Water for the World

Determining the Need for Water Storage

Technical Note No. RWS. 5.P.1

Many water systems require some form of storage. Storage is necessary (1) when rainwater is collected for drinking water, (2) for most distribution systems where the source's continuous supply is barely sufficient or is insufficient to meet the daily demand and (3) where a single well serves a community through a distribution system. Storage ensures that an adequate quantity of water is always available to users and that water quality is protected.

This technical note describes the procedure to follow in determining whether storage should be provided for a water system and establishes methods to determine the quantity of storage required.

Several factors should be considered in determining water storage needs: (1) the source of water, (2) the amount of water available for consumption (3) the demand for water and (4) the materials available and economic resources of the families in the community. From this information, the most appropriate form of water storage can be chosen.

Rainfall Storage in a Cistern

Rainwater needs to be collected and stored if people are to use it for drinking. In order to plan for adequate storage and design the most appropriate type of storage facility data on the following items should be collected:

- amount of monthly rainfall,
- potential rainfall supply available each month,
- the amount of water likely to be consumed by the family.

With this information, the size of the cistern can be estimated.

Data on average monthly rainfall can be acquired from a national weather agency, the military, or an airport. Data for a specific location may not be available, but regional data can be used for an estimate. Table 1 and Figure 1 show an example of distribution of rain by month for a location receiving an average annual rainfall of 1032.5mm.

The potential available water supply depends on the amount of rainfall and the catchment surface area. If a catchment area has a length of 8m and a width of 6m, the area of the catchment is 8m x 6m or $48m^2$. To determine the amount of available water, multiply the monthly rainfall figures by $48m^2$ and then by 0.8, a loss factor which takes into account water that does not make it to storage from the catchment area. For example, using January rainfall figures, the total amount of water available to the family is 8678 liters. This amount is arrived at using the following formula:

Volume of water = Catchment area x rainfall x 0.8

Table 1. Average Monthly Rainfall in Millimeters

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
Rainfall	226	188	173	46	2.5	0	0	5	5	41	130	216	1032.5

This data can be represented graphically as shown in Figure 1.

MONTH	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
RAINFALL (in mmm.)	226	188	173	46	2.5	0	0	5	5	41	130	210	1,032.5

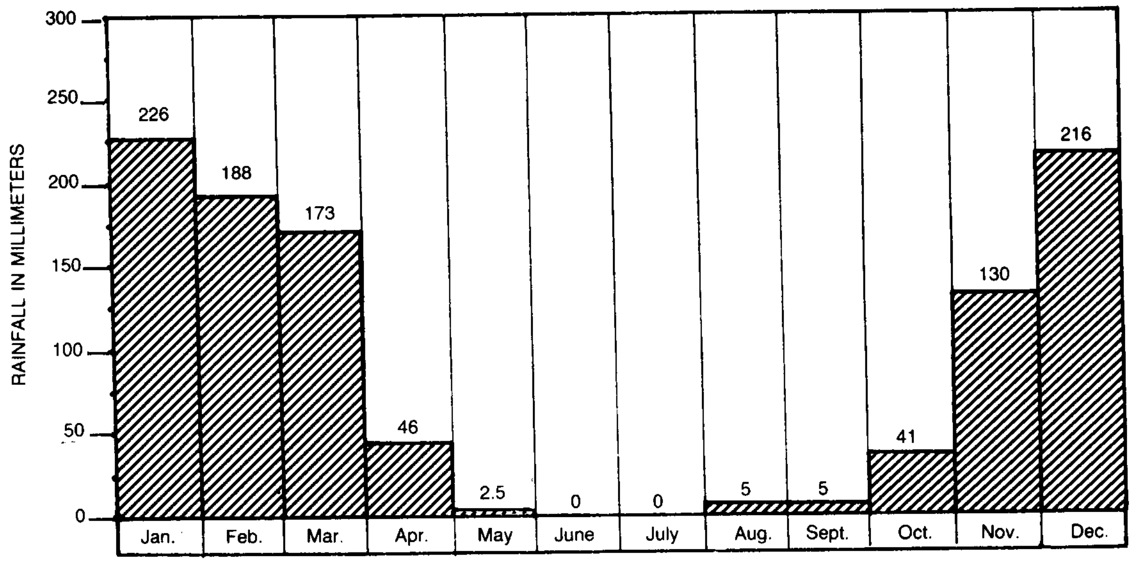

Figure 1. Average Monthly Rainfall in Millimeters

Volume = $48m^2 \times 226mm \times 0.8$

Volume = 8678 liters

Table 2 and Figure 2 give an example of the average amount of water available during each month of the year. Remember that these are average estimates that will differ with cyclical climatic changes. Each number is arrived at by taking the average monthly rainfall figure and using it in the above equation.

The next step in determining storage requirements is shown in Figure 3. First, a graph of the cumulative available rainfall is made. The graph represents the amount of rainfall run-off available from a catchment throughout the year. The heights of the bars are determined by adding a particular month's average rainfall to the sum of the rainfall for the previous months. For example, April shows a cumulative run-off of 24306 liters which is the sum of the run-off for January, February, March and April.

Secondly, a diagonal line representing yearly demand is drawn. The line assumes that people will use the same quantity of water each month, although generally greater quantities are used in the wet season and much less in the dry. The demand line should touch only one point on the run-off curve as shown. The desirable amount of storage is shown on the graph. It is the greatest distance between the demand line and the run-off curve. This amount of storage should be provided to ensure that water is available throughout the year at this level of consumption.

In this example, the yearly demand for water is 31000 liters, and average of approximately 2600 liters per month, or 87 liters per day per family. In order to supply a family with 87 liters per day throughout the entire year, a cistern or storage jar with a 16.5-17m^3 (16500 -17000 liters) capacity would be needed. Unless inexpensive ferrocement storage jars are constructed, the construction of a

Table 2. Potential Monthly Available Supply of Water

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL (year)
Available Water (liters)	8678	7219	6643	1766	96	0	0	192	192	1574	4992	8294	39646

This data appears in graphical form in Figure 2.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL (year)
Available Water (in liters)	8,678	7,219	6,643	1,766	96	0	0	192	192	1,574	4,992	8,294	39,646

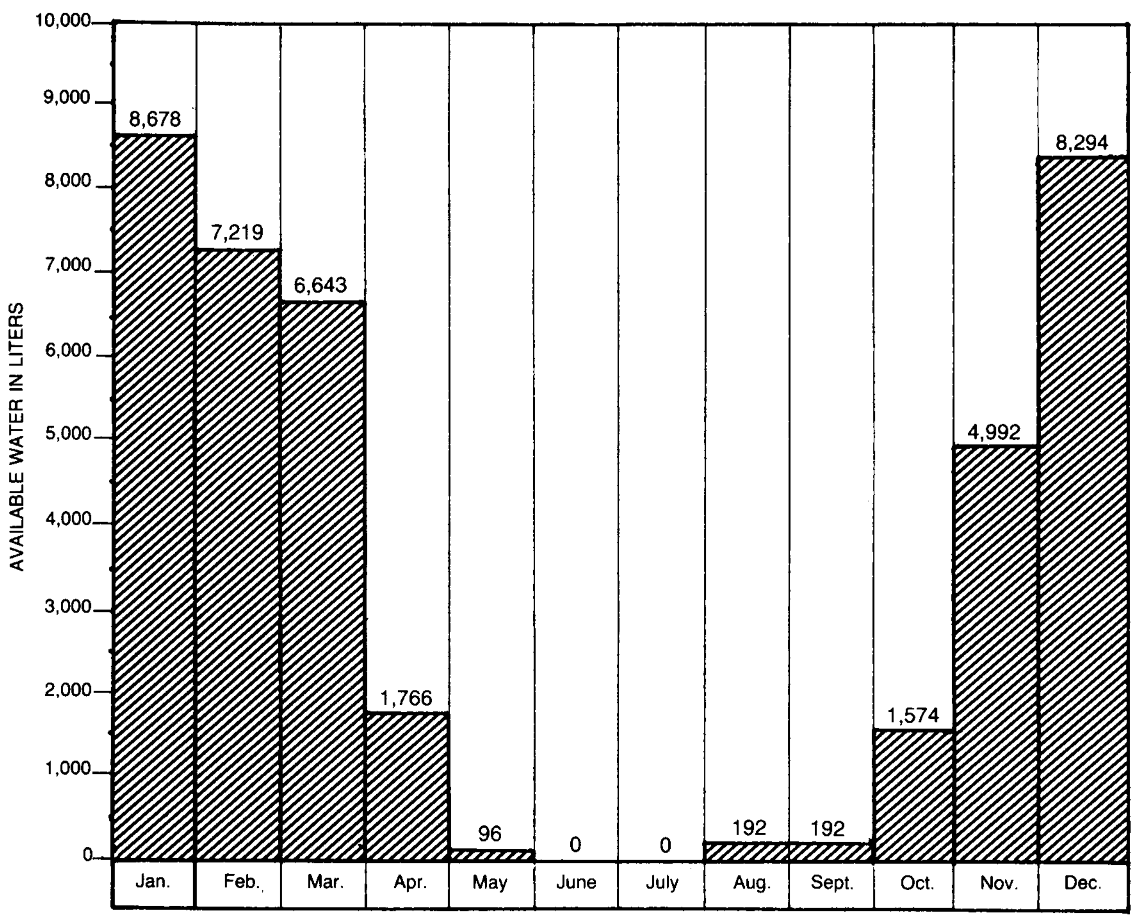

Figure 2. Available Monthly Water Supply in Liters

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall (millimeters)	226	188	173	46	2.5	0	0	5	5	41	130	216	1,032.5
Available Water (in liters)	8,678	7,219	6,643	1,766	96	0	0	192	192	1,574	4,992	8,294	39,646

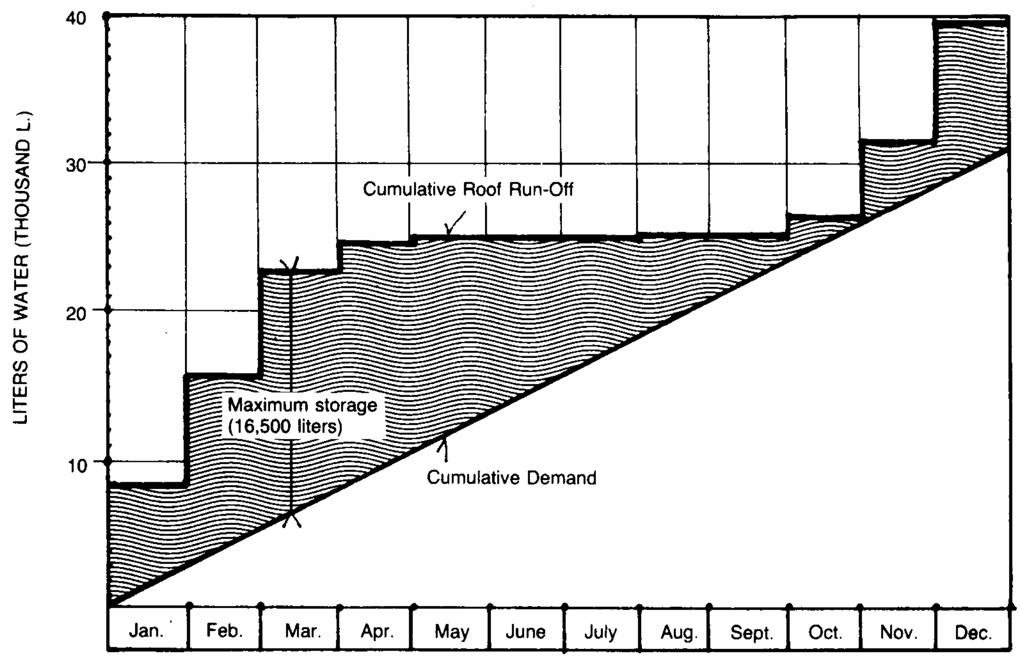

Figure 3. Determining Maximum Storage Capacity

cistern of such a large volume would be beyond the means of most families. A smaller structure would be designed instead. With a smaller cistern, water use during the dry season would have to be restricted to the essential minimum of drinking and some cooking.

Ideally, cisterns and storage jars should be large enough to store water for the entire year. Where economic conditions prevent this, special measures, like the use of storage jars, should be taken. Water should be collected during the rainy season and stored for use during the dry season. Special care should be taken to prevent water loss through evaporation. When planning a cistern or storage reservoir, attempt to build a cistern either of adequate volume or as close to the desired volume as economic resources permit. This is necessary when no other water source of suitable quantity, quality, accessibility or reliability is available.

Ground and Surface Water Storage for Distribution Systems

Storage of surface and ground water is necessary to provide sufficient quantities of water to the users. In some cases, a storage reservoir is not needed. When hand dug wells are installed in villages and water is extracted by buckets or hand pumps, no storage other than what the well holds is necessary. Where reservoirs are formed by dams, water sometimes can move from the reservoir to the users with no further storage. Usually, some sort of storage is required in systems where water is piped to the users.

To ensure that adequate storage capacity is provided, proper planning of the storage reservoir is necessary. The following factors should be considered in determining required storage capacity:

(1) Population served by the system taking into account population growth.

(2) Total daily demand for water in the community. This is found by multiplying the population to be served by the daily per capita consumption. Special consideration has to be shown for peak demand periods.

(3) Hourly demand and peak hour demand.

(4) The length of operation of the pump each day.

In planning for a water system and sufficient storage capacity for it, the number of people to be served should be determined. It is best to plan for a system that will operate effectively for 20 years. If a community has a present population of 1535 people who will be served by the system and the population growth is estimated at 2.5 percent per year, use Table 3 to determine the population in 20 years.

Table 3. Population Growth Factors

Design Period Years	Yearly Growth Rate (%)					
	1.5	2	2.5	3	3.5	4
7	1.1	1.15	1.19	1.23	1.27	1.32
10	1.16	1.22	1.28	1.34	1.41	1.48
15	1.25	1.35	1.45	1.56	1.68	1.80
20	1.35	1.49	1.64	1.81	1.99	2.19

Multiply the present population, 1535 in this example, by the population growth factor located in the row marked "20 years" under the column for a 2.5 percent yearly growth rate. This gives 1535 x 1.64 = 2520. The volume of the storage reservoir should be calculated assuming a population of 2520 people.

Next, the amount of water per day consumed by the population should be calculated. Assume that the average per capita daily consumption is 40 liters. Per capita water demand is:

Total consumption = Per capita consumption x population =
40 liters x 2520

Total consumption = 100800 liters per day.

To find hourly demand, use the following formula:

$$\text{Hourly demand} = \frac{100800 \text{ liters/day}}{24 \text{ hours}}$$

Hourly demand = 4200 liters per/ hour.

The peak hourly demand generally occurs in the morning with a second smaller peak later in the afternoon. The peak demand ranges between four and five times the hourly demand.

The length that the pump is in operation should be determined. In some cases, the pump may work for a few hours in the morning and a few in the afternoon or it may be operated continously for eight to ten hours. Assuming 10 hours continuous pumping between 7:00am and 5:00pm, the pumping rate necessary would be 10080 liters/ hour. From this information and the data on water demands as a percentage of the average hourly consumption rate, the required storage capacity can be determined. Table 4 shows a way to collect this information and determine the required storage. Figure 4 shows how this can be done graphically.

The storage capacity required is the sum of the excess supply of water after the pumping stops at 5:00pm, 32500 liters, and the maximum volume required during the morning. This volume is 13650 liters at 7:00am. The total storage required is 32550 + 13650 = 46200 liters or $46.2 m^3$. The same figure is arrived at graphically by looking at the distance between point A and point B on Figure 4.

In Figure 4, a diagonal line is drawn marking a continuous 24-hour pumping rate of 4200 liters per hour. Line PQ represents a pumping rate of 10800 liters per hour for ten hours. The curved line is the cumulative demand for water. To determine the storage capacity, draw a perpendicular line from the point at 7:00am (point Q) to the cumulative demand curve. From that point, draw a line parallel to PQ extending it to the vertical line at 17 hours, 5:00pm. Where this line ends is point A. Then draw a straight line

Table 4. Determining Storage Requirements

Daily Demand = 100800 liters

Average Hourly Demand = $\frac{100800 \text{ liter}}{24 \text{ hour}}$ = 4200 liters/hour

1 Time (hours)	2 Hourly Demand in Liters	3 Hourly Demand as % of Average Hour*	4 Cumulative Demand (liters)	5 Supply from Pump (liters/hour)	6 Supply Minus Draft Liters (5 - 2)	7 Storage Variation (liters) (6 + 7)
0-1	1050	25	1050	---	-1050	-1050
1-2	1050	25	2100	---	-1050	-2100
2-3	420	10	2520	---	-420	-2520
3-4	420	10	2940	---	-420	-2940
4-5	630	15	3570	---	-630	-3570
5-6	2520	60	6090	---	-2520	-6090
6-7	7560	180	13650	---	-7560	-13650
7-8	9660	230	23310	10080	420	-13230
8-9	4200	100	27510	10080	5880	-7350
9-10	4200	100	31710	10080	5880	-1470
10-11	5040	120	36750	10080	5040	+3570
11-12	6300	150	43050	10080	3780	+7350
12-13	6300	150	49350	10080	+3780	+11130
13-14	6300	150	55650	10080	+3780	+14910
14-15	5040	120	60690	10080	+5040	+19950
15-16	3780	90	64470	10080	+6300	+26250
16-17	3780	90	68250	10080	+6300	+32550
17-18	7770	185	76020	---	-7770	+24780
18-19	7140	170	83160	---	-7140	+17640
19-20	6300	150	89460	---	-6300	+11340
20-21	3780	90	93240	---	-3780	+7560
21-22	3150	75	96399	---	-3150	+4410
22-23	2310	55	98700	---	-2310	+2100
23-24	2100	50	100800	---	-2100	0

*Precentages are estimated averages.

**The storage capacity required is the sum the excess available at the end of the pumping period (32,550 liters) and the maximum volume during the morning hours (13,650 liters) or 32,550 + 13,650 = 46,200 liters.

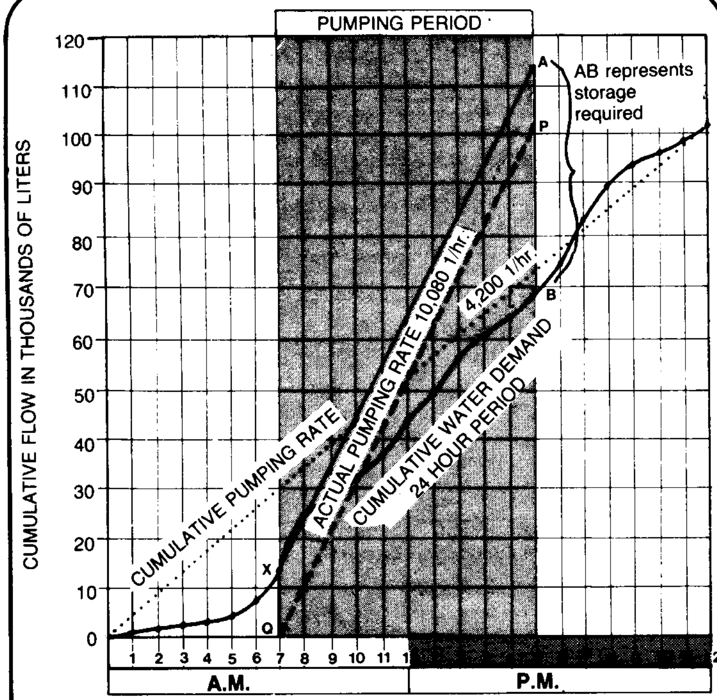

Figure 4. Determining Storage Requirements

from A through P to the cumulative demand curve, point B. The line AB represents the storage required, which is 46200 liters, or 46.2m^3. When designing the storage tank, some extra capacity can be included. In this case, a storage reservoir with a capacity of 50000 liters, 50m^3, would be appropriate.

Summary

Most water systems should have storage so that people can depend on a sufficient quantity, a certain quality and improved access and reliability. When rainwater roof run-off is used, storage is always necessary. For surface and ground water, either storage is provided for at the source or a storage reservoir must be constructed. Most water distribution systems rely on man-made storage reservoirs.

The most important factor in planning for the use of storage is determining the capacity of the reservoir. Capacity should be sufficient to adequately meet all water needs of the users throughout the year. The minimum goal should be to provide sufficient storage to at least meet basic drinking needs and minimal washing and cooking needs. Given scarce resources, these minimal needs may be all that can be met. When determining storage needs, follow the procedures outlined in Worksheet A.

It is desirable to project a storage capacity to meet needs caused by future population increases and water demand increases. In this example, 20 year future increase have been used. This requires a substantial commitment of money and materials. This may not be possible because funds are not available or the money may be needed for more immediate community needs. A careful review will help to make the best engineering and management decision. In any event, storage sites and facilities can be designed and built so that future expansion can be made readily and with least cost.

Worksheet A. Determining Water Storage Requirements

Identify water supply source ____________________

1. If rainfall roof catchment, determine:

   a. area of catchment ____________________

   b. number of people to be served ____________________

   c. materials available for cistern or storage tank construction __________

   d. economic resources of family ____________________

   e. capacity of storage reservoir from Figures 1, 2, 3 __________

2. If a ground water source:

   a. identify type of well--dug, bored, drilled ____________________

   b. determine best method of extraction--hand pump, windmill, fuel or electric pump ____________________

   c. determine well yield and well storage capacity ____________________

   d. find out how many people use the source for water supply and whether storage is sufficient to meet demand ____________________

   e. if there is a community well with a pump serving people who must carry water, evaluate whether a distribution system or public stand posts would most benefit the community ____________________

   f. evaluate whether the community has sufficient resources to install some sort of storage ____________________

   g. determine storage capacity required using the methods described in this technical note and demonstrated in Table 4 or Figure 4 __________

   h. choose the appropriate storage method for the community given resources and available materials ____________________

3. If a surface water source:

   a. identify the supply source ____________________

   b. determine the number of uses and calculate demand for water using 40 liters per capita per day ____________________

   c. determine whether sufficient storage is already provided; for example, a dam and reservoir may hold sufficient water to meet demand __________

   d. determine whether storage is necessary or how much storage is required, using Table 4 or Figure 4 ____________________

   e. choose the most appropriate design given available materials and resources, needs and topographical features ____________________

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

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