Water for the World

Determining Pumping Requirements
Technical Note No. RWS. 4.D.2

Before pumping requirements can be determined, a water source must be identified, water use must be estimated based on the population to be served and the type of system must be chosen. If a Level 1 or 2 system, described in "Methods of Delivering Water," RWS.4.M, is selected, then much less water is required and pumping costs will be lower.

The World Health Organization recommends that provision be made for a minimum of forty (40) liters of water per person per day if a communal distribution point is used. Where water must be hauled, fifteen (15) liters per person per day should be provided. For water piped to the home, one hundred (100) liters or more per person per day is desirable.

The next most important factor in determining pumping requirements is the pumping head. This head includes the difference in height between the pump and the highest point in the system, usually the storage tank, and the head needed to overcome friction. See Figure 1. Part of the head may be fixed, as in the case of the location of the pump and the storage tank, and part may vary depending on the difference in flow or pipe size. Since pipe size can be changed, as can flow by using longer or shorter pumping times, these are the primary variables in designing a pumping system. Provision must be made for friction requirements of valves, bends and meters, if used.

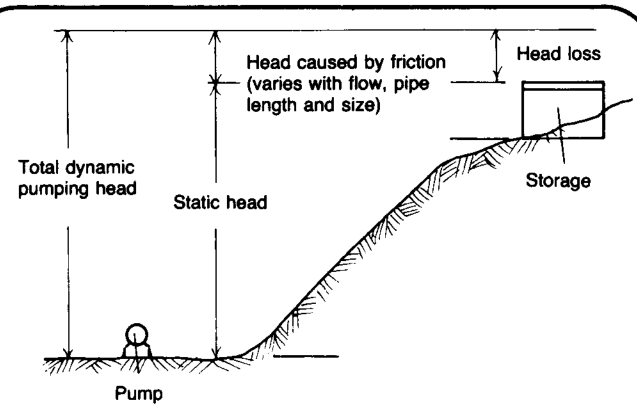

Figure 1. Total Dynamic Pumping Head

Useful Definitions

DRAWDOWN - The distance between the water table and the water level in a well during continued pumping.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

HEAD LOSS - The head required to overcome friction.

PUMPING HEAD - The height to which a pump must raise water including the height of the highest point in the system plus the equivalent height to overcome friction; expressed as meters of water.

STATIC HEAD - The difference in meters between the elevation of the pump and the highest point in the system, usually the top of a storage tank, to which the pump must raise water.

STATIC WATER LEVEL - The water level in a well when the pump is not operating.

TOTAL DYNAMIC HEAD (TDH) - The total energy which the pump must provide to lift water to the pump, to raise water to the maximum elevation, and to meet all friction requirements; expressed in meters of water.

When a water source has been selected and the type of system chosen, then quantity, pumping distance and elevation of storage can be measured or calculated. Once these are known and flow is estimated, a pipe diameter can be selected. This information is then used to determine pump size.

Windmill Pumping Systems

Windmills can be used to pump water in quantities ranging from 380-12000 liters per hour depending on wind speed, windmill diameter, pump size and pumping head or lift. Wind speed determines pumping capacity. Although windmills are under development which can pump at much lower windspeeds, the most widely available windmill pumps at its maximum rate at wind speeds of 25-32km per hour. At 16km per hour, the capacity is reduced 37 percent and at 20km per hour it is reduced 22 percent. The wind normally blows at the most usable speeds for only a few hours per day and this must be taken into consideration. If the wind blew strong enough to pump water for six hours per day, then the quantity of water produced would be 2400-73000 liters per day.

Since wind speeds vary over the course of a year, this must be taken into account. It is advisable to provide for a storage tank near the windmill to provide for times when the wind does not blow.

To design a windmill system, the quantity of water needed must be determined, the total dynamic head (TDH) found and the expected wind speed predicted. These data can then be used to size the system.

<u>Example</u>: A village of 150 people have decided to develop a Level 2 water system with several distribution points near the population center. Water is available in a well 30m deep. Wind energy measurements have been taken and it has been determined that the wind speed is between 25 and 32km per hour an average of three hours per day; 16km per hour for six hours per day; and 20km per hour for four hours per day. What size windmill and pump cylinder would be required?

1. Calculate the amount of water needed: 150 people x 50 liters per day = 7500 liters. Next, convert average wind speed to effective wind speed. This is done by multiplying the number of hours the wind blows times the percentage of the windmill pump's full power.

Wind speed	Percent of full power	Hours/ day	Equivalent hours
25-32 km/hr	100%	3	3.0
20 km/hr	78%	4	3.1
12 km/hr	63%	6	3.8
		Total	9.9 hours

The wind will have optimum power 9.9 hours per day.

2. Then find the liters of water per hour required to meet the community's needs.

$$\frac{\text{Water required}}{\text{Pumping time in hours}} = \frac{7500 \text{ liters}}{9.9 \text{ hrs}} =$$

758 liters/hour

Once the quantity of water required per hour and the elevation to which the water must be lifted are known, the windmill can be sized using Table 1.

Table 1. Windmill Data

Pump cylinder size in mm	Capacity in liters/hour		Elevation to which water can be raised SIZE OF FAN					
	2m	2.4-4.8m	2m	2.4m	3m	3.6m	4.2m	4.8m
44	397	568	40	56	85	128	183	305
48	473	681	37	53	79	119	171	280
50	492	719	29	43	66	98	140	229
57	681	984	23	34	52	76	110	180
64	852	1230	20	29	43	64	91	149
70	1003	1457	17	24	37	55	79	130
80	1211	1779	14	21	30	47	67	110
83	-	2082	-	-	27	40	56	93
89	1666	2438	11	15	23	35	49	81
95	-	2763	-	-	20	30	44	70
100	2158	3142	8	12	18	26	38	61
108	-	3558	-	-	16	23	34	55
114	2744	3975	6	9	14	21	30	49
121	-	4429	-	-	-	19	27	43
127	3407	4921	5	8	11	17	24	40
146	-	6435	-	-	-	12	18	30
152	-	7098	-	5	8	12	17	26
178	-	9653	-	-	6	9	12	20
203	-	12492	-	-	4	7	9	15

In the example, the pumping rate of 758 liters/hour and the pumping head of 30m can almost be met by a windmill with a 2.4m diameter fan and a 50mm cylinder. To determine that this is true, look down column 3 in Table 1 to the number 719 liters/hour. The number is in the column under 2.4-4.8m. Looking to the left under column 1, pump cylinder size, the capacity corresponds to a cylinder size of 50mm. However, 719 liters/hour is somewhat below the needed capacity. Therefore, looking down column 3 the next greatest capacity is 984 liters/hour which is sufficient to supply community needs. A pipe cylinder of 57mm would be needed for this windmill as shown in column 1.

Now the exact size of the windmill fan can be determined. Columns 4-9 represent the height which water can be raised by a certain sized fan. In our example, water needs to be raised 30m. Look across the fourth row where the figure 984 liters/hour is located until a figure of 30 or greater is found. In column 5, the number 34m is found under a fan size of 2.4m. Therefore, a 2.4m diameter fan is needed. If a relatively high storage tank and friction requirements mean the water must be raised over 34m, the next largest diameter fan should be chosen.

Electric Pumping Systems

There are many combinations of electric pumps available and often the pump and motor come as a unit. There are two main methods of selecting electric pumps. One is to design the system and select the pump from manufacturers' catalogs. The other is to give the supplier complete details of the pumping conditions and have him determine the pump needed. The information needed to select an electric pump includes:

1. Quantity of water required.

2. Pumping head.

3. Type of power available, number of phases, and voltage type (AC or DC).

4. Size of well. If applicable, depth to water, drawdown, and production capability.

5. Special considerations such as limited pumping times and elevation above sea level.

Quantity of water required. Identify the number of people to be served and the type of system to be used. From this, estimate the total quantity of water needed.

Pumping head. Provide the elevation difference between the pump and the high point in the system and the head losses due to friction.

Type of power available. Determine what is available from the electric utility organization and any restrictions that may be placed on the use of the electricity. This is important because restrictions may limit the amount of power available and in some locations electricity may not be available 24 hours per day.

Size of well. If a well is to be used, its diameter, the depth to water, and the drawdown at the rate it is pumped are required.

Special considerations. These include such items as any operation limitations, pump controls desired, elevation of the water source above sea level, and other considerations which might influence pump size.

For flows in the range of .3-13 liters per second, pumps are readily available and can be selected directly from manufacturers' catalogs. In sizing the pump, an optimum pumping time is 10-12 hours. Pumping can be timed manually, by using a time clock or by using other types of pump controls. If the system is to be manually operated, the pumping rates must be based on the availability of an operator. In any case, the pumps should be sized for population increases expected over the next five years. The pump should meet the maximum daily water requirement supplemented by elevated storage. If no other information is available, use a factor for maximum daily use of twice the average use.

Calculating Pumping Requirements

The following example describes how to determine pumping requirements:

A pump is to be selected for a Level 3 system with distribution to every household in a village with a current population of 500 people. There are no commercial operations or institutions in the village and livestock will obtain water from a nearby stream. No growth is expected in the next five years. There is a dug well 20m deep with the static water level at 10m. Pumping tests show the well can produce 5 liters of water per second with a drawdown of 3m. Single phase, 120/230 volt AC electricity is available. Because of electric line size, the electric utility agency has limited motor size to 5 HP. The site is not favorable for use of a windmill and no water that could be delivered by gravity flow is available. The storage tank will be located on a hill 300m from the well and the top of the tank will be 20m above the top of the well.

It is always a good idea to draw a graphic representation of the information prior to designing a solution. This example is illustrated in Figure 2.

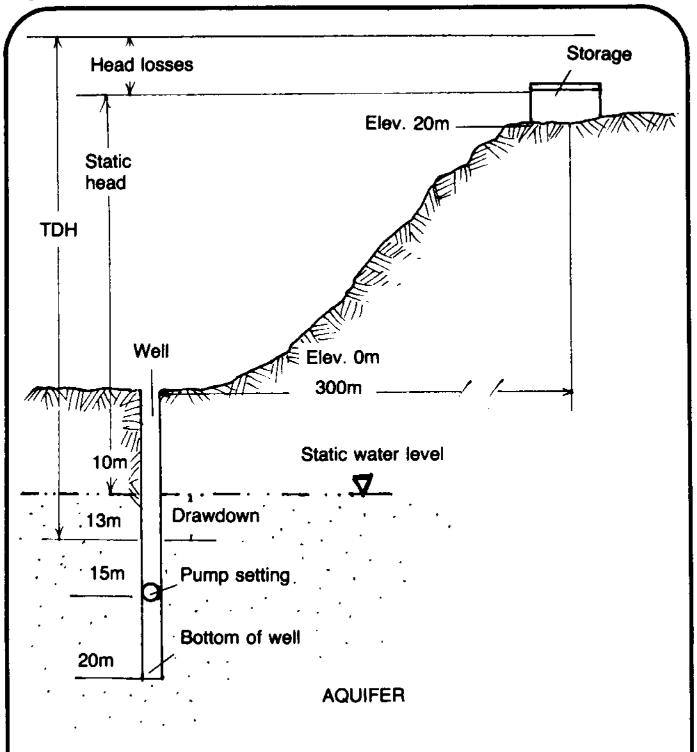

Figure 2. Graphical Representation of Data

Worksheet A shows the steps described below in sizing the system.

Step 1. Estimating present water needs.

Since the system is to serve only the village, the present estimated needs are 50000 liters per day.

Step 2. Estimating future water needs.

Worksheet A provides a way to estimate future water needs if other information is not known. In this case, future needs are 200000 liters of water per day.

Step 3. Estimating storage needs.

Convert liters to cubic meters to find the storage needed. In this example, storage is 200m^3.

Step 4. Pump production requirements.

Pumps and motors are more efficient and last longer if they have relatively long interrupted pumping cycles. This also permits the use of lower yield wells. In this case, 4.6 liters per second are required for a 12 hour pumping cycle at the design life of 20 years.

In comparing the water available, 5 liters per second, with that required, 4.6 liters per second, the source appears to be sufficient for the design period of 20 years.

Step 5. Determine pipe size.

The selection of a pipe size is influenced by the cost of pumping. The larger the pipe size, the lower the pumping costs so larger pipe sizes should be selected where the cost of energy is high. Since energy requirements are directly related to the velocity of water in the pipe, the costs can be minimized by using a relatively slow velocity. A velocity of 0.75m per second is considered optimal and is used in this formula.

The exact calculated pipe size is 88mm. A pipe could be selected from available sizes of 80mm or 100mm. Friction losses could be calculated for each size and a total dynamic head (TDH) found. If the friction head were approximately 10 percent or less of the TDH for one or both pipes, then either would be suitable. In this case, 100mm pipe was chosen as being more readily available.

Step 6. Motor size.

The horsepower requirements were calculated based on needs for 20 years. It is better to size pumps for a shorter period as they only have an estimated life of five to ten years.

If a ten year design were used and the water required were estimated to be 50 percent of the 20 year use, the pump would be designed for a flow of 2.3 liters/second and the necessary HP would be:

$HP = \frac{2.3 \times 33.5}{76 \times .6}$ (recalculated for lower friction loss) =

$\frac{77.05}{45.6} = 1.68$ HP (use 1 3/4 HP)

Diesel oil or gasoline powered pumps. The information needed for a diesel oil or gasoline powered pump is the same as for an electric pump. The primary difference is in the power required. This will be greater due to inefficiencies in the drive mechanism to the pump. It is best to rely on the pump supplier for this data.

Worksheet A. Designing a Small Water Pumping System

1. Estimated present water needs in liters:

		Number of		Unit use		Total
Population	Persons	500	x	100	=	50,000
School	Students		x		=	
Church	Attendees		x		=	
Commerical			x		=	
Large animals (cows)			x		=	
Small animals (sheep)			x		=	
Public watering fountains			x		=	

Total present water needs = 50,000

2. Estimated future water use:
Use a 20 year design life. If no better information is available, use a population growth of 2 times the present population and an increase in animals of 1.25 times the present number. In addition, assume an increase in the rate of use of 2 times.

Population — Present use 50,000 x 4 = 200,000 liters

Institutions & public fountains — Present use _____ x 2 = _____ liters

Animals — Present use _____ x 1.25 = _____ liters

Total future water use = 200,000 liters/day

3. Storage reservoir:
Take the future water use and convert it to cubic meters

Reservoir = $\frac{200{,}000}{1000}$ liters = 200 m^3

4. Pump production requirements:
Determine the estimated pumping rate in liters/second

Total daily demand = $\frac{200{,}000 \text{ liters}}{43{,}200 \text{ second}}$ = 4.6 liters/second

If a pumping time is not given use 12 hours or 43200 seconds

5. Determine pipe size from pump to storage:

Pipe diameter d = 1.3 $\sqrt{m^3 \text{ per second}}$

= 1.3 $\sqrt{.0046 \text{ liters/second}}$ = 0.088 m

Convert meters to mm: 1000 x 0.088 m = 88 mm

Round mm calculated to available pipe size: d = 100 mm

(Note: This method of pipe sizing is based on limiting the velocity of water in the pipe to 0.75 m/second).

6. Motor size:
To calculate the pump size, first find the total dynamic head (TDH).

TDH = static head + friction losses

Friction losses

a. Determine head required to overcome friction.

Fitting	Number	x	Equivalent length	=	
Gate valve	1	x	2.7	=	2.7 m
Elbow, 90°	2	x	13.2	=	26.4 m
Elbow, 45°		x		=	m
Tee (straight through)		x		=	m
Tee (through side)		x		=	m
Swing check valve	1	x	38.2	=	38.2 m

Total equivalent length 67.3 m

Length of pipe from pump to storage = 300 m

Total pipe length = 367 m

Friction loss = $\frac{367 \text{ m} \times 4.2 \text{ head loss per}}{1000}$ 1000/m = 1.5 m

b. Determine static head
Static head = elevation at top of storage - pump elevation
= -13 m - 20 m = 33 m

c. TDH = a+b = Friction loss + static head = 1.5 + 33 = 34.5 m

d. Horsepower requirements:

Horsepower = $\frac{Q \times H}{76\ e}$

Q = Flow in liters/second
H = System head in meters
76 = Constant
e = Pump efficiency

Horsepower = $\frac{4.6 \text{ liters/second}}{76 \times e}$ x 34.5 meters = 3.48 HP

Round to nearest available motor size = 3.5 HP

If the efficiency is unknown, assume 60 percent, 0.6.