North Dakota Solar-Powered Water Pump Systems Design Tool User Guide

July 2017
USDA NATURAL RESOURCES CONSERVATION SERVICE
NORTH DAKOTA

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Section 1 - Preface

1.1 – *Introduction*

The following user guide outlines the basic use of the ND_Solar_Pump Excel workbook to assist with the design and evaluation of solar-powered water pump systems. The design tool follows the guidance and design procedures outlined in North Dakota Technical Note #1 – Solar-Powered Water Systems for Stockwater Design.

Use of the design workbook is dependent on the user having a basic knowledge of pump and pipeline hydraulics and the information contained within the NRCS-ND Conservation Practice Standards 516 – Livestock Pipeline, 533 – Pumping Plant, and 614 – Watering Facility. The design workbook is to be used to assist the designer in the computation for the requirements of a solar pump system and the evaluation of installed systems. The designer is the ultimate decision maker in the design process and should not rely on the design workbook to do so.

Selection of the solar pump and supporting solar panel array is typically completed by an equipment supplier hired by the agricultural producer on the basis of the daily demand, total dynamic head, and solar insolation value specified by NRCS in the design. NRCS employees, however, are expected to verify that the selected equipment was correctly chosen and installed.

The use of this design tool is for the design and evaluation of solar-powered pumps and solar array only. Design of any associated livestock pipeline and other appurtenances of the watering system will need to be done independently. The completed datasheets of this design tool are to be included in a complete construction design package that is compiled for the overall watering system.

1.2 – *Required Information*

As with planning for any livestock watering system, the initial step is to do a thorough job of identifying needs and collecting information. It is good practice to determine the landowner's objectives and determine if those objectives are consistent with the purpose of the conservation practice. A complete inventory of existing resources and conditions gives the basic information necessary to provide the landowner/producer with a competent, functional, and cost effective design that meets the intended objectives. Asking the right questions and collecting pertinent information during the initial stages of a project will be extremely beneficial during the design process and ultimately save time during the installation phase. Information which must be obtained for a water system can vary considerably depending on the complexity of the water sources to be utilized, existing installations, and the physical size of the area being served.

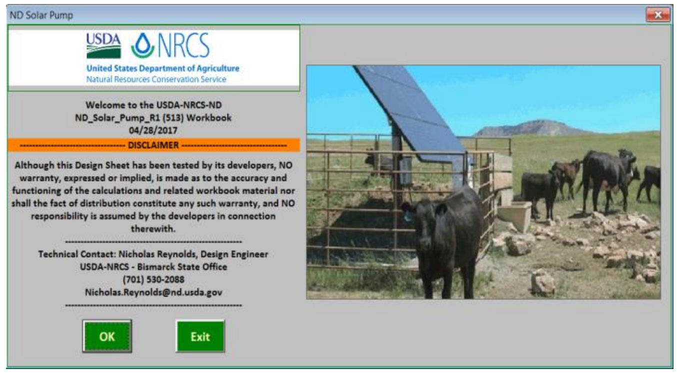
Before use of the workbook the following data should be collected from the appropriate sources. Refer to the North Dakota NRCS Engineering Planning Guide for Livestock Watering for further guidance: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/nd/technical/engineering/?cid=nrcseprd366085

For solar powered watering systems, the following information is critical in design of an effective system:

- The site-specific solar energy available ("solar insolation").
- The daily volume of water required by the livestock being grazed; including storage.
- The quantity and quality of available water.
- The total dynamic head (TDH) for the pump.
- The system's proposed layout.

Section 2 – Workbook Instructions and Title Page

2.1 – *Opening the Workbook*



a) Open the spreadsheet named: **ND_Solar_Pump_R2.xlsm**
   i. The number after the R in the workbook name reflects what revision of the workbook is being used. R1 was the initial version.

b) The Disclaimer Screen
   i. Review the disclaimer
   ii. Click **OK** to accept the conditions

2.2 – *Workbook Instructions*

The Instruction tab contains information on the features and functions of each tab within the workbook. It also explains the overall format of the workbook and instructions for data input.

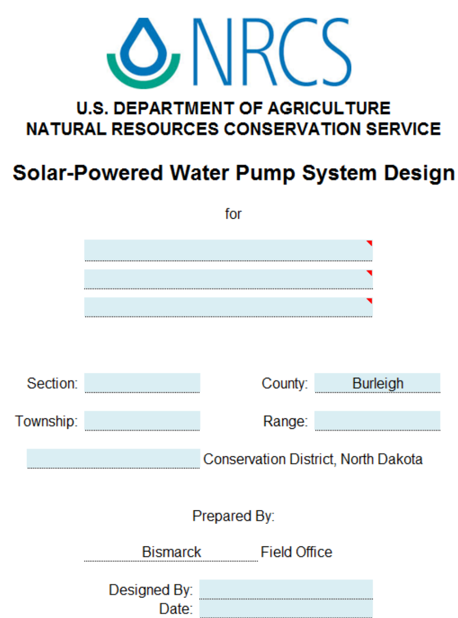
All data entry within the workbook is located in light blue cells and the user entry is blue: Blue. All other cells within the workbook are locked and cannot be changed by the user.

If you have any questions during the use of the workbook, read the red flag help comments first (Red Triangles). If that doesn't answer it, refer back to the Instructions tab.

If you have questions or issues with the functions of the workbook, the following person may be contacted for user support:
Nick Reynolds
Nicholas.Reynolds@nd.usda.gov
Bismarck SO, North Dakota
Office 701-530-2088
Cell: 701-426-5753

There is additional information about the workbook in the Developer Notes tab.

2.3 – *Title Page*

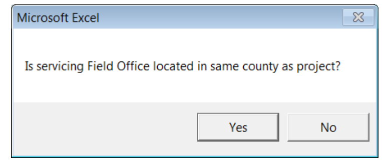


The Title Page tab is an informational page to record the who, what, when, and where information relevant to the design. This information is used to populate other cells throughout the workbook. The information copied will be locked on subsequent tabs and would need to be changed on the Title Page tab if so desired.

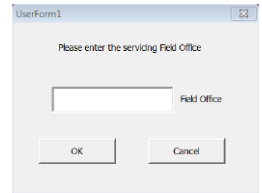
a) Enter information for the producer/landowner
   i. Name of contract participant
   ii. Additional information could include address, contact info, executor of entity/estate, etc.

b) Enter the legal location and county information for the project including:

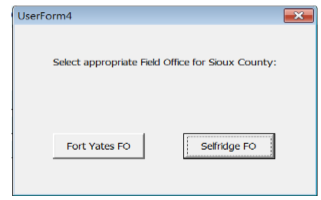
i. Section, Township, and Range of the project location
   - Section descriptors can be included as necessary



ii. County where the project is located (Select from dropdown box)
   - A message box is displayed asking if the servicing field office is located in the same county as the project.
     - Select **YES** if true and the name of the field office associated with the selected county is then populated.
     - Select **NO** if false and enter the name of the field office that services the project contract.



   - If multiple offices are located within the county then select the appropriate one from the dialog box.



iii. Name of the Local Conservation District that services the project area location

iv. Name of Field Office that is servicing the project contract
   - The field office name is set as the servicing field office for the county previously selected.

c) Enter designer information

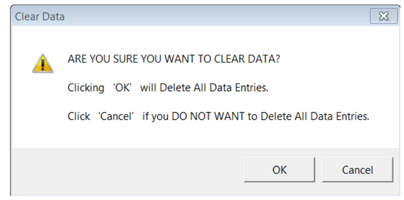
i. Designed by:
   - This is the designer of the solar pump design and who is responsible for the content there within. The entered name is transferred to the rest of the design tool tabs.

ii. Date
   - This is the date of when the design was completed. The entered date is transferred to the rest of the design tool tabs.

3.1 – *ND-ENG-39 (Solar)*

The purpose of the ND-ENG-39 (Solar) is to document and design the water requirements of the planned solar-powered watering system. The ND-ENG-39 (Solar) consists of two main sections; Resource Planning and Inventory and Watering Facility Sizing and Delivery Requirements. The following steps are a guide for the ENG-39 tab of the workbook.

It is good practice to start with a blank workbook for all new projects. A **Clear Data** button is available to clear out all existing data on the ENG_39 worksheet. A message box will appear to confirm that all existing data entries will be deleted.



a) Choose **OK** to continue deleting all existing data entries

b) Choose **Cancel** if existing data is not to be deleted

A title block located at the top of the ND-ENG-39 (Solar) form is available for documentation of the NRCS contract information. Data previously entered on the Title Page tab is automatically transferred into the title block. If any of this information needs to be changed then it is to be done on the Title Page tab.

United States Department of Agriculture
Natural Resources Conservation Service
Clear Data
ND_Solar_Pump_R2.xlsm, 07/07
Version: 7/07/17
North Dakota

WATERING SYSTEM RESOURCE INVENTORY and WATERING FACILITY DESIGN WORKSHEET
ND-ENG-39 (Solar)

Producer:		Field Office:	Bismarck
Contract No.:		CIN(s):	
Location:	Section Township Range	Field(s) No.:	
Designed by:		Date:	
Checked by:		Date:	

a) Enter the Contract Number of the NRCS conservation contract

b) Enter the Contract Item Number ($CIN_{(S)}$) of items being designed and contracted

c) Enter the Field/Pasture Number associated with each CIN within the contract

d) Checked by:
   i. To be completed by NRCS personnel with the experience in the type of design. The checker shall be someone other than the designer.

e) Planned Watering System Description:
   i. Enter a detailed description of the watering system being designed. Include description and location of the water source, layout and configuration of the solar array, type and location of watering facilities, etc. Continue the description on the back of the ND-ENG-39 (bottom of the ENG-39 worksheet) as needed.
      - Example: A new solar pump and solar array is to be installed at an existing well located in Field 1. The solar-powered water pump system is to supply a 3,000 gallon storage tank in Field 1 that will gravity feed two 500 gallon water tanks in Fields 1 and 2.

Planned Watering System Description:

3.2 – *ND-ENG-39 (Solar); Resource Planning and Inventory*

The design workbook utilizes the maximum daily summer drinking demands for the primary users of the watering system.

These values are shown in **Table 3.1**. There is limited published data on water requirements for bison; however, it is generally assumed that the daily requirements are similar if not slightly less for bison cows, calves, and bulls as it is for beef cattle.

Animal	Gal/Day
Beef - Lactating Cow and Calf	20
Beef - Bred/Dry Cow or Heifer	15
Beef - Growers (600 lb avg)	13
Beef - Yearlings/Finishers (800 lb avg)	18
Bulls	19
Dairy - Lactating Cows	25
Dairy - Dry Cows	17
Horses	18
Hogs	3
Sheep and Goats	2
Elk	8
Deer/Antelope	2
Upland Game Birds	5

Table 3.1

If the watering system will supply water to different species other than shown, ensure that sufficient water is provided to meet the sum of the seasonal high daily water requirements of all the animals. Design documentation is required for water requirement values not included in this design workbook.

Daily Water Requirements:
The **ENG-39** worksheet is set up to document up to 4 different species of livestock or wildlife.

Type of Livestock	Number of Livestock		Water Requirement			Daily Water Use		Required Drinking Spaces
Beef - Lactating Cow and Calf	50	x	20	gpd	=	1,000	gals.	2
		x	0	gpd	=	0	gals.	
		x	0	gpd	=	0	gals.	
		x	0	gpd	=	0	gals.	
					Total: =	**1,000**	**gals.**	**2**

a) Enter the **Type of Livestock** that is to utilize the watering system
   i. Multiple types of livestock may be selected. Several species of wildlife may be selected as well.

b) Enter the **Number of Livestock** or wildlife for each type selected
   i. If multiple herds or pastures are to be managed throughout the year, use the maximum number of animals that will utilize the system at one time.

c) Review the determined **Water Requirement**:
   i. The maximum daily summer drinking requirement for 1 animal of the selected animal type in units of gallons per day (GPD).

d) Review the determined **Daily Water Use**:
   i. The calculated total daily drinking requirement for each selected animal type in units of gallons.
   ii. A grand total is calculated for the daily drinking requirements of all animal types selected. This is the value used for sizing of the watering system.

e) Review the **Required Drinking Spaces**:
   i. For purposes of improving grazing distributions of beef cattle herds the required number of drinking spaces have been calculated for each animal type; as per the ND NRCS Conservation Practice Standard 614 – Watering Facility.
      - 1 drinking space per 20 animals for pasture or range units with maximum travel distance to water is in excess of ½ mile.
      - 1 drinking space per 40 animals for pasture of range units with maximum travel distance to water is less than ½ mile.
      - 1 drinking space per 100 animals for high density beef cattle operations such as feedlots, calving pens, winter feeding areas, or intensively managed grazing systems.

ii. A grand total is calculated for the number of required drinking spaces that is to be provided by the watering system. Note: The value depends on the selection of a grazing system type. See **Step g)**.

Grazing Management and Water Source Information:
Information is to be entered for how livestock is managed and the planned source of water for the system. This is to determine the watering system requirements utilized in the design process.

Grazing Dates Livestock Utilize System:	From:	March	to	October	
Type of Stocking / Grazing System:	Range/Pasture with less than 1/2 mile max travel to water				
Source of Water Supply:	Solar				
Source Water Surface Elevation:	740.0	MSL	ND SWC Well Data		
Source Max Flow Rate:		gpm			

f) Select the appropriate months associated with the grazing dates that livestock will be utilizing the water system.

g) Choose one of the following management style of the grazing or stocking system from the drop down menu. The choice determines the required # of drinking spaces needed for each pasture or range unit and the storage requirements of the watering system.
   i. Range/Pasture with greater than ½ mile max travel to water
   ii. Range/Pasture with less than ½ mile max travel to water
   iii. Lots or High Density / Intensively Managed Grazing Systems

h) Select "Solar" from the drop down menu to set the water source that will provide water to the system. The choice determines the required storage needed within the watering system.

i) Enter the water surface elevation, in feet, of the water source
   i. For water wells this is the dynamic or pumped water elevation in the well
      - Example: The ground elevation at the well is 1,000 ft MSL and the dynamic water level in the well when the pump is pumping is 260 feet below the surface. The water surface elevation is then 1,000 minus 260 or 740 ft.
   ii. For surface water such as streams and ponds, it is recommended that the water surface elevation be a minimum of 5ft below the average water level in the stream/pond in order to account for evaporation and seasonal fluctuations.

j) Enter the maximum flow rate, in gallons per minute (GPM), supplied by the water source
   i. This is what a water well is capable of producing. The entered value should be supported by a well log; as appropriate.

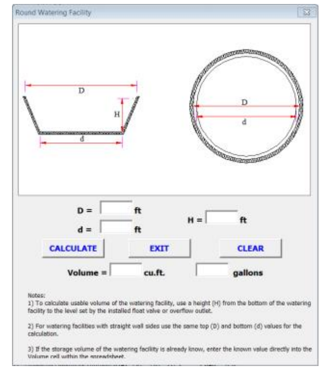
3.3 – *ND-ENG-39 (Solar); Watering Facility Sizing and Delivery*

Calculators are included within the **ENG-39** worksheet to aid in the sizing of several different types of watering facilities. These types include Round, Rectangle/Square, Rubber Tire, and Prefab Drinkers. For the Round, Rectangle/Square, and Rubber Tire facilities the calculators can be used to compute the perimeter and storage volume by entering the dimensions of the watering facility. For the Prefab Drinkers the minimum # of drinking spaces and # of waters needed can be computed by entering the # of animals to utilize the drinkers and the number of watering spaces provided by the desired drinker. The use of the calculators are optional. If the perimeter and storage volume values of a watering facility or the # of spaces of a drinker are already known then they can be entered directly without the use of a calculator.

Watering Facility Type:
Round
Rectangle/Square
Rubber Tire
Prefab Drinkers

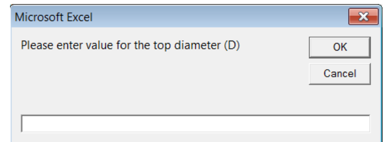
a) Click on the desired watering facility type to open the calculator

b) Enter each dimension or value, as shown on the figure, into the appropriate boxes



i. The dimension for the watering facility depth (H) is the height from the bottom of the facility to the level set by a float valve or overflow outlet. On a 2ft tall tank this is typically 1.75ft. This height is used to determine the usable water volume of the facility.

c) Click **CALCULATE** to compute the Volume or # of Drinking Spaces & Waterers
   i. For the Round, Rectangle/Square, and Rubber Tire facilities a perimeter is computed and entered directly into the **ENG-39** worksheet as well.
   ii. If a required entery was left blank and the Calculate button is clicked then an input box will appear.
      - Enter the desired value
      - Click **OK** to have the value placed into the calculator



d) To clear the calculator click the **CLEAR** button

e) Click **EXIT** to return to the **ENG-39** worksheet

After use of the watering facility calculators, the computed values are automatically populated into the **ENG-39** worksheet. If the computed values need to be adjusted or if the values are already known then they can be manually entered.

Watering Facility Type:		Perimeter		Volume			# of Facilities				Actual Drinking Spaces Per Tank
Round	:	30	ft	500	gals	x	2	=	1,000	gals.	30
Rectangle/Square	:		ft		gals	x		=	0	gals.	
Rubber Tire	:		ft		gals	x		=	0	gals.	
Prefab Drinkers	:	Rqrd. Drinking Spaces:			# of Spaces per Waterer:			x		waters	0
				Total Watering Facility Volume (WFV) =					**1,000**	gals.	**30**

f) Enter the # of Facilities of each type of watering facility desired

g) Total Watering Facility Volume (**WFV**):
   i. The volume is in units of gallons.
   ii. A grand total of the volume is calculated for all entered watering facilities in Cell R36.

h) Actual Drinking Spaces per Tank:
   i. The actual # of drinking spaces is calculated from the watering facility perimeter and the spacing requirements based on the watering facility shape.
      - For round or rubber tire facilities; allow 12-inches per animal.
      - For rectangle/square facilities; allow 18-inches per animal.
   ii. The number of spaces computed is for a single tank of the selected type.
   iii. This value is compared to the Required Drinking Spaces previously calculated.
      - If the value is less than the required value then a warning message appears in red.

      * Additional space is required for drinking access! Increase tank perimeter or provide more tanks.

i) Total Daily Water Use (**WU**):

Total Daily Water Use **(WU)**:	Use 10% for evaporation and spillage?	Yes	WU = Daily Water Use + 10% Added for Evaporation and Spillage
			WU = 5,000 x 1.1 = **5,500** gals. / day

   i. The Total Daily Water Use (**WU**) is based on the entered animal numbers and the type of stocking and grazing system.
   ii. For watering facilities with surface areas over 20 square feet it is recommended to account for an additional 10% of water volume for losses associated with evaporation and spillage.

   Note: The majority of water storage tanks used in solar-powered water systems are closed top and evaporation is not a concern.

      - Choose YES/NO from the drop down menu
         - If YES; Daily Water Use is multiplied by 1.1

Storage Requirements:
In North Dakota, NRCS requires 3 days of storage be supplied by a solar powered system. The storage can be a combination of drinking tanks and/or storage tanks.

Required Days of Storage in Pasture (DSmin):	3	day(s)	Design **(DS)**:	3	day(s)		*
Required Storage in Pasture (RS): RS = DS x WU =	3	x	1,000	=	3,000	gals.	
Required Additional Storage **(AS_{min})**: AS = RS-WFV =	2,000	gals.	*				
Design **(AS)** =	2,500	gals.					

j) Required Days of Storage in Pasture (**DS_{min}**):
   i. **DS_{min}** is determined based on the following criteria:
      ▪ For watering facilities supplied by solar power:
         - 3 days storage

k) Enter the Design Days of Storage (**DS**) for the watering system
   i. If the **DS** value is less than **DS_{min}** then a warning message appears in red.
   * Min. days of required storage not met!

l) Required Storage in Pasture (**RS**):
   i. **RS** is the product of the design days of storage (**DS**) and the total daily water use (**WU**).
      Example: RS = DS x WU = 3 x 1,000 = 3,000 gallons.

m) Required Additional Storage (**AS_{min}**):
   i. **AS_{min}** is the difference between the required storage in the pasture (**RS**) and the total watering facility volume (**WFV**).
      Example: AS = RS – WFV = 3,000 – 1,000 = 2,000 gallons
   ii. Additional storage may be required if the required storage (**RS**) is greater than what has been planned in the sizing of the watering facilities; **WFV**.

n) Enter the additional storage (**AS**) needed
   i. If the value is less than **AS_{min}** then a warning message appears in blue.
   * Min. additional storage not met: Consider providing more volume in the watering facilities or design a storage tank.

3.4 – *ND-ENG-39 (Solar); Existing Water Sources and Documentation*

A complete inventory of existing resources and conditions is needed to provide justification for the watering system that is being planned. Some information may include the location and details of the existing water sources (i.e. quality and reliability) in the areas to be serviced by the new watering system.

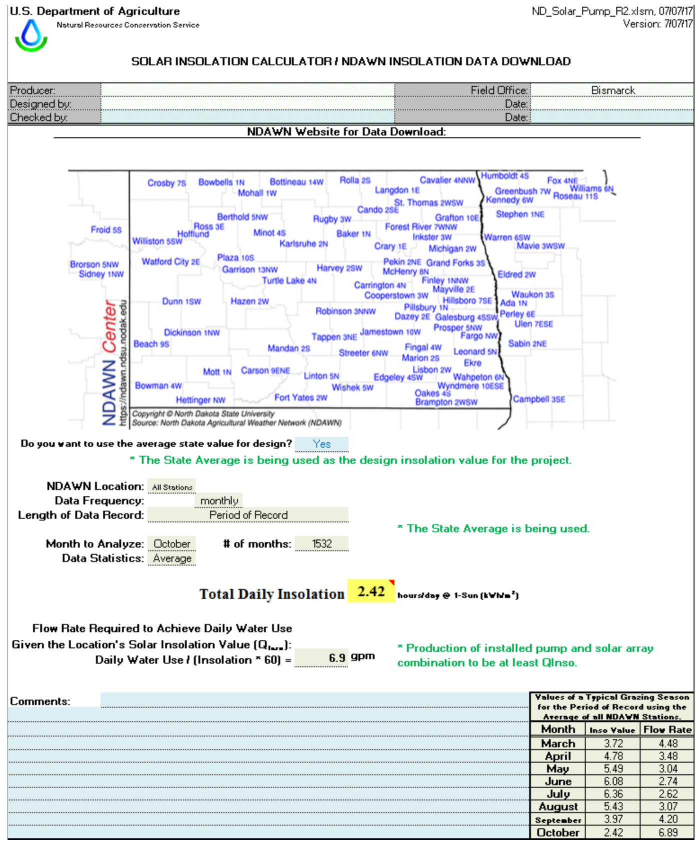
Field No.	Existing Water Sources	Dependability/Quality

a) Enter the following information for any existing water sources available to the livestock/wildlife in the area to be serviced by the new watering system:
   i. Field Number where the existing water source is located
   ii. Type of Existing Water Source; i.e. pond, creek, wetland
   iii. Dependability/Quality of the existing water source

Use of design notes are an essential part of documenting the decisions that are made during the design process. A design note section is available on the back of the ND-ENG-39 (Solar) (bottom of the ENG-39 worksheet) for extra documentation as needed.

Design Notes:

4.1 – *Determining Design Solar Insolation*



Design values for solar insolation can determined from a network of weather stations across North Dakota that are part of the North Dakota Agricultural Weather Network (NDAWN). Based on parameters selected, corresponding solar insolation values are downloaded from the NDAWN website into the design tool.

A statewide averaged insolation value can be chosen or a specific value for a selected NDAWN station can be used. A user inputted value can also be directly entered. The following steps are a guide for the Solar Resource tab of the workbook.

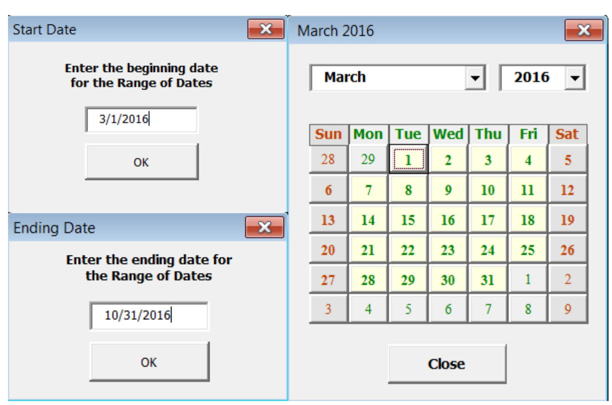
a) Choose either **Yes** or **No** from the dropdown menu for "**Do you want to use the average state value for design?**"
   i. **Yes** uses the average monthly value from October for the Period of Record of all NDAWN stations. As of July 2017, this value is 2.42. Skip to **Step (h)** if state average is used.
   ii. **No** requires a selection of a specific NDAWN station. Continue to **Step (b)** if selecting a NDAWN station.

b) Select a **NDAWN Station** from the dropdown list that is nearest to the project site.

c) Select the **Data Frequency** from the dropdown list for the frequency of the data downloaded from the NDAWN station.
   i. **daily** sets to download the daily data for the selected **NDAWN Station** for the **Length of Data Record**. Proceed to **Step (d.i)**.
   ii. **monthly** sets to download the monthly data for the selected **NDAWN Station** for the **Length of Data Record**. Proceed to **Step (d.ii)**.

   Note: monthly is the most common frequency used in design. **daily** can be used when a more detailed analysis of the site is desired.

d) Select the **Length of Data Record** from the dropdown list for the time frame of data downloaded from the NDAWN station.
   i. A data frequency of **daily** gives the following options:
      - **Range of Dates**
        - From the popup box, click in the space and select the beginning date from the calendar and click **OK**.
        - Choose a date from the calendar for the ending date and click **OK**.



- The resulting date range sets to download the daily data for only the listed range of dates for the selected **NDAWN Station**.

▪ **Previous # of Days**
  - Select the **Previous # of Days** from the dropdown menu:
    7, 14, 30, 60, 90, 100
  - Sets to download the daily data for only the past # of days chosen for the selected **NDAWN Station**.

ii. A data frequency of **monthly** gives the following options:

▪ **Period of Record**
  - Sets to download all months of the selected **NDAWN Station**'s period of record up to the current previous month.

▪ **Last Two Years**
  - Sets to download all months from the previous 2 years starting with the current previous month for the selected **NDAWN Station**.

▪ **Beginning Month and Year**
  - Select the **Beginning Month #** from the dropdown menu.
  - Enter the corresponding year (i.e. 2007) for the selected **Beginning Month**.

e) Click the [Get NDAWN Data] button to download the data table from the NDAWN website for the parameters set in **Step (d)**.

i. Internet access is required for the download to execute.

ii. The URL for the website where the data table is downloaded from is located at the top of the Solar Resource tab under the heading **NDAWN Website for Data Download**.

iii. The downloaded data is transferred into the workbook and can be viewed in the Solar Data tab.

iv. A message in red appears when the **NDAWN Station** is changed and is different than the data currently loaded in the Solar Data tab.

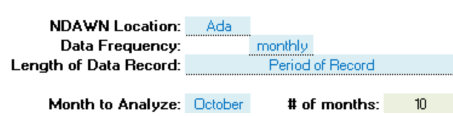
* NDAWN Station has changed. Please click on Get NDAWN Data button to download the Station data.

v. A message in red appears when inputs for **Data Frequency** and **Length of Data Record** are changed.

* Data inputs have changed. Please click on the Get NDAWN Data button to update values.

f) Select the **Month to Analyze** from the dropdown menu.

i. Either a **# of months** or **# of days**, depending on the **Data Frequency** selected, will be calculated from the data downloaded and located in the Solar Data tab. The number is representative of the number of solar insolation values for the month being analyzed.



Example: There are 10 October solar insolation values for the Period of Record from the Ada NDAWN station.

g) Select a **Data Statics** from the dropdown menu to determine the design solar insolation value.

i. **Average** – Returns an average solar insolation value from all values of the downloaded data set for the selected **Month to Analyze** and displays it as the **Total Daily Insolation** value.

ii. **Minimum** – Returns the minimum solar insolation value from all values of the downloaded data set for the selected **Month to Analyze** and displays it as the **Total Daily Insolation** value.

iii. **Percentile** – Returns the n^{th} percentile of the solar insolation value from all values of the downloaded data set for the selected **Month to Analyze** and displays it as the **Total Daily Insolation** value.

▪ Enter a percentage as a whole number.

Example: 0% returns the minimum value
10% returns a value that is less than 90% of all other values.
90% returns a value that is greater than all but 10% of all values.
100% returns the maximum value.

h) Review the resulting **Total Daily Insolation** value.
   i. This is the design insolation value to use for the design and is representative of the number of peak sun hours at 1-Sun (1kW/m^2) the site receives per day based on the **Month to Analyze** and set **Data Statistics**.
   ii. The **Total Daily Insolation** value can be overridden as a user input.

   Example: When analyzing a design from a solar dealer, installer or other design software, the solar insolation value used can be manually entered to evaluate the resulting flow rate and system production.
   - A message in purple appears when the Total Daily Insolation value is overridden. *** Insolation value does not match the NDAWN value for the selected site. A user defined value is being used. NDAWN value for the selected site is: ___.**

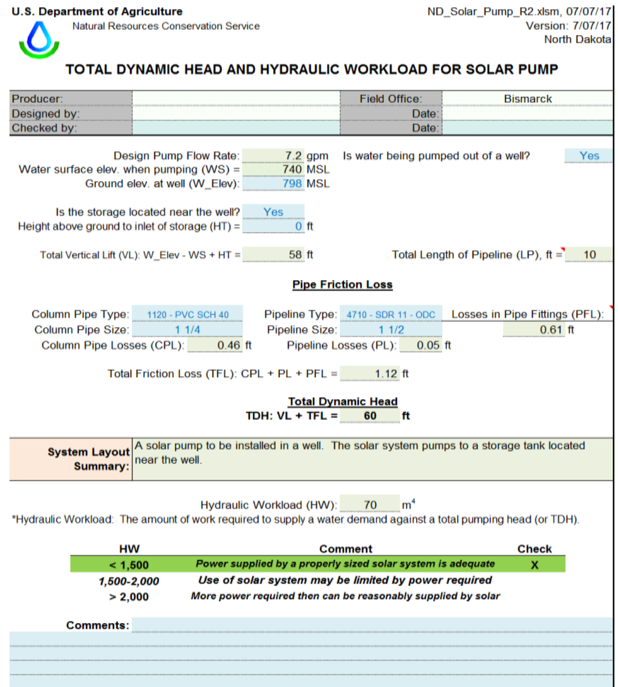
i) Review the calculated **Flow Rate Required to Achieve Daily Water Use Given the Location's Solar Insolation Value (Q_{Inso})**.
   i. The resulting flow rate, in gallons per minute (GPM), that the pump and solar array combination has to meet in order to supply the daily water requirements of the livestock determined on the ND-ENG-39 (Solar) data sheet.
   ii. **Q_{Inso}** is one of the characteristics to be used in the evaluation and selection of a pump/controller.

j) A table is provided in the lower right hand corner of the data sheet that lists the average solar insolation values and resulting required flow rate for the months of March – October for the selected **NDAWN Station**.
   i. The table is only applicable for a **Data Frequency** of **monthly** and a **Length of Data Record** set to **Period of Record**.

Values of a Typical Grazing Season for the Period of Record of the Ada NDAWN Station		
Month	**Inso Value**	**Flow Rate**
March	3.68	4.53
April	4.66	3.58
May	5.26	3.17
June	5.79	2.88
July	6.21	2.68
August	5.24	3.18
September	3.93	4.24
October	2.30	7.23

k) A comments section is available at the bottom of the data sheet for documentation of design decisions and justifications for values used.

5.1 – *Calculating the Required Total Dynamic Head (TDH) for the System*



U.S. Department of Agriculture
Natural Resources Conservation Service

ND_Solar_Pump_R2.xlsm, 07/07/17
Version: 7/07/17
North Dakota

TOTAL DYNAMIC HEAD AND HYDRAULIC WORKLOAD FOR SOLAR PUMP

Producer:		Field Office:	Bismarck
Designed by:		Date:	
Checked by:		Date:	

Design Pump Flow Rate: 7.2 gpm
Water surface elev. when pumping (WS) = 740 MSL
Ground elev. at well (W_Elev): 798 MSL
Is water being pumped out of a well? Yes

Is the storage located near the well? Yes
Height above ground to inlet of storage (HT) = 0 ft

Total Vertical Lift (VL): W_Elev - WS + HT = 58 ft
Total Length of Pipeline (LP), ft = 10

Pipe Friction Loss

Column Pipe Type: 1120 - PVC SCH 40
Column Pipe Size: 1 1/4
Column Pipe Losses (CPL): 0.46 ft
Pipeline Type: 4710 - SDR 11 - ODC
Pipeline Size: 1 1/2
Pipeline Losses (PL): 0.05 ft
Losses in Pipe Fittings (PFL): 0.61 ft

Total Friction Loss (TFL): CPL + PL + PFL = 1.12 ft

Total Dynamic Head
TDH: VL + TFL = 60 ft

System Layout Summary: A solar pump to be installed in a well. The solar system pumps to a storage tank located near the well.

Hydraulic Workload (HW): 70 m^4
*Hydraulic Workload: The amount of work required to supply a water demand against a total pumping head (or TDH).

HW	Comment	Check
< 1,500	*Power supplied by a properly sized solar system is adequate*	X
1,500-2,000	*Use of solar system may be limited by power required*	
> 2,000	*More power required then can be reasonably supplied by solar*	

Comments:

The total dynamic head (TDH) of a solar-power watering system can be calculated for both a submersible pump installation such as a well or for a surface pump installation such as pumping out of a pond or stream. The location of the watering facility that stores the outputted water also is a factor in determining the required TDH of the system. The following steps are a guide for the TDH tab of the workbook.

a) Review the **Design Pump Flow Rate**
   i. This value is the calculated $\mathbf{Q_{Inso}}$ from the Solar Resource tab. See **Section 4.1** for the process of determining this value; if a change is necessary.

b) Review the **Water Surface Elev. When Pumping (WS)**
   i. WS is the water surface elevation of the water source when pumping and is populated from the entry on the ENG-39 tab. See **Section 3.2, Step (i)**.

c) **Is water being pumped out of a well?** Select **Yes** or **No** from the dropdown menu.
   i. **Yes** – Enter the **Ground elev. at well (W_Elev)**; skip to **Step (g)**.
   ii. **No** – Enter the **Ground elev. at pump (P_Elev)**; continue to **Step (d)**.
      - For use with surface pumps that are set to pump out of a pond or stream.

d) Enter a description of the **Pump Location** if using a surface pump.

   Example: "an existing dugout pond"

e) Review the calculated **Suction lift (SL)** of the surface pump.
   i. The suction lift is the elevation difference from the ground elevation at the surface pump to the water surface elevation of the pond or stream when pumping.
   ii. If the suction lift exceeds 25ft, a warning message appears in red.
   *Warning: Suction Lift >25ft. Cavitation is likely. System layout needs to be modified.

f) Enter the **Length of pump suction hose (LSH)** if using a surface pump.
   i. The hose length is from the suction inlet of the surface pump to the beginning of the intake screen in the pond or stream.

g) **Is the storage located near the well/pump outlet?** Select **Yes** or **No** from the dropdown menu.
   i. **Yes** – Enter the **Height above ground to inlet of storage (HT)**; skip to **Step (j)**.
   ii. **No** – Enter the **Height above ground to inlet of storage (HT)**; continue to **Step (h)**.

h) Enter the **Distance from well to storage (DS)** for a storage tank located remotely.

i) Enter the **Ground elev. at storage (S_Elev)** for a storage tank located remotely.

j) Review the calculated **Total Vertical Lift (VL)**.
   i. For a storage located near a well; VL = W_Elev – WS + HT
   ii. For water storage located remotely from a well; VL = S_Elev – WS + HT

iii. For a storage located near a surface pump; VL = SL + HT

iv. For water storage located remotely from a surface pump; VL = S_Elev – P_Elev + SL + HT

k) Review the calculated **Total Length of Pipeline (LP)**.
Note: The pipeline length is only for pipe between the water source and the water storage at the outlet of the pump. Pipeline extending from the outlet of the water storage is to be designed separately.

i. For a storage located near a well; LP = HT + 10’ of miscellaneous plumbing between well and storage.

ii. For water storage located remotely from a well; LP = VL + DS

iii. For a storage located near a surface pump; LP = LSH

iv. For water storage located remotely from a surface pump; LP = LSH + DS

Pipe Friction Loss:

l) Select the **Column/Suction Pipe Type** from the dropdown menu.

i. For a well; column pipe is the pipe that connects to the pump and is placed down into the well.
  - Typical column pipe is 1120 – PVC SCH 40

ii. For a surface pump; suction pipe is the pipe that runs from the pump down into the pond or stream.
  - Suction pipe should be rated for above ground use.

m) Select the **Column/Suction Pipe Size** from the dropdown menu.

i. For column pipe; the size depends on the NPT outlet of the pump and typically ranges from 1” to 2”.

ii. For suction pipe; the size depends on the size of the suction inlet of the pump.

n) Review the calculated **Column/Suction Pipe Losses (CPL/SPL)**.

i. The friction loss through the column/suction pipe is automatically calculated by solving for the head loss from the Hazen-Williams equation.

o) Select the **Pipeline Type** from the dropdown menu.

p) Select the **Pipeline Size** from the dropdown menu.

q) Review the calculated **Pipeline Losses (PL)**.
Note: The pipeline length is only for pipe between the water source and the water storage at the outlet of the pump. Pipeline extending from the outlet of the water storage is to be designed separately.

i. The friction loss through the pipeline is automatically calculated by solving for the head loss from the Hazen-Williams equation.

r) Review the calculated **Losses in Pipe Fittings (PFL)**.

i. The friction loss is for the piping at the well or surface pump. Default fittings and values are included in a chart located to the right of the data sheet. The fitting’s size is assumed to be the same as for the **Pipeline Size**. At the very least, the fitting’s material should be changed; as needed.

Select Fittings for Plumbing Within Well Pit / Pump House			
Type	*Material*	*Quantity*	*Head Loss (ft)*
Elbow-90 deg	Steel	4	0.29
Standard Tee	Steel	1	0.05
Gate Valve	Steel	1	0.02
Check Valve	Steel	1	0.24
		Pipe Fitting Loss (ft):	**0.61**

ii. The friction loss through the fittings is automatically calculated by solving for the head loss from the Hazen-Williams equation.

s) Review the **Total Friction Loss (TFL)**.

i. The total friction loss through all piping between the pump and the water storage.

ii. For a pump within a well; TFL = CPL + PL + PFL

iii. For a surface pump; TFL = SPL + PL + PFL

Total Dynamic Head:

t) Review the calculated **Total Dynamic Head (TDH)**.

  i. The total head the pump has to work against to deliver the required flow rate $\mathbf{Q_{Inso}}$.

  ii. TDH = VL + TFL

  iii. **TDH** is one of the characteristics to be used in the evaluation and selection of a pump/controller.

5.2 – System Layout Summary and Hydraulic Evaluation

a) Review the **System Layout Summary** as compiled by the design choices made in **Section 5.1**.

b) Review the calculated **Hydraulic Workload (HW)** of the system.

  i. Hydraulic workload is the amount of work required of a watering system to supply water; Q_{Inso}, against a total pumping head; TDH.

c) Review the hydraulic workload table to determine if solar-power is a viable option for the system. The row in which the calculated HW falls is highlighted green, yellow, or red.

  i. If HW is < 1,500 then the power supplied by a properly sized solar system is adequate.

    - Row is highlighted **GREEN**

  ii. If HW is 1,500 – 2,000 then the power required by the system may be limited by the use of solar-power.

    - Row is highlighted **YELLOW**

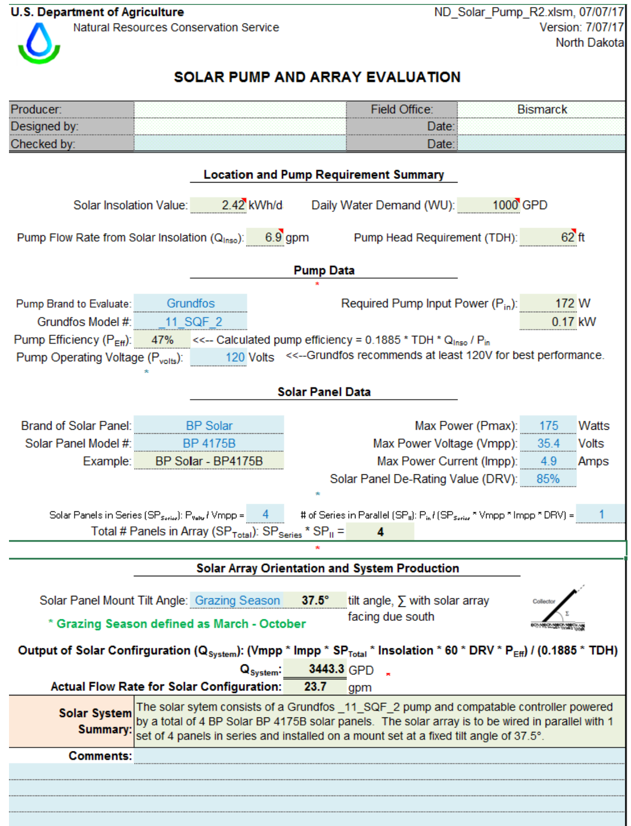
  iii. If HW is > 2,000 then more power is required by the system then can be reasonably supplied by solar.

    - Row is highlighted **RED**

d) A comments section is available at the bottom of the data sheet for documentation of design decisions and justifications for values used.

6.1 – *Solar Pump Evaluation*

Solar insolation, daily livestock water demand, and total dynamic head are the three main factors in determining the right solar pump and panel array combination. The orientation and tilt angle of the solar array is also key in assuring that the system performs efficiently. The following steps are a guide for the Pump and Array tab of the workbook.



U.S. Department of Agriculture
Natural Resources Conservation Service
ND_Solar_Pump_R2.xlsm, 07/07/17
Version: 7/07/17
North Dakota

SOLAR PUMP AND ARRAY EVALUATION

Producer:		Field Office:	Bismarck
Designed by:		Date:	
Checked by:		Date:	

Location and Pump Requirement Summary

Solar Insolation Value: 2.42 kWh/d — Daily Water Demand (WU): 1000 GPD

Pump Flow Rate from Solar Insolation (Q_{Inso}): 6.9 gpm — Pump Head Requirement (TDH): 62 ft

Pump Data

Pump Brand to Evaluate: Grundfos — Required Pump Input Power (P_{in}): 172 W

Grundfos Model #: _11_SQF_2 — 0.17 kW

Pump Efficiency (P_{Eff}): 47% <<-- Calculated pump efficiency = 0.1885 * TDH * Q_{Inso} / P_{in}

Pump Operating Voltage (P_{volts}): 120 Volts <<--Grundfos recommends at least 120V for best performance.

Solar Panel Data

Brand of Solar Panel: BP Solar — Max Power (Pmax): 175 Watts

Solar Panel Model #: BP 4175B — Max Power Voltage (Vmpp): 35.4 Volts

Example: BP Solar - BP4175B — Max Power Current (Impp): 4.9 Amps

Solar Panel De-Rating Value (DRV): 85%

Solar Panels in Series (SP_{Series}): P_{Volts} / Vmpp = 4 — # of Series in Parallel (SP_{II}): P_{in} / (SP_{Series} * Vmpp * Impp * DRV) = 1

Total # Panels in Array (SP_{Total}): SP_{Series} * SP_{II} = 4

Solar Array Orientation and System Production

Solar Panel Mount Tilt Angle: Grazing Season 37.5° tilt angle, ∑ with solar array facing due south

* Grazing Season defined as March - October

Output of Solar Confirguration (Q_{System}): (Vmpp * Impp * SP_{Total} * Insolation * 60 * DRV * P_{Eff}) / (0.1885 * TDH)

Q_{System}: 3443.3 GPD

Actual Flow Rate for Solar Configuration: 23.7 gpm

Solar System Summary: The solar sytem consists of a Grundfos _11_SQF_2 pump and compatable controller powered by a total of 4 BP Solar BP 4175B solar panels. The solar array is to be wired in parallel with 1 set of 4 panels in series and installed on a mount set at a fixed tilt angle of 37.5°.

Comments:

a) Review the **Solar Insolation Value**

i. This is the **Total Daily Insolation** value determined on the Solar Resource tab. See **Section 4.1** for the process of determining this value; if a change is necessary.

b) Review the **Daily Water Demand (WU)**

i. WU is the total daily water use of the livestock that is documented on the ENG-39 tab. See **Section 3.2, Steps (a-d)**.

c) Review the **Pump Flow from Solar Insolation (Q_{Inso})**

i. Q_{Inso} is the calculated flow rate required to meet the daily demand based on the design solar insolation value. See **Section 4.1** for the process of determining this value; if a change is necessary.

d) Review the **Pump Head Requirement (TDH)**

i. TDH is the total dynamic head calculated in the TDH tab. See **Section 5.1** for the process of calculating this value; if a change is necessary.

Pump Data:

e) Select the **Pump Brand to Evaluate** from the dropdown menu.

i. **Grundfos**
   - A preloaded list of Grundfos solar pumps are available for evaluation; continue to **Step (f)**.

ii. **Lorentz**
   - A preloaded list of Lorentz solar pumps and compatible controllers are available for evaluation; continue to **Step (f)**.

iii. **SunPumps**
   - A preloaded list of SunPumps solar pumps are available for evaluation; continue to **Step (f)**

iv. **Other**
   - Any brand of solar pump can be evaluated by entering the pump's specific characteristics; skip to **Step (g)** for the process of entering a custom pump.

f) Select the pump **Model #** from the dropdown menu.

i. If both the required Q_{Inso} and **TDH** fall within the performance curve of the pump then the resulting **Required Pump Input Power (P_{in})**, **Pump Efficiency (P_{Eff})**, and **Pump Operating Voltage (P_{volts})** are displayed.
   - The Pump Tables tab contains the pump data tables for each of the preloaded pumps and can be reviewed as necessary.

ii. If the required **TDH** falls within the performance curve of the pump but the required **Q_{Inso}** is greater than what the pump can produce; a message in blue appears noting the max flow rate the pump is able to produce against the required **TDH**.

- *** The max production of the selected pump for the required TDH is __ GPM.**

iii. If the required **Q_{Inso}** falls within the performance curve but the **TDH** is less than the minimum TDH of the pump performance curve; a message in red appears noting the minimum TDH required of the pump.

- *** The min TDH of the selected pump for Q_{Inso} is ___ft. Please try a different pump or model.**

iv. If the required **Q_{Inso}** falls within the performance curve but the **TDH** is more than the maximum TDH of the pump performance curve; a message in red appears noting the maximum TDH of the pump.

- *** The max TDH of the selected pump for Q_{Inso} is ___ft. Please try a different pump or model.**

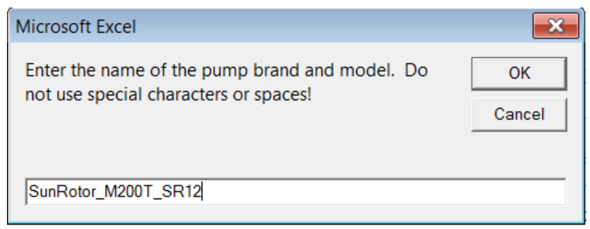
v. If both the required **Q_{Inso}** and **TDH** fall are outside the performance curve of the pump; a message in red appears noting that both the flow and head are outside the operating conditions of the pump. A message highlighted in red will also display showing the pump limits for flow and TDH.

- *** Both Q and TDH are outside the operating range of the pump model. Please try a different pump or model.**
- **Selected pump has a min/max operating TDH of ___' and min/max Q of ___ gpm.**

g) Select **Other** from the **Model #** dropdown menu if the desired pump is not available from those listed.

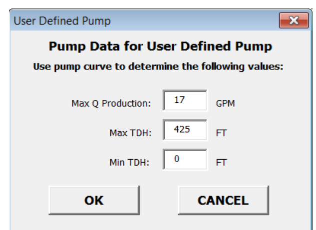
i. Enter the name of the pump brand and model for the pump to be analyzed and click **OK**.

- The entry cannot contain any spaces or special characters such as / \ . - , ect.
- Example: For a SunRotor SR-12 pump with a M200T controller, the entry would be SunRotor_M200T_SR12



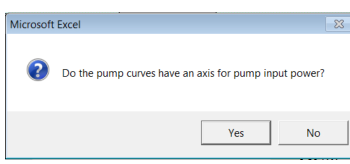
ii. Using the pump's performance curve, enter the pump data for the user defined pump and click **OK.**

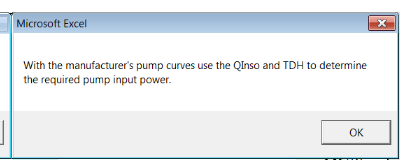
- **Max Q Production** in GPM
- **Max TDH** in FT
- **Min TDH** in FT

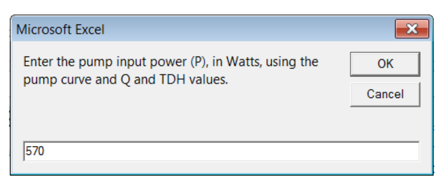


iii. Click **Yes** or **No** to the question of **"Does the pump curve have an axis for pump input power?"**

- **Yes** – A box appears asking to use the pump curve with **Q_{Inso}** and **TDH** to determine the required pump input power. Click **OK**. Continue to **Step (g.iv)**
- **No –** The required pump input power is manually calculated. Skip to **Step (g.v)**

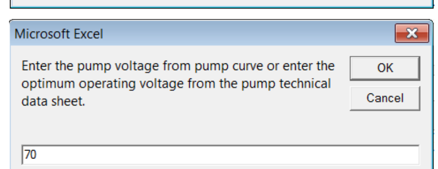






iv. Enter the required pump input power in Watts using the pump curve for the systems **Q_{Inso}** and **TDH** and click **OK**.

v. Enter the pump voltage from the pump curve, if applicable, or enter the optimal operating voltage from the pump technical data sheet and click **OK**.



h) Review the **Required Pump Input Power (P_{in})** for the selected pump model.

i. **P_{in}** is determined from the pump performance curve of the selected pump model using the system's required **Q_{inso}** and **TDH**.

ii. **P_{in}** is the amount of power required by the pump and to be supplied by the solar array.

i) Review the **Pump Efficiency (P_{Eff})** calculated for the selected pump model.

i. **P_{Eff}** = 0.1885 * **TDH** * **Q_{inso}** / **P_{in}**

j) Review the **Pump Operating Voltage (P_{volts})** for the selected pump model.

i. For Grundfos and Lorentz pumps, the optimum operating voltage of the pump model is used as the default. This value is found in the technical data documentation for the pump and preloaded into the workbook on the Pump Tables tab.

ii. For SunPumps pumps, the optimum operating voltage is part of the pump performance curve and is determined using the system's required **Q_{inso}** and **TDH**.

6.2 – Solar Panel Evaluation

a) Enter the **Brand of Solar Panel**.

i. Example: BP Solar

b) Enter the **Solar Panel Model #**.

i. Example: BP 4175B

Use the technical data sheet or sticker label on the panel to determine the values for Steps (c-f):

c) Enter the **Max Power (Pmax)** of the selected solar panel.

i. **Pmax** is the rated maximum power supplied by the solar panel

d) Enter the **Max Power Voltage (Vmpp)** of the selected solar panel.

i. **Vmpp** is the rated voltage supplied by the panel at rated max power.

e) Enter the **Max Power Current (Impp)** of the selected solar panel.

i. **Impp** is the rated current supplied by the panel at rated max power.

f) Enter the **Solar Panel De-Rating Value (DRV)** of the selected solar panel.

i. DRV is the percentage of max power that the panel can supply over the rated life of the panel.

ii. 80-85% is a common DRV for most solar panels used in solar-powered watering systems.

g) Review the calculated # of **Solar Panels in Series (SP_{Series})**.

i. The number of panels to be wired in series is calculated by dividing the optimum operating voltage required of the pump by the max power voltage supplied by the solar panel.

$$SP_{Series} = P_{volts} / Vmpp$$

ii. The value can be overridden with a user input if evaluating an existing system or to check if fewer solar panels can be used.

- Voltages supplied by the solar array that are less than the optimum operating voltage of the pump can result in decreased production of the system.

h) Review the calculated **# of Series in Parallel (SP_{II})**.

i. The number of panel strings (string = panels wired in series) to be wired in parallel

$$SP_{II} = P_{in} / (SP_{Series} \times Vmpp \times Impp \times DRV)$$

ii. The value can be overridden with a user input if evaluating an existing system or to check if fewer solar panels can be used.

i) Review the calculated **Total # of Panels in Array (SPTotal)**.

i. The total number of panels that make up the solar array is calculated by multiplying the number of panels wired in series by the number of panel strings wired in parallel.

$$SP_{Total} = SP_{Series} \times SP_{II}$$

j) Review the configuration of the solar array and selected pump/controller.

i. Solar pumps and their associated controllers are rated for a maximum allowable input wattage, voltage, and current. A message in red will appear when an entered solar array configuration exceeds the limits of the pump/controller combination.
    - *** Warning: Solar array produces a wattage exceeding the rating of the pump system! Damage to the system may occur!**

k) Select the **Solar Panel Mount Tilt Angle** from the dropdown menu.

i. **Annual –** The determined optimal tilt angle of a fixed-axis mount for year round production.
    - The optimal tilt angle for the best production of the system year round is equal to the latitude of the local site.

ii. **Summer –** The determined optimal tilt angle of a fixed-axis mount for production in May-Aug.
    - The optimal tilt angle for the best production of the system during the summer is equal to the latitude of the local site –15°.

iii. **Grazing Season –** The determined optimal tilt angle of a fixed-axis mount for production during a typical grazing season from March-October.
    - The optimal tilt angle for the best production of the system during a typical grazing season.

iv. **Single-Axis Tracker –** A mount with a fixed vertical axis set at an angle of the local latitude and a horizontal axis that tracks the movement of the sun from east to west.

v. **Double-Axis Tracker –** A mount with both a vertical and horizontal axis that tracks the movement of the sun across the sky.

l) Review the resulting **Solar Panel Mount Tilt Angle**.

i. The tilt angle is determined based on the location of the selected NDAWN station used in determining the project site's solar insolation value.

6.3 – System Evaluation and Summary

It is important to evaluate the actual production of the solar pump and solar array configuration to determine if the planned or installed system meets the watering requirements of the design.

a) Review the calculated **Output of Solar Configuration (Q_{System})**.

i. A production output is calculated for the pump and solar array combination evaluated in **Section 6.1 and 6.2**; respectively.
    - Q_{System} = (Vmpp x Impp x SP_{Total} x Solar Insolation x 60 x DRV x P_{Eff}) / (0.1885 x TDH)
    - A message in red appears when the pump and array configuration do not meet the daily water requirements of the system.

*** Q_{System} less than daily water use (WU). The pump and panel configuration do not meet the daily waster demand of ____GPD.**

b) Review the **Actual Flow Rate for Solar Configuration**.

i. The actual flow rate in GPM that the system produces based on the configuration of the pump and solar array.
    - The rate is calculated by dividing the output of the solar configuration by the system's design solar insolation value; **Flow Rate = QSystem / (Solar Insolation x 60)**.

c) Review the **Solar System Summary** as compiled by the design choices made in **Section 6.1 and 6.2**.

d) A comments section is available at the bottom of the data sheet for documentation of design decisions and justifications for values used.

7.1 – Running a Water Budget

An effective way to determine if the storage provided is sufficient is through a water balance. A water balance will determine how much storage is still available during any period of time by keeping track of the production and demands into and out of the system. The water budget within the design workbook analyzes the monthly production and demands of the system and determines the months when the volume of the provide storage is exceed and supplemental water is needed. Additional statistical information is calculated as well. The following steps are a guide for the Water Budget tab of the workbook.

Historic Water Storage Budget Summary						
Year	Month	Average Insolation Value	Production of Solar Setup	Demand, Gallons	Storage, Gallons	Supplimental Water, Gallons
2014	3	3.16	54,006	31,000	3,000	0
2014	4	4.44	73,298	30,000	3,000	0
2014	5	5.02	85,698	31,000	3,000	0
2014	6	4.63	76,480	30,000	3,000	0
2014	7	6.30	107,599	31,000	3,000	0
2014	8	4.12	70,257	31,000	3,000	0
2014	9	3.98	65,768	30,000	3,000	0
2014	10	2.39	40,795	31,000	3,000	0
2014	11	1.41	23,292	30,000	3,000	3,708
2014	12	1.13	19,225	31,000	0	11,775
2015	1	1.50	25,589	31,000	0	5,411
2015	2	2.26	34,794	28,000	0	0
2015	3	3.73	63,703	31,000	3,000	0
2015	4	4.81	79,429	30,000	3,000	0
2015	5	5.46	93,210	31,000	3,000	0
2015	6	5.95	98,294	30,000	3,000	0
2015	7	6.47	110,424	31,000	3,000	0
2015	8	5.83	99,564	31,000	3,000	0
2015	9	4.60	75,942	30,000	3,000	0
2015	10	2.56	43,724	31,000	3,000	0
2015	11	1.66	27,414	30,000	3,000	0
2015	12	1.16	19,787	31,000	414	10,798
2016	1	1.47	25,042	31,000	0	5,958
2016	2	2.09	32,155	28,000	0	0
2016	3	3.62	61,711	31,000	3,000	0
2016	4	4.27	70,588	30,000	3,000	0
2016	5	6.13	104,582	31,000	3,000	0
2016	6	7.47	123,338	30,000	3,000	0
2016	7	6.29	107,317	31,000	3,000	0
2016	8	5.89	100,559	31,000	3,000	0
2016	9	3.58	59,092	30,000	3,000	0
2016	10	2.25	38,376	31,000	3,000	0
2016	11	1.68	27,668	30,000	3,000	0
2016	12	1.34	22,953	31,000	668	7,380
2017	1	1.73	29,444	31,000	0	1,556
2017	2	2.61	40,243	28,000	0	0
2017	3	3.52	60,043	31,000	3,000	0
2017	4	4.70	77,629	30,000	3,000	0
2017	5	6.54	111,575	31,000	3,000	0
2017	6	6.96	115,012	30,000	3,000	0

Get Inso

Press: **Get Inso** to update insolation values!

Historic Water Storage Budget Sumary		
Storage Volume:	3,000	gallons
Budget Starting Volume:	0	gallons
Low Volume Check:	100	gallons
NDAWN Station:	**Hazen**	

a) Click the Get Inso to import the historical insolation values for the selected NDAWN Station on the Solar Resource tab; see **Section 4.1(b)**.
   i. A table is populated for each month of the NDAWN Station's Length of Data Record selected on the Solar Resource tab; see **Section 4.1(d)**.
   ii. Production of the system is calculated for each month using the month's average solar insolation value as determined on the Solar Resource tab; see **Section 4.1(b-h)**.
   iii. A monthly system demand is calculated for each month using the total daily water (**WU**) use of the livestock documented on the ENG-39 tab. See **Section 3.2(a-d)**.

b) Enter the **Storage Volume** of the system.
   i. The storage volume must meet the North Dakota minimum 3 days storage.
      - **Minimum Storage Volume = WU x 3**

c) Enter the **Budget Starting Volume** of the storage tank.
   i. It is recommended that the starting volume be 0; assuming that the storage will be empty initially.

d) Enter a **Low Volume Check** for the storage tank, if desired.
   i. If you would like to know how many times the storage tank gets lower than some point, enter that volume in gallons or enter 0 if you don't care.

e) Review the data in the **Historic Water Storage Budget Summary** table.
   i. The table shows the monthly historical production and demand of the system and calculates whether supplemental water is needed over what the storage tank is able to provide in a given month.
      - **Supplemental Water = Demand – Production – Remaining Storage of Previous Month**
   ii. If the table shows no supplemental water needed during the months when the system is being used; i.e. March – October, then the provided storage volume is sufficient for the system.
   iii. If supplemental water is shown to be needed during the system's season of use then revisit the system design parameters to either increase the production of the system or decrease the demands on the system.

f) Review the **Historic Water Storage Budget Statistics**.

i. **Start Year – End Year**
ii. **NDAWN Station Period of Record**
iii. **Average Insolation**
iv. **Min Insolation**
v. **Max Insolation**
vi. **Average Production**
vii. **Median Production**
viii. **Average Demand**
ix. **Average Storage**
x. **Median Storage**
xi. **Storage was Dry**
xii. **Storage < Low Volume Check**
xiii. **Average Supplemental Water**
xiv. **Median Supplemental Water**
xv. **Total Supplemental Water**

Start Year =	1993		End Year =	2017		
NDAWN Station Period of Record =	287	months	23.9	years		
Average Insolation =	3.84	hr/day				
Min Insolation =	0.98	hr/day	December	2004		
Max Insolation =	7.47	hr/day	June	2016		
Average Production =	2146	gal/day	64,384	gal/month	772,605	gal/yr
Median Production =	2206	gal/day	66,168	gal/month	794,019	gal/yr
Average Demand =	1014	gal/day	30,415	gal/month	364,976	gal/yr
Average Storage =	2,285	gallons				
Median Storage =	3,000	gallons				
Storage was Dry =	64	months	22%			
Storage < 100 gal =	65	months	23%			
Average Supplemental Water =	40	gal/day	1,197	gal/month	14362	gal/yr
Median Supplemental Water =	0	gal/day	0	gal/month	0	gal/yr
Total Supplemental Water =	343,489	gallons				

APPENDIX

Appendix 1 – *Design Example*

This example uses the ND_Solar_Pump design workbook and follows the design steps from North Dakota Technical Note 1 – Design of Small Photovoltaic (PV) Solar-Powered Water Pump Systems.

Determine:

Design a solar-powered water pump system that consists of a midsize cow/calf operation near Hazen, North Dakota. Determine the size of the system needed, including the pump, piping, PV panels, mounting tilt angle, tank size, etc.

Given:

- The landowner runs 50 cow/calf pairs on 85 acres of pasture land.
- The landowner intends to use an existing well in the pasture for the water supply.
- The grazing season is planned from March through October.
- The landowner lives nearby and is on site daily for routine maintenance but would like a storage tank sized for a minimum of three days of water storage in the event of extended cloudy weather or maintenance issues that prevent the pump from operating.
- The storage tank is located near the well and the inlet into the tank is 7' above the ground.
- The landowner intends to gravity feed two watering troughs located 1,000ft and 1,150ft from the proposed storage tank.
- Two 500-gallon troughs are to be used. Each trough will be equipped with a float valve that requires 2 psi to operate properly.

Analysis:

Step 1. Water Requirement

Use the ENG-39 tab to enter the planned livestock numbers and grazing information as shown:

Type of Livestock	Number of Livestock		Water Requirement			Daily Water Use		Required Drinking Spaces
Beef - Lactating Cow and Calf	50	x	20	gpd	=	1,000	gals.	2
		x	0	gpd	=	0	gals.	
		x	0	gpd	=	0	gals.	
		x	0	gpd	=	0	gals.	
					Total: =	**1,000**	**gals.**	**2**

Grazing Dates Livestock Utilize System:	From: March to October
Type of Stocking / Grazing System:	Range/Pasture with less than 1/2 mile max travel to water
Source of Water Supply:	Solar

Step 2. Water Source

A search of the ND State Water Commission MapService found the well log for the existing well.

The well log contains the following pertinent information with respect to a ground elevation of 1,000ft:

- Depth of Well Below Surface – 285ft
- Static Water Level Below Surface – 190ft
- Dynamic Water Level Below Surface – 70ft of drawdown after 2hrs @ 10gmp (260ft)
  - Elevation = 1,000' – 260' = 740'
- Depth of Pump Below Surface – 275ft

Enter the water source information on the ENG-39 tab as shown:

Source Water Surface Elevation:	740.0	MSL	ND SWC Well Data
Source Max Flow Rate:	10.0	gpm	

Step 3. System Layout

The identified distances and elevations for the well, pump, PV panels, storage tank, and water troughs are shown in **Figure A1**. For this example, based on the site-specific data provided in the aerial view, the site has good south-facing exposure and appears well suited for solar power. Flow from the storage tank to the water troughs will be gravity fed. Based on the given elevations, the natural layout of the site appears to provide an adequate elevation difference between the storage tank and the water troughs to operate the tank float valves in the water troughs. In addition, the storage, pump, and PV panels can all be located in close proximity to one other in order to minimize electric power and pipeline friction losses.

Figure A2 depicts the profile of the proposed layout of the pump and PV panels.

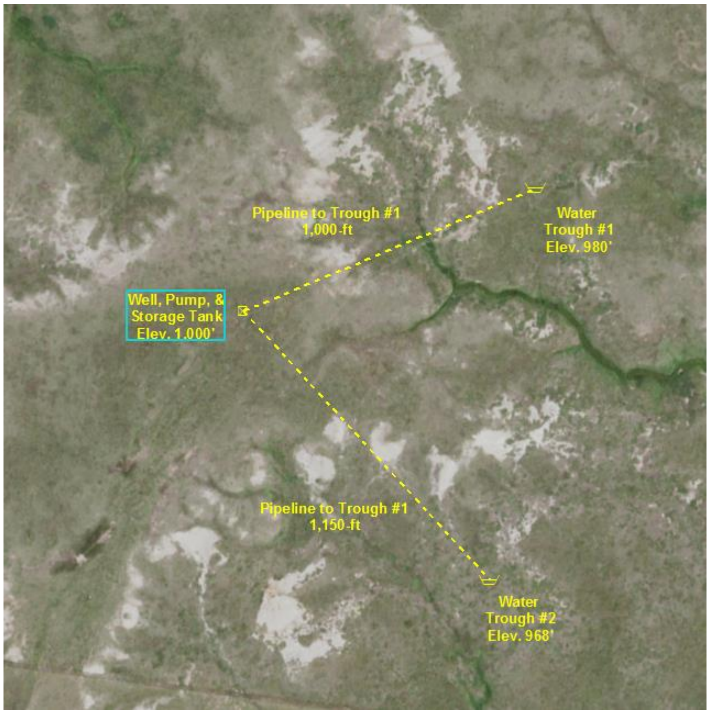


***Figure A1** – System Layout for Design Example.*

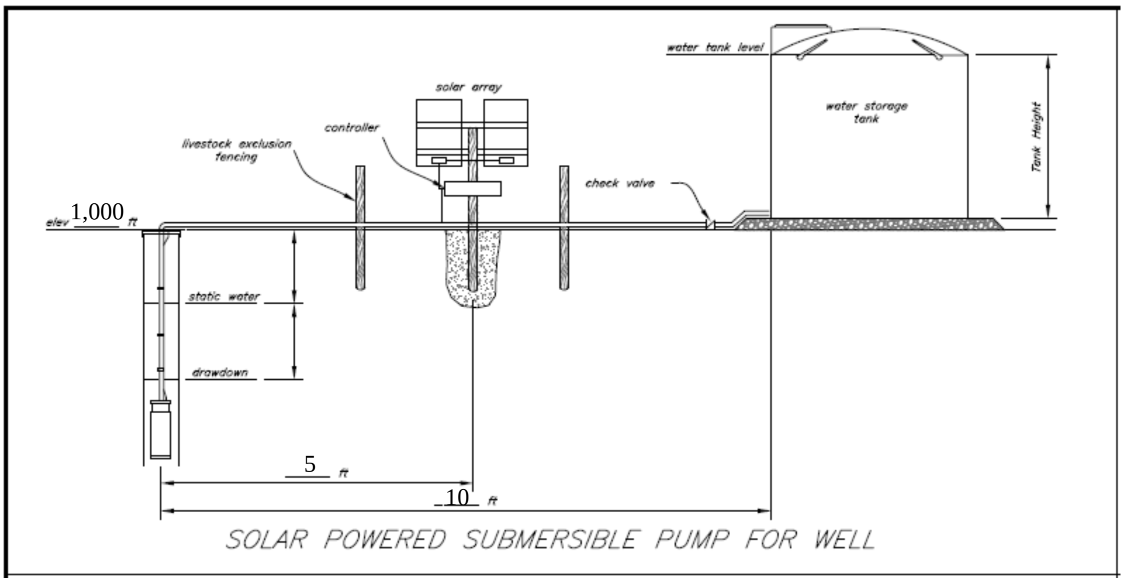


***Figure A2** – System Layout Profile for Design Example.*

Use the given information and enter the watering facility and storage information on the ENG-39 tab as shown:

Watering Facility Sizing and Delivery Requirements:

Watering Facility Type:		Perimeter		Volume			# of Facilities				Actual Drinking Spaces Per Tank
Round	:	30	ft	500	gals	x	2	=	1,000	gals.	30
Rectangle/Square	:		ft		gals	x		=	0	gals.	
Rubber Tire	:		ft		gals	x		=	0	gals.	
Prefab Drinkers	:	Rqrd. Drinking Spaces:		# of Spaces per Waterer:		x				waters	0
				Total Watering Facility Volume (WFV) =					1,000	gals.	30

Total Daily Water Use **(WU)**: Use 10% for evaporation and spillage? No

WU = Daily Water Use

WU = 1,000 x 1.0 = **1,000** gals. / day

Required Days of Storage in Pasture (DSmin): **3** day(s) Design **(DS)**: 3 day(s)

Required Storage in Pasture (RS): RS = DS x WU = 3 x 1,000 = 3,000 gals.

Required Additional Storage **(AS_{min})**: AS = RS-WFV = **2,000** gals.

Design **(AS)** = 2,500 gals.

Step 4. Solar Insolation and Solar Array Layout

The closest observed solar insolation values for the project site is from the NDAWN station near Hazen, ND. Given that grazing is planned March – October, the month with the lowest average value, October, will be the target insolation value used for the design.

Using the Hazen NDAWN Station, enter the information on the Solar Resource tab as shown (click the Get NDAWN Data button if station data has not been already downloaded):

Do you want to use the average state value for design? No

* **Please use the options below to determine the local solar insolation value for the project.**

NDAWN Station: Hazen
Data Frequency: monthly
Length of Data Record: Period of Record

* **The entered data is valid for the selected NDAWN Station.**

Month to Analyze: October **# of months:** 24
Data Statistics: Average

Total Daily Insolation **2.52** **hours/day @ 1-Sun (kWh/m²)**

Step 5. Design Flow Rate for Pump

The pump's design flow rate is based on the operation's estimated daily water needs of **Step 1** divided by the number of peak sun hours per day of **Step 4**. The flow rate is calculated on the Solar Resource tab as shown:

Flow Rate Required to Achieve Daily Water Use Given the Location's Solar Insolation Value (Q_{Inso}): Daily Water Use / (Insolation * 60) = **6.6 gpm**

* **Production of installed pump and solar array combination to be at least QInso.**

Insolation values for other months may be considered if supported by the grazing plan through either adjusted livestock numbers or grazing period or some combination of the two. The decision of which values to use is up to the discretion of the designer and should be based on good engineering judgment and supporting documentation. A table of insolation values and resulting flow rates for each month in a typical grazing season is shown below:

Values of a Typical Grazing Season for the Period of Record of the Hazen NDAWN Station		
Month	**Inso Value**	**Flow Rate**
March	3.75	4.44
April	4.88	3.42
May	5.59	2.98
June	6.21	2.68
July	6.58	2.53
August	5.52	3.02
September	4.09	4.07
October	2.52	6.62

Step 6. Total Dynamic Head (TDH) for the Pump

Using the given planning data and well information, the TDH for the proposed system is calculated on the TDH tab as shown below:

Design Pump Flow Rate:	6.6	gpm	Is water being pumped out of a well?	Yes
Water surface elev. when pumping (WS) =	740	MSL		
Ground elev. at well (W_Elev):	1000	MSL		
Is the storage located near the well?	Yes			
Height above ground to inlet of storage (HT) =	7	ft		
Total Vertical Lift (VL): W_Elev - WS + HT =	267	ft	Total Length of Pipeline (LP), ft =	17

Pipe Friction Loss

Column Pipe Type:	1120 - PVC SCH 40	Pipeline Type:	4710 - SDR 11 - ODC	Losses in Pipe Fittings (PFL):
Column Pipe Size:	1 1/4	Pipeline Size:	1 1/2	0.51 ft
Column Pipe Losses (CPL):	1.75 ft	Pipeline Losses (PL):	0.07 ft	

Total Friction Loss (TFL): CPL + PL + PFL = 2.33 ft

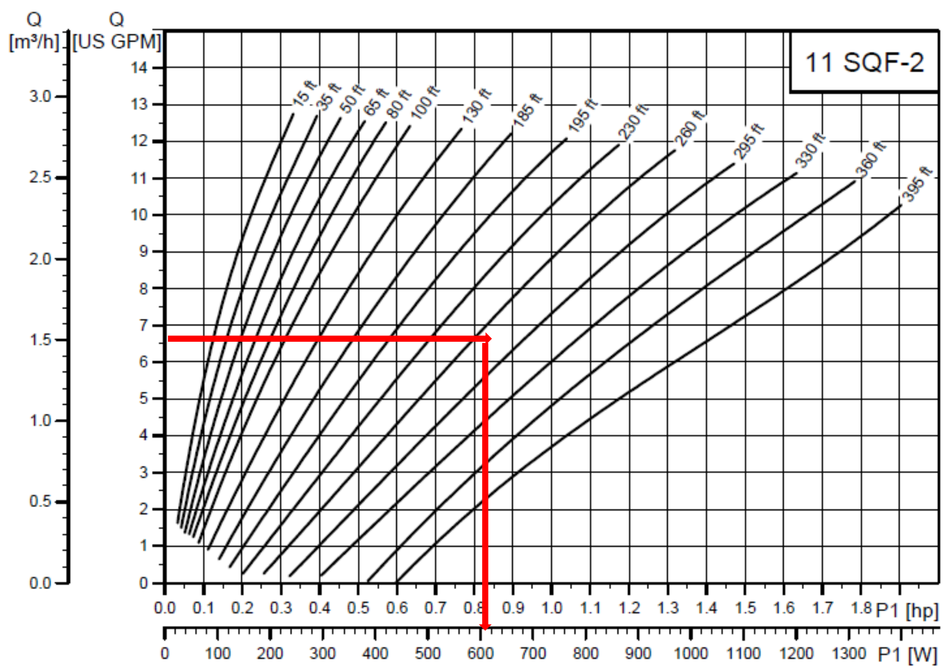
Total Dynamic Head

TDH: VL + TFL = 270 ft

Step 7. Pump Selection and Associated Voltage and Power Requirement

The pump can be selected by comparing the $\mathbf{Q_{Inso}}$ and **TDH** calculated in **Steps 5 and 6** with the information from the manufacturer's pump curves. A Grundfos 11 SQF-2 pump and CU-200 controller combination has been selected for use and the associated pump curve is shown below.

11 SQF-2



As on the pump curve, based on a calculated flow rate of 6.6 gpm and a TDH of 270ft, a minimum input of 610 Watts of peak power is required. The pump literature states that the optimal operating voltage for the pump is specified as a 120 volts. The Pump and Array tab of the workbook automatically looks up these values, as well as the pump's efficiency, based on the selection of the pump brand and model through the use of the tables in the Pump Tables tab.

Location and Pump Requirement Summary

Solar Insolation Value:	2.52 kWh/d	Daily Water Demand (WU):	1000 GPD
Pump Flow Rate from Solar Insolation (Q_{Inso}):	6.6 gpm	Pump Head Requirement (TDH):	270 ft

Pump Data

Pump Brand to Evaluate:	Grundfos	Required Pump Input Power (P_{in}):	611 W
Grundfos Model #:	_11_SQF_2		0.61 kW
Pump Efficiency (P_{Eff}):	55%	<<-- Calculated pump efficiency = 0.1885 * TDH * Q_{Inso} / P_{in}	
Pump Operating Voltage (P_{volts}):	120 Volts	<<--Grundfos recommends at least 120V for best performance.	

Step 8. PV Panel Selection and Wiring of Solar Array

The PV panels selected for this system must be able to provide the minimum energy requirement to run the pump. As determined in **Step 7**, the minimum power needed is 610 Watts and the voltage requirement is 120 Volts.

A PV panel is selected that has the electrical characteristics shown below: a peak power output of 250 W at a V_{mpp} of 30.6 V and an I_{mpp} of 8.17 A.

Entering these values into the Pump and Array tab, the solar array calculates to be composed of 1 string of 4 panels wired in series.

Solar Panel Data

Brand of Solar Panel:	Helios Solar Works	Max Power (Pmax):	250 Watts
Solar Panel Model #:	HSE250-60P	Max Power Voltage (Vmpp):	30.6 Volts
Example:	BP Solar - BP4175B	Max Power Current (Impp):	8.17 Amps
		Solar Panel De-Rating Value (DRV):	85%
Solar Panels in Series (SP_{Series}): P_{Volts} / Vmpp =	4	# of Series in Parallel (SP_{ll}): P_{in} / (SP_{Series} * Vmpp * Impp * DRV) =	1
Total # Panels in Array (SP_{Total}): SP_{Series} * SP_{ll} =	4		

Given that a single PV panel is rated at 250W, the 4 panel (4 x 250W = 1,000W) will easily meet the 610W requirement of the pump. It is important, however, to make sure that the total power supplied by the solar array does not exceed the maximum rated limit of the pump and controller.

Step 9. PV Array Mounting and Foundation Requirements

It has been determined that site conditions permit (i.e. the depth of embedment is not limited by shallow bedrock) so the details for mounting structure embedded posts listed in the ND NRCS Standard Drawing - Installation of a PV Watering System may be used. A post height above ground of 6ft has been determined for this site. For a quad mounted solar array and from the Mounting Post Selection Table of the Standard Drawing, a minimum post diameter of 6” will be needed. The posthole will need to be a minimum diameter of 36” with the post being embedded a minimum of 60” and encased with a minimum of 1.49CY of concrete.

MOUNTING POST SELECTION TABLE
(Producer shall install mounting configuration circled below)

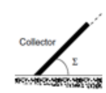
POST HEIGHT (FT)	PANELS	MIN. POST DIA. (IN)	POST HOLE DIA. (IN)	MIN. EMBEDMENT DEPTH (IN)	CONCRETE VOLUME (CY)
4 FT	Single Panel (A = 13.9 ft²)	4	24	38	0.46
	Double Panel (A = 27.8 ft²)	4	24	48	0.55
	Triple Panel (A = 41.7 ft²)	4	30	54	0.96
	Quad Panel (A = 55.6 ft²)	4	36	56	1.42
6 FT	Single Panel (A = 13.9 ft²)	4	24	36	0.44
	Double Panel (A = 27.8 ft²)	4	30	50	0.90
	Triple Panel (A = 41.7 ft²)	4	36	54	1.38
	Quad Panel (A = 55.6 ft²)	6	36	60	1.49
8 FT	Single Panel (A = 13.9 ft²)	4	30	38	0.72
	Double Panel (A = 27.8 ft²)	4	30	50	0.90
	Triple Panel (A = 41.7 ft²)	6	36	54	1.36
	Quad Panel (A = 55.6 ft²)	6	36	60	1.49
10 FT	Single Panel (A = 13.9 ft²)	4	24	44	0.51
	Double Panel (A = 27.8 ft²)	6	30	52	0.91
	Triple Panel (A = 41.7 ft²)	6	36	58	1.45
	Quad Panel (A = 55.6 ft²)	8	36	64	1.58

The **Total Daily Insolation** value determined in **Step 4** assumes that the solar array faces south at an optimal tilt angle. It has been determined that an optimal tilt angle for the designated grazing period of March – October is to be used.

Solar Array Orientation and System Production

Solar Panel Mount Tilt Angle: Grazing Season **38°** tilt angle, ∑ with solar array facing due south

*** Grazing Season defined as March - October**



Step 10. System Production and Flow Rate

Now that the pump requirements and size of the solar array has been determined (**Steps 7 and 8**; respectively), the actual production and flow rate of the system can be calculated as shown in the Pump and Array tab.

Output of Solar Confirguration (Q_{System}): (Vmpp * Impp * SP_{Total} * Insolation * 60 * DRV * P_{Eff}) / (0.1885 * TDH)

Q_{System}:	**1387.3**	GPD
Actual Flow Rate for Solar Configuration:	**9.2**	gpm

Note: It is important to check that the actual produced flow rate of the system does not cause velocities within the connecting pipeline to exceed 5ft/sec.

Step 11. Water Storage

The system’s total water storage capacity should be sufficient for a minimum of three days water use. This minimum storage capacity is calculated below using the water requirement derived in **Step 1**.

1,000 gallons/day x 3 days
= 3,000 gallons

Two 500-gallon water troughs are included in the system, providing a total storage capacity of 1,000 gallons (2 x 500 = 1,000). Therefore, the storage tank must be sized to hold a minimum of 2,000 gallons (3,000 – 1,000 = 2,000). Based on information from different distributors, a 2,500-gallon water tank is a readily available size. A common tank of this size is 95 inches in diameter and 91 inches tall. The actual system production only shows to produce 1,386 GPD of the 3,000 gallons required for storage. A more detailed analysis needs to be done to determine if the provided storage volume is adequate.

From the system production calculated in **Step 10**, a water balance for the past several years can be done to check if the provided storage is sufficient. From the Water Balance tab click the **Get Inso** button to download the solar insolation values for the table:

Historic Water Storage Budget Summary

Year	Month	Average Insolation Value	Production of Solar Setup	Demand, Gallons	Storage, Gallons	Supplimental Water, Gallons
2014	3	3.16	54,006	31,000	2,500	0
2014	4	4.44	73,298	30,000	2,500	0
2014	5	5.02	85,698	31,000	2,500	0
2014	6	4.63	76,480	30,000	2,500	0
2014	7	6.30	107,599	31,000	2,500	0
2014	8	4.12	70,257	31,000	2,500	0
2014	9	3.98	65,768	30,000	2,500	0
2014	10	2.39	40,795	31,000	2,500	0
2014	11	1.41	23,292	30,000	2,500	4,208
2014	12	1.13	19,225	31,000	0	11,775
2015	1	1.50	25,589	31,000	0	5,411
2015	2	2.26	34,794	28,000	0	0
2015	3	3.73	63,703	31,000	2,500	0
2015	4	4.81	79,429	30,000	2,500	0
2015	5	5.46	93,210	31,000	2,500	0
2015	6	5.95	98,294	30,000	2,500	0
2015	7	6.47	110,424	31,000	2,500	0
2015	8	5.83	99,564	31,000	2,500	0
2015	9	4.60	75,942	30,000	2,500	0
2015	10	2.56	43,724	31,000	2,500	0
2015	11	1.66	27,414	30,000	2,500	86
2015	12	1.16	19,787	31,000	0	11,213
2016	1	1.47	25,042	31,000	0	5,958
2016	2	2.09	32,155	28,000	0	0
2016	3	3.62	61,711	31,000	2,500	0
2016	4	4.27	70,588	30,000	2,500	0
2016	5	6.13	104,582	31,000	2,500	0
2016	6	7.47	123,338	30,000	2,500	0
2016	7	6.29	107,317	31,000	2,500	0
2016	8	5.89	100,559	31,000	2,500	0
2016	9	3.58	59,092	30,000	2,500	0
2016	10	2.25	38,376	31,000	2,500	0
2016	11	1.68	27,668	30,000	2,500	0
2016	12	1.34	22,953	31,000	168	7,880

The shown water balance compares the actual monthly production of the system against the monthly demand of the livestock and determines if the provided storage is adequate in meeting the demand. The water balance assumes that the storage tank is initially empty. As the table shows, the only periods which the storage tank would not provide the required demand is November – January. During the period of the noted grazing season, March – October, the provided storage is sufficient for the design.

Installation requirements of the storage tank is provided in the **ND Construction Specification 614 – Watering Facility** and **ND Standard Drawing ND-100 – Above Ground Storage Tank**.

Step 12. Summary Description of the System

The system information can be summarized as followed:

Storage Tank: **2,500 Gallon 95" x 91" Poly Tank**

Pump Requirements:

Flow Rate = **6.6 GPM** TDH = **270ft**

From Performance Curve (Grundfos 11 SQF-2):

Power Required = **610 Watts** Voltage Required = **120 Volts**

Solar Panel Rating (Helios Solar Works HSE250-60P):

250 Watts **30.6 Volts** **8.17 Amps**

Layout of Solar Array:

4 panels wired in series and mounted to a quad solar rack attached to a post with a minimum diameter of 6" and extending 6ft above ground. The post is to set in a hole with a minimum diameter of 36" and embedded a minimum of 60" and encased with a minimum of 1.49CY of concrete.

System Production: **1,387 GPD** **9.2 GPM**

The **ND134 Standard Drawing – Installation of a PV Watering System** is located in the Standard Drawing tab and is pre-populated with the design requirements calculated from each of the datasheets. The standard drawing is to be included as part of the complete design construction package; see the North Dakota Stockwater Design Tool for the development of the construction package.

END OF FILE