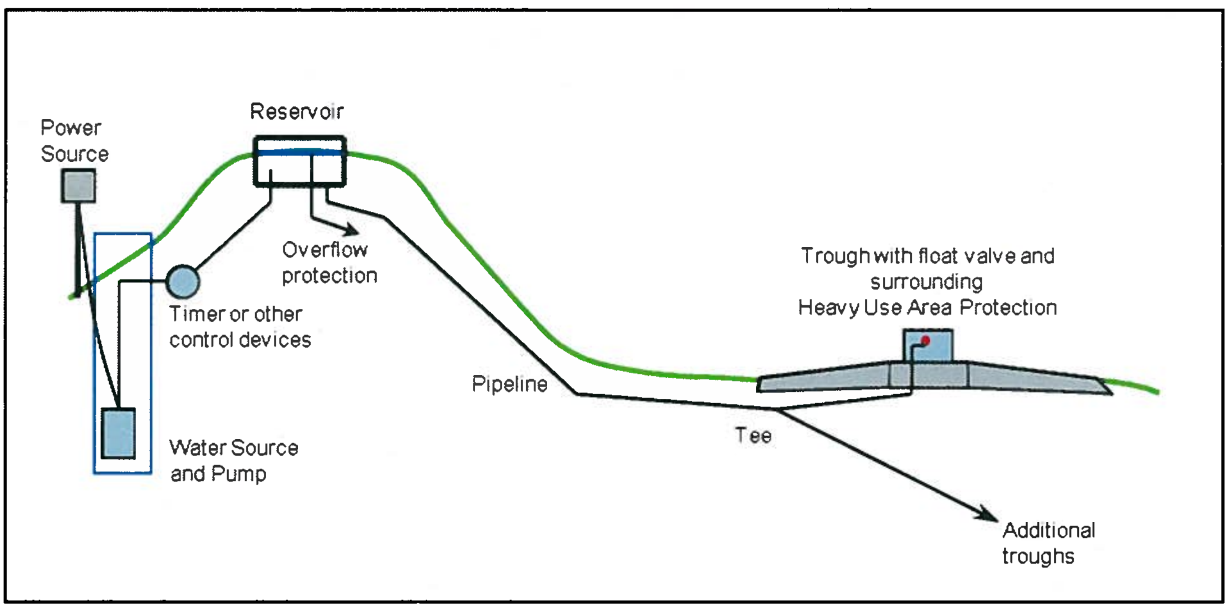


Figure I-1. Typical components of a watering system.

1. Water Budget

The water supply must be adequate to meet the needs of the livestock, take into account losses due to leakage, spillage, and evaporation, and provide storage or a factor of safety to handle fluctuations in supply or demand. Determining water demand is central to system design. Key concepts are **daily water demand** and **peak water demand**. The **daily water demand** will determine if a water **source** is adequate, while **peak water demand** governs sizing of system components.

Daily Water Demand. Total number of animals, species, age, weight, season, and water content of feed all influence how much water a herd will use per day. Appendix A-2 lists some typical daily water requirements for various livestock. However, there is very little information as to the conditions under which the data presented in Appendix A-2 were collected. Use Appendix A-2 as a starting point for most year-round applications and adjust if deemed appropriate based on local and landowner experience.

The water source needs to be evaluated to make sure it can meet the daily water demand for the herd. For example, 100 beef cow-calf pairs consuming a total of 2000 gallons per day require a water source yielding more than 1.4 gallons per minute (with continuous gravity flow or a pump running 24 hours a day):

$$Minimum\ required\ source\ flow\ rate = \frac{daily\ demand\ (gal/day)}{source\ flow\ duration\ \left(\frac{hrs}{day}\right) \times 60 min/hr}$$

$$= \frac{2000\ gal/day}{24\frac{hrs}{day} \times 60\ min/hr} = 1.4\ gpm$$

If the water source for that example only yields 1 gpm, then supplemental or alternative sources need to be identified. Limited access to a stream, for example, may be one option.

Peak Water Demand. Daily water usage will not be spread out evenly over 24 hours. Distance to the trough, trough design, herd behavior, and weather will determine how often the livestock drink and how many drink at one time, and thus, how much water needs to be available at a given time. Peak demand is often estimated by dividing the total daily demand for the herd by the number of times per day the herd will drink (typically 2-5 times per day), and then again by the number of minutes it takes for the whole herd to drink (typically 30 minutes to 2 hours). For example, if the same beef herd consumes a total of 2000 gallons per day by drinking three times a day, and the operator desires the whole herd to be watered in one hour each of those three times, then the average peak demand is 11 gallons per minute:

$$Avg.\ peak\ demand = \frac{daily\ demand\ \left(\frac{gal}{day}\right)}{no.\ of\ times\ herd\ drinks\ per\ day\ x\ minutes\ to\ water\ herd}$$

$$= \frac{2000\ gal/day}{3\ times\ per\ day\ x\ 60\ minutes} = 11\ gpm$$

However, peak demand could be much higher. A cow in Floyd County, Virginia, was timed to consume 5 gallons of water in 30 seconds (10 gpm). If four such cows drank simultaneously from a trough, peak demand would be 40 gpm. Grazing Lands Specialists with USDA-NRCS ENTSC GLCI (2008) report typical individual cattle drinking rates of 1-2 gpm for 2-3 minutes per event, with the rate and duration increasing dramatically with increased travel distance and stress. Peak demand at a trough serving four individuals each drinking at a rate of 2 gpm would be 8 gpm, with each group of four consuming about 24 gallons. A four-ball freeze proof trough might hold 40 gallons. If the trough does not have sufficient volume to meet the needs of the drinking group and that of the groups that come in behind, the pump will need to compensate at the rate of consumption or the animals will have to wait. The consequences of livestock waiting for water will depend on the operation. In some situations, the lead animal (who drinks first) will leave and the herd will follow to go back to grazing or shade even if some members have not had a chance to drink. This will likely not be the case in a well-planned rotational grazing system with the trough visible to the herd from all parts of the paddock.

So what is the "correct" peak demand value to use in watering system design? In Virginia, common watering system delivery rates range from 5-20 gpm. Ogles and Hall (USDA-NRCS ENTSC, 2008) do not recommend sizing a system to meet the most extreme hot weather condition (although there should be a contingency plan for such days). Start with the average peak demand and increase if justified by local field office or landowner experience and knowledge of the specific operation. Some experienced field staff use a minimum of 8 gpm for systems with frost-free troughs and a minimum of 5 gpm for systems with large volume troughs (HETT or concrete). The planner needs to work with the landowner to match the troughs and other system components to the herd size and management system. If water cannot be delivered at the peak rate required to water the herd in an acceptable time period (due to source flow rate limitations), storage (either larger troughs or a reservoir) will need to be incorporated into the system. System design may also need to accommodate occasions when supply exceeds demand by providing overflow protection, such as a float valve, dry well, or routing to a stream.

2. Energy Budget

System design involves, among other things, making sure there is enough energy to get water from the source to the trough and allowing for energy "lost" along the way. It is convenient to consider four categories of energy:

1) Potential energy: Energy due to the elevation of water.
2) Kinetic energy: Energy due to the velocity of flowing water.
3) Pressure energy: Energy added to water by mechanical means, such as a pump.
4) Energy "losses": Energy that is not useful for moving water in the watering system because it is dissipated as heat to the surroundings. This includes energy due to friction and other losses. Losses increase with:
   - Increasing pipe length
   - Decreasing pipe diameter
   - Increasing inside surface roughness of the pipe
   - Increasing flow rate
   - Increasing number of fittings (couplings, tees, elbows, valves, etc.)

Energy can be converted from one category to another and the different types can be added together to assess the energy budget. The energy budget is based on the fact that, as water moves from one point to another, total energy remains constant after accounting for energy expended along the way due to friction and other losses.

Energy has units of distance and force (foot-pounds). However, these are not the easiest terms by which to discuss energy budgets in watering systems. A concrete sidewalk has a length, width, and thickness. If the width and thickness are uniform, one could, for convenience, talk about so many linear feet of concrete and could quickly convert to square feet or cubic feet as needed. Similarly, it is practical to talk about energy of water in terms of feet of "head" or in terms of pressure (psi or pounds per square inch).

- **Head is energy per unit weight:** ft-lbs/lb = feet
- **Pressure is energy per unit volume:** ft-lbs/ft^3 = lbs/ft^2 or lbs/144 in^2

Since liquid water consistently weighs 62.4 lbs/ft^3 (for all practical purposes within the scope of this document), there is no ambiguity in using whichever units are convenient.

Useful Conversions

62.4 ft-lbs = 1 ft of head
1 ft of head = 0.433 psi
1 psi = 2.31 ft of head
1 psi = 144 ft-lbs

Energy Budget Example:

A 1000' section of 1½"-diameter PE pipeline carries water from point A at an elevation of 100' to point B at an elevation of 150.' Flow rate is 8 gpm. Pipe diameter, pipe material, and flow rate influence the magnitude of the losses in going from A to B which are estimated to be 5 feet of head. Desired pressure for point B is 10 psi. How much energy (pressure) will need to be added to point A to accomplish the desired conditions at point B?

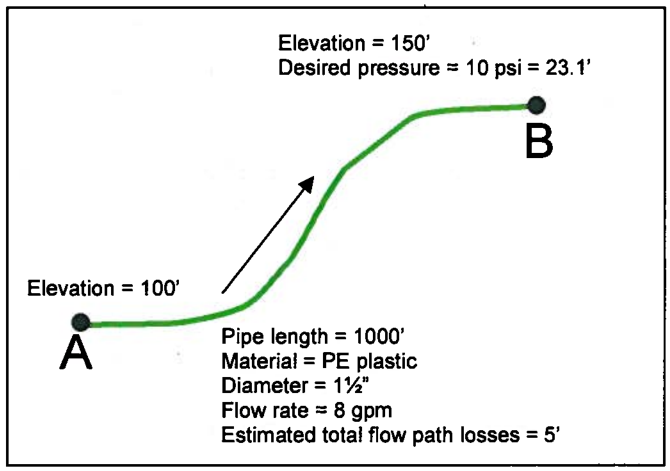


Figure I-2. Relative elevations for points A and B.

Solution:

Examine potential and pressure energy at both ends of the system and the losses incurred along the flow path. Kinetic energy usually does not need to be included in the mathematical balance: if the water starts and ends at rest, kinetic energy is 0 at both ends. If water is moving, velocity (and kinetic energy) will be the same at both ends if the flow rate and the pipe diameter are constant.

Point A:		Point B:	
Potential energy = 100' (given)		Potential energy	= 150' (given)
Pressure energy = ?		Pressure energy = 10 psi	= 23.1' (desired)
		Losses along the way	= 5' (given)
Total energy at A = 100' + ?		Total energy plus losses at B = 178.1'	

Since total energy at A has to equal total energy at B plus losses, the Pressure energy at A = 78.1'. Thus, a pump will need to add 78.1' of energy (or about 34 psi) to point A in order to deliver it to point B with 10 psi available pressure. (Note: the pump selected for the system will need to provide more than 78.1' if the water is below the ground elevation in a well, as will be discussed in later sections.)

3. Delivery Methods

There are two methods for delivering water from a source to a trough: gravity (or potential energy) and pressure (or mechanical energy). These two methods can be strategically combined.

Gravity Systems:

Consider a pond or reservoir at an elevation above a watering trough. Due to its position, the water in the pond has greater potential energy than in the trough. Water flows into a pipeline and runs down the topographic hill to its new, lower elevation in the trough. As the water moves, it bumps against the sides of the pipe, fittings, and trough, causing kinetic energy to be lost to the surroundings as heat. There must be enough energy in the system to overcome these losses in the flow path. The layout of the pipeline will affect the system losses. Avoid having a pipeline profile with hills and valleys and sharp changes in grade or horizontal direction. Undulations will add to the energy expended along the flow path and also provide opportunity for air to be trapped at the high points in the pipeline. If enough air is trapped, water flow may be partially or totally blocked. Devices for air venting can be added to prevent **airlocks** if undulations cannot be avoided.

Pressure tank. Photograph courtesy of Stuart Bayne, Boydton Service Center.

Pressure Systems: Pressure systems provide mechanical energy in situations where there is insufficient elevation change for gravity alone to transport water to the desired locations. Water in a well has less potential energy than in a trough at a higher elevation. To make the water flow from the well to the trough, the energy of the water in the well must be increased with a pump. The pump must be able to provide enough energy to lift the water from the well to the delivery system, lift the water to the highest point in the delivery system, and compensate for losses due to friction in the flow path. See Appendix A-5 for more information on pumps.

A **pressure tank** allows the system to remain pressurized without running the pump every time an animal takes a drink. Figure I-3 illustrates how a pressure tank works. As water is consumed at the troughs, water is replenished from the pressure tank. The larger the storage capacity of the pressure tank, the less frequently the pump will need to turn on which saves wear on the pump. The storage capacity, or **effective drawdown** volume, is selected based on the desired pumping rate and the recommended minimum pump run time. For example, a pump operating at 8 gpm with a recommended minimum run time of 1 minute should be paired with a pressure tank with an effective drawdown volume of at least 8 gallons.

The lower and upper settings of the **pressure switch** determine when the pump turns on and off, respectively. The pump, pressure tank, and pressure switch are typically located close to each other. There are situations, however, where it is useful not to co-locate these components. These strategies are discussed in Part II, Examples 2 and 3.

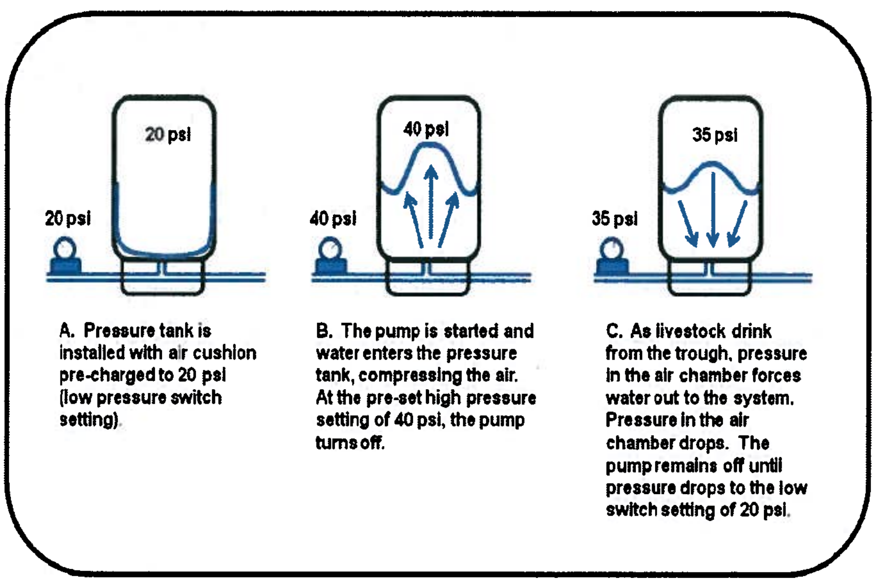


Figure I-3. How a Pressure Tank Works. (Adapted from the Montana Stockwater Pipeline Manual, USDA-NRCS, 2004.)

Pressure switch (inside gray box). Photograph courtesy of Barney Tickle, Wytheville Service Center.

Hybrid or Pressure-Energy Systems:

A hybrid system uses pressure energy from a pump to transport water to a reservoir and then uses the reservoir's potential energy to deliver the water to the troughs which are topographically downhill. The pump can be placed on a timer to ensure that the pump is on for a given amount of time to fill the reservoir. This approach replaces the pressure tank and pressure switch for preventing pump burn-out due to short-cycle pumping. Reservoirs can also serve as pressure reducers in cases where troughs are much lower in elevation than the source. Part II discusses a variety of energy strategies.

Chapter 2. The Planning Process

A step-by-step procedure for designing a livestock watering system cannot cover all the variations one will encounter in the field. Some guidelines for organizing the task are presented here. This chapter reviews the NRCS Three-Phase Planning Process and then outlines the planning and design of watering systems within that framework.

A system may successfully deliver water from point A to point B, but if it fails to meet the landowner's objectives, time and money have been wasted. Before going through the detailed steps of designing the watering system, the landowner and conservation planner need to look at the larger picture of the Resource Management System so that the watering facility fits with the overall farm operation. The NRCS Three-Phase Planning Process illustrated in Figure I-4 is designed to encourage careful consideration of the overall objectives and problems to be solved. The process has three phases:

1) Data Collection and Analysis
2) Decision Support
3) Application and Evaluation

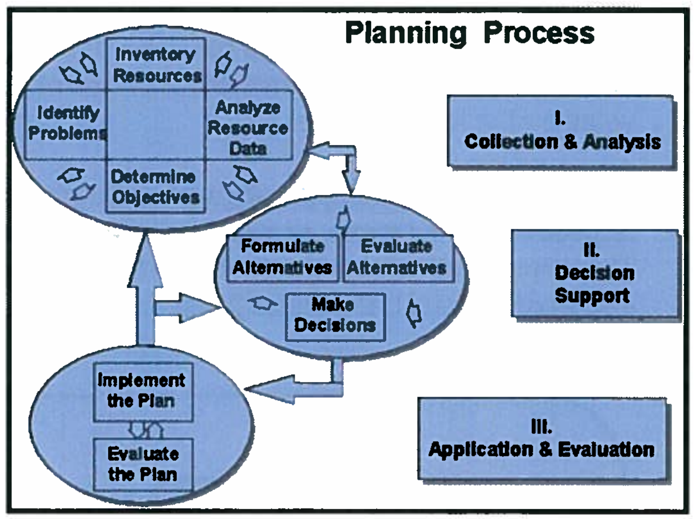


Figure I-4. NRCS Three-Phase Planning Process. (National Planning Procedures Handbook, 600.11.)

As the double-headed arrows suggest, however, the process is not linear. Figure I-4 offers only a framework for organizing considerations. The actual process will vary with each individual and each system designed.

1. Data Collection and Analysis Phase

Early in the process, clearly identify the resource concerns and objectives. What is the problem to be solved? Is it a matter of improving water quality downstream of the pasture, or a matter of increasing water quantity in times of drought? What are the landowner's objectives? What are your objectives as a conservation partner? You are there to assist the landowner, but within the context of protecting the resource base.

A. Inventory

Once the resource concerns and objectives are identified, inventory the resources and system requirements. A sample checklist for use in the field is provided in Appendix A-1. Consider the following in conducting the inventory:

- **Livestock to be Served:** What type, age, weight, and number of livestock? What are their daily water needs? Appendix A-2 suggests values for various types of livestock. How does the grazing plan impact the number and placement of troughs? (See Appendix A-4 for trough placement considerations.) In how many hours does the landowner want the whole herd to be watered? How many times per day will the livestock drink? How many days' supply would the landowner like to have available in storage? Will the system be used all year round? Does the landowner have a preference for the type of watering trough?

- **Water Resources:** What surface and subsurface sources are available? Wells and springs are generally preferred over ponds and streams to avoid problems with siltation and surface contamination. However, a fenced stream with limited access might provide an emergency water source. Are quality and quantity adequate? Water quality parameters of interest include bacteria, nitrate, sulfur, and salinity. Guidelines for acceptable limits are provided in Appendix A-3. Is the supply reliable throughout the year? Water yield for a well should be recorded on the well-driller's certificate. Water yield for some sources can be estimated by measuring the time it takes to fill a bucket of known volume. Is there an existing system that can be upgraded or that should be retired? If an existing system is to be expanded, what diameter pipe is present?

- **Energy Resources:** If water is to be pumped, how accessible is electrical power? While commercially-generated electricity is generally the most reliable and economical choice, Virginia Cooperative Extension suggests that alternative sources, such as solar or wind, might be worth considering if power lines are more than a third of a mile away (Marsh, 2001).

- **Soil Resources:** What soils are present in the area? Is the soil deep enough to be able to bury the pipeline below the frost line? Are wetlands an issue? Are there rock outcrops which may influence pipeline placement? Pipeline protection measures should be considered if soils are rocky or corrosive. Are there places suitable for placing a trough (level, well-drained)?

- **Site Limitations:** Discuss with the landowner any features that might restrict where pipelines or troughs are placed. Is there existing pipeline to which the system needs to connect and what diameter is that pipeline? Are there underground or overhead utilities present? Make sure Miss Utility is called prior to any excavation. Are there property lines that will limit pipeline placement? If possible, avoid crossing streams, roads, and travel lanes with pipelines.

B. Analysis

After collecting pertinent information, work with the landowner to develop a plan sketch of the system on top of an aerial photograph or topographic map. Approximately where should troughs go to support the grazing system and reduce livestock travel distance? It may be desirable to put troughs in fence lines or in a box configuration so that different pastures can make use of the same facility. (See Appendix A-4.) Avoid putting troughs in wet spots or drainage ways. Easy access for checking and maintenance should also be a consideration. Mark the locations of the water source, power source, troughs, pressure tank/reservoir, as applicable, on the map.

C. Documentation

Be sure to document the planning effort. Documents to save in the case file include:

- Conservation Assistance Notes
- Conservation Plan
- Plan map
- CPA-52 (environmental evaluation)
- Record of on-site soils investigation. See Appendix A-1.

Having a written record provides facts for future planning efforts or for analyzing causes of failure or success. It is also a tool to help the planner remember to go through certain thought processes, as well as a reference to use when planning similar projects or for training new employees.

2. Decision Support Phase

Once the general layout of the system has been planned, measurements are needed to aid in considering alternatives in system design and placement of components. Such measurements are usually made in conjunction with the design survey.

A. Survey

The goal of the survey is to determine relative elevations of the water source, reservoir or pressure tank, and troughs, to locate high and low points in the system and changes in pipeline direction, and also to determine distances required for pipeline conveyance. This information will be used to:

- plot the system layout (plan view and, for gravity systems, profile view)
- size the pipeline and estimate total length of material needed
- size the pump, if applicable
- compute static pressures to make sure they will not exceed material and control device limits.

Survey shots of interest include:

- benchmark(s)
- well site, spring development site, or other water source
- pressure tank site, if applicable
- reservoir site, if applicable
- trough sites
- pipeline tees and elbows
- grade breaks along the pipeline route if designing a gravity system.
- highest point to which water will need to be pumped in a pressure system

An auto-level or total station should be used for measuring elevations. A total station can be used for measuring elevations and horizontal distances. Pipeline lengths (for design purposes) can also be measured with a wheel, estimated with pacing, or estimated from a topographic map or aerial photo.

A standard GPS unit is also appropriate for estimating horizontal distances and for marking locations for download to GIS (Toolkit), but should not be used for measuring elevations except in cases where elevation differences are obviously adequate for the application. Standard-grade GPS measures vertical distances using mathematically-derived reference surfaces which may or may not correspond with the physical surface of the earth. The accuracy of the vertical distance derived using GPS can also vary based on time of day, weather, and location. Such a reference surface is likely to be uniform with respect to a physical datum within the small area of a farm operation and for the short duration of the survey, such that relative elevations of GPS points will reflect reality; however, traditional means of surveying (or survey-grade GPS) are more reliable and should be used if an error of 25' would influence system design.

In some cases, a topographic map is adequate for determining elevations and distances. The user should be aware, however, that USGS 7.5 minute quadrangles are intended for use at 1:24,000 which may not have enough detail for use at the field level, particularly for gravity systems where it is important to have sufficient fall and to avoid undulations.

B. Considering Alternatives in the Field

While conducting the survey, note the measured elevation differences so that alternative locations of troughs, reservoir, or pressure tank can be considered, if necessary, before leaving the field. The elevation difference between the water source (or reservoir) and gravity-fed troughs needs to be great enough so that there is enough energy to overcome frictional losses. Pressure-fed troughs should not be so high above the pressure switch that the static pressure (pressure from the weight of the water in the pipeline) exceeds the low setting of the pressure switch – if this is the case, the pump will not turn on. In general, elevation differences should not be so great that static pressures exceed the strength of the pipe material, fittings, or the pressure limits of control valves. While there are design solutions to these obstacles (as will be discussed in other sections), a change in location may prove to be the most viable option. Discuss alternatives with the landowner to determine what is most desirable and proceed with the design.

3. Application and Evaluation Phase

At this point in the process, a water source has been evaluated, water demand has been estimated, and trough locations have been identified to fit the grazing plan. Some initial decisions have been made regarding energy source and whether gravity, mechanical means, or a combination of energy strategies will be used for water transport. The system components can now be designed and the system as a whole evaluated on paper and discussed with the landowner. A design package is assembled, signatures obtained, and installation begins. Once the installed system is tested, it is put into operation and a maintenance schedule is followed by the landowner. Maintenance provides opportunity for overall evaluation, with system deficiencies corrected or noted as "lessons learned." The nature of the deficiencies will determine the need to repeat the steps of the three-phase cycle. Good engineering design and adherence to conservation practice standards and construction specifications should prevent most deficiencies. Design calculations for different types of watering systems are discussed in Chapter 3. Installation, operation, and maintenance are discussed in Chapter 4 of this Overview.

Chapter 3. Design Calculations

The Virginia Livestock Watering Systems spreadsheet accompanying this Design Note addresses:

- Pressure systems
- Public water connections
- Gravity systems
- Pressure-energy systems (combination of pressure and gravity systems)

This chapter outlines the design calculations needed for most types of watering systems. The equations presented are coded into the spreadsheet. Design examples are provided in Part II. Design calculations are usually performed before some critical quantities are known (such as well recharge rate). It is important to check the design calculations once estimates are replaced with measured values to make sure that the design is still valid.

1. Pressure Systems

A typical pressure system scenario involves using a pump to move water from a source to one or more troughs using utility-supplied electricity to power the pump motor. A pressure tank is used to protect the pump from rapid on and off cycling. The design calculations are aimed at sizing the pipeline, determining the energy required by the distribution system (to aid pump selection), sizing the pressure tank, and checking that system pressures are within mechanical and material limits. Usually the pressure tank and pressure switch are located near the pump. The calculations presented in this section cover the typical case. However, there may be good reason to place the pressure tank (and possibly the pressure switch) at a location remote from the pump – these situations are addressed with examples in Part II. The basic design steps are the same, however.

Step 1: Assistance Information. Record customer information and summarize items of note from the Resource Inventory (see Appendix A-1.)

Step 2: Water Budget.

a) Compute the **total daily water demand**:

$$Total\ daily\ demand\ (gpd) = no.of\ animals \times gallons\ of\ water\ required\ per\ animal\ per\ day$$

Use Appendix A-2 as a guideline for determining the water needs of various types of livestock.

b) Determine the **daily peak water demand**:

$$Avg.peak\ demand = \frac{daily\ demand\ \left(\frac{gal}{day}\right)}{no.\ of\ times\ herd\ drinks\ per\ day \times minutes\ to\ water\ herd}$$

If needed, adjust the resulting average peak demand based on local practice, knowledge of the operation, likelihood of future system expansion, and landowner preference. Some experienced staff use a minimum peak demand of 8 gpm for systems with freeze-proof troughs and a minimum of 5 gpm for systems with storage troughs. The spreadsheet provides a space to record this adjusted value as an **alternate peak demand**.

c) Evaluate the water source in terms of flow rate and daily yield:

   i. Estimate the **source flow rate** (gpm): For a well, this should be recorded on the water well completion report filled out by the well-driller. If the well has not yet been drilled, use a conservative estimate based on local knowledge and check the design once the flow rate is known.

   Source flow rate for springs can be estimated by measuring how long it takes to fill a container of known volume. Another option is to create a channel for the spring outflow with known cross-sectional area, A, measure the time it takes for a floating object to travel a known distance downstream to compute the velocity, V, and then compute the flow rate, Q, as the product of V and A (with appropriate unit conversion factors).

   Both peak demand and source flow rate can fluctuate, so it is good to be conservative in the evaluation to avoid pumping the source dry. ***If the source flow rate is less than or close to the peak demand, consider using storage troughs or a reservoir.*** In the case of a deep well, water storage volume in the well casing may be significant enough to justify using the source when peak demand is close to the supply rate. See Appendix B-4. If a reservoir is justified, follow the design steps presented in **Section 3. Pressure-Energy and Gravity Systems**.

   ii. Evaluate the **daily yield** of the source.

$$
\begin{aligned}
&Source\ daily\ yield\ (gpd) \\
&\qquad = Source\ flow\ rate\ (gpm) \times\ hours\ of\ flow\ per\ day\ \times\ 60\ min/hr
\end{aligned}
$$

   The purpose of this calculation is to determine the maximum amount of water the source can yield per day to see if it will meet the daily demand computed in Step 2a. The spreadsheet calculation uses 24 hours as the number of hours of flow per day to cover the typical situation where the pump could potentially run 24 hours on utility-supplied electricity. However, energy to run the pump will not be available 24 hours a day in the case of solar or wind-powered applications (without a supplemental system). Thus, the value from the spreadsheet will need to be adjusted accordingly.

   If daily yield is less than daily demand, then an alternate or a supplemental source of water will need to be used or the number of animals served will need to be reduced.

Step 3: Design Parameters

This step provides for the recording or computation of three categories of the energy budget: energy desired at the trough; energy "losses" due to friction; and energy required to change the elevation of the water.

a) Trough Information

   i. Record the type(s) of troughs to be used (e.g., freeze-proof, HETT, concrete). Freeze-proof troughs are typically used with pressure systems. However, if there were doubt about meeting the peak demand, HETT or concrete troughs might be used because they provide more storage. Such troughs will need to have float valves so that water will not continue to flow once they are full.

ii. Decide what the design flow rate to the troughs will be, choosing from:
   - **average peak demand** computed in Step 2b
   - an **alternate peak demand** based on local experience, or
   - the **source flow rate** if it is the limiting factor and over-pumping is not an issue.

   This design flow rate, Q, will be used in evaluating friction loss which increases with increasing flow rate. The design flow rate will also be the design pumping rate.

iii. Record the operating pressure range of the float valve, as recommended by the manufacturer.

   The maximum pressure at which the float valve can operate is particularly important to note in areas of strong topographic relief where some troughs may be downhill of the pressure switch. If the elevation difference is greater than 100', static pressures can approach or exceed the float valve maximum pressure rating (which ranges from 50-140 psi for commonly used brands of troughs).

   For the minimum operating pressure, use the manufacturer's recommended value or 10 psi, whichever is greater. It is energy that the pump will have to supply.

b) Pipe Information

i. Select a pipe material.

ii. Select a nominal pipe diameter. The diameter may be adjusted depending on the outcome of later calculations.

iii. Determine the inner diameter of the pipe. The spreadsheet uses a tabulated value based on the selections of material and nominal diameter. Inner diameters are also provided in Appendix B-1.

iv. Compute the cross-sectional area, A, of the pipe:

$$Pipe\ cross\ sectional\ area\ (ft^2) = \pi\left(\frac{inner\ pipe\ diameter\ in\ inches}{2\ \times\ 12\ in/ft}\right)^2$$

v. Compute friction loss per 100 feet of pipe using the Hazen-Williams friction loss equation presented in MWPS, 1987 or the tables in Appendix B-1.

$$h = 1043.8\ \frac{\left(\frac{Q}{C}\right)^{1.85}}{d^{4.87}}$$

where: h = head loss in feet per 100 feet of pipe
Q = design flow rate in gpm
C = Hazen-Williams friction coefficient
d = inner pipe diameter in inches

Typical C values for various pipe materials are:
Plastic: 140
Copper: 130
Steel: 100

vi. Compute the velocity in the pipe based on the cross-sectional area and design flow rate:

$$Velocity\ (fps) = \frac{Q}{A} = \frac{design\ flow\ rate\ (gpm)}{pipe\ cross\ sectional\ area\ (ft^2)} \left(\frac{1\ ft^3/s}{448.8\ gpm}\right)$$

When fast-moving water is suddenly brought to a stop, such as when a valve is abruptly closed, the resulting surge (**water hammer**) can weaken the system joints. A velocity of less than 5 fps is desirable to minimize this phenomenon and to meet the requirements of Virginia CPS 516, *Pipeline*. If the computed velocity is too high, consider using a larger diameter pipe.

vii. Compute total friction loss based on pipeline length to the farthest trough:

$$h_t = h \times \frac{L \times 1.1}{100}$$

Where: h_t = total friction loss for the system in feet
h = friction loss per 100 feet of pipe
L = pipe length to the farthest trough
1.1 = factor to account for slope distance, added friction due to pipe fittings and valves

The factor of 1.1 accounts for miscellaneous losses. Although references such as MWPS, 1987, provide estimated head losses for a variety of fittings, the livestock watering system designer usually does not know what or how many fittings will be used prior to installation. Adding 10% to the pipeline length is a practical means for estimating these losses.

As a guideline, total friction loss to the farthest trough should be less than 23 ft or 10 psi. Consider increasing the pipe diameter if friction loss is greater than 10 psi.

viii. Specify a pipe pressure rating. The values listed in Appendix B-2 can be used to select a rating likely to be commercially available. Compute 72% of this value to reference in Step 5. Virginia CPS 516, *Pipeline,* specifies that maximum pipe pressure should not exceed 72% of the manufacturer's rated value. If calculations in Step 5 indicate that the specified pipe pressure rating is too low, a pipe with a higher rating can be chosen or a pressure reducer can be used. The rated pressure is stamped on the pipeline and should be checked prior to installation to make sure it meets the pressure rating specified in the design.

c) Vertical Pumping Distance

i. Record the ground elevation of the high point to pump "to."
ii. Record the ground elevation of the low point to pump "from."
iii. Compute the difference between the two values. This is the elevation head.

The spreadsheet computes the elevation difference and displays this energy in terms of both feet and psi.

Ordinarily, the high point to pump "to" will be the highest point in the system and the low point to pump "from" will be the water source. The spreadsheet provides spaces to enter a description of each point to provide clarity for cases where multiple analyses are needed, such as when using a remote pressure tank. See Examples 2 and 3 in Part II.

The highest point in the system need not be a trough – it may be a high point in the pipeline if the terrain is undulating. Also, in some cases, the ground elevation of the source may be higher than some points in the system. Pumping water downhill is not unusual, but a strategy that takes advantage of potential energy may be more appropriate. See Examples 5 and 6 in Part II.

Step 4: Pump and Pressure Tank Design

a) Summarize the energy budget items.

Elevation head:	_____	psi (Step 3c)
Friction loss:	_____	psi (Step 3b)
Float valve minimum pressure:	_____	psi (Step 3a)
Other: __________________	_____	psi
TOTAL REQUIREMENTS:	_____	psi (summation of above)

The "Other" category" is used when performing multiple analyses to account for energy losses calculated for a subsystem. See Examples 2 and 3 in Part II. Ordinarily, there is no need to use this item.

b) Determine Pressure Switch Settings from the Total System Requirements:

The pressure switch settings govern when the pump turns on and off. The pump turns on at the low pressure switch setting and will remain on until the pressure reaches the high setting. As water is consumed, the pressure drops. When it drops to the low setting, the pump switches on again.

i. Low switch setting: Round the total system energy requirement from Step 4a to the nearest 10 psi. The minimum low switch setting is 20 psi for common applications.

ii. High switch setting: Add 20 psi to the low switch setting to determine the upper switch setting. A wider range (e.g. 30 psi) can be specified for some switches, but 20 psi is the most common.

Typical applications have high pressure settings of less than 80 psi. Commercially available pressure tanks are generally rated for 100-150 psi, although it is possible to obtain ASME-rated tanks for extreme applications (over 200 psi) (CMC Supply, Inc., 2010). The latter can be very expensive. In general, one should consider other strategies for pressure requirements above 80 psi. Alternative strategies might include re-locating the troughs or pressure tank to reduce the elevation head or pumping to a reservoir.

c) Dynamic head added to pump by the watering system:

This value represents the maximum energy demand of the watering system itself (excluding the energy needed to bring the water up to the distribution system) and is the energy needed to achieve the high pressure setting.

$$Dynamic\ head\ in\ feet = High\ switch\ setting\ (psi) \times 2.31\ ft/psi$$

The person selecting the pump will add this value to the head needed to get the water from the source to the distribution system.

d) Minimum Effective Drawdown for Pressure Tank:
The pressure tank needs to have enough available volume to allow the pump to operate for at least the manufacturer's recommended minimum run time. The spreadsheet uses a minimum pumping time of 1 minute.

$$\text{Minimum effective drawdown volume (gal)} = \text{design pumping rate (gpm)} \times 1\ min.$$

The design pumping rate is equal to the design flow rate for the system. The pressure tank itself will be larger than the effective drawdown volume to accommodate the air chamber. The multiplication factor is supplied by the tank manufacturer and is a function of the high and low pressure switch settings. The higher the operating pressure, the greater the tank volume needed (and more expensive the tank). See Part II, Example 2 for a discussion of using remote pressure tanks.

Step 5: Static Pressure Checks
Water in the system exerts pressure on the pressure switch sensor, the pipe, float valves, and other hardware. This step checks to make sure that static pressures do not exceed the operating limits of the components.

a) Check static pressure at the pressure switch:
If points in the watering system are higher in elevation than the pressure switch, there may be enough static pressure to prevent the pressure from dropping low enough to cause the pump to turn on. Compute the static pressure as follows and compare with the low pressure switch setting. If the computed value is less than the low switch setting, the pump will turn on.

$$\text{Static pressure (psi)} = \left(\frac{\text{Elevation of highest point in the system} - \text{Pressure switch elevation}}{2.31\ ft/psi}\right)$$

b) Check static pressure at lowest trough:
For troughs lower in elevation than the pressure switch, pipes and float valves need to be able to withstand the sum of the pressure due to elevation and the system pressure at the high pressure setting.

$$\text{Pressure at lowest trough (psi)} = \left(\frac{\text{Pressure switch elev.} - \text{low trough elev.}}{2.31\ ft/psi}\right) + \text{high switch setting}$$

Check to see that the computed value is less than the maximum float valve pressure specified in Step 3a. If the pressure is too great, the float valve will leak. Also check that the pressure is less than 72% of the pipe pressure rating determined in Step 3b.

If total pressure exceeds either of these ratings at the lowest trough, a design change is needed. Troughs at higher elevations should also be analyzed. Alternatives for dealing with excessive pressures include:

- Using higher-rated float valves/pipe material
- Installing a pressure reducer
- Re-locating troughs to reduce the elevation head
- Incorporating a reservoir as demonstrated in Part II, Example 5.

2. Public Water Connection

Increasingly, landowners in some parts of the state are using public water for their livestock operations. Be sure to check with local authorities regarding public-water hook-up regulations in the process of considering this alternative.

A worksheet tab (second tab of the Virginia Livestock Watering Systems spreadsheet) was developed to evaluate designs using pressure at the public water hookup as the energy source for moving water to the troughs. The main question to be answered is: what are the energy requirements of the watering system and is the pressure at the public water connection adequate to meet that demand? If the pressure is insufficient to meet the energy demand of the watering system, the water can be directed to a reservoir and then pumped to the watering system. The system would then be evaluated using the Pressure System Calculation Worksheet (first tab).

The design steps are similar to those coded into the Pressure System worksheet and discussed in section 1 above, but do not include calculations related to the pump and pressure tank.

Step 1: Assistance Information. Same as **Pressure System** above.

Step 2: Water Budget. Steps a and b are the same as for **Pressure System.** However, the water source is assumed to be adequate in terms of quantity and is therefore not evaluated.
Step 3: Design Parameters. Steps a, b, and c are the same as for **Pressure System** except that the elevation head is computed as the difference between the elevation of the highest point in the system and the elevation of the public water connection.

Step 4: Pressure Requirements. Summarize the energy requirements as in Step 4a for **Pressure System.** Compare the total requirements with the available pressure at the public water connection. If available pressure is less than the total required by the watering system, pursue other options.

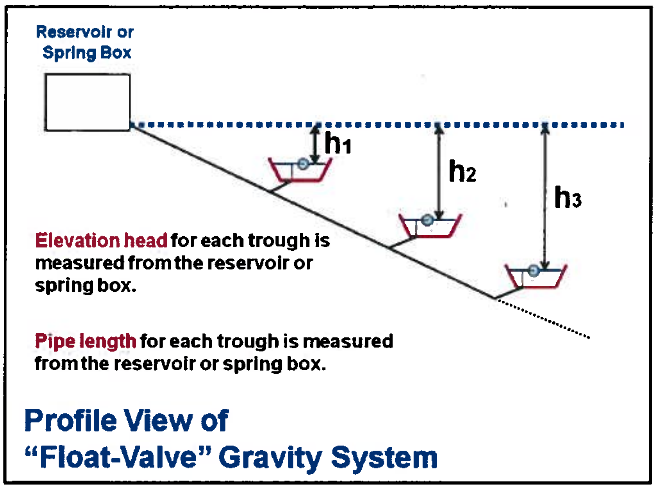
Step 5: Static Pressure Checks. This step is similar to Step 5 for **Pressure System**. Check static pressure at the lowest trough. If pressure is excessive, check troughs at higher elevations and consider the alternatives outlined under **Pressure System.**

$$Pressure\ at\ lowest\ trough\ (psi) = \left(\frac{Public\ connection\ elev. - low\ trough\ elev.}{2.31\ ft/psi}\right) + Pressure\ at\ meter\ (psi)$$

3. Pressure-Energy and Gravity Systems

The third tab of the Virginia Livestock Watering Systems spreadsheet addresses design strategies that make use of potential energy. Water may be pumped to a reservoir and then allowed to flow by gravity to troughs (**pressure-energy systems**), or water may flow directly from the source (typically a spring) downhill to the troughs ("pure" **gravity systems).** In a pressure system, each trough has a float valve so that water to the trough shuts off when the trough is full. Troughs in reservoir systems also have float valves, while troughs in pure gravity systems do not. The hydraulic relationships associated with the use of float valves are outlined below:

- Float-valve systems: Troughs are tee-ed off from a main line with flow to each trough controlled by a float valve. Flow to a trough shuts off when the trough is filled, and thus, static pressure can be of concern if there is sufficient head.
- Cascading systems: Troughs are connected in series by way of their overflow pipes. There are no float valves – instead, water overflows from one trough to the next lower trough. Overflow from the last trough is generally directed back to the natural drainage system.



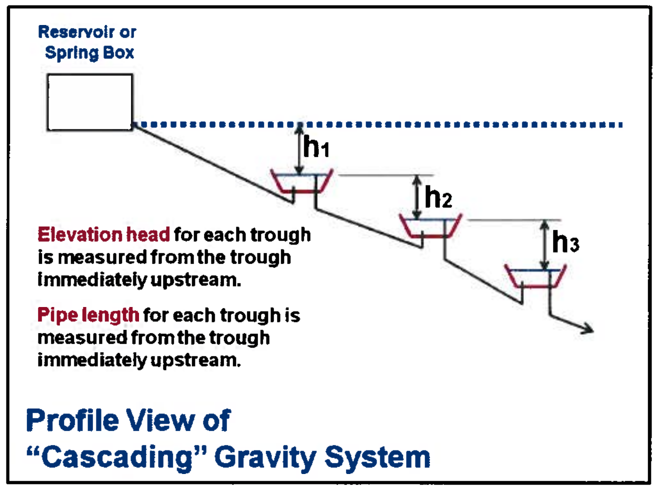


Figure I-5. Float Valve vs. Cascading Trough Arrangements.

Step 1: Assistance Information. Same as **Pressure System**.

Step 2: Water Budget. Same as **Pressure System**.

Step 3: Design Parameters.

a) **Trough Information:** Same as **Pressure System**. However, if there are no float valves, then the minimum and maximum float valve pressures should be left blank.

b) **Pipe Information:**

   i. Select a pipe material.
   ii. Select a nominal pipe diameter.
   iii. Determine the inner diameter of the pipe. The spreadsheet uses a tabulated value based on the selections of material and nominal diameter. Inner diameters are also provided in Appendix B-1.

iv. Compute the cross-sectional area, A, of the pipe:

$$Pipe\ cross\ sectional\ area\ (ft^2) = \pi\left(\frac{inner\ pipe\ diameter\ in\ inches}{2\ \times\ 12\ in/ft}\right)^2$$

v. Determine the head loss coefficient, K_p, using EFH Chapter 3, Equation 3-9:

$$K_p = \frac{5087\ n^2}{d_i^{4/3}}$$

where: n = Manning's n for the pipe material (0.009 for plastic)
d_i = inner diameter of pipe in inches

K_p values used in the spreadsheet are as follows:

Nominal Pipe Dia. (in.)	Head Loss Coefficient, K_p			
	SIDR-PR PE plastic n = 0.009	SCH 40 PVC plastic n = 0.009	Copper n = 0.011	Steel n = 0.012
1"	0.387	0.397	0.596	0.687
1-1/4"	0.268	0.273	0.450	0.477
1-1/2"	0.218	0.222	0.357	0.388
2"	0.156	0.159	0.247	0.278

The head loss coefficient will be used to compute the maximum flow rate in Step 4.

vi. Compute the velocity in the pipe based on the cross-sectional area and design flow rate:

$$Velocity\ (fps) = \frac{Q}{A} = \frac{design\ flow\ rate\ (gpm)}{pipe\ cross\ sectional\ area\ (ft^2)} \frac{1\ ft^3/s}{\times\ 448.8\ gpm}$$

A velocity of less than 5 fps is desirable to minimize **water hammer** and to meet the requirements of Virginia CPS 516, *Pipeline*. If the computed velocity is too high, consider using a larger diameter pipe.

vii. Record the pipe pressure rating specified by the manufacturer. Compute 72% of this value to reference in later computations. Virginia CPS 516, *Pipeline,* specifies that maximum pipe pressure should not exceed 72% of the manufacturer's rated value. See Appendix B-2 for more information on pipeline pressure ratings.

c) **Gravity System Parameters.** This step defines the high elevation from which head computations will be made in Steps 3d and 4.

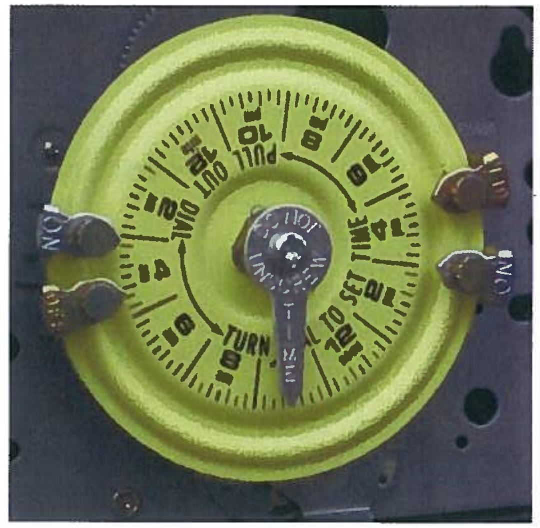
i. Record the ground elevation of the reservoir or the spring box outlet.

ii. If a reservoir is being used, record the depth below the ground at which the bottom of the reservoir is placed. This value is typically 6'. (Use 0 if there is no reservoir or if the reservoir sits on the ground.)

iii. Subtract the depth from the ground elevation to get the elevation of the bottom of the reservoir to use in head calculations. (If there is no reservoir, the spring box outlet elevation will be used in head calculations.)

d) **If Pumping to a Reservoir,** compute the following to determine the energy that needs to be supplied by the pump to get the water to the reservoir:

i. Record the desired pumping rate (gpm) to the reservoir. This value is **not** the same as the design flow rate to the troughs. Choose a rate that will fill the reservoir in a timely manner without exceeding the flow rate of the source. Choose a flow rate that will allow the selected pump to run long enough to avoid premature wear from short cycling. A run time of 3-6 hours, two times a day is typical. A timer controls when the pump is on. The timer in the photograph is set to run the pump from 3:00 AM-4:30 AM and again from 3:00 PM–4:30 PM.



Pump timer. Photograph courtesy of Mountain Castles SWCD.

The pumping rate and corresponding head must also be compatible with the pumps available from the supplier. Once the pump has been selected, re-work the calculations below using the flow rate from the pump's performance curve.

ii. Determine the pumping duration required to meet the daily water demand from Step 2a:

$$Pumping\ duration\ (min.) = \frac{Daily\ demand\ (gpd)}{Desired\ pumping\ rate\ (gpm)}$$

iii. Record the ground elevation of the water source (such as a well).

iv. Compute the elevation head by subtracting the water source elevation from the reservoir bottom or spring box outlet elevation. This is one component of the energy budget needed to size the pump.

v. Compute static pressure in the pipe at the source ground elevation and make sure the pipe is suitably rated in accordance with Virginia CPS 516, *Pipeline*:

$$Static\ pressure\ (psi) = \frac{Reservoir\ ground\ elev. - Water\ source\ ground\ elev.}{2.31\ ft/psi}$$

vi. Compute friction loss per 100' of pipeline from the source to the reservoir, using the Hazen-Williams method:

$$h = 1043.8\ \frac{\left(\frac{Q}{C}\right)^{1.85}}{d^{4.87}}$$

where: h = head loss in feet per 100 feet of pipe
Q = pumping rate in gpm
C = Hazen-Williams friction coefficient (use 140 for plastic)
d = inner pipe diameter in inches

vii. Compute total friction loss in the pipeline from the source to the reservoir:

$$h_t = h \times \frac{L \times 1.1}{100}$$

where: h_t = total friction loss for the system in feet
h = friction loss per 100 feet of pipe
L = pipe length to the farthest trough
1.1= factor to account for slope distance, pipe fittings and valves

Consider choosing a larger pipe diameter if total friction loss exceeds 23 ft (10 psi).

viii. Compute dynamic head added to the pump by the pressure component of the system

$$Dynamic\ head = Elevation\ head\ + h_t$$

Pump selection will be based on this number added to the head required to bring the water up to ground elevation.

Step 4: Flow and Static Pressure Checks.

a) **Trough Elevations.** List all troughs and their ground elevations. If the system is "cascading," list the troughs in order from higher to lower elevation. Compute the water surface elevation for each trough by adding 2' to the ground elevation.

b) **Maximum Pipe Flow.** A pipe of a given diameter on a given slope can only carry so much flow under the power of gravity. The purpose of this set of calculations is to make sure the pipe can carry the desired design flow from Step 3a. If not, consider using a larger pipe diameter, changing the trough locations to adjust the slope, or using larger volume troughs to provide more storage. In the case of a cascading system, the calculation is also used to check if inflow to a trough exceeds outflow from a trough. Assuming the supply flow rate is not limiting, alternatives include using a flow restrictor, installing a larger diameter pipe on the downhill side, or changing trough locations.

Maximum flow rate is computed based on equations from EFH Chapter 3:

$$Q_{max}\,(cfs) = A \times \sqrt{\frac{2gH}{K_pL}} \times \left(450\ \frac{gpm}{cfs}\right) \times F$$

where:
Q_{max} = maximum flow rate the pipe can carry (cfs)
A = cross-sectional area of the inside of the pipe (ft^2)
g = gravitational constant = 32.2 ft/s^2
H = elevation head (ft)
K_p = head loss coefficient
L = pipe length (ft)
450 = unit conversion factor
F = float valve efficiency factor = 0.8 with float valves; = 1 without float valves.

For float valve systems (see Figure I-5):

H = head for each trough as measured from the reservoir bottom or spring box outlet elevation to the trough water surface elevation

L = pipe length for each trough as measured from the reservoir or spring box.

For cascading systems (see Figure I-5):

H = head for each trough as measured from the water surface of the trough immediately upstream.

L = pipe length for each trough as measured from the trough immediately upstream.

c) **Static Pressure Check.** This calculation is needed for float valve systems to make sure that pressures are within the operating range of the float valves and that pressure does not exceed 72% of the pipe pressure rating. Elevation difference is computed conservatively using the ground elevation of the reservoir or spring box outlet elevation and the ground elevation of the trough.

$$Static\ pressure\ (psi) = \frac{Ground\ elev.\ of\ reservoir\ or\ spring\ box\ outlet - Ground\ elev.\ of\ trough}{2.31\ ft/psi}$$

Chapter 4. Installation, Operation, and Maintenance

Paperwork, funding, weather, farming activities, and contractor and landowner schedules all influence when a system actually goes in and notice given for the start of construction may be very brief. Heavy equipment will be involved and attention to safety is paramount. Once construction starts, things can progress rapidly and "details" can quickly be covered up with soil. The quality of the installation will directly impact operation and maintenance and ease of correcting problems. This chapter covers safety tips, basics for construction inspection, and maintenance considerations.

1. Safety Considerations

By signing the watering system design cover sheet, the landowner/operator accepts responsibility for ensuring that the excavator or contractor contacts Miss Utility at least three working days before construction begins. **Make every effort to be sure this is done.** Damaging buried pipelines can be an extreme hazard for those working in the immediate area and anything from an inconvenience to a life-threatening situation for those whose utilities are suddenly interrupted.

Digging the trench will require heavy construction equipment. Make sure the equipment operator is aware of your presence when you enter the job site. Be far enough away so that you are out of the range of the bucket arm and are not in an operator blind spot. Make eye contact with the operator before you approach.

Concrete trough installation. Photograph courtesy of Roger Canfield, Warm Springs Service Center.

Stay out of trenches. Failing trench walls can produce crushing weights of soil that make breathing impossible. Trenches should be backfilled as soon as the necessary quality inspections are completed to prevent people and animals from falling in them.

Pipeline trench leading to trough site. Photograph courtesy of Bill Keith, Jonesville Service Center.

Excavation Safety and Virginia's Miss Utility

By Jerry Wright, NRCS Project Engineer

We have all heard of the horrors of construction crews hitting unknown objects while excavating for whatever reason, be it trenching for a new pipe line or excavating a building foundation. The arrival of black SUVs with official security staff jumping out to investigate a fiber optic cable breach that had national security implications is the outcome of some. Others end with a fire ball that engulfs excavation, equipment, and men as a result of a broken gas pipeline. Most likely the excavation will expose a rat's nest of wires or a broken pipe that may or may not leak gas but may be carrying water or sanitary waste. Regardless, such incidents can result in lost time, lost dollars, potentially high fines, loss of equipment, or worst of all ... loss of life.

These situations can be avoided by contacting Miss Utility, the Commonwealth's utility locator. They are an exceptional and dedicated group of individuals. One phone call is all it takes to avoid a potential calamity. Whenever any excavation takes place, regardless of the size of the hole or how far away from civilization it may be, the site should be marked by Miss Utility. Don't take the chance and have something happen – **Make the call three days before.**

I have had a number of instances where I wish I could have done things differently: one was a gas explosion similar to a gas line break and ensuing fire. I spent one week in the hospital with first and second degree burns. The pain and trauma of a burn is not to be taken lightly. So avoid your trip to the hospital, whether it's for you, a co-worker, or someone on the site. Call Miss Utility three days prior to any excavation.

Dial 811 in VA, or 1-800-552-7001

www.missutilityofvirginia.com

It's too simple to have an excuse for not doing it!

811 Know what's **below.** **Call** before you dig.

"The mission of Virginia Utility Protection Service (VUPS) is to operate a high performance organization composed of experienced utility operators, excavators, locators and State regulatory agencies, dedicated to providing a premier Damage Prevention Program to protect the utilities for the safety and benefit of the citizens within the Commonwealth of Virginia."

Inspect materials and devices with care. Black widow spiders and other small creatures enjoy the shelter of structures built for control devices.

Housing for pressure switch box. Photograph courtesy of Tara Anderson, Harrisonburg Area Office.

2. Construction Inspection Basics

No matter how good the design, the project will only be as good as the materials, workmanship, and placement of the components. It is important to have an NRCS or conservation partner design representative present prior to backfilling the trench. Discuss key points with the landowner or operator if they have limited experience with watering system installation. General considerations include:

A. Pipeline

- Look for the stamp on the pipe: was the material specified in the design actually installed? Hopefully some leftover electrical conduit (grey plastic) was not used as a substitute!
- Is the trench consistently deep enough to protect the pipe from freezing (2 feet in Virginia)?
- The trench should not run straight up a slope as this will provide a conduit for surface runoff.
- For gravity systems, the trench should have a consistent grade without humps. If undulations cannot be avoided, make sure the high points are vented to prevent air locks. A trough or hydrant can function as a vent.
- For gravity systems, the trench should be dug with a backhoe rather than a trencher. Most trenchers do not create a wide enough cut to allow use of a shovel to smooth out inconsistencies in grade.

*Trench dug with a **backhoe** for a gravity system. Photographs courtesy Cephas Hobbs, VA NRCS State Office.*

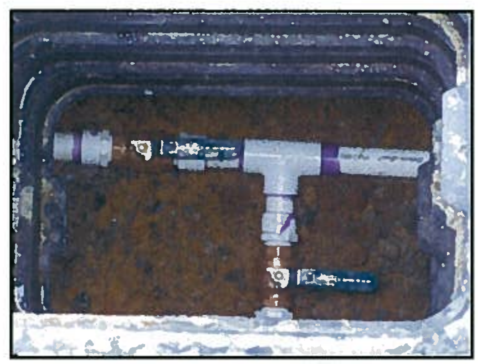
*Trench dug with a **trencher** for a pressure system where consistent grade is not essential. Photograph courtesy John Cooke, VA NRCS State Office.*

- Bell ends of PVC pipe sections should point upstream so that water flows away from potentially failed joint seals.
- The pipe should be "sleeved" (placed in a larger diameter pipe or other protective covering) in areas where the soil is rocky or in high traffic areas where the pipeline is subject to abrasion.
- Is there a purple stain where PVC pipe sections and fittings were joined? This is good because it means primer was used before gluing the joints.

Above: Purple stains from primer used before connecting fittings. Photograph courtesy Hugh Markham, Tappahannock Service Center.

Left: Settling in pipeline trench. Photograph courtesy of Larry Wilkinson, Leesburg Service Center.

- Paint or wrap any PVC pipe intentionally exposed above ground to protect from deterioration from UV rays.
- Pressure-test pipeline to locate leaks before backfilling the trench.
- Take care in backfilling the trench to prevent excessive settling.



Above: Ball valve and drain. Photograph courtesy of Chris Barbour, Skyline SWCD.

B. Troughs

For a freeze-proof trough, check the balls to make sure they are at the proper tension (not too tight). The float valve pressure rating should meet or exceed that specified in the design. Check that the trough is connected to the concrete pad according to the manufacturer's specifications. The concrete pad dimensions and quality should be as specified in the design. Install a ball valve and drain so that the trough can be disconnected from the main line and drained if not in use.

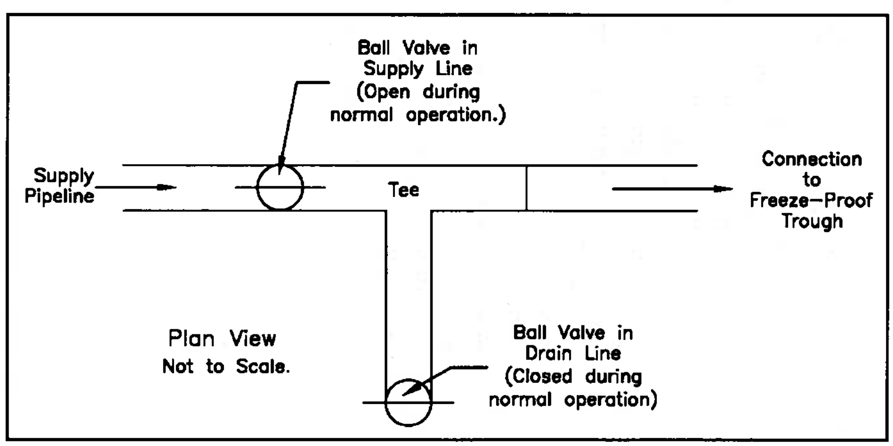


Figure I-6. Plan View of Ball Valve and Drain for Freeze-Proof Trough

For other types of troughs, make sure the inlet and overflow pipes are protected to prevent damage to both the pipes and the animals. A flexible coupling on the overflow pipe will help prevent livestock from impaling themselves. Physical barriers will help protect standpipes and float valves.

Physical barrier used to protect plumbing on concrete trough in Highland County.

C. Heavy Use Area Protection (surrounding the trough)

- The sod should be removed and geotextile put down before placing the gravel.
- Check that the area surrounding the trough is conducive to good drainage.
- Be sure that the heavy use area protection extends the specified width (minimum of 8') from the edge of the trough, has sufficient depth, and that the specified sizes of stone are used.

Photograph courtesy John Cooke, NRCS VA State Office.

D. Seeding: All disturbed areas should be seeded and mulched before signing off on the project.

3. Operation & Maintenance

Every design package must include copies of Operation and Maintenance plans for the conservation practices that make up the watering system (Watering Facility, Pipeline, Water Well, etc.). These are available from eFOTG (http://www.nrcs.usda.gov/technical/efotg/). Following these plans will help ensure that the watering system meets or exceeds its expected life span of 10 years. While it is the landowner's responsibility to properly operate and maintain the watering system, the conservation partner is charged with providing technical advice to assist the landowner and also protect the public's investment. An overview of maintenance considerations is provided in this section.

A. Pipeline

Avoid crossing the pipeline with equipment (especially in wet areas) and try to keep livestock from using the pipeline ditch as a walkway. Good system planning ahead of time can help strategically locate pipelines away from travelled areas. Running pipes along fence lines may be one option.

Gravity pipelines should be flushed twice a year to prevent sediment or debris build-up. Pipelines not in use should be drained by way of bleeder valves. All valves should be operated at least twice a year to make sure they still work. Open and close valves slowly to reduce risk of water hammer.

B. Troughs

Troughs should be inspected every few days to make sure that water is available, float valves are working, and overflow pipes are not clogged. Clean out leaves or other debris as needed. Once a year, troughs should be drained and cleaned to prevent build-up of mineral deposits and algae.

Frost-free troughs not in active use should be shut off and drained. A ball valve and drain is specified in the design for this purpose (see Figure I-6). The float valve should be checked and cleaned before re-activating the trough.

For heavy equipment tire or concrete troughs not in active use, remove the standpipe to diminish the amount of water available for freezing or for breeding mosquitoes. A wintertime option is to put a log or wooden post in a full trough to absorb the stress from freezing and thawing. Be sure the post is made of untreated wood to prevent poisoning the livestock when the trough is in use again.

During summer months, algae can become a problem. Options for controlling algae include:

- Chemical solutions: Use with caution and follow label directions and applicable laws.
- Scrap copper pipe: The copper will need to be sanded every few weeks. Check with a veterinarian before using this method for troughs supplying water for sheep because sheep do not tolerate high levels of copper.
- Shading the trough: In general, this is not recommended because it encourages livestock to stay congregated in the shaded area which leads to poor distribution of nutrients.
- Barley straw: The straw can be contained in plastic floating balls.
- Goldfish: Place concrete blocks in the bottom of the trough so that the fish have shade and a place to hide from predators. Some people prefer not to use goldfish because of the risk of bacterial contamination.

Tire trough with goldfish. Photograph courtesy Cephas Hobbs, NRCS VA State Office.

C. Heavy Use Area Protection

One of the most commonly neglected maintenance items is the gravel heavy use area protection. Gravel tends to migrate with animal activity and needs to be replenished periodically. These photographs illustrate the results of poor maintenance and inadequate slope for drainage.

Photograph courtesy Peter Acker, Culpeper Service Center.

Photograph courtesy Bill Keith, Jonesville Service Center.

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Part II: Design Examples

Part I presented an overview of concepts and the general process for planning, designing, installing, and maintaining a livestock watering system. Part II presents eight examples to illustrate different design strategies. Calculations and discussion are based on the Virginia Livestock Watering Systems calculation worksheets. The spreadsheet tool addresses pressure systems, gravity systems, and hybrid systems and provides a means for performing design calculations as well as for documenting key information.

Example 1 – Pressure System

This example represents a typical pressure system application. Water is to be pumped from a well to four troughs. The pressure tank and pressure switch will be located close to the well. The system layout is shown in Figure II-1.

- Livestock: 165 beef stockers
- Estimated water demand = 8 gpd/animal
- Water source: 10 gpm well
- Troughs: 4 frost-free troughs with ball valve and drain cut-offs.

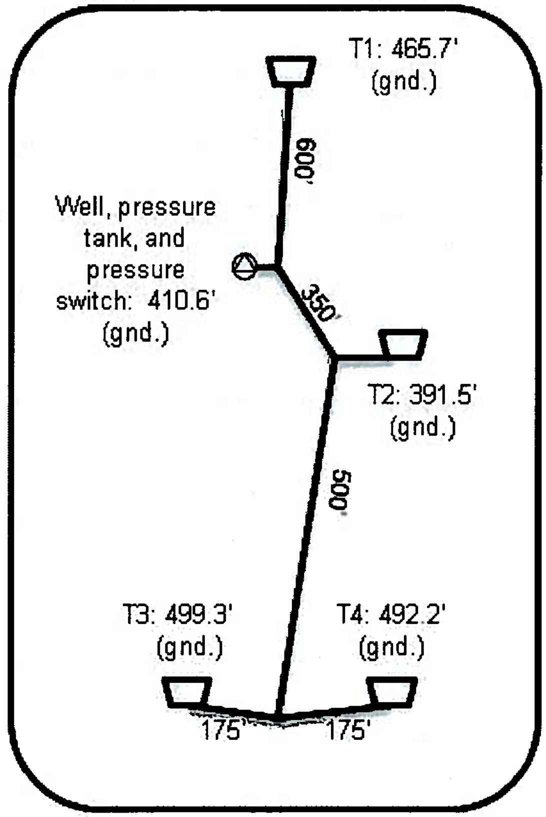


Figure II-1. Layout for Example 1: Pressure System

<u>Solution:</u> See the worksheet in Figure II-2.

- **Steps 1 and 2:** Given information was entered. A total daily demand of 1320 gpd and an average peak demand of 7.3 gpm were computed. An alternate peak demand of 8 gpm was chosen based on the recommended minimum for frost-free troughs. This value is the design flow rate and design pumping rate.
- **Step 3:** Maximum and minimum float valve pressures were chosen based on manufacturer's recommendations. PVC plastic was selected for the pipeline material. A diameter of 1¼" was selected. Later checks on velocity and friction loss confirmed the adequacy of this size. Length to farthest trough was measured to be 1025' and total friction loss was computed as 5.7 psi. The pressure rating for the selected pipe material and diameter is 370 psi (see Appendix B-2). Vertical pumping distance was determined from the elevations of Trough 3 (the highest point in the system) and the well. The resulting elevation head was 88.7'.
- **Step 4:** The energy requirements were summed for a total of 54.1 psi. Rounding to the nearest 10 psi resulted in a low pressure switch setting of 50 psi. The high switch setting is 70 psi, resulting in a dynamic head of 162'. Minimum effective drawdown volume is 8 gal.
- **Step 5:** Static pressure on the pressure switch is 38.4 psi which is less than the low switch setting. Pressure at the lowest trough is 78.3 psi which is less than the float valve rated value of 85 psi and less than 72% of the pipeline pressure rating.

Virginia Livestock Watering Systems - Pressure System Worksheet

1) Assistance Information

Customer:	J. B. Swift
County:	Smyth
Date:	8/25/2010
Assisted By:	sw

Project Notes: Figure II-2. Example 1: Pressure System.

2) Water Budget

a) Total Daily Water Demand

Type of livestock:	Beef stockers	
Number of Animals:	165	
Water demand/animal/day:	8	gpd
Total Daily Demand:	1320	gpd

See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

Number of times herd drinks/day	3	events
Time desired to water herd:	60	minutes/event
Average peak demand:	7.3	gpm
Alternate peak demand:	8	gpm

See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate:	10	gpm
Source daily yield:	14400	gpd

If source flow rate is close to or less than Peak Demand, consider storage alternatives (see 2nd Tab).

If source daily yield is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

a) Trough Information

Trough type(s):	Freeze-proof	
Design flow rate: Alternate Peak Demand	8.0	gpm

Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.

Maximum float valve pressure:	85	psi

Typical values range from 50-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure:	10	psi

Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material:	Plastic: SCH 40 PVC	
Pipe nominal diameter:	1 1/4"	
Pipe avg. inner diameter:	1.36	in.
Pipe cross-sectional area:	0.0101	sq. ft.
Friction loss/100 ft	1.2	ft./100 ft.
Velocity check (<5 fps):	1.8	fps

If velocity is greater than 5 fps, consider a larger diameter pipe.

Pipe length to farthest watering point:	1025	feet
Add 10% for slope and fittings:	1127.5	feet
Total friction loss:	13	ft. OR
Total friction loss:	5.7	psi

If friction loss is greater than 10 psi, consider using a larger diameter pipe.

Pipe pressure rating:	370	psi
72% of rating (See VA CPS 516):	266	psi

Compare with result in Step 5b.

c) Vertical Pumping Distance

High point to pump "to":	Trough 3	
Ground elev. of high point:	499.3	feet
Low point to pump "from":	Well	
Ground elev. of low point:	410.6	feet
Elevation difference:	88.7	feet
OR	38.4	psi

4) Pump and Pressure Tank Design

a) Summary of energy requirements for the watering system:

Elevation head:	38.4	psi	OR	89	feet
Friction loss:	5.7	psi	OR	13	feet
Minimum float valve pressure:	10	psi	OR	23	feet
Other:		psi	OR		feet
TOTAL REQUIREMENTS:	54.1	psi	OR	125	feet

b) Pressure Switch Settings Based on System Load:

Low pressure switch setting:	50	psi (Minimum is 20 psi.)
High pressure switch setting:	70	psi (Max. is usually 80 psi.)

If a high pressure switch setting of 80 psi or more is required, consider alternate design or high pressure-rated tank.

c) Dynamic Head added to pump by the watering system:

Dynamic head = higher switch setting of 70 psi x 2.31 = 162 feet

Total Dynamic Head will equal this number plus the 'Lift' Head required to get the water from the source up to the distribution system. The flow rate and the Total Dynamic Head will be used to size the pump for the project.

d) Minimum Effective Drawdown for Pressure Tank:

Design pumping rate of	8.0	gpm x
Minimum pumping time of	1	minute =
Minimum pressure tank volume of	8.0	gallons

This is the minimum drawdown volume required to allow the pump to run for at least one minute before shutting off. A larger volume can be used.

5) Static Pressure Checks

a) Static pressure at pressure switch:

Elevation of highest point:	499.3	ft
Elevation of pressure switch:	410.6	ft
Low pressure switch setting =	50	psi
Static pressure on switch =	38.4	psi

If static pressure on the switch exceeds low pressure switch setting (red cell), the pump will not turn back on after trough is initially filled and then emptied.

b) Check static pressure at lowest trough:

Elevation of pressure switch:	410.6	feet
Elevation of lowest trough:	391.5	feet
Difference:	19.1	feet OR 8.3 psi
Add high pressure switch setting:	70	psi
Total pressure at lowest trough:	78.3	psi

Orange cell: pressure exceeds max float valve pressure; red cell: pipe pressure limit exceeded. Check troughs at higher elevations if pressure is excessive at lowest trough.

Example 2 – Pressure System with a Remote Pressure Tank

In Example 1, the pump, pressure tank, and pressure switch are located close to each other. In some cases, it is advantageous to locate the pressure tank at some distance from the pump. Reasons for using a remote pressure tank include:

- Reducing the pressure, size, and expense of the pressure tank by placing it at an elevation between the pump and the highest trough.
- Convenience of location (for example, using an existing shelter to house the pressure tank). See Example 3 for such a scenario.

In such cases, consideration should also be given to the location of the pressure switch.

1) If the pressure switch is located with the pressure tank, the wire to the pump will have to be placed in the pipeline ditch where it is subject to damage by lightning or burrowing animals. As distance from the pump increases, the heavier the wire gauge required and the greater the wire cost. (See Appendix A-6.)

2) If the pressure switch is located near the pump and away from the pressure tank, there is greater fluctuation in the pressure sensed at the switch due to the increased distance from the tank. To reduce "flutter" (rapid switching on and off), and thus to protect the pump from premature wear, a snubber (small orifice) can be installed. See Appendix B-3 for a pressure switch with a snubber detail drawing.

This example illustrates the use of a remote pressure tank for the purpose of reducing the pressure at the pressure tank. The pressure switch, with a snubber, will be located near the pump. The layout is shown in Figure II-3.

- Livestock: 20 beef cow/calf pairs
- Estimated water demand = 20 gpd/pair
- Water source: 7 gpm well
- Troughs: Four freeze proof troughs with ball valve and drain cut-offs.

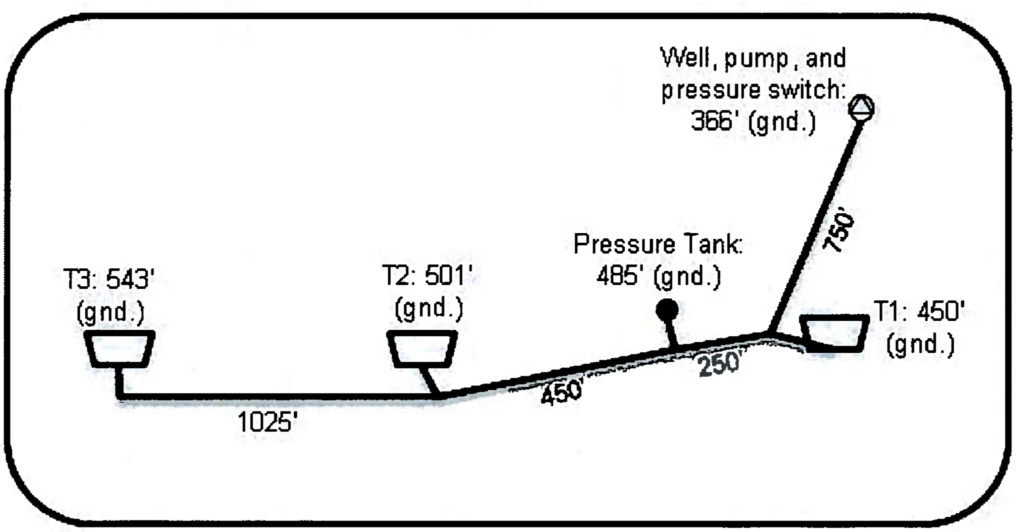


Figure II-3. Layout for Example 2 - Remote Pressure Tank

The layout shows an elevation difference of 177' between the highest trough (T3) and the ground elevation of the well. If the pressure tank is located near the well, the tank will have to operate at pressures approaching 100 psi (the upper limit for non-industrial pressure tanks). In order to keep the tank pressure comfortably below 100 psi and to limit the tank size, the landowner has chosen to locate the tank at elevation 485' which is 119' above the well. The pressure switch settings, however, will still need to reflect the total energy requirements of the system since the switch is located near the well. The **Pressure System** worksheet will be used twice to:

1) Determine the pressure and effective drawdown volume for the pressure tank by analyzing the system from Trough 3 to the proposed tank location.
2) Determine the energy required to bring the water from the pump to the pressure tank. Add the results from both sets of energy calculations to determine the pressure switch settings.

Solution:

Analysis 1 – Trough 3 to Pressure Tank. See Figure II-4.

- **Steps 1 and 2:** Given information was entered and an average peak demand of 2.2 was computed. An alternate peak demand of 5 gpm was chosen as a sufficiently conservative flow rate. The rule-of-thumb minimum of 8 gpm for frost-free systems would over-pump the source that is producing water at 7 gpm. This alternate value was used as the design flow rate and design pumping rate. The source daily yield is sufficient to meet the daily demand.
- **Step 3:** The maximum and minimum float valve operating pressures were entered based on manufacturer's recommendations. PE plastic pipe with a pressure rating of 160 psi was chosen with a nominal diameter of 1¼". Length to the farthest trough was measured to be 1475'. The high point for this part of the analysis is Trough 3 at ground elevation = 543'. The low point for this part of the analysis is the pressure tank at ground elevation = 485'. The resulting elevation head is 58' or 25.1 psi.
- **Step 4:** Total energy requirements for this part of the system = **38.3 psi**. Therefore, the pressure tank will be sized to operate at 40-60 psi with a minimum effective drawdown of 5 gallons. However, the pressure settings for the switch will be determined in Analysis 2. The dynamic head calculation should be ignored for Analysis 1.
- **Step 5:** This step is left blank. Static pressure checks will be done in Analysis 2 once the pressure switch settings are known.

Analysis 2 – Pressure Tank to Pressure Switch near Pump. See Figure II-5.

- **Steps 1 and 2** are identical to Analysis 1.
- **Step 3:** The design flow rate is 5.0 gpm as chosen in Analysis 1. The maximum float valve pressure of 85 psi is also as chosen in Analysis 1. However, 0 was used as the minimum float valve pressure because this component of the energy budget has already been accounted for in Analysis 1. The same pipe material is used as in Analysis 1, but the length used for computing friction loss is 1000' (pipe length from the pressure tank to the pressure switch). After adding 10% to this length, friction loss is computed to be 2.2 psi. The vertical pumping distance of interest in this analysis is between the pressure tank and the pressure switch, resulting in an elevation head of 119' or 51.5 psi.
- **Step 4:** The energy budget item listed as "Other" allows entry of the total from Analysis 1 (38.3 psi). The energy requirements for the whole system sum to 92 psi resulting in pressure switch settings of 90-110 psi. Dynamic head added by the watering system = 254'.
- **Step 5:** Static pressure at the pressure switch = (543-366)/2.31 = 76.6 psi < 90 psi (OK)
  Static pressure at the troughs: all troughs are sufficiently high above the pressure switch such that static pressure on the float valves and in the pipeline is not a problem.

Virginia Livestock Watering Systems - Pressure System Worksheet

1) Assistance Information

Customer:	M. J. Producer
County:	Dickenson
Date:	8/25/2010
Assisted By:	TR

Project Notes: Figure II-4. Example 2: Remote pressure Tank. Pressure switch to be located near pump. Pressure tank to be located 119' above pressure switch ground elevation. Analysis 1: System from Trough 3 to the pressure tank.

2) Water Budget

a) Total Daily Water Demand

Type of livestock:	Beef cow/calf pairs	
Number of Animals:	20	
Water demand/animal/day:	20	gpd
Total Daily Demand:	400	gpd

See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

Number of times herd drinks/day	3	events
Time desired to water herd:	60	minutes/event
Average peak demand:	2.2	gpm
Alternate peak demand:	5	gpm

See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate:	7	gpm
Source daily yield:	10080	gpd

If source flow rate is close to or less than Peak Demand, consider storage alternatives (see 2nd Tab).

If source daily yield is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

a) Trough Information

Trough type(s):	Freeze-proof	
Design flow rate:	Alternate Peak Demand 5.0	gpm

Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.

Maximum float valve pressure: 85 psi

Typical values range from 50-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure: 10 psi

Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material:	Plastic: PE SIDR-PR	
Pipe nominal diameter:	1 1/4"	
Pipe avg. inner diameter:	1.38	in.
Pipe cross-sectional area:	0.0104	sq. ft.
Friction loss/100 ft	0.5	ft./100 ft.
Velocity check (<5 fps):	1.1	fps

If velocity is greater than 5 fps, consider a larger diameter pipe.

Pipe length to farthest watering point:	1475	feet
Add 10% for slope and fittings:	1622.5	feet
Total friction loss:	7	ft. OR
Total friction loss:	3.2	psi

If friction loss is greater than 10 psi, consider using a larger diameter pipe.

Pipe pressure rating:	160	psi
72% of rating (See VA CPS 516):	115	psi

Compare with result in Step 5b.

c) Vertical Pumping Distance

High point to pump "to":	Trough 3	
Ground elev. of high point:	543	feet
Low point to pump "from":	Pressure Tank	
Ground elev. of low point:	485	feet
Elevation difference:	58	feet
OR	25.1	psi

4) Pump and Pressure Tank Design

a) Summary of energy requirements for the watering system:

	psi		feet
Elevation head:	25.1 psi	OR	58 feet
Friction loss:	3.2 psi	OR	7 feet
Minimum float valve pressure:	10 psi	OR	23 feet
Other:	psi	OR	feet
TOTAL REQUIREMENTS:	38.3 psi	OR	89 feet

~~c) Dynamic Head added to pump by the watering system:~~

Dynamic head = ~~higher switch setting of~~ 60 psi x 2.31 = ~~139 feet~~

~~Total Dynamic Head will equal this number plus the [illegible] required to get the water from the source up to the distribution system. The flow rate and the Total Dynamic Head will be used to size the pump for the project.~~

b) Pressure Switch Settings Based on System Load:

Low pressure switch setting:	40	psi (Minimum is 20 psi.)
High pressure switch setting:	60	psi (Max. is usually 80 psi.)

If a high pressure switch setting of 80 psi or more is required, consider alternate design or high pressure-rated tank.

d) Minimum Effective Drawdown for Pressure Tank:

Design pumping rate of	5.0	gpm x
Minimum pumping time of	1	minute =
Minimum pressure tank volume of	5.0	gallons

This is the minimum drawdown volume required to allow the pump to run for at least one minute before shutting off. A larger volume can be used.

5) Static Pressure Checks

a) Static pressure at pressure switch:

Elevation of highest point:		ft
Elevation of pressure switch:		ft
Low pressure switch setting =		psi
Static pressure on switch =		psi

If static pressure on the switch exceeds low pressure switch setting (red cell), the pump will not turn back on after trough is initially filled and then emptied.

b) Check static pressure at lowest trough:

Elevation of pressure switch:		feet
Elevation of lowest trough:		feet
Difference:		feet OR psi
Add high pressure switch setting:		psi
Total pressure at lowest trough:		psi

Orange cell: pressure exceeds max float valve pressure; red cell: pipe pressure limit exceeded. Check troughs at higher elevations if pressure is excessive at lowest trough.

Virginia Livestock Watering Systems - Pressure System Worksheet

1) Assistance Information

Customer:	M. J. Producer
County:	Dickenson
Date:	8/27/2010
Assisted By:	TR

Project Notes: Figure II-5. Example 2: Remote pressure Tank. Pressure switch to be located near pump. Pressure tank to be located 119' above pressure switch ground elevation. Analysis 2: System from the pressure tank to the pressure switch near the well..

2) Water Budget

a) Total Daily Water Demand

Type of livestock:	Beef cow/calf pairs	
Number of Animals:	20	
Water demand/animal/day:	20	gpd
Total Daily Demand:	400	gpd

See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

Number of times herd drinks/day	3	events
Time desired to water herd:	60	minutes/event
Average peak demand:	2.2	gpm
Alternate peak demand:	5	gpm

See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate:	7	gpm
Source daily yield:	10080	gpd

If source flow rate is close to or less than Peak Demand, consider storage alternatives (see 2nd Tab).

If source daily yield is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

a) Trough Information

Trough type(s):	Freeze-proof	
Design flow rate:	Alternate Peak Demand 5.0	gpm

Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.

Maximum float valve pressure:	85	psi

Typical values range from 50-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure:	0	psi

Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material:	Plastic: PE SIDR-PR	
Pipe nominal diameter:	1 1/4"	
Pipe avg. inner diameter:	1.38	in.
Pipe cross-sectional area:	0.0104	sq. ft.
Friction loss/100 ft	0.5	ft./100 ft.
Velocity check (<5 fps):	1.1	fps

If velocity is greater than 5 fps, consider a larger diameter pipe.

Pipe length to farthest watering point:	1000	feet
Add 10% for slope and fittings:	1100	feet
Total friction loss:	5	ft. OR
Total friction loss:	2.2	psi

If friction loss is greater than 10 psi, consider using a larger diameter pipe.

Pipe pressure rating:	160	psi
72% of rating (See VA CPS 516):	115	psi

Compare with result in Step 5b.

c) Vertical Pumping Distance

High point to pump "to":	Pressure tank	
Ground elev. of high point:	485	feet
Low point to pump "from":	Pressure switch	
Ground elev. of low point:	366	feet
Elevation difference:	119	feet
OR	51.5	psi

4) Pump and Pressure Tank Design

a) Summary of energy requirements for the watering system:

Elevation head:	51.5	psi	OR	119	feet
Friction loss:	2.2	psi	OR	5	feet
Minimum float valve pressure:	0	psi	OR	0	feet
Other: Total from Analysis 1:	38.3	psi	OR	88	feet
TOTAL REQUIREMENTS:	92.0	psi	OR	213	feet

b) Pressure Switch Settings Based on System Load:

Low pressure switch setting:	90	psi (Minimum is 20 psi.)
High pressure switch setting:	110	psi (Max. is usually 80 psi.)

If a high pressure switch setting of 80 psi or more is required, consider alternate design or high pressure-rated tank.

c) Dynamic Head added to pump by the watering system:

Dynamic head = higher switch setting of 110 psi x 2.31 = 254 feet

Total Dynamic Head will equal this number plus the 'Lift' Head required to get the water from the source up to the distribution system. The flow rate and the Total Dynamic Head will be used to size the pump for the project.

d) Minimum Effective Drawdown for Pressure Tank:

Design pumping rate of	5.0	gpm x
Minimum pumping time of	1	minute =
Minimum pressure tank volume of	5.0	gallons

This is the minimum drawdown volume required to allow the pump to run for at least one minute before shutting off. A larger volume can be used.

5) Static Pressure Checks

a) Static pressure at pressure switch:

Elevation of highest point:	543.0	ft
Elevation of pressure switch:	366	ft
Low pressure switch setting =	90	psi
Static pressure on switch =	76.6	psi

If static pressure on the switch exceeds low pressure switch setting (red cell), the pump will not turn back on after trough is initially filled and then emptied.

b) Check static pressure at lowest trough:

Elevation of pressure switch:	366	feet			
Elevation of lowest trough:	450	feet			
Difference:	-84	feet	OR	-36.4	psi
Add high pressure switch setting:				110	psi
Total pressure at lowest trough:				73.6	psi

Orange cell: pressure exceeds max float valve pressure; red cell: pipe pressure limit exceeded. Check troughs at higher elevations if pressure is excessive at lowest trough.

Example 3 – Adding to an Existing Pressure System

In this example, (see layout in Figure II-6) the pressure tank and switch are remotely located for convenience in the basement of a house. Existing PVC pipe is 1" in diameter. The landowner wishes to add three troughs (T4-T6) to the system which may require larger diameter pipe and different pressure switch settings.

- Livestock: 50 milking dairy cows
- Estimated water demand = 30 gpd/animal
- Water source: 25 gpm well
- Troughs: Six freeze proof troughs (3 existing and 3 planned)

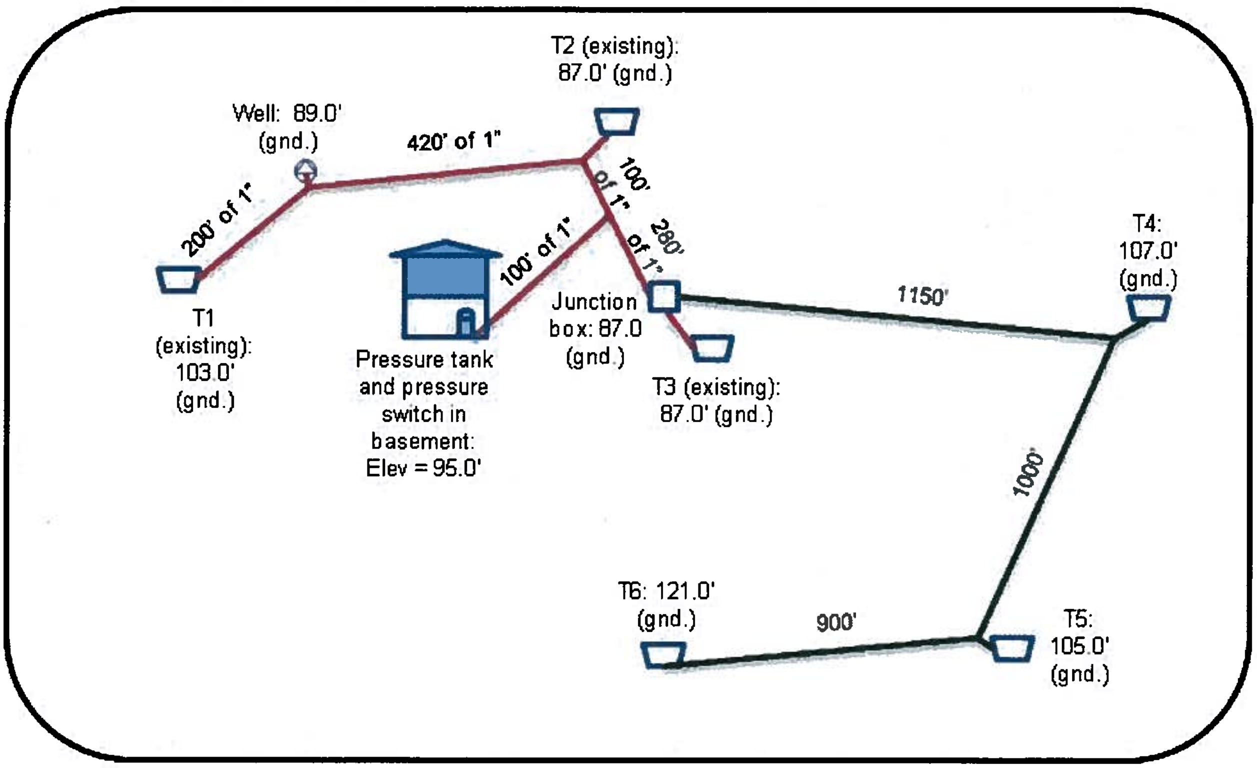


Figure II-6. Layout for Example 3 – Adding to an Existing Pressure System

Three analyses will be made to determine:

1) Friction loss in the 1" line from the pressure tank to the junction box (Figure II-7)
2) Energy requirement of the watering system extension in order to determine the operating pressure range of the pressure tank and the pressure switch settings (Figure II-8)
3) Energy needed to get water from the pump to the pressure tank to aid in evaluating the existing pump (Figure II-9).

Solution:

Analysis 1– Friction loss between the pressure tank and the junction box.

Only one pipe size can be evaluated at a time with the spreadsheet. Therefore, the purpose of this analysis is to determine the friction loss in the existing 1" diameter pipe from the pressure tank to the junction box so that this energy requirement can be added into the energy budget of Analysis 2 for the watering system addition.

- **Steps 1 and 2:** Given information was entered and an average peak demand of 8.3 was computed. This average peak demand will be used as the design flow rate and design pumping rate to see if the existing pump can produce this flow rate with the increased load from the system expansion.
- **Step 3:** The purpose of Analysis 1 is to compute friction loss in the 1" pipeline **only.** Other energy budget items are not of interest at this point. Thus, maximum and minimum float valve pressures were not entered in **3a** and elevations were not entered in **3c**. Parameters for the existing pipeline were entered in **3b**. Friction loss for the pipeline = **8.9 psi.**
- **Steps 4 and 5:** Not needed for Analysis 1.

Analysis 2 – Energy required to deliver water from the pressure tank to Trough 6.

- **Steps 1 and 2:** Same as for Analysis 1.
- **Step 3:** Maximum float valve pressure of 80 psi and minimum pressure of 10 psi were entered in 3a based on the manufacturer's recommendations. A pipe diameter of 1½" was selected with measured length of 3050' (from the junction box to Trough 6). This results in a friction loss of 8.6 psi. Appendix B-2 was used to determine the pressure rating of 330 psi. Vertical pumping distance was determined from the elevations of the pressure tank and Trough 6. The resulting elevation head is 26' or 11.3 psi.
- **Step 4:** The friction loss from Analysis 1 (8.9 psi) was added to the system energy requirements under the category of "Other." The total energy requirement for the system above the pressure tank is 38.7 psi or 89'. Rounding to the nearest 10 psi results in a low pressure switch setting of 40 psi. Adding 20 results in a high pressure switch setting of 60 psi. Dynamic head is computed from the high pressure switch setting and is 139'. However, since the pressure switch is located with the pressure tank some distance away from the pump, an additional calculation is needed to account for the elevation head and friction loss between the pump and the pressure tank. This calculation will be performed in Analysis 3. The minimum effective drawdown volume of the pressure tank is 8.3 gallons, based on the design pumping rate of 8.3 gallons.
- **Step 5:** Static pressure at the switch is less than the low switch setting (OK). Pressure at the lowest trough is less than the maximum ratings for the float valves and pipeline (OK).

Analysis 3 – Energy required to deliver water from the well to the pressure tank.

- **Steps 1 and 2:** Same as for Analysis 1.
- **Step 3:** No minimum float valve pressure is entered in **3a** because this energy budget item was accounted for in Analysis 2. The purpose of Analysis 3 is to determine the friction loss and elevation head for the existing 1" pipeline connecting the pump to the pressure tank. Parameters for 1" PVC were entered in **3b** resulting in a calculated friction loss of **14.5 psi**. The difference in elevation between the pump and the pressure tank is 6' or **2.6** psi.
- **Step 4:** The sum of the friction loss and elevation head is 17.1 psi or 40'. The remainder of the spreadsheet is not needed. Ignore the pressure switch settings and dynamic head.
- Dynamic head for whole system = 139' (from Analysis 2) + 40' (from Step 4 above) = 179'.

The specifications of the existing pump need to be checked to see if the pump can deliver the design flow rate with a dynamic head of 179' plus the head required to bring the water out of the ground. It may be worthwhile to experiment with the pipe diameter in Analysis 2. A smaller diameter will result in greater friction loss and a larger pressure tank; a larger diameter will result in a smaller pressure tank. Work with the landowner to select the most cost effective arrangement.

Virginia Livestock Watering Systems - Pressure System Worksheet

1) Assistance Information

Project Notes: Figure II-7. Example 3: Adding to an Existing Pressure System. Analysis 1: Friction loss between pressure tank and junction box.

Customer:	J. Q. Customer
County:	Charlotte
Date:	8/25/2010
Assisted By:	DY

2) Water Budget

a) Total Daily Water Demand

Type of livestock:	Dairy cows	
Number of Animals:	50	
Water demand/animal/day:	30	gpd
Total Daily Demand:	1500	gpd

See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

Number of times herd drinks/day	3	events
Time desired to water herd:	60	minutes/event
Average peak demand:	8.3	gpm
Alternate peak demand:		gpm

See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate:	25	gpm
Source daily yield:	36000	gpd

If source flow rate is close to or less than Peak Demand, consider storage alternatives (see 2nd Tab).

If source daily yield is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

a) Trough Information

Trough type(s):	Freeze-proof	
Design flow rate: Avg. Peak Demand	8.3	gpm

Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.

Maximum float valve pressure: ______ psi

Typical values range from 50-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure: ______ psi

Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material:	Plastic: SCH 40 PVC	
Pipe nominal diameter:	1"	
Pipe avg. inner diameter:	1.029	in.
Pipe cross-sectional area:	0.0058	sq. ft.
Friction loss/100 ft	4.9	ft./100 ft.
Velocity check (<5 fps):	3.2	fps

If velocity is greater than 5 fps, consider a larger diameter pipe.

Pipe length to farthest watering point:	380	feet
Add 10% for slope and fittings:	418	feet
Total friction loss:	21	ft. OR
Total friction loss:	8.9	psi

If friction loss is greater than 10 psi, consider using a larger diameter pipe.

Pipe pressure rating:		psi
72% of rating (See VA CPS 516):		psi

Compare with result in Step 5b.

c) Vertical Pumping Distance

High point to pump "to": ______

Ground elev. of high point: ______ feet

Low point to pump "from": ______

Ground elev. of low point: ______ feet

Elevation difference: ______ feet OR ______ psi

4) Pump and Pressure Tank Design

a) Summary of energy requirements for the watering system:

Elevation head:		psi	OR		feet
Friction loss:	8.9	psi	OR	21	feet
Minimum float valve pressure:		psi	OR		feet
Other:		psi	OR		feet
TOTAL REQUIREMENTS:		psi	OR		feet

b) Pressure Switch Settings Based on System Load:

Low pressure switch setting: ______ psi (Minimum is 20 psi.)

High pressure switch setting: ______ psi (Max. is usually 80 psi.)

If a high pressure switch setting of 80 psi or more is required, consider alternate design or high pressure-rated tank.

c) Dynamic Head added to pump by the watering system:

Dynamic head = higher switch setting of ______ psi x 2.31 = ______ feet

Total Dynamic Head will equal this number plus the 'Lift' Head required to get the water from the source up to the distribution system. The flow rate and the Total Dynamic Head will be used to size the pump for the project.

d) Minimum Effective Drawdown for Pressure Tank:

Design pumping rate of	8.3	gpm x
Minimum pumping time of	1	minute =
Minimum pressure tank volume of	8.3	gallons

This is the minimum drawdown volume required to allow the pump to run for at least one minute before shutting off. A larger volume can be used.

5) Static Pressure Checks

a) Static pressure at pressure switch:

Elevation of highest point: ______ ft

Elevation of pressure switch: ______ ft

Low pressure switch setting = ______ psi

Static pressure on switch = ______ psi

If static pressure on the switch exceeds low pressure switch setting (red cell), the pump will not turn back on after trough is initially filled and then emptied.

b) Check static pressure at lowest trough:

Elevation of pressure switch: ______ feet

Elevation of lowest trough: ______ feet

Difference: ______ feet OR ______ psi

Add high pressure switch setting: ______ psi

Total pressure at lowest trough: ______ psi

Orange cell: pressure exceeds max float valve pressure; red cell: pipe pressure limit exceeded. Check troughs at higher elevations if pressure is excessive at lowest trough.

Virginia Livestock Watering Systems - Pressure System Worksheet

1) Assistance Information

Customer: J. Q. Customer
County: Charlotte
Date: 8/25/2010
Assisted By: DY

Project Notes: Figure II-8. Example 3: Adding to an Existing Pressure System. Analysis 2: Energy required to deliver water from the pressure tank to Trough 6.

2) Water Budget

a) Total Daily Water Demand

Type of livestock: Dairy cows
Number of Animals: 50
Water demand/animal/day: 30 gpd
Total Daily Demand: 1500 gpd
See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

Number of times herd drinks/day: 3 events
Time desired to water herd: 60 minutes/event
Average peak demand: 8.3 gpm
Alternate peak demand: gpm
See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate: 25 gpm
Source daily yield: 36000 gpd
If source flow rate is close to or less than Peak Demand, consider storage alternatives (see 2nd Tab).
If source daily yield is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

a) Trough Information

Trough type(s): Freeze-proof
Design flow rate: Avg. Peak Demand 8.3 gpm
Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.
Maximum float valve pressure: 80 psi
Typical values range from 50-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure: 10 psi
Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material: Plastic: SCH 40 PVC
Pipe nominal diameter: 1 1/2"
Pipe avg. inner diameter: 1.59 in.
Pipe cross-sectional area: 0.0138 sq. ft.
Friction loss/100 ft: 0.6 ft./100 ft.
Velocity check (<5 fps): 1.3 fps
If velocity is greater than 5 fps, consider a larger diameter pipe.

Pipe length to farthest watering point: 3050 feet
Add 10% for slope and fittings: 3355 feet
Total friction loss: 20 ft. OR
Total friction loss: 8.6 psi If friction loss is greater than 10 psi, consider using a larger diameter pipe.

Pipe pressure rating: 330 psi
72% of rating (See VA CPS 516): 238 psi Compare with result in Step 5b.

c) Vertical Pumping Distance

High point to pump "to": Trough 6
Ground elev. of high point: 121 feet

Low point to pump "from": Pressure tank
Ground elev. of low point: 95 feet

Elevation difference: 26 feet
OR 11.3 psi

4) Pump and Pressure Tank Design

a) Summary of energy requirements for the watering system:

	psi		feet
Elevation head:	11.3 psi	OR	26 feet
Friction loss:	8.6 psi	OR	20 feet
Minimum float valve pressure:	10 psi	OR	23 feet
Other: Analysis 1 friction loss:	8.9 psi	OR	21 feet
TOTAL REQUIREMENTS:	38.7 psi	OR	89 feet

b) Pressure Switch Settings Based on System Load:

Low pressure switch setting: 40 psi (Minimum is 20 psi.)
High pressure switch setting: 60 psi (Max. is usually 80 psi.)
If a high pressure switch setting of 80 psi or more is required, consider alternate design or high pressure-rated tank.

c) Dynamic Head added to pump by the watering system:

Dynamic head = higher switch setting of 60 psi x 2.31 = 139 feet
Total Dynamic Head will equal this number plus the 'Lift' Head required to get the water from the source up to the distribution system. The flow rate and the Total Dynamic Head will be used to size the pump for the project.

d) Minimum Effective Drawdown for Pressure Tank:

Design pumping rate of 8.3 gpm x
Minimum pumping time of 1 minute =
Minimum pressure tank volume of 8.3 gallons

This is the minimum drawdown volume required to allow the pump to run for at least one minute before shutting off. A larger volume can be used.

5) Static Pressure Checks

a) Static pressure at pressure switch:

Elevation of highest point: 121.0 ft
Elevation of pressure switch: 95 ft
Low pressure switch setting = 40 psi

Static pressure on switch = 11.3 psi

If static pressure on the switch exceeds low pressure switch setting (red cell), the pump will not turn back on after trough is initially filled and then emptied.

b) Check static pressure at lowest trough:

Elevation of pressure switch: 95 feet
Elevation of lowest trough: 87 feet
Difference: 8 feet OR 3.5 psi
Add high pressure switch setting: 60 psi
Total pressure at lowest trough: 63.5 psi

Orange cell: pressure exceeds max float valve pressure; red cell: pipe pressure limit exceeded. Check troughs at higher elevations if pressure is excessive at lowest trough.

Virginia Livestock Watering Systems - Pressure System Worksheet

1) Assistance Information

Customer:	J. Q. Customer
County:	Charlotte
Date:	8/25/2010
Assisted By:	DY

Project Notes: Figure II-9. Example 3: Adding to an Existing Pressure System. Analysis 3: Energy required to deliver water from the pump to the pressure tank.

2) Water Budget

a) Total Daily Water Demand

Type of livestock:	Dairy cows	
Number of Animals:	50	
Water demand/animal/day:	30	gpd
Total Daily Demand:	1500	gpd

See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

Number of times herd drinks/day	3	events
Time desired to water herd:	60	minutes/event
Average peak demand:	8.3	gpm
Alternate peak demand:		gpm

See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate:	25	gpm
Source daily yield:	36000	gpd

If source flow rate is close to or less than Peak Demand, consider storage alternatives (see 2nd Tab).

If source daily yield is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

a) Trough Information

Trough type(s):	Freeze-proof	
Design flow rate: Avg. Peak Demand	8.3	gpm

Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.

Maximum float valve pressure:	80	psi

Typical values range from 50-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure:	0	psi

Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material:	Plastic: SCH 40 PVC	
Pipe nominal diameter:	1"	
Pipe avg. inner diameter:	1.029	in.
Pipe cross-sectional area:	0.0058	sq. ft.
Friction loss/100 ft	4.9	ft./100 ft.
Velocity check (<5 fps):	3.2	fps

If velocity is greater than 5 fps, consider a larger diameter pipe.

Pipe length to farthest watering point:	620	feet
Add 10% for slope and fittings:	682	feet
Total friction loss:	34	ft. OR
Total friction loss:	14.5	psi

If friction loss is greater than 10 psi, consider using a larger diameter pipe.

Pipe pressure rating:	450	psi
72% of rating (See VA CPS 516):	324	psi

Compare with result in Step 5b.

c) Vertical Pumping Distance

High point to pump "to":	Pressure tank	
Ground elev. of high point:	95	feet
Low point to pump "from":	Pump (well)	
Ground elev. of low point:	89	feet
Elevation difference:	6	feet
OR	2.6	psi

4) Pump and Pressure Tank Design

a) Summary of energy requirements for the watering system:

Elevation head:	2.6	psi	OR	6	feet
Friction loss:	14.5	psi	OR	34	feet
Minimum float valve pressure:	0	psi	OR	0	feet
Other:		psi	OR		feet
TOTAL REQUIREMENTS:	17.1	psi	OR	40	feet

~~c) Dynamic Head added to pump by the watering system:~~

~~Dynamic head = higher switch setting of 40 psi x 2.31 = 92 feet~~

~~Total Dynamic Head will equal this number plus the Lift Head required to get the water from the source up to the distribution system. The flow rate and the Total Dynamic Head will be used to size the pump for the project.~~

~~b) Pressure Switch Settings Based on System Load:~~

~~Low pressure switch setting:~~	~~20~~	~~psi (Minimum is 20 psi.)~~
~~High pressure switch setting:~~	~~40~~	~~psi (Max. is usually 80 psi.)~~

~~If a high pressure switch setting of 80 psi or more is required, consider alternate design or high pressure-rated tank.~~

d) Minimum Effective Drawdown for Pressure Tank:

Design pumping rate of	8.3	gpm x
Minimum pumping time of	1	minute =
Minimum pressure tank volume of	8.3	gallons

This is the minimum drawdown volume required to allow the pump to run for at least one minute before shutting off. A larger volume can be used.

5) Static Pressure Checks

a) Static pressure at pressure switch:

Elevation of highest point:		ft
Elevation of pressure switch:		ft
Low pressure switch setting =		psi
Static pressure on switch =		psi

If static pressure on the switch exceeds low pressure switch setting (red cell), the pump will not turn back on after trough is initially filled and then emptied.

b) Check static pressure at lowest trough:

Elevation of pressure switch:		feet		
Elevation of lowest trough:		feet		
Difference:		feet	OR	psi
Add high pressure switch setting:				psi
Total pressure at lowest trough:				psi

Orange cell: pressure exceeds max float valve pressure; red cell: pipe pressure limit exceeded. Check troughs at higher elevations if pressure is excessive at lowest trough.

Example 4 – Public Water Connection

This example, with layout as shown in Figure II-10, demonstrates the use of the **Public Water Connection** worksheet (second tab) of the Virginia Livestock Watering Systems spreadsheet (Figure II-11). Be sure to check with local authorities regarding public water connection regulations. In this example, the county deemed the frost-free troughs proposed for this system adequate to prevent accidental backflow into the public water supply.

- Livestock: 60 beef cow/calf pairs
- Estimated water demand: 20 gpd/pair
- Water source: Public water supply with available pressure = 90 psi.
- Troughs: Seven frost-free troughs, each with ball valve and drain cutoffs.

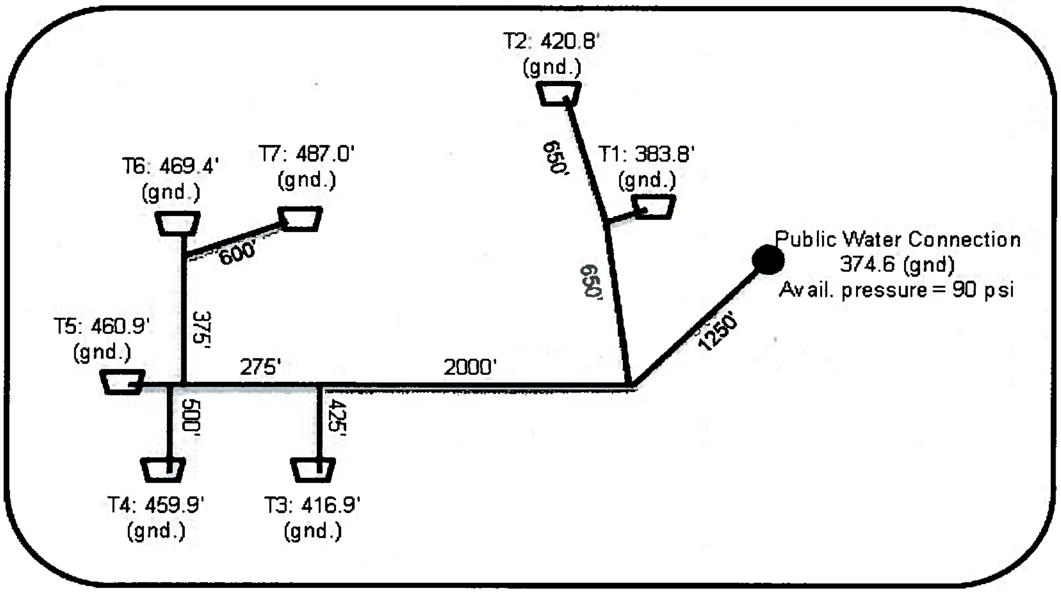


Figure II-10. Layout for Example 4: Public Water

Solution:

- **Steps 1 and 2:** Given information was entered and an average peak demand of 6.7 gpm was computed. An alternate peak demand of 8 gpm was selected to serve as the design flow rate.
- **Step 3:** The float valve operating range of 10-80 psi was determined from the manufacturer's recommendations. SCH 40 PVC plastic, 1½" diameter was chosen for the pipeline. Pipeline length to Trough 7 was measured to be 4500', resulting in a total friction loss of 11.7 psi. This value is greater than the recommended maximum of 10 psi, but is acceptable if there is sufficient pressure available (as will be determined in Step 4). Friction loss for a 2" pipe would be less, but the pipe may be more expensive. The highest point in the system is Trough 7 at 487' which is 112.4' above the public water connection.
- **Step 4:** The energy requirements are summed for a total of 70.4 psi. Since the public connection can supply 90 psi, the available pressure is adequate. If the public water pressure was insufficient, the water could be directed to a reservoir and then pumped to the watering system. The design would be evaluated using the **Pressure System Worksheet**.
- **Step 5:** Pressure at the lowest trough (Trough1) is 86 psi. This exceeds the maximum pressure for the trough float valve (80 psi). Install a pressure reducer or use a higher-rated float valve. The remaining troughs are high enough above the public water connection such that a pressure reducer is not needed.

Virginia Livestock Watering Systems - Public Water Connection Worksheet

1) Assistance Information

Customer:	J. Q. Public
County:	Washington
Date:	8/26/2010
Assisted By:	JH

Project Notes: Figure II-11. Example 4. Public Water Connection. Note: A pressure reducer will be needed at Trough 1.

2) Water Budget

a) Total Daily Water Demand

Type of livestock:	Beef cow/calf pairs	
Number of Animals:	60	
Water demand/animal/day:	20	gpd
Total Daily Demand:	1200	gpd

See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

Number of times herd drinks/day	3	events
Time desired to water herd:	60	minutes/event
Average peak demand:	6.7	gpm
Alternate peak demand:	8	gpm

See Design Note for considerations for estimating peak demand.

3) Design Parameters

a) Trough Information

Trough type(s):	Freeze-proof	
Design flow rate: Alternate Peak Demand	8.0	gpm

Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.

Maximum float valve pressure: 80 psi

Typical values range from 75-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure: 10 psi

Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material:	Plastic: SCH 40 PVC	
Plastic pipe nominal diameter:	1 1/2"	
Plastic pipe actual diameter:	1.59	in.
Pipe cross-sectional area:	0.0138	sq. ft.
Friction loss/100 ft	0.5	ft./100 ft.
Velocity check (<5 fps):	1.3	fps

If velocity is greater than 5 fps, consider a larger diameter pipe.

Pipe length to farthest watering point:	4500	feet
Add 10% for slope and fittings:	4950	feet
Total friction loss:	27	ft. OR
Total friction loss:	11.7	psi

If friction loss is greater than 10 psi, consider using a larger diameter pipe.

Pipe pressure rating:	330	psi
72% of rating (See VA CPS 516):	238	psi

Compare with result in Step 5.

c) Vertical Lift

Elevation of highest point in system:	487	feet
Elevation of public water connection:	374.6	feet
Elevation difference:	112.4	feet
OR	48.7	psi

4) Pressure Requirements

Summary of energy requirements for the watering system:

Elevation head:	48.7	psi
Friction loss:	11.7	psi
Minimum float valve pressure:	10	psi
TOTAL REQUIREMENTS:	70.4	psi
Pressure at water meter:	90	psi
Available pressure is:	Adequate	

5) Static Pressure Checks

Check static pressure at lowest trough:

Elevation of public water connection:	374.6	feet		
Elevation of lowest trough:	383.8	feet		
Difference:	-9.2	feet OR	-4.0	psi
Add pressure at meter:			90.0	psi
Total pressure at lowest trough:			86.0	psi

Orange cell: pressure exceeds max float valve pressure; red cell: pipe pressure limit exceeded. Check troughs at higher elevations if pressure is excessive at lowest trough.

Example 5 – Use of a Reservoir for Pressure Relief

- Livestock: 32 beef cow/calf pairs
- Estimated water demand: 20 gpd/pair
- Water source: 9 gpm well
- Troughs: 5 frost-free, with ball valve & drain cutoffs.
- Landowner would like to use existing 1¼" PVC pipe.

A quick analysis of the elevations shown in Figure II-12 indicates that a high pressure system will be needed to keep Trough 1 filled and that static pressures will be high in the lower troughs. One way to avoid excessive pressures at the lower troughs is to use a hybrid system: pumping up to the high trough, pumping to fill a reservoir, and then using gravity to fill the lower troughs from the reservoir. The addition of a reservoir on a float valve relieves the lower troughs from the system pressure. Calculations for this system will be done in two parts, using first the **Pressure System Worksheet** (Figure II-13), and then the **Pressure-Energy/Gravity Flow Worksheet**. (Figure II-14).

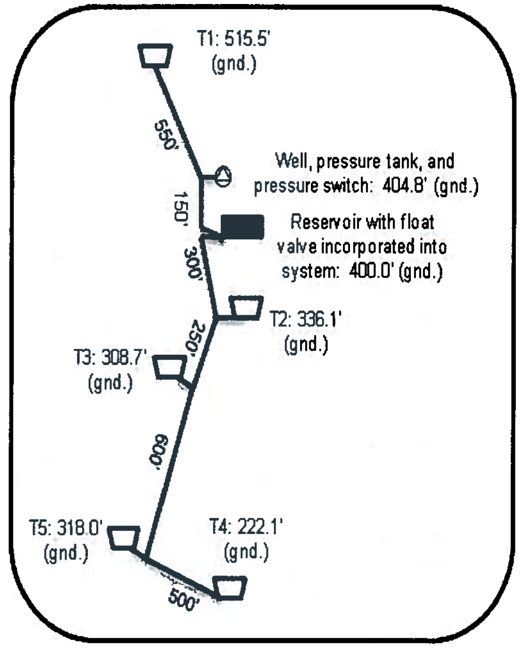


Figure II-12. Layout for Example 5: Reservoir for Pressure Relief

Solution:

Analysis 1 – Pressure System to Deliver Water to Trough 1.

- **Steps 1 and 2:** Enter given information. Compute an average peak demand of 3.6 gpm. Select an alternate flow rate of 5 gpm. The herd is small, expansion is not likely, and the reservoir will provide storage, so the recommended minimum of 8 gpm for frost-free troughs is not necessary.
- **Step 3:** Input minimum and maximum operating pressures for the float valves based on the manufacturer's recommendations. Select SCH 40 PVC plastic, 1¼" diameter (existing pipeline). Pipe length from the pump to Trough 1 is 550 feet with friction loss = 1.3 psi. The vertical pumping distance from the well to Trough 1 is 110.7'.
- **Step 4:** Energy requirements for the system total 59.2 psi. Rounding to the nearest 10 psi results in a low pressure switch setting of 60 psi. The dynamic head is computed from the high switch setting of 80 psi and is 185'. The pressure tank should be sized to operate at 60-80 psi with a minimum effective drawdown volume of 5 gallons.
- **Step 5:** Static pressure at the pressure switch = 47.9 psi which is less than the low switch setting of 60 psi. In **5b**, substitute the elevation of the reservoir for the elevation of the lowest trough since the reservoir is located below the pressure switch. The static pressure is 2.1 psi and the maximum system pressure is 80 psi. Select a reservoir float valve rated for greater than 82 psi.

Virginia Livestock Watering Systems - Pressure System Worksheet

1) Assistance Information

Customer:	R. G. Farmer
County:	Smyth
Date:	8/26/2010
Assisted By:	sw

Project Notes: Figure II-13. Example 5. Use of a Reservoir for Pressure Relief. Analysis 1: Pressure system for Trough 1 and reservoir. Note: Float valve on reservoir needs to be rated for more than 82 psi.

2) Water Budget

a) Total Daily Water Demand

Type of livestock:	Beef cow/calf pairs	
Number of Animals:	32	
Water demand/animal/day:	20	gpd
Total Daily Demand:	640	gpd

See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

Number of times herd drinks/day	3	events
Time desired to water herd:	60	minutes/event
Average peak demand:	3.6	gpm
Alternate peak demand:	5	gpm

See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate:	9	gpm
Source daily yield:	12960	gpd

If source flow rate is close to or less than Peak Demand, consider storage alternatives (see 2nd Tab).

If source daily yield is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

a) Trough Information

Trough type(s):	Freeze-proof	
Design flow rate: Alternate Peak Demand	5.0	gpm

Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.

Maximum float valve pressure:	80	psi

Typical values range from 50-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure:	10	psi

Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material:	Plastic: SCH 40 PVC	
Pipe nominal diameter:	1 1/4"	
Pipe avg. inner diameter:	1.36	in.
Pipe cross-sectional area:	0.0101	sq. ft.
Friction loss/100 ft	0.5	ft./100 ft.
Velocity check (<5 fps):	1.1	fps

If velocity is greater than 5 fps, consider a larger diameter pipe.

Pipe length to farthest watering point:	550	feet
Add 10% for slope and fittings:	605	feet
Total friction loss:	3	ft. OR
Total friction loss:	1.3	psi

If friction loss is greater than 10 psi, consider using a larger diameter pipe.

Pipe pressure rating:	370	psi
72% of rating (See VA CPS 516):	266	psi

Compare with result in Step 5b.

c) Vertical Pumping Distance

High point to pump "to":	Trough 1	
Ground elev. of high point:	515.5	feet
Low point to pump "from":	Well	
Ground elev. of low point:	404.8	feet
Elevation difference:	110.7	feet
OR	47.9	psi

4) Pump and Pressure Tank Design

a) Summary of energy requirements for the watering system:

Elevation head:	47.9	psi	OR	111	feet
Friction loss:	1.3	psi	OR	3	feet
Minimum float valve pressure:	10	psi	OR	23	feet
Other:		psi	OR		feet
TOTAL REQUIREMENTS:	59.2	psi	OR	137	feet

b) Pressure Switch Settings Based on System Load:

Low pressure switch setting:	60	psi (Minimum is 20 psi.)
High pressure switch setting:	80	psi (Max. is usually 80 psi.)

If a high pressure switch setting of 80 psi or more is required, consider alternate design or high pressure-rated tank.

c) Dynamic Head added to pump by the watering system:

Dynamic head = higher switch setting of 80 psi x 2.31 = 185 feet

Total Dynamic Head will equal this number plus the 'Lift' Head required to get the water from the source up to the distribution system. The flow rate and the Total Dynamic Head will be used to size the pump for the project.

d) Minimum Effective Drawdown for Pressure Tank:

Design pumping rate of	5.0	gpm x
Minimum pumping time of	1	minute =
Minimum pressure tank volume of	5.0	gallons

This is the minimum drawdown volume required to allow the pump to run for at least one minute before shutting off. A larger volume can be used.

5) Static Pressure Checks

a) Static pressure at pressure switch:

Elevation of highest point:	515.5	ft
Elevation of pressure switch:	404.8	ft
Low pressure switch setting =	60	psi
Static pressure on switch =	47.9	psi

If static pressure on the switch exceeds low pressure switch setting (red cell), the pump will not turn back on after trough is initially filled and then emptied.

b) Check static pressure at lowest trough:

Elevation of pressure switch:	404.8	feet
Elevation of ~~lowest trough~~ reservoir:	400	feet
Difference:	4.8	feet OR 2.1 psi
Add high pressure switch setting:	80	psi
Total pressure at ~~lowest trough~~ reservoir:	82.1	psi

Orange cell: pressure exceeds max float valve pressure; red cell: pipe pressure limit exceeded. Check troughs at higher elevations if pressure is excessive at lowest trough.

Analysis 2 – Gravity Flow to Troughs 2-5.

A reservoir is placed at a convenient location above the troughs that are downhill of the pressure tank. The reservoir should be sized to hold at least one day's water supply. A 900 gallon tank was chosen for this application. The purpose of the reservoir is to disconnect the lower troughs from the pressurized system so that pressures on pipes and valves are not excessive. The selected reservoir location is at elevation 400', which is more than 30' above Trough 2. A minimum head of 30' is recommended to overcome friction loss and provide a minimum float valve operating pressure. The reservoir could have been located above the highest trough to supply all troughs, but there was no suitable location in that area. From the reservoir, water flows by gravity to four troughs with float valves. The **Pressure-Energy/Gravity Flow Worksheet** (Figure II-14) is used to analyze the system downhill of the reservoir.

- **Steps 1 and 2:** Same as for Analysis 1.

- **Step 3:** Troughs 2-5 will all have float valves. Enter the appropriate maximum and minimum pressures as recommended by the manufacturer. Select 1¼" PVC pipe. A head loss coefficient of 0.273 is computed. In **Step 3c**, enter the ground elevation of the reservoir (400'). The reservoir will be placed in the ground 6' deep so that the reservoir bottom elevation is 394'. Elevation head for the troughs will be computed from 394'. **Step 3d** is not needed since dynamic head was determined in Analysis 1.

- **Step 4:** Enter ground elevations for the four troughs below the reservoir. The spreadsheet adds 2' to these elevations to estimate the water surface elevation. Elevation head will be computed from the bottom of the reservoir to the water surface in the trough. Enter the pipe length from the reservoir to each of the troughs in the table for float valve systems. The spreadsheet computes the head, maximum flow rate by gravity, and the static pressure. All flow rates exceed the design flow rate of 5 gpm and static pressures are below the maximum float valve pressure rating of 80 psi, so no adjustments are needed. The table for cascading systems is not needed for this analysis.

Virginia Livestock Watering Systems - Pressure-Energy/Gravity Flow Worksheet

1) Assistance Information

Customer:	R. G. Farmer
County:	Smyth
Date:	8/26/2010
Assisted By:	sw

Project Notes: Figure II-14. Example 5. Use of a Reservoir for Pressure Relief. Analysis 2: Gravity flow to four troughs..

2) Water Budget

a) Total Daily Water Demand

Type of livestock:	Beef cow/calf pairs	
Number of Animals:	32	
Water demand/animal/day:	20	gpd
Total Daily Demand	640	gpd

See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

No. of times herd drinks/day:	3	events
Time desired to water herd:	60	minutes/event
Average peak demand:	3.6	gpm
Alternate peak demand:	5	gpm

See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate:	9	gpm
Source daily yield:	12960	gpd

If **source flow rate** is close to or less than Peak Demand, consider storage alternatives.
If **source daily yield** is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

See Design Note or EFH Ch. 12 for guidance on pipe size selection.

a) Trough Information

Trough type(s):	Freeze-proof	
Design flow rate: Alternate Peak Demand	5.0	gpm

Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.

Maximum float valve pressure, if applicable: 80 psi

Typical values range from 75-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure, if applicable: 10 psi

Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material:	Plastic: SCH 40 PVC	
Pipe nominal diameter:	1 1/4"	
Pipe avg. inner diameter:	1.36	in.
Pipe cross-sectional area:	0.0101	sq. ft.
Kp (head loss coefficient):	0.273	
Velocity check (<5 fps):	1.1	fps

If velocity is greater than 5 fps, consider a larger diameter pipe.
Note: For flows greater than design flow, velocities will be greater.

Pipe pressure rating:	370	psi
72% of rating (See VA CPS 516):	266	psi

c) Gravity System Parameters

Reservoir gnd elev or spring box outlet elev:	400	ft
Reservoir depth below ground (typically 6'):	6	ft
Reservoir bottom (elev for computing head):	394	ft

d) If Pumping to a Reservoir: Pumping rate should not exceed source rate.

Desired pumping rate to reservoir:		gpm
Pumping duration required to meet daily demand:		min/day
Ground elevation of water source:		ft.
Elevation head:		ft.
Static pressure in pipe (check against max. allowed):		psi

Dynamic Head Calculations:

Pipe length to reservoir:		ft
Add 10% for slope, fittings:		ft
Friction loss/100':		ft/100 ft
Total friction loss:		ft

Note: If total friction loss exceeds 23.1 ft (10 psi), consider choosing a larger pipe diameter.

Dynamic Head added to pump by pressure component of system	Friction + elev. head		ft.
		OR	
			psi

4) Flow and Static Pressure Checks

TROUGH ELEVATIONS:

Enter trough elevations from survey data. For cascade-type systems, enter trough elevations in order from highest to lowest.

Trough ID and Type	Trough Ground Elev. (ft)	Estimated Water Surface Elev. (ft)
T2: Freeze-Proof	336.1	338.1
T3: Freeze-Proof	308.7	310.7
T4: Freeze-Proof	222.1	224.1
T5: Freeze-Proof	318.0	320.0

Trough water surface elevation is assumed to be 2 ft above ground elevation.

CALCULATIONS FOR FLOAT-VALVE SYSTEMS:

Troughs are tee-ed off from the main line, with flow to each trough controlled by a float valve. Pipe length is measured from the reservoir or spring box.

Pipe Length from Reservoir or Spring Box to Trough (ft)	Head from Reservoir or Spring Box (ft)	Maximum Flow Rate (gpm)	Static Pressure (psi)
300	55.9	24.1	27.7
550	83.3	21.7	39.5
1650	169.9	17.9	77.0
1150	74.0	14.1	35.5

Flow calculations assume a float valve efficiency of 80%. For flow rates less than the design rate (yellow cells), consider modifying the system or using storage troughs (such as HETT or concrete). If static pressures exceed the manufacturer's recommended value for the float valve, consider using a pressure reducer, adjusting the orifice, or relocating the trough. If static pressures are less than the recommended minimum (red cells), consider moving the trough to a lower elevation. Cells are coded orange for static pressures exceeding either maximum recommended float valve or pipe pressures.

CALCULATIONS FOR CASCADING SYSTEMS:

Troughs are connected in series by way of their overflow pipes. Pipe length for Trough 1 is measured from the spring box. Subsequent lengths are measured from the previous trough.

Sub-System	Pipe Length from Trough above (ft)	Head from Upper Trough (ft)	Max. Flow Rate (gpm)
Spring box - T1			
T1-T2			
T2-T3			
T3-T4			
T4-T5			
T5-T6			
T6-T7			
T7-T8			
T8-T9			
T9-T10			

Air lock can be a problem in spring-fed systems due to dissolved oxygen. Use a minimum diameter of 1-1/2" for pipe grades between 0.5-1.0%. Use a minimum pipe diameter of 2" for pipe grades less than 0.5%. See EFH Ch. 12.

For flow rates less than the design rate (yellow cells), consider modifying the system or using larger volume troughs. If trough in-flow rate exceeds trough outflow rate (red cells), a flow restrictor, larger pipe diameter, or change in trough location may be necessary. This may not be an issue if source flow rate is always less than the maximum flow possible.

Example 6 – Reservoir System on Timer

In this example, a pump is used to fill a reservoir which gravity-feeds six frost-free troughs as shown in Figure II-15. A timer governs when the pump operates rather than a pressure tank with pressure switch settings. A hydrant is placed strategically to alleviate airlock at the high point between Troughs 2 and 3, shown in profile view in Figure II-16. The **Pressure-Energy/Gravity Flow Worksheet** is presented in Figure II-17.

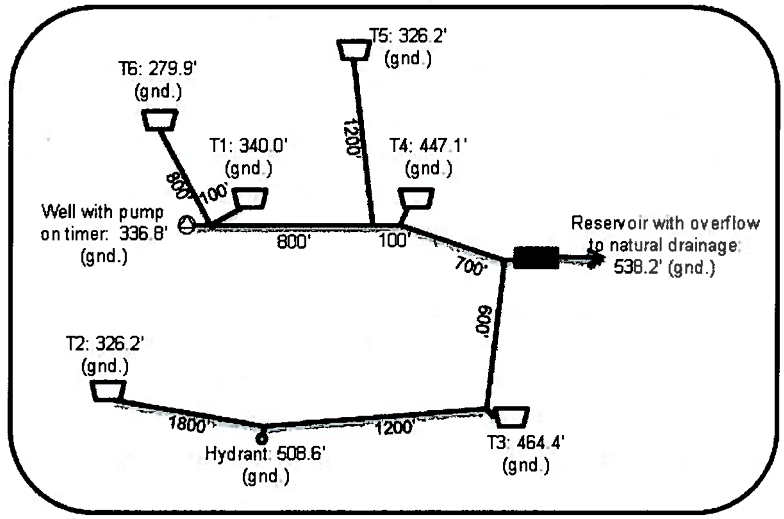


Figure II-15. Layout for Example 6 – Reservoir System on Timer

Given data include:

- Livestock: 54 beef cow/calf pairs
- Water demand: 20 gpd per pair
- Water source: well with estimated supply rate of 20 gpm
- Six frost-free troughs on short laterals with ball valve and drain cut-offs.

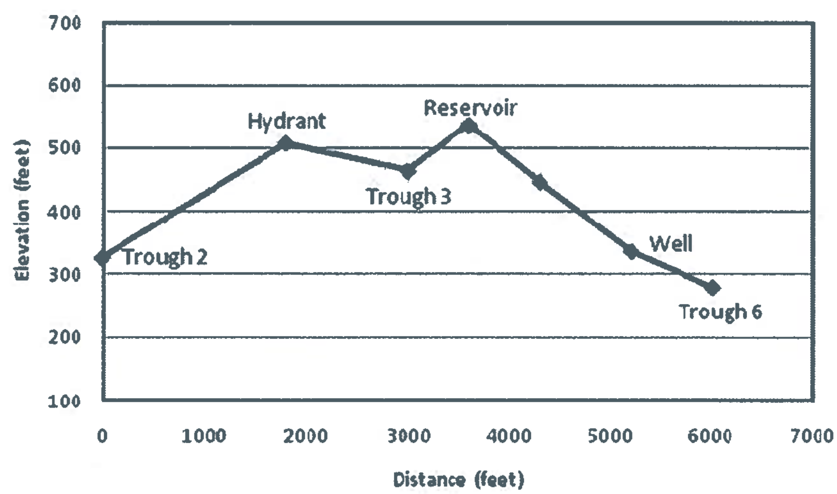


Figure II-16. Profile for Example 6.

Solution:

- **Steps 1 and 2:** Enter known information. Total daily demand is 1080 gallons. The reservoir should be sized to hold at least this volume. Average peak demand is computed to be 6.0 gpm. An alternate peak rate of 8 gpm is chosen as recommended for frost-free trough systems. The source is evaluated in **2c** and is more than adequate.

- **Step 3:** The design flow rate to the troughs is selected to be 8.0 gpm in Step **3a**. Maximum and minimum float valve pressures are entered based on manufacturer's recommendations. PE plastic pipe is selected with diameter of 1¼" with pressure rating of 160 psi in Step **3b**. The computed head loss coefficient is 0.268. The reservoir ground elevation of 538.2' is entered in Step **3c.** The reservoir will be placed 6' in the ground resulting in a bottom elevation of 532.2'. In Step **3d**, specify a desired pumping rate to the reservoir. This is not the same as the design flow rate to the troughs. In this example, 3 gpm was chosen. This pumping rate allows the pump to run 6 hours a day without over-pumping the source. The analysis should be re-run once the actual well yield is known and the pump specifications are known. The pump supplier may not have a pump that operates at the specified rate and head. The elevation head is computed from the reservoir bottom elevation of 532.2' and the well ground elevation of 336.8' and equals 195.4'. The static head is measured from the ground elevation of the reservoir (5382') to the ground elevation of the well (336.8') and is 201.4' or 87.2 psi which is much less than the pressure rating of the PVC pipe. Pipe length from the pump to the reservoir is 1600' which results in a friction loss of 11.3' or 4.9 psi. The dynamic head is the sum of the elevation head and friction loss and equals 207'. This value will be added to the head required to bring the water up to the ground elevation of the well and will be used to select the pump.

- **Step 4:** Enter trough ground elevations. Enter pipe lengths from the reservoir for each trough in the float-valve system table. The spreadsheet computes maximum flow rate and static pressure for each location. Flow rate exceeds the 8 gpm design flow rate for all troughs. Yellow shading indicates that flow is less than 8 gpm at T7 which is the hydrant placed at the high point between Troughs 2 and 3. The orange cells in the static pressure column indicate that pressure exceeds the maximum float valve pressure at several locations (T1, T2, T5, and T6). Pressure reducers or different valves will be needed at these sites. The table for Cascading Systems is not used in this analysis.

Virginia Livestock Watering Systems - Pressure-Energy/Gravity Flow Worksheet

1) Assistance Information

Customer:	John Smith
County:	Craig
Date:	8/26/2010
Assisted By:	DH

Project Notes: Figure II-17. Example 6. Reservoir System with Pump on a Timer. Note: Pressure reducers will be needed at several trough locations. Trough 7 is a hydrant located at a high point to relieve airlock.

2) Water Budget

a) Total Daily Water Demand

Type of livestock:	Beef cow/calf pairs	
Number of Animals:	54	
Water demand/animal/day	20	gpd
Total Daily Demand	1080	gpd

See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

No. of times herd drinks/day:	3	events
Time desired to water herd:	60	minutes/event
Average peak demand:	6.0	gpm
Alternate peak demand:	8	gpm

See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate	20	gpm
Source daily yield:	28800	gpd

If **source flow rate** is close to or less than Peak Demand, consider storage alternatives.
If **source daily yield** is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

See Design Note or EFH Ch. 12 for guidance on pipe size selection.

a) Trough Information

Trough type(s)	Freeze-proof	
Design flow rate	Alternate Peak Demand 8.0	gpm

Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.

Maximum float valve pressure, if applicable: 80 psi

Typical values range from 75-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure, if applicable: 10 psi

Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material:	Plastic: PE SIDR-PR	
Pipe nominal diameter:	1 1/4"	
Pipe avg. inner diameter:	1.38	in
Pipe cross-sectional area:	0.0104	sq. ft.
Kp (head loss coefficient):	0.268	
Velocity check (<5 fps):	1.7	fps

If velocity is greater than 5 fps, consider a larger diameter pipe.
Note: For flows greater than design flow, velocities will be greater.

Pipe pressure rating:	160	psi
72% of rating (See VA CPS 516):	115	psi

c) Gravity System Parameters

Reservoir gnd elev or spring box outlet elev:	538.2	ft
Reservoir depth below ground (typically 6'):	6	ft
Reservoir bottom (elev for computing head):	532.2	ft

d) If Pumping to a Reservoir: Pumping rate should not exceed source rate.

Desired pumping rate to reservoir	3	gpm
Pumping duration required to meet daily demand:	360	min/day
Ground elevation of water source:	336.8	ft
Elevation head:	195.4	ft
Static pressure in pipe (check against max. allowed):	87.2	psi

Dynamic Head Calculations:

Pipe length to reservoir:	1600	ft
Add 10% for slope, fittings:	1760	ft
Friction loss/100':	0.2	ft/100 ft
Total friction loss:	3.1	ft

Note: If total friction loss exceeds 23.1 ft (10 psi), consider choosing a larger pipe diameter.

Dynamic Head added to pump by pressure component of system:	Friction + elev. head	199	ft
		OR	
		85.9	psi

4) Flow and Static Pressure Checks

TROUGH ELEVATIONS:

Enter trough elevations from survey data. For cascade-type systems, enter trough elevations in order from highest to lowest.

CALCULATIONS FOR FLOAT-VALVE SYSTEMS:

Troughs are tee-ed off from the main line, with flow to each trough controlled by a float valve. Pipe length is measured from the reservoir or spring box.

Trough ID and Type	Trough Ground Elev. (ft)	Estimated Water Surface Elev. (ft)	Pipe Length from Reservoir or Spring Box to Trough (ft)	Head from Reservoir or Spring Box (ft)	Maximum Flow Rate (gpm)	Static Pressure (psi)
T1: Freeze-Proof	340.0	342.0	1700	190.2	19.4	85.8
T2: Freeze-Proof	326.2	328.2	3600	204.0	13.8	91.8
T3: Freeze-Proof	464.4	468.4	800	65.8	19.2	31.9
T4: Freeze-Proof	447.1	449.1	700	83.1	20.0	39.4
T5: Freeze-Proof	326.2	328.2	2000	204.0	18.5	91.8
T6: Freeze-Proof	279.9	281.9	2400	250.3	18.7	111.8
T7: Freeze-Proof	508.6	510.6	1800	21.6	6.3	12.8

Trough water surface elevation is assumed to be 2 ft above ground elevation.

Flow calculations assume a float valve efficiency of 80%. For flow rates less than the design rate (yellow cells), consider modifying the system or using storage troughs (such as HETT or concrete). If static pressures exceed the manufacturer's recommended maximum for the float valve, consider using a pressure reducer, adjusting the orifice, or relocating the trough. If static pressures are less than the recommended minimum (red cells), consider moving the trough to a lower elevation. Cells are coded orange for static pressures exceeding either maximum recommended float valve or pipe pressures.

CALCULATIONS FOR CASCADING SYSTEMS:

Troughs are connected in series by way of their overflow pipes. Pipe length for Trough 1 is measured from the spring box. Subsequent lengths are measured from the previous trough.

Sub-System	Pipe Length from Trough above (ft)	Head from Upper Trough (ft)	Max. Flow Rate (gpm)
Spring box - T1			
T1-T2			
T2-T3			
T3-T4			
T4-T5			
T5-T6			
T6-T7			
T7-T8			
T8-T9			
T9-T10			

Air lock can be a problem in spring-fed systems due to dissolved oxygen. Use a minimum diameter of 1-1/2" for pipe grades bewteen 0.5-1.0%. Use a minimum pipe diameter of 2" for pipe grades less than 0.5%. See EFH Ch. 12.

For flow rates less than the design rate (yellow cells), consider modifying the system or using larger volume troughs. If trough in-flow rate exceeds trough outflow rate (red cells), a flow restrictor, larger pipe diameter, or change in trough location may be necessary. This may not be an issue if source flow rate is always less than the maximum flow possible.

Example 7 – Cascading Gravity System

In this example, a gravity system is designed to water sheep from a spring. Water will flow from the spring box to three concrete troughs in series, as illustrated in Figure II-18. Trough 1 overflows to Trough 2 which overflows to Trough 3. Overflow from Trough 3 will re-join the natural drainage system. The **Pressure-Energy/Gravity Flow Worksheet** for this example is provided in Figure II-19.

- Livestock: 50 sheep
- Water demand: 3 gpd/animal
- Water source: Spring yielding 3 gpm
- Three concrete troughs in series.

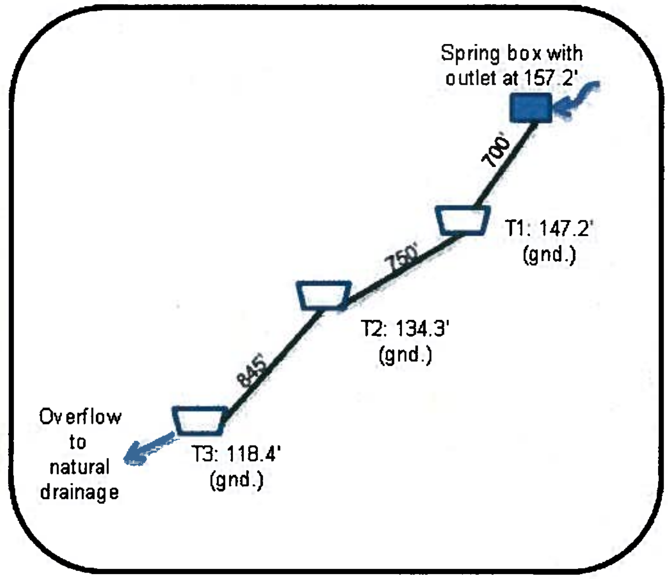


Figure II-18. Layout for Example 7 - Cascading Gravity System.

Solution:

- **Steps 1 and 2:** Enter known information. The computed average peak demand is 0.8 gpm. The source flow rate of 3 gpm is more than adequate to meet the daily and peak demands.
- **Step 3:** For this case, the source flow rate is chosen as the design flow rate for the system. Troughs in a cascading system have no float valves, so no float valve pressure limits are entered. PE plastic is chosen and calculations are made based on a nominal diameter of 1¼". The pressure rating for PE pipe is 160 psi and the spring box is located at 157.2'. Step **3d** is not applicable.
- **Step 4:** Enter the trough ground elevations. Use the Cascading Systems table in the lower right portion of the spreadsheet. For each trough, enter the pipe length as measured from the trough above it. For Trough 1, enter the pipe length coming from the spring box. The spreadsheet computes the maximum possible flow rate. Maximum flows into all three troughs are greater than the supply rate. The supply rate is the limiting factor and inflow will equal outflow for all three troughs. A diameter of 1" would be adequate according to the worksheet, but as noted in Step 4, spring-fed systems tend to carry a lot of air that can come out of solution, particularly in warm weather, which can lead to airlocks. The larger pipe diameter provides some allowance for air. EFH Chapter 12 recommends 2" diameter pipe for grades less than 0.5%, 1½" diameter for pipeline grades between 0.5-1.0%, and a minimum of 1¼" for grades above 1%. Computed grades in this example are just over 1%.

Since sheep are being watered, additional thought should be put into the design of the troughs so that the sheep and their offspring can reach the water as well as have a way to get out if they fall in.

Virginia Livestock Watering Systems - Pressure-Energy/Gravity Flow Worksheet

1) Assistance Information

Customer: Jane Doe
County: Grayson
Date: 8/26/2010
Assisted By: sw

Project Notes: Figure II-19. Example 7. Cascading Gravity System.

2) Water Budget

a) Total Daily Water Demand

Type of livestock: Sheep
Number of Animals: 50
Water demand/animal/day: 3 gpd
Total Daily Demand: 150 gpd
See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

No. of times herd drinks/day: 3 events
Time desired to water herd: 60 minutes/event
Average peak demand: 0.8 gpm
Alternate peak demand: gpm
See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate: 3 gpm
Source daily yield: 4320 gpd
If **source flow rate** is close to or less than Peak Demand, consider storage alternatives.
If **source daily yield** is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

See Design Note or EFH Ch. 12 for guidance on pipe size selection.

a) Trough Information

Trough type(s): Concrete
Design flow rate: Source Flow Rate 3.0 gpm
Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.
Maximum float valve pressure, if applicable: psi
Typical values range from 75-140 psi. Check manufacturer's recommendations.
Minimum float valve pressure, if applicable: psi
Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material: Plastic: PE SIDR-PR
Pipe nominal diameter: 1 1/4"
Pipe avg. inner diameter: 1.38 in
Pipe cross-sectional area: 0.0104 sq. ft.
Kp (head loss coefficient): 0.268
Velocity check (<5 fps): 0.8 fps
If velocity is greater than 5 fps, consider a larger diameter pipe.
Note: For flows greater than design flow, velocities will be greater.
Pipe pressure rating: 160 psi
72% of rating (See VA CPS 516): 115 psi

c) Gravity System Parameters

Reservoir gnd elev or spring box outlet elev: 157.2 ft
Reservoir depth below ground (typically 6'): 0 ft
Reservoir bottom (elev for computing head): 157.2 ft

d) If Pumping to a Reservoir: Pumping rate should not exceed source rate.

Desired pumping rate to reservoir: gpm
Pumping duration required to meet daily demand: min/day
Ground elevation of water source: ft
Elevation head: ft
Static pressure in pipe (check against max. allowed): psi
Dynamic Head Calculations:
Pipe length to reservoir: ft
Add 10% for slope, fittings: ft
Friction loss/100': ft/100 ft
Total friction loss: ft
Note: If total friction loss exceeds 23.1 ft (10 psi), consider choosing a larger pipe diameter.
Dynamic Head added to pump by pressure component of system: Friction + elev. head: ft OR psi

4) Flow and Static Pressure Checks

TROUGH ELEVATIONS:

Enter trough elevations from survey data. For cascade-type systems, enter trough elevations in order from highest to lowest.

Trough ID and Type	Trough Ground Elev. (ft)	Estimated Water Surface Elev. (ft)
T1: Storage	147.2	149.2
T2: Storage	134.3	136.3
T3: Storage	118.4	120.4

Trough water surface elevation is assumed to be 2 ft above ground elevation.

CALCULATIONS FOR FLOAT-VALVE SYSTEMS:

Troughs are tee-ed off from the main line, with flow to each trough controlled by a float valve. Pipe length is measured from the reservoir or spring box.

Pipe Length from Reservoir or Spring Box to Trough (ft)	Head from Reservoir or Spring Box (ft)	Maximum Flow Rate (gpm)	Static Pressure (psi)

Flow calculations assume a float valve efficiency of 80%. For flow rates less than the design rate (yellow cells), consider modifying the system or using storage troughs (such as HETT or concrete). If static pressures exceed the manufacturer's recommended maximum for the float valve, consider using a pressure reducer, adjusting the orifice, or relocating the trough. If static pressures are less than the recommended minimum (red cells), consider moving the trough to a lower elevation. Cells are coded orange for static pressures exceeding either maximum recommended float valve or pipe pressures.

CALCULATIONS FOR CASCADING SYSTEMS:

Troughs are connected in series by way of their overflow pipes. Pipe length for Trough 1 is measured from the spring box. Subsequent lengths are measured from the previous trough.

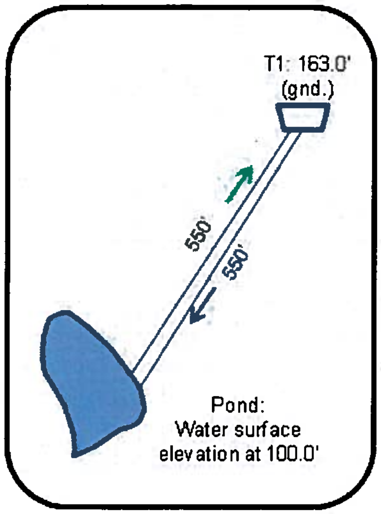
Sub-System	Pipe Length from Trough above (ft)	Head from Upper Trough (ft)	Max. Flow Rate (gpm)
Spring box - T1	700	8.0	7.7
T1-T2	750	12.9	9.5
T2-T3	845	15.9	9.9
T3-T4			
T4-T5			
T5-T6			
T6-T7			
T7-T8			
T8-T9			
T9-T10			

Air lock can be a problem in spring-fed systems due to dissolved oxygen. Use a minimum diameter of 1-1/2" for pipe grades bewteen 0.5-1.0%. Use a minimum pipe diameter of 2" for pipe grades less than 0.5%. See EFH Ch. 12.

For flow rates less than the design rate (yellow cells), consider modifying the system or using larger volume troughs. If trough in-flow rate exceeds trough outflow rate (red cells), a flow restrictor, larger pipe diameter, or change in trough location may be necessary. This may not be an issue if source flow rate is always less than the maximum flow possible.

Example 8 – Pumping from a Pond with a Solar-Powered Pump

A solar-powered pump is used to fill a tire trough 63 feet above a pond. The trough is accessible to four grazing paddocks. The layout for the system is shown in Figure II-20; the completed **Pressure-Energy/Gravity Flow Worksheet** is provided in Figure II-21.



Photographs taken in Craig County during Mountain Castle SWCD's 2009 Farm Tour.

Figure II-20. Layout for Example 8: Pumping from a pond to HETT using a solar pump.

- Livestock: 50 beef cow/calf pairs
- Water demand: 20 gpd/pair
- Water source: Pond
- 1300-gallon heavy equipment tire trough.

The trough serves as an above-ground reservoir for the purpose of filling out the worksheet. The trough does not have a float valve: overflow from the trough returns to the pond through a separate line.

Adequate storage volume is important for solar and wind-powered systems in order to provide water when there is insufficient power to run the pump or when maintenance is needed. Factors influencing design storage volume include climate for the area and the landowner's tolerance to risk and cost. Solar insolation data from the pump manufacturer indicate that the region for this example receives an average of 4.5 hours of full sunshine per day. A reservoir with a minimum of 2-3 days of storage is appropriate in this case to provide water on cloudy days. For 50 cow/calf pairs consuming 20 gpd per pair, the 1300-gallon trough may be inadequate unless the landowner has a back-up power source or allows the cattle limited access to the pond.

The pumping rate of a solar-powered pump varies with available sunlight. Consult the manufacturer for the pump's performance curve. The design rate should be sufficient to fill the reservoir in one day. Because of the limitations of the solar cells and the expected dynamic head, the pump in this example probably will not deliver over 5 gpm unless an alternate source of energy is used.

Solution:

- **Steps 1 and 2:** Enter known information. The average peak demand is 5.6 gpd. The solar pump can likely deliver 5 gpm when the sun is shining. The spreadsheet's computed source daily yield is based on 24 hours of pumping which is incorrect for this application unless there is a back-up source of energy. For an average pumping duration of 4.5 sunlight hours at 5 gpm, the daily yield is 1350 gallons which is adequate to meet the daily demand.

- **Step 3:** Choose a design flow rate of 5 gpm to match the expected output of the solar pump. Since the trough is a 1300-gallon tire, it is not critical that the design flow rate meet the average peak demand. The trough does not have a float valve, so pressure limits are not entered. Try a 1" diameter PE plastic pipe with pressure rating of 160 psi. The reservoir ground elevation is the elevation of the tire trough in this case. Water is expected to be pumped at 5 gpm from the pond to a height of 63 feet through a pipe length of 550 feet. The resulting friction loss is 10.5 feet or 4.5 psi for the 1" pipe. Resulting dynamic head is 74'. This value plus the depth below the pond surface at which the pump operates is the total dynamic head. Use the total dynamic head and the pump's performance data to see if 5 gpm is a reasonable average pumping rate. Re-work the spreadsheet if needed.

Step 4: This step is not needed since no troughs are connected to the tire trough.

Virginia Livestock Watering Systems - Pressure-Energy/Gravity Flow Worksheet

1) Assistance Information

Customer:	Going Solar
County:	Craig
Date:	8/26/2010
Assisted By:	DH

Project Notes: Figure II-21. Example 8. Pumping from a Pond with a Solar-Powered Pump

2) Water Budget

a) Total Daily Water Demand

Type of livestock:	Beef cow/calf pairs	
Number of Animals:	50	
Water demand/animal/day:	20	gpd
Total Daily Demand:	1000	gpd

See Design Note for watering recommendations for various types of livestock.

b) Daily Peak Water Demand

No. of times herd drinks/day:	3	events
Time desired to water herd:	60	minutes/event
Average peak demand:	5.6	gpm
Alternate peak demand:		gpm

See Design Note for considerations for estimating peak demand.

c) Evaluate Source

Source flow rate:	5	gpm
Source daily yield:	7200	gpd

If **source flow rate** is close to or less than Peak Demand, consider storage alternatives.
If **source daily yield** is less than Daily Demand, consider an alternate or supplemental water source.

3) Design Parameters

See Design Note or EFH Ch. 12 for guidance on pipe size selection.

a) Trough Information

Trough type(s):	1300 gallon HETT	
Design flow rate: Source Flow Rate	5.0	gpm

Select flow rate to troughs as guided by Step 2 and Design Note. Typical design flow rates are: 8 gpm for frost-free troughs; 5 gpm for storage troughs.

Maximum float valve pressure, if applicable: ____ psi

Typical values range from 75-140 psi. Check manufacturer's recommendations.

Minimum float valve pressure, if applicable: ____ psi

Varies depending on type of float. Use manufacturer's recommended minimum. Typical value is 10 psi.

b) Pipe Information

Pipe material:	Plastic: PE SIDR-PR	
Pipe nominal diameter:	1"	
Pipe avg. inner diameter:	1.049	in.
Pipe cross-sectional area:	0.0060	sq. ft.
Kp (head loss coefficient):	0.387	
Velocity check (<5 fps):	1.9	fps

If velocity is greater than 5 fps, consider a larger diameter pipe.
Note: For flows greater than design flow, velocities will be greater.

Pipe pressure rating:	160	psi
72% of rating (See VA CPS 516):	115	psi

c) Gravity System Parameters

Reservoir gnd elev or spring box outlet elev:	163	ft
Reservoir depth below ground (typically 6'):	0	ft
Reservoir bottom (elev for computing head):	163	ft

d) If Pumping to a Reservoir: Pumping rate should not exceed source rate

Desired pumping rate to reservoir:	5	gpm
Pumping duration required to meet daily demand:	200	min/day
Ground elevation of water source:	100	ft.
Elevation head:	63.0	ft.
Static pressure in pipe (check against max. allowed):	27.3	psi

Dynamic Head Calculations:

Pipe length to reservoir:	550	ft
Add 10% for slope, fittings:	605	ft
Friction loss/100':	1.7	ft/100 ft
Total friction loss:	10.5	ft

Note: If total friction loss exceeds 23.1 ft (10 psi), consider choosing a larger pipe diameter.

Dynamic Head added to pump by pressure component of system: Friction + elev. head	74	ft.
	OR	
	31.8	psi

4) Flow and Static Pressure Checks

TROUGH ELEVATIONS:

Enter trough elevations from survey data. For cascade-type systems, enter trough elevations in order from highest to lowest.

Trough ID and Type	Trough Ground Elev. (ft)	Estimated Water Surface Elev. (ft)

Trough water surface elevation is assumed to be 2 ft above ground elevation.

CALCULATIONS FOR FLOAT-VALVE SYSTEMS:

Troughs are tee-ed off from the main line, with flow to each trough controlled by a float valve. Pipe length is measured from the reservoir or spring box.

Pipe Length from Reservoir or Spring Box to Trough (ft)	Head from Reservoir or Spring Box (ft)	Maximum Flow Rate (gpm)	Static Pressure (psi)

Flow calculations assume a float valve efficiency of 80%. For flow rates less than the design rate (yellow cells), consider modifying the system or using storage troughs (such as HETT or concrete). If static pressures exceed the manufacturer's recommended maximum for the float valve, consider using a pressure reducer, adjusting the orifice, or relocating the trough. If static pressures are less than the recommended minimum (red cells), consider moving the trough to a lower elevation. Cells are coded orange for static pressures exceeding either maximum recommended float valve or pipe pressures.

CALCULATIONS FOR CASCADING SYSTEMS:

Troughs are connected in series by way of their overflow pipes. Pipe length for Trough 1 is measured from the spring box. Subsequent lengths are measured from the previous trough.

Sub-System	Pipe Length from Trough above (ft)	Head from Upper Trough (ft)	Max. Flow Rate (gpm)
Spring box - T1			
T1-T2			
T2-T3			
T3-T4			
T4-T5			
T5-T6			
T6-T7			
T7-T8			
T8-T9			
T9-T10			

Air lock can be a problem in spring-fed systems due to dissolved oxygen. Use a minimum diameter of 1-1/2" for pipe grades bewteen 0.5-1.0%. Use a minimum pipe diameter of 2" for pipe grades less than 0.5%. See EFH Ch. 12.

For flow rates less than the design rate (yellow cells), consider modifying the system or using larger volume troughs. If trough in-flow rate exceeds trough outflow rate (red cells), a flow restrictor, larger pipe diameter, or change in trough location may be necessary. This may not be an issue if source flow rate is always less than the maximum flow possible.

NATURAL RESOURCES CONSERVATION SERVICE
VIRGINIA ENGINEERING DESIGN NOTE 614 (DN-614)
WATERING FACILITY

APPENDICES

Appendix A. Planning Tools and Background Information

Appendix B. Design Tools

Appendix C. Installation Notes

*Courtesy of Tony Rhoton, Jonesville Service Center

Watering System Resource Inventory Checklist

Client: ____________________ Assisted by: ____________________

Tract: ____________________ Date: ____________________

County: ____________________

A. Livestock to be Served:

Type of Animal	Number of Animals	Average Age	Average Weight	Maximum Daily Water Consumption/Animal (gpd)

How many times a day do the animals drink? ____________________

Time needed to water herd: ____________________

Notes on grazing season and system: ____________________

Trough type preference: ____________________

B. Water Resources:

Water Source (well, spring, pond, stream, public)	Estimated Yield (gpm)	Comments on Quality	Comments on Reliability

C. Energy Resources

Energy Source (utility-supplied electricity, wind, solar, other)	Comments on Preference, Accessibility, or Practicality

D. Soil Resources:

Comments on wetlands, rock outcrops, abrasive soils, soil depth, or other soil features influencing pipeline or trough placement. Use this space, Soil Investigation Form 538, or note in the field book.

E. Site Limitations

Diameter and material of any existing pipeline: ____________________

Note utilities, property lines, or other areas to avoid in a sketch in the field book or back of this page. Emphasize the importance of contacting Miss Utility at 811.

Water Quantity Guidelines for Various Livestock

Type of Livestock		Estimated Daily Water Consumption per Animal (gallons per day)	References
Cattle	Beef adult	15	VA USDA-NRCS Introduction to Conservation Engineering
		8-12	Structures and Environment Handbook (MWPS, 1987)
	Calf	5	VA USDA-NRCS Introduction to Conservation Engineering
		1 to 1.5 gal/100 lb body weight	Structures and Environment Handbook (MWPS, 1987)
	Beef cow/calf pair	20	VA USDA-NRCS Introduction to Conservation Engineering
		6-18	National Range and Pasture Handbook (USDA-NRCS, 1997)
	Growing steers/ pregnant heifers	6-18	National Range and Pasture Handbook (USDA-NRCS, 1997)
	Heifer	10-15	Structures and Environment Handbook (MWPS, 1987)
	Milking cow	30	VA USDA-NRCS Introduction to Conservation Engineering
		10-30	National Range and Pasture Handbook (USDA-NRCS, 1997)
		35-45	Structures and Environment Handbook (MWPS, 1987)
	Dry cow	20	VA USDA-NRCS Introduction to Conservation Engineering
		20-30	Structures and Environment Handbook (MWPS, 1987)
Swine	Swine	4	VA USDA-NRCS Introduction to Conservation Engineering
	Finishing swine	3-5	Structures and Environment Handbook (MWPS, 1987)
	Nursery	1	Structures and Environment Handbook (MWPS, 1987)
	Gestating sow	6	Structures and Environment Handbook (MWPS, 1987)
	Sow and litter	8	Structures and Environment Handbook (MWPS, 1987)
Other Grazing Mammals	Horse	12	Structures and Environment Handbook (MWPS, 1987); VA USDA-NRCS Introduction to Conservation Engineering
		8-12	National Range and Pasture Handbook (USDA-NRCS, 1997)
	Llama	4	VA USDA-NRCS Introduction to Conservation Engineering
	Sheep, Goat	3	VA USDA-NRCS Introduction to Conservation Engineering
		2	Structures and Environment Handbook (MWPS, 1987)
		1-4	National Range and Pasture Handbook (USDA-NRCS, 1997)
Poultry	100 chicken layers	9	Structures and Environment Handbook (MWPS, 1987)
	100 turkeys	15	Structures and Environment Handbook (MWPS, 1987)
General	1000 lb live weight (AU)	30	Indiana USDA-NRCS IN-ENG-Pipeline-4-09.xls

Note: The numbers listed above are guidelines for planning in the absence of better information. Actual daily water demand will vary with the weather, water content of the feed, age, weight, and health of the animals, etc. Values from the Midwest Plan Service (MWPS, 1987) are "average summer values." These values can be multiplied by 0.6 if water is to be supplied only during cool weather. Values listed from VA USDA-NRCS *Introduction to Conservation Engineering* are values used by experienced field staff in the state.

Water Quality Guidelines

Reference: National Engineering Handbook, Part 651, Agricultural Waste Management Field Handbook, pages 1-18 through 1-19.

Parameter	Upper Limit or Desired Range
Dissolved solids	500 mg/L
Fecal coliform bacteria	0 for young, 10/100 mL for adult
pH	6.8-7.5
Salinity	1000 mg/L
Turbidity Jackson units	30
Aluminum	5.0 mg/L
Arsenic	0.02 mg/L
Barium	1.0 mg/L
Boron	5.0 mg/L
Cadmium	0.05 mg/L
Chromium	1.0 mg/L
Cobalt	1.0 mg/L
Copper	0.5 mg/L
Fluoride	2.0 mg/L
Lead	0.1 mg/L
Mercury	0.001 mg/L
Nitrate-N	10 mg/L for young, 100 mg/L for adults
Selenium	0.05 mg/L
Sulfate	250 mg/L
Vanadium	0.1 mg/L
Zinc	25.0 mg/L

Useful information can also be found in "Water for Dairy Cattle," Oklahoma Cooperative Extension Service ANSI-4275. This publication includes discussion of blue-green algae poisoning. Consult a veterinarian for information on species-specific pollutant tolerance levels.

Trough Placement Considerations to Complement a Grazing System

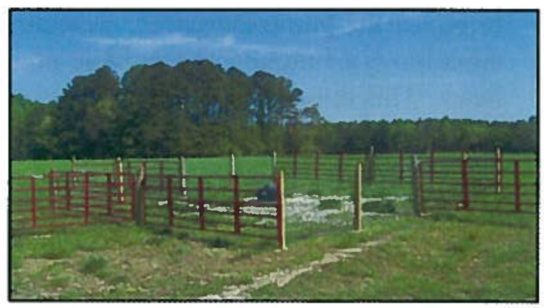
by J. B. Daniel, NRCS Forage and Grassland Agronomist

How and where to provide the necessary water for grazing livestock is usually the first challenge for farmers transitioning to a rotational grazing system or a management-intensive grazing system. The availability of clean water in sufficient quantity to meet livestock needs should be of concern to the farmer. The placement of watering troughs is site-dependent and will vary from farm to farm depending on topography, size and shape of pastures/paddocks, location of the paddocks relative to each other and the terrain, and the size of the herd.

1. The optimal situation is to have water available in all paddocks with walking distances no greater than 600-800 feet. This minimizes the time and energy the animal expends traveling to and from the water source and allows more time for grazing which impacts rates of gain or milk production.

Trough split by fence line (above) vs. trough shared by four paddocks in box configuration (below).

Photographs from VA NRCS Introduction to Conservation Engineering and Dennis Thompson, Farmville Area Office.

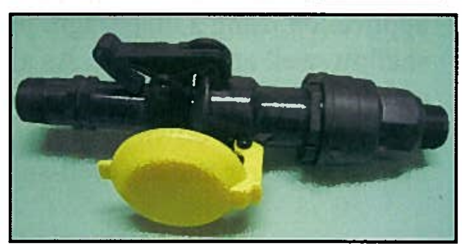


2. If the paddock is relatively large, place the watering point in a central location. This minimizes walking distance to the watering point. It also increases the farmer's ability to manage the grazing system more intensively by using cross fencing (temporary or permanent) to rotate livestock more frequently and still have access to the same watering point.

3. If the paddock is relatively small based on herd size, place the watering point on a fence line which separates two paddocks. To maximize accessibility to the drinking point so livestock can return to grazing faster, consider making the entire water trough available to both paddocks by boxing it into the fence line with access gates from both sides. This allows four animals to drink at a time on a four ball trough instead of having it separated by the fence and only having access to two balls from one paddock at a time.

4. Remember to plan for access to water at the location of the handling facility. A pipeline spur over to the handling facility with a frost-proof spigot for a hose can be used to supply water to a temporary trough as needed at the handling facility or corral areas.

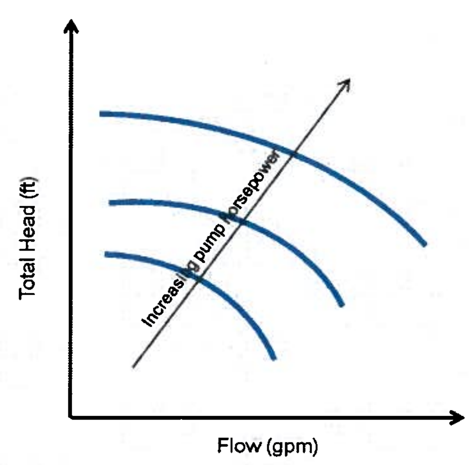
5. Quick-connect valves can be used to connect portable watering troughs as needed to improve efficiency of the overall grazing system. Also, running a pipeline spur off the end of the last trough on a supply line with a cut off or quick-connect valve allows the opportunity for the farmer to use temporary above ground piping and a portable trough to experiment with watering point locations in the next paddock before extending the permanent pipeline and setting up a permanent watering site.



Quick-connect valve courtesy of Big Walker SWCD.

6. Place water troughs on high ground or relatively flat side slopes that are well-drained. Do not place troughs in drainage swales or on low-lying, poorly-drained soils. Proper trough placement will minimize maintenance of the area immediately around the trough and prolong the useful life of the structure.

Pump Basics



Generic Pump Performance Curves

Experienced field staff will say that watering system design is "all about the pump." Although it is usually someone else's job to select the pump to be used in a watering system application, system components are designed with the pump in mind.

Pump manufacturers publish performance curves for their products, plotting total dynamic head against design flow rate for each model. These curves are used to select a pump for a given design flow rate that can deliver the necessary **total dynamic head** (energy demand of the watering system itself plus the energy needed to get the water from the source to the watering system). It is important to NOT oversize the pump because this will cause the pump to have short run times which will lead to premature wear.

Pumps are designed to move water high and far away from the source at a low flow rate, (high head, low flow systems) or to move water short distances at a high flow rate (low head, high flow systems). As flow rate, elevation difference, and horizontal distance increase, the energy needed to power the pump increases. Selecting the most cost-effective pumping system for a given situation is a function of available power source, water source, desired flow rate, and total dynamic head. This appendix describes basic pump types and situations for which they are best suited.

Pump Types

Pumps for watering systems can be divided into two categories:

- Positive displacement pumps
- Kinetic energy pumps

Positive displacement pumps mechanically capture a given volume of water and then force it out a discharge pipe with each pump cycle. Kinetic pumps increase the velocity of the water and then by containing the water, convert the kinetic energy to pressure energy for discharge. Pump characteristics for several types of designs are described below and are summarized in a table at the end of this appendix.

Positive Displacement Pumps

Positive displacement pumps include **diaphragm pumps**, **piston pumps**, and **helical rotor pumps**. Diaphragm pumps have a membrane which is flexed to suck in and squeeze out water and are suitable for applications not requiring a lot of lift. Animal-operated nose pumps are one application using a diaphragm pump. Double-acting piston (or reciprocating) pumps are used in shallow-well applications. As a piston moves back and forth, water flows in on the suction side of a chamber and is pushed out from the pressure side. The piston in a deep well piston pump moves a plunger up and down to bring water up through the drop pipe. Helical rotor pumps draw water up like an auger and are well-suited for handling sandy water.

Kinetic Energy Pumps

Kinetic pumps include **centrifugal pumps** and variations on that type. Centrifugal pumps use an electrical motor to rotate an impeller which sucks water from the source. The rotating action increases the velocity of the water, spinning it to the outer edges of the impeller. The casing confines the water resulting in pressurized outflow. Single impeller designs are used to pump from a pond or shallow well. A **submersible multistage centrifugal pump** has several impellers in series and is typically used for pumping deeper wells. Submersible pumps do not need to be primed and are less subject to freezing. A **turbine pump** is similar, but it is designed to work at the higher pressures needed for pumping deeper wells at higher flow rates.

Jet (or ejector) pumps combine a centrifugal pump with a venturi. A venturi (narrow throat that expands to a wider throat) creates a vacuum for drawing in the water, while the centrifugal pump boosts the pressure for discharge. Jet pumps have the advantage of few moving parts and can also be installed away from the well. They work well for low head systems, but become less efficient as head increases. **Hydraulic rams** and **sling pumps** use the kinetic energy of flowing water to build up pressure to force water uphill. They are generally used in low-to-medium head and low flow applications where water supply is plentiful.

Power Supply

Utility-generated AC electrical power will generally be the most cost-effective choice for livestock watering systems where it is readily available. As distance to the power supply increases, however, consideration has to be given to **voltage drop** and the cost of overcoming it. Voltage drop is analogous to pressure loss in a pipeline due to friction. The longer the wire and the smaller the diameter, the greater the drop in voltage (or electrical "pressure") going from the power source to the pump. MWPS, 1987 recommends choosing a wire large enough to limit voltage drop to 2%. Excessive voltage drop can damage pump motors. Appendix A-6 presents a method for selecting wire size (for planning purposes only).

According to Virginia Cooperative Extension, alternative energy sources may be worth considering if electrical service is more than a third of a mile away from the pump (Marsh, 2001). One option to consider is a **variable frequency drive** or "constant pressure" system. Some products within the family of this relatively new technology can increase the distance from the power source at which it is economical to bring utility-generated power to the pump. Other advantages include use of a smaller pressure tank, more gradual pump starts and stops to reduce stress on system components, and increased energy efficiency. If it is cost-prohibitive to bring AC electrical power to the pump, other options include use of solar, wind, or hydraulic power.

Solar Power

Solar-powered pumps are designed to use direct current (DC) rather than AC electricity. Electricity is generated by light striking photovoltaic (PV) panels. Current output from a PV panel will vary with available light over the course of the day, so either water or electricity will need to be stored so that water is available when the sun isn't shining. Systems are classified as either "**direct-coupled**" or "**battery-coupled**" depending on whether power is supplied directly from photovoltaic (PV) panels or from batteries charged by PV panels. Direct-coupled systems typically employ a centrifugal-type pump, with flow varying according to the amount of current available. Since no water is pumped when the sun is not shining, direct-coupled systems must include either a water reservoir or large-volume troughs with enough capacity to supply water over long stretches of cloudy days. Battery-coupled systems allow for pumping over longer periods of time at a steady rate.

Wind Power

Wind can be used to provide mechanical power directly to pumps or can be used to charge batteries to provide DC electricity to power electrical pumps. Wind generators are sometimes combined with solar-powered systems. Not all sites are suitable for wind power generators: adequate wind speed and clear space can be limiting factors. Wind systems also tend to require more maintenance than solar-powered systems. Water storage is recommended to provide water when the wind isn't strong enough or when the system is being maintained.

Hydraulic Power

Hydraulic rams and sling pumps require no electricity and operate continuously as long as the source water is flowing. Rams use flow from a spring or stream, valves, and an air chamber to build up pressure to pump water to the distribution system. Only a fraction (generally less than 20%) of the flow from the source is captured, so it is important to have a high-yielding source as well as adequate storage to satisfy peak demand. Flow rate is dependent on the height of the source above the ram. A minimum fall of 10' and minimum source yield of 10 gpm are recommended by Burns and Buschermohle (University of Tennessee Agricultural Extension Service). Due to the pulsing action of this system, steel pipe must be used for connecting the source to the ram which can add significant cost.

Sling pumps operate from a flowing stream. The flowing water rotates the pump body forcing water through a coil inside the pump body and into a pipe to a reservoir. The stream should be at least 2.5' deep and have a velocity of at least 1.5 fps (Burns and Buschermohle). Slings are subject to damage by debris in the stream and require frequent checking.

References

Burns, R., and M. Buschermohle, Selection of Alternative Livestock Watering Systems. University of Tennessee Agricultural Extension Service, PB 1641. http://utextension.tennessee.edu/publications/pbfiles/PB1641.pdf

Buschermohle, M., and R. Burns. Solar-Powered Livestock Watering Systems. University of Tennessee Agricultural Extension Service, PB 1640. http://utextension.tennessee.edu/publications/pbfiles/pb1640.pdf

Marsh, L. 2001. Pumping Water from Remote Locations for Livestock Watering. Virginia Cooperative Extension, Publication 442-755. http://www.ext.vt.edu/pubs/bse/442-755/442-755.pdf

Midwest Plan Service, 1987. Structures and Environment Handbook. Iowa State University, Ames Iowa.

Pump Comparisons (based on MWPS, 1987).

Type of Pump	Description	Typical Applications	Water Source	Power Source	Typical Max. Lift	Limitations	Comments
Diaphragm	A membrane is flexed to draw in and squeeze out water.	Nose pump	• Spring • Surface water	• Animal/Manual • Solar/Wind • AC Electricity	15'	Can be difficult to freeze-proof	Nose pumps can be portable to facilitate rotational grazing.
Centrifugal	Rotating impeller sucks water up and forces it out a discharge pipe	Booster pump	• Shallow well • Surface water	• AC Electricity • Solar/Wind	15'	Subject to loss of prime	Some designs ("open impeller") can tolerate sandy water.
Submersible Multistage Centrifugal	Series of impellers are mounted close together and immersed with a motor in the well.	Most commonly used pump for systems using a well as the water source.	Well	• AC Electricity • Solar/Wind	1000'	Sandy water can cause damage. Repair requires pulling from well.	Capacity is dependent on impeller design. Impeller diameter, speed, and number govern pressure.
Turbine	Similar to a submersible multistage centrifugal pump, but components are designed for higher pressures.	Deep wells and high capacity systems	Well	AC Electricity	1500'	Repair requires pulling from well.	
Submersible Helical Rotor	Rotor brings water up like an auger.		Well: 4" dia. or greater	• AC Electricity • Solar/Wind	1000'	Repair requires pulling from well.	Handles sand better than other pump types.
Jet or Ejector (Shallow-well design)	A centrifugal pump is combined with a venturi. A venturi creates a vacuum for drawing in the water, while the centrifugal pump boosts the pressure for discharge.	Shallow well or spring reservoir	Well	• AC Electricity • Solar/Wind	22'	Sandy water can cause damage.	Few moving parts and can be installed away from the well, above ground.
Jet or Ejector (Deep-well design)					85'		
Reciprocating or Piston (Shallow-well design)	As a piston moves back and forth, water flows in on the suction side of a chamber and is pushed out from the pressure side.	A typical choice for wind-powered systems.	Well	• AC Electricity • Manual • Solar/Wind	22'	Vibration and noise due to pulsating discharge.	
Reciprocating or Piston (Deep-well design)	A piston moves a plunger up and down bringing water up through the drop pipe.				600'		
Hydraulic Ram	Flow of water used to create pressure to force water uphill	High-flow spring remote from electricity with adequate topography for a reservoir to support gravity flow to troughs.	• Spring • Stream	Water flow	500'	Low flow output: combine with storage system. Requires 10' min. fall from source to ram and 10 gpm source yield to be practical.	Steel pipe drive line can be expensive.
Sling	Stream flow rotates the pump body forcing water to the delivery system.	Large stream remote from electricity with adequate topography for a reservoir to support gravity flow to troughs.	Large stream (2.5' deep and 1.5 fps, min.)	Water flow	50'	High maintenance: subject to damage by floating debris and high water events.	

Wire Sizing

(For planning purposes only.)

Reference: Southwest Photovoltaic Systems, Inc., "Pumping Water with Solar Energy for Livestock Operations," March 28-29, 2000.

As water flows through a pipe, the pressure drops due to friction. The pressure drop increases with increasing distance and flow rate and with decreasing pipe diameter. Similarly, voltage in an electrical wire drops as electricity flows through a wire. Voltage drop becomes more significant with increasing wire length and amperage and with decreasing wire diameter. The greater the distance from the power source, the larger, heavier, and more expensive the wire needed.

The Voltage Drop Index (VDI) can be used to select the correct wire size for a particular application.

$$VDI = \frac{\text{Amps} \times \text{Feet}}{\%\ \text{Voltage Drop} \times \text{Voltage}}$$

where:

VDI = Voltage Drop Index
Amps = amperage drawn by the pump or other device
Feet = one-way wiring distance in feet
% Voltage Drop = acceptable voltage loss (as a %)
Voltage = system voltage

Once the VDI is computed, select the corresponding wire size from the chart below. If the computed VDI is not listed, round to the next larger VDI. The listed ampacity is the maximum amperage the wire can withstand before heat due to friction melts the wire.

Wire Size (AWG)	Area (mm^2)	Copper Wire	
		VDI	Ampacity
16	1.31	1	10
14	2.08	2	15
12	3.31	3	20
10	5.26	5	30
8	8.37	8	55
6	13.3	12	75
4	21.1	20	95
2	33.6	31	130
0	53.5	49	170
00	67.4	62	195
000	85.0	78	225
0000	107	99	260

Example: A pump draws 10 amps on a 120 V system and is located 600' from utility-supplied power. Maximum desired voltage drop is 5%. Determine the appropriate wire size.

Solution:

$$VDI = \frac{10 \times 600}{5 \times 120} = 10$$

From the chart, choose the next largest VDI of 12, which corresponds to a #6 wire.

If the distance were reduced to 200', VDI = 3.33, indicating a #10 wire.

Pipeline Friction Loss Tables

Reference: Midwest Plan Service Structures and Environment Handbook, 1987.

The Hazen-Williams equation for computing friction loss can be written (MWPS, 1987):

$$h = 1043.8 \frac{\left(\frac{Q}{C}\right)^{1.85}}{d^{4.87}}$$

where:

h = friction loss in feet per 100' of pipe
Q = flow rate in gpm
C = 140 for plastic; 130 for copper; 100 for 17-yr old steel
d = pipe diameter in inches

Friction loss using this method has been tabulated as a function of flow rate, Q, for a variety of pipe diameters and materials. These values can be used for making quick calculations in the field. Velocity for PE pipe is also shown to help the user avoid designs with pipe flow velocity greater than 5 fps.

Friction loss in feet per 100' for 1" Pipe

Q (gpm)		PE SIDR-PR Plastic	SCH 40 PVC Plastic	Copper	Steel	Velocity for I.D. = 1.049" (fps)
	I.D. =	1.049"	1.029"	1.025"	1.049"	
	C =	140	140	130	100	
2		0.3	0.4	0.4	0.6	0.7
3		0.7	0.7	0.9	1.3	1.1
4		1.2	1.3	1.5	2.1	1.5
5		1.7	1.9	2.2	3.2	1.9
6		2.4	2.7	3.1	4.5	2.2
7		3.2	3.6	4.2	6.0	2.6
8		4.1	4.6	5.3	7.7	3.0
9		5.2	5.7	6.6	9.6	3.3
10		6.3	6.9	8.0	11.7	3.7
11		7.5	8.2	9.6	13.9	4.1
12		8.8	9.6	11.3	16.4	4.5
13		10.2	11.2	13.1	19.0	4.8

Friction loss in feet per 100' for 1-1/4" Pipe

Q (gpm)		PE SIDR-PR Plastic	SCH 40 PVC Plastic	Copper	Steel	Velocity for I.D. = 1.38" (fps)
	I.D. =	1.38"	1.36	1.265"	1.38"	
	C =	140	140	130	100	
4		0.3	0.3	0.5	0.6	0.9
5		0.5	0.5	0.8	0.9	1.1
6		0.6	0.7	1.1	1.2	1.3
7		0.9	0.9	1.5	1.6	1.5
8		1.1	1.2	1.9	2.0	1.7
9		1.4	1.5	2.4	2.5	1.9
10		1.6	1.8	2.9	3.1	2.2
12		2.3	2.5	4.0	4.3	2.6
14		3.1	3.3	5.4	5.7	3.0
16		3.9	4.2	6.9	7.3	3.4
18		4.9	5.3	8.6	9.1	3.9
20		5.9	6.4	10.4	11.1	4.3

Friction loss in feet per 100' for 1-1/2" Pipe

Q (gpm)		PE SIDR-PR Plastic	SCH 40 PVC Plastic	Copper	Steel	Velocity for I.D. = 1.61" (fps)
	I.D. =	1.61"	1.59"	1.505"	1.61"	
	C =	140	140	130	100	
4		0.1	0.2	0.2	0.3	0.6
6		0.3	0.3	0.5	0.6	0.9
8		0.5	0.5	0.8	1.0	1.3
10		0.8	0.8	1.2	1.5	1.6
12		1.1	1.2	1.7	2.0	1.9
14		1.5	1.5	2.3	2.7	2.2
16		1.9	2.0	3.0	3.5	2.5
18		2.3	2.5	3.7	4.3	2.8
20		2.8	3.0	4.5	5.2	3.2
22		3.3	3.6	5.3	6.2	3.5
24		3.9	4.2	6.3	7.3	3.8
26		4.6	4.8	7.3	8.5	4.1
28		5.2	5.6	8.3	9.7	4.4

Friction loss in feet per 100' for 2" Pipe

Q (gpm)		PE SIDR-PR Plastic	SCH 40 PVC Plastic	Copper	Steel	Velocity for I.D. = 2.067" (fps)
	I.D. =	2.067"	2.047"	1.985"	2.067 "	
	C =	140	140	130	100	
10		0.2	0.2	0.3	0.4	1.0
12		0.3	0.3	0.5	0.6	1.2
14		0.4	0.5	0.6	0.8	1.3
16		0.5	0.6	0.8	1.0	1.5
18		0.7	0.7	1.0	1.3	1.7
20		0.8	0.9	1.2	1.5	1.9
25		1.3	1.3	1.8	2.3	2.4
30		1.8	1.8	2.5	3.3	2.9
35		2.3	2.5	3.3	4.4	3.4
40		3.0	3.1	4.2	5.6	3.8
45		3.7	3.9	5.2	6.9	4.3
50		4.5	4.7	6.3	8.4	4.8
55		5.4	5.7	7.5	10.1	5.3

Pipeline Pressure Ratings

References:

American Society for Testing and Materials, 2003. D-2239-03. Standard Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter.

American Society for Testing and Materials, 2006. D-1785-06. Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.

Polyethylene (PE) Plastic Pipe

Water pressure rating for SIDR-PR PE pipe varies with material and Standard Thermoplastic Pipe Dimension Ratio (SIDR) and is not diameter-dependent. PE pipeline is manufactured with the following water pressure ratings (at 73° F):

- 250 psi
- 200 psi
- 160 psi
- 125 psi
- 100 psi
- 80 psi

PE pipe rated for 160 psi is commonly used for watering systems in Virginia.

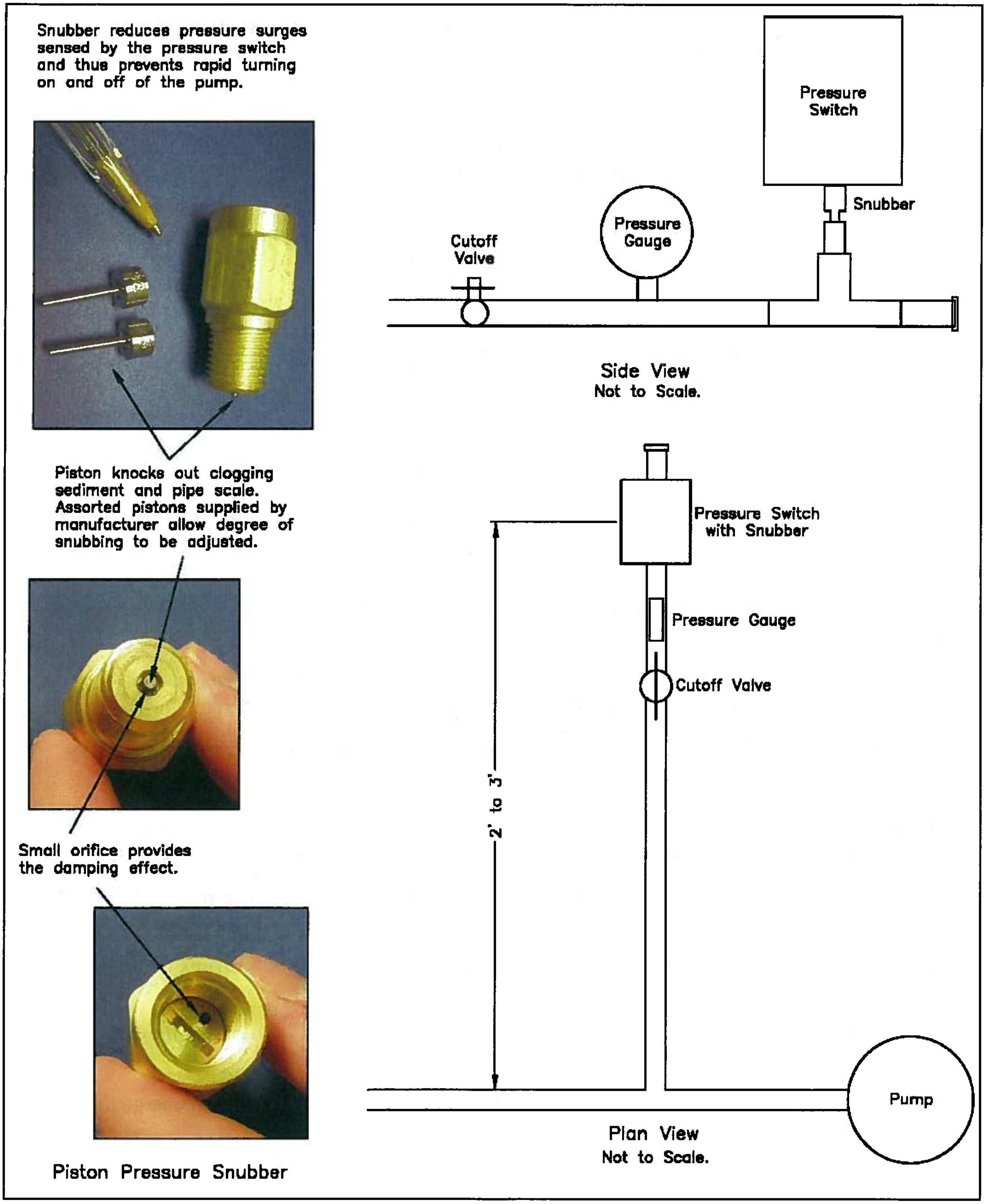
Polyvinyl Chloride (PVC) Plastic Pipe

Water pressure rating for PVC pipe varies with material and decreases with increasing diameter. Water pressure ratings for Schedule 40 PVC Pipe (PVC1120, PVC1220, PVC2120) are:

Nominal Diameter	Pressure Rating at 73° F
1"	450 psi
1-1/4"	370 psi
1-1/2"	330 psi
2"	280 psi

Refer to the manufacturer or appropriate ASTM specification for information on other pipe materials.

Pressure Snubber Detail



Water Storage in Well Casing or Pipe

Water storage volume in the well casing may be significant enough to justify using the source when peak demand is close to the supply rate. Storage per foot of depth is tabulated below for well diameters ranging from 2 inches to 9 feet.

Well Diameter	Storage per Foot of Depth (gallons)
2"	0.163
3"	0.367
4"	0.653
5"	1.02
6"	1.47
8"	2.61
10"	4.08
1'	5.87
2'	23.50
3'	52.87
4'	94.00
5'	146.87
7'	287.86
9'	475.86

Example:

A well has a recharge rate of 3 gpm, a standing water depth of 510 feet, and a casing diameter of 6 inches.

A livestock watering system is proposed to supply a total of 900 gpd. On average, water is consumed in three, 60-minute drinking events per day, with peak demand of 5 gpm.

Given that the peak demand exceeds the well recharge rate, will a reservoir be needed to use this water source?

Solution:

From the table above, the storage in the casing is 1.47 gal per foot of depth.

$$Water\ volume\ in\ casing = 1.47\frac{gal}{ft} \times 510\ feet = 750\ gal$$

$$Volume\ needed\ per\ drinking\ event = 5\ gpm\ \times 60\ minutes\ = 300\ gallons$$

$$Time\ to\ recharge\ consumed\ water = \frac{300\ gallons}{3\ gpm\ \times 60\ min/hr} = 1.7\ hours$$

Therefore, the well casing has sufficient volume to meet the peak demand and the recharge time is short enough to replace the consumed water between drinking events.

Pump Installation Notes

Client: ____________________ Assisted by: ____________________

Tract: ____________________ Date: ____________________

County: ____________________

Pump will be located in:
- Well _____ Known depth ____ Depth to water ____
- Spring _____
- Reservoir _____

Pump will be powered by:
- Electric _____
- Solar _____
- Hydraulic _____
- Generator _____
- Wind _____

Type of Pump:
- Submersible _____
- Above Ground _____
- Hydraulic Ram _____
- Solar _____

Pump will be controlled by:
- Pressure switch _____ *(See calculation worksheet.)*
- Timer _____
  - Increments needed:
    - Quarter hour ____
    - Half hour ____
    - Hour ____
- Electronic Float _____
- Manual Float _____

Pumping Rate needed: _______ gpm

Pump to elevation: _______

Pump from elevation: _______

Total lift: _______

Longest pumping distance: ________

Kind and size of pipe to be used: ________

Materials Needed

____

____

____

____

____

Reservoir Installation Notes

Client: ____________________ Assisted by: ____________________

Tract: ____________________ Date: ____________________

County: ____________________

Type of Reservoir: Concrete _______
Plastic _______
Other _______

Reservoir Size: __________ gallons (generally at least 1 day supply; more for wind or solar powered systems)

Overflow Needed: Yes / No

Bedding Needed: Yes / No
Type __________
Depth __________ inches

Installation Notes:

1) Locate reservoir at an elevation high enough to supply the peak demand to the highest trough when the reservoir is nearly empty.
2) Do not use septic tanks as reservoirs.
3) Prepare foundation according to manufacturer's recommendations and sound engineering principles.
4) Reservoir shall be buried at a minimum of two-thirds the height.
5) Leave top of reservoir out of the ground 6"-8" to prevent entrance of surface water.
6) Overflow (if needed) should flow into a natural channel or into a gravel sump.
7) Prevent pipe from shearing off during reservoir settlement: plumb brass or galvanized nipples into the reservoir. Then connect PVC pipe with female fittings.
8) The outflow pipe must be installed with sufficient grade to prevent airlocks.
9) If multiple reservoirs are used, place in such a way so that they do not collapse when filling.
10) Follow manufacturer's instructions for installing plastic reservoirs.

Appendix D. Unit Conversion Factors

Category	Existing Units	Multiplied By	Equals Desired Units
Energy	feet of head (ft)	62.4	foot-pounds (ft-lbs)
	feet of head (ft)	0.433	pounds per square inch (psi)
	pounds per square inch (psi)	2.31	feet of head
	pounds per square inch (psi)	144	foot-pounds (ft-lbs)
Volume	cubic feet (ft^3)	7.48	US gallons (gal)
	cubic feet (ft^3)	0.037	cubic yards (yd^3)
	cubic yards (yd^3)	27	cubic feet (ft^3)
	cubic feet (ft^3)	7.48	US gallons (gal)
	US gallons (gal)	0.1337	cubic feet (ft^3)
Flow	cubic feet per second (cfs)	448.8	US gallons per minute (gpm)
	US gallons per minute (gpm)	0.002228	cubic feet per second (cfs)
	US gallons per minute (gpm)	1440	US gallons per day (gpd)
Length	mile (mi)	5280	feet (ft)
Area	square feet (ft^2)	144	square inches (in^2)
	square inches (in^2)	0.0069	square feet (ft^2)
	acre	43,560	square feet (ft^2)

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