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Considerations for Solar-Powered Water Pumping Systems

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Introduction

This introductory information is primarily focused on solar-powered water pumping systems for tenant farmers and for systems designed for use only during freeze-free months. The information and the referenced demonstration systems are to help enhance pasture management options, while excluding livestock from surface streams, in situations where a permanent watering system may not currently be possible for the site. A permanent watering system is needed for ongoing year-round usage. Please refer to the resources listed in this publication for more general information and contact your local USDA Service Center to explore options for permanent livestock watering systems.

There are many factors to evaluate when considering a solar-powered water pumping system. This publication explores some of the key elements through a 10-step process (Figure 1). Similar information is also available in a short video (Figure 2). A pilot project webpage also houses this content with additional information on: farmer experiences, safety, design, regulations, financial incentives, and related topics, and is accessible at: Solar Water Pumping for Livestock: Exploring Options for Tenant Farmers

Figure 1. Ten Step Overview Highlighting Key Elements

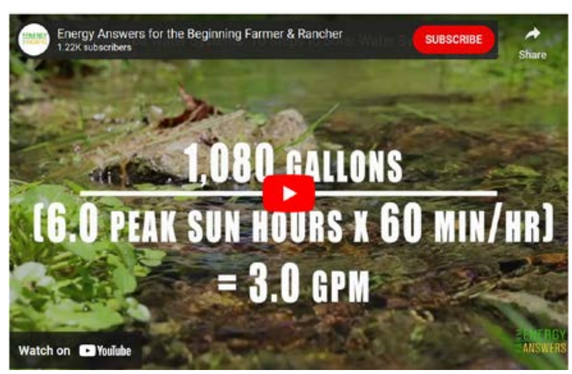

Figure 2. Video Tutorial Outlining Key Steps

https://youtu.be/L6dnNcT6VMM?si=Gu8nanD8dL0BZnNd

Step 1:
Determine Your Water Requirements

The first step in designing a solar-powered livestock watering system is to estimate the daily water requirements for the livestock. Different species, breeds, and age ranges of animals have different water requirements which may fluctuate seasonally, and from site to site, among other factors.

Different informational resources (table estimates, etc.) can help with estimating ranges of water intake requirements. However, your observations and experiences are key to adjusting these estimates to reflect reality in order to provide adequate water and to meet needs.

Step 2:
Evaluate the Water Source

Next, it is important to evaluate the water source you plan to use (Figure 3). Is it a natural or manmade water source? Is it free-flowing, or standing? Does the volume or flow rate fluctuate throughout the year? Is there enough water available (i.e., is the rate of recharge greater than the rate of your withdrawals)? Is there sand, silt, or organic matter? Do you need to consider using more than one source? Is there a risk of high-water events, and could they potentially damage your equipment? Will low water events affect your water quality? Finally, you should be aware of applicable local, state, or national regulations which may limit its use for your purposes.

Step 3:
Consider the System Layout

Your third step is designing your system layout. You need to consider the location of the major elements in your system, including:

1. Water Source
2. Pump
3. Solar PV Array
4. Reservoir
5. Stock Tanks
6. Routing of Pipelines

Figure 3. Sample Collection from a Surface Water Source

One major consideration for this step is to analyze different possible configurations and system layouts, taking into account the topography of the land, distances covered, and elevation changes from the water source to the storage reservoir to the troughs. Additionally, it is important to estimate the length of any slopes you need to consider with each alternative layout. Typically, a smaller footprint requires less materials which can help improve system economics and system installation time.

The freely available Google Earth Pro mapping tools can be an excellent resource for this kind of site layout planning and evaluation. Please see this link for more information on measuring distances in Google Earth. Note, the option "clamped to ground" is selected to display slope length measurements based on estimates of surface distances corresponding to terrain features along the selected path (Figure 4). More details on related settings are available at this link.

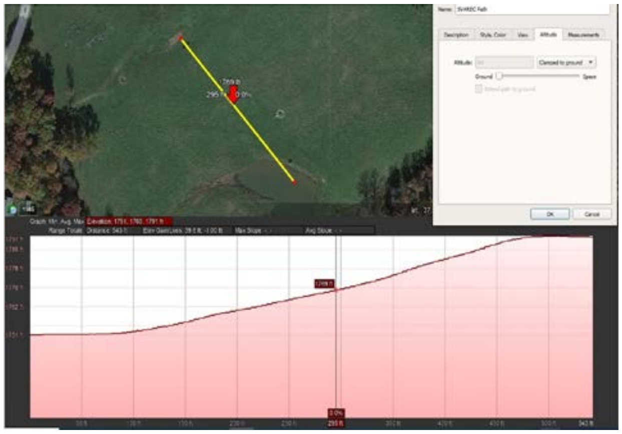

Figure 4. Screenshot from the Free Google Earth Pro Software Tool Showing the Elevation Profile Between Two Points

Step 4:
Determine Water Storage Requirements

Determine your daily water storage requirements. Solar photovoltaic (PV) systems require sunshine to function, since it is not always sunny its recommended to have some amount of storage within the watering system. This additional storage can also be helpful when there are equipment and maintenance issues by permitting gravity flow from storage while system issues are addressed. A common "rule of thumb" is to plan for plan for at least three days of water storage. However, more or less storage may be warranted depending on availability of site-specific alternative back-up options. This can be calculated by taking your estimated daily water requirement for your livestock (from STEP 1) and multiplying that number by a factor of three. Some system operators have explored using batteries to store energy for later use in pumping water (e.g., during cloudy days, etc.), which may be an effective option for some installations. However, often storage in the form of "already pumped water" (i.e., into a reservoir uphill) can be more viable by avoiding the potential operation and maintenance costs associated with battery banks and letting gravity do the work (Figures 5 and 6).

Figure 5. Overhead View of Two Plastic Reservoir Tanks

Figure 6. Host Farmer Demonstrating Reservoir Storage at System High Spot to Enable Gravity Flow to Stock Tanks

Step 5:
Determine the Solar Resource

The next step is to determine the solar resource for your site. Solar resource analysis relates to the amount of solar energy that typically reaches your solar PV system at your location. This information is needed to calculate the energy that can be generated to run the pumping system. Actual solar radiation values vary depending on latitude, time of year, site factors (e.g., slope aspect, shading from terrain, trees, buildings, etc.), among other factors.

A good tool for solar resource analysis is the free online calculator PV Watts maintained by the US Department of Energy's National Renewable Energy Lab (NREL) (Figure 7). The PV Watts tool will provide an estimate of the average solar radiation ($kWh/m^2/day$) for the site. Often, these generated values are also referred to as "peak sun hours" which are basically an estimate of the hours in a day that the solar radiation is equal to 1 kW/m^2. This value from PV Watts will be useful in further calculations.

Figure 7. Screenshot of NREL PV Watts Online Tool

For consideration of site shading analysis a shade analysis too, like a Solar Pathfinder or similar device, can be used to better assess site-specific impacts due to local shading. The combined data from these two sources can be used to estimate the solar resource typically available at the site.

Step 6: Determine the Design Flowrate for Pump

The next step is to determine the design flowrate, in gallons per minute (GPM) for the pump. This is defined as daily water needs, in gallons per day (GPD), divided by the peak sun hours, for the specified time of year, from STEP 1 and STEP 5 above. The formula for this calculation is included below (Figure 8), and an interactive online calculator is also available (Figure 9).

$$Pump\ Flow\ (GPM) = \frac{\text{Daily Water Need (Gallons per Day)}}{\text{Peak Sun Hours} \times 60\text{ minutes}}$$

Figure 8. Formula for Estimating Pumping Requirements in Gallons per Minute (GPM)

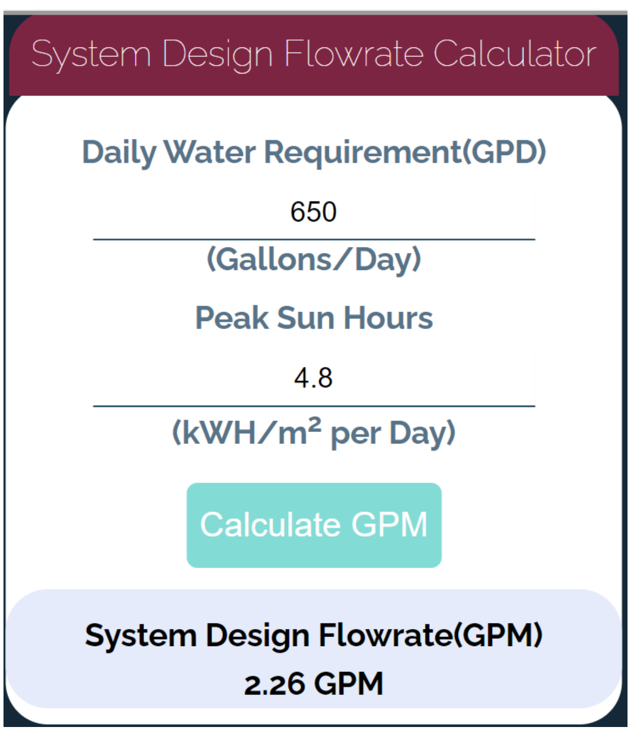

Figure 9. Online System Design Flowrate Calculator

Step 7: Determine Total Dynamic Head

Now determine the Total Dynamic Head (TDH) of your system. This is the pressure required to move the water from its source to the desired location. Three factors are key to determine the Total Dynamic Head:

- **Vertical Lift:** The difference in elevation between the water source and delivery point
- **Friction Loss:** The loss in pressure due to the friction of the flowing water along the internal walls of the pipeline, as well as from the presence and type of pipe elbows, valves, fittings, etc.; which varies across types and sizes of materials used
- **Pressure Head:** Any pressure requirements at system delivery points

Online calculators can be helpful in estimating TDH (Figure 10). Specific information on the properties of different pipe materials, calculation formulas, and related details are provided in the more comprehensive information resources referenced in this publication.

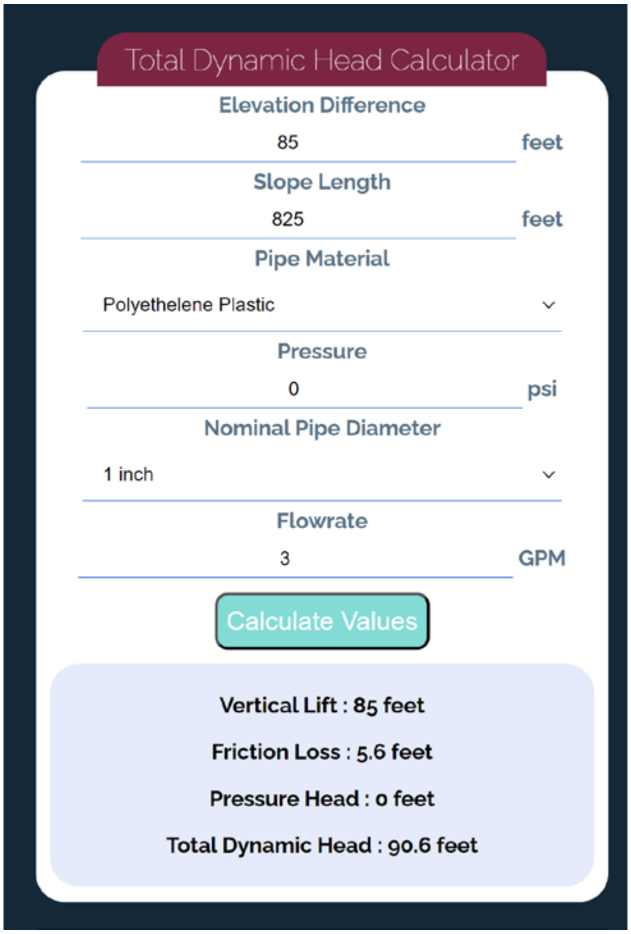

Figure 10. Example Online Total Dynamic Head Calculator

Step 8: Pump Curve Analysis & Determine System Power Requirements

Next pump curve analysis is performed to select an appropriate pump for the system design and also to help determine the power requirements of the pump motor and system controls. These requirements are primarily based on the following three factors:

- **Design Flowrate,** in gallons per minute (GPM) as determined in STEP 6 above
- **Total Dynamic Head,** as determined in STEP 7 above, and
- **Pump Curve,** a description of a pump's performance (e.g., varying head and flowrates, etc.), typically provided by the manufacturer.

Figure 11. Photo of Small Submersible Positive Displacement Pump

Step 9: Determine Solar Array Components and Configuration

The next step is to specify your solar panel array (Figure 11). You select the panels based on your calculated system requirements. The general recommendation is to oversize your PV panels by a factor of 125%, to ensure that the system will have sufficient power. It is important to verify that voltage and current are within the specifications for operating all of the system components, including controllers, pump motors, etc.

Figure 12. Photo of a 400W PV Array for a Solar Water Pumping System

Step 10: Verify System Pressure and Flow Rates at Delivery Points

Verify that system pressure and flow rates are sufficient to provide adequate water at your delivery points, such as watering troughs. Make sure that there is adequate water pressure to operate any valves or float switches in the system (Figure 12). If you are using a gravity fed system to bring water from your reservoir to the troughs, you need to allow for sufficient fall to meet pressure requirements of the float valves. Periodically check the system to ensure that it is working as it should be, accumulated algae growth, among other issues, can restrict flowrates and impact float valve function.

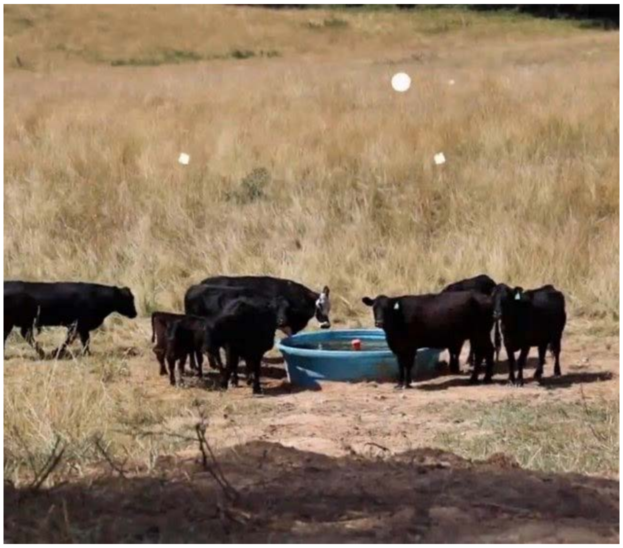

Figure 13. Cattle Accessing Livestock Waterer Stock Tank with Float Valve from a Demonstration Site

Summary

Solar-powered water pumping systems represent an option for producers exploring off-grid water options. Applications can include systems that are designed for permanent year-round use. For certain sites, solar-powered water pumping systems may be adapted for periodic use on rented ground to enhance off-stream water options for tenant farmers. This introductory publication outlined some of the intial considerations for exploring solar-powered water pumping systems. For more details please review the publications referenced below. Finally, for more information on farmer experiences using these systems on rented ground, and related resources, please visit: Solar Water Pumping for Livestock Exploring Options for Tenant Farmers

Additional Resources

Buschermohle, M. & Burns, R. (2000). *Solar-Powered Livestock Watering Systems - PB1640*. The University of Tennessee Agricultural Extension Service.

Ignosh, J. & Booher, M. (2022). *Solar Water Pumping for Livestock Exploring Options for Tenant Farmers*. Pilot Project Webpage.

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Van Pelt, R. S., & Waskom, R. M. (2008). *Solar-powered groundwater pumping systems*. Colorado State University Extension.

Virginia NRCS (2010). *Watering Facility: Virginia Engineering Design Note. 614.* USDA NRCS – Virginia.

Acknowledgements

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