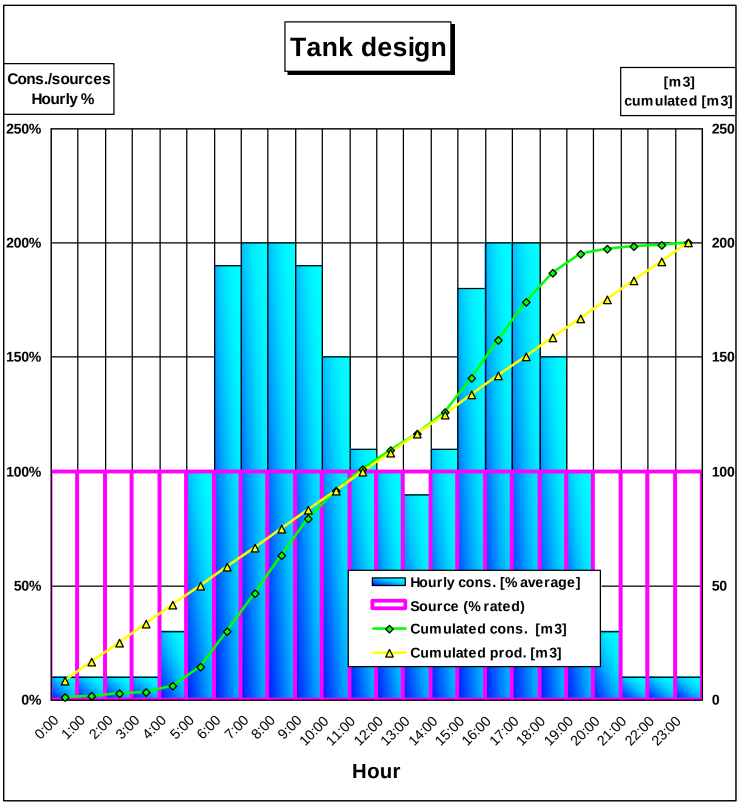
3. Storage

3.1. Roles and needed size of tanks

Balance the supply and the demand

In the case where the hourly volume of water delivered by the source is smaller than the hourly peak demand, the main role of a tank is to balance the supply and the demand. To understand how to dimension a tank, the following figure is used.

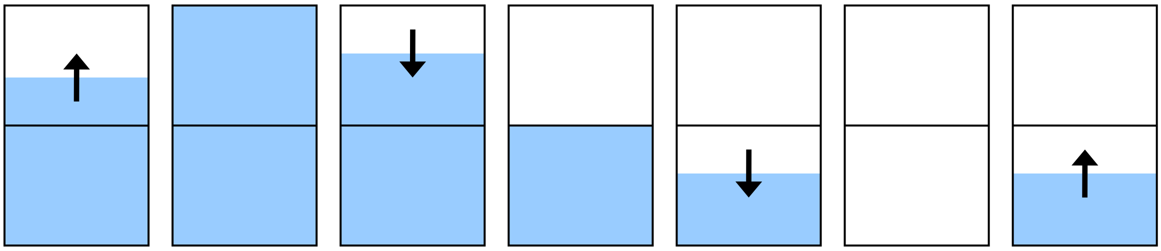


The blue bars represent the hourly consumption in % (to be read on the left axis), as explained in the section about the demand. The green line represents the added consumption in unit of volume (to be read on the right axis). The bigger the hourly consumption rate will be, the steepest the slope of this line will be.

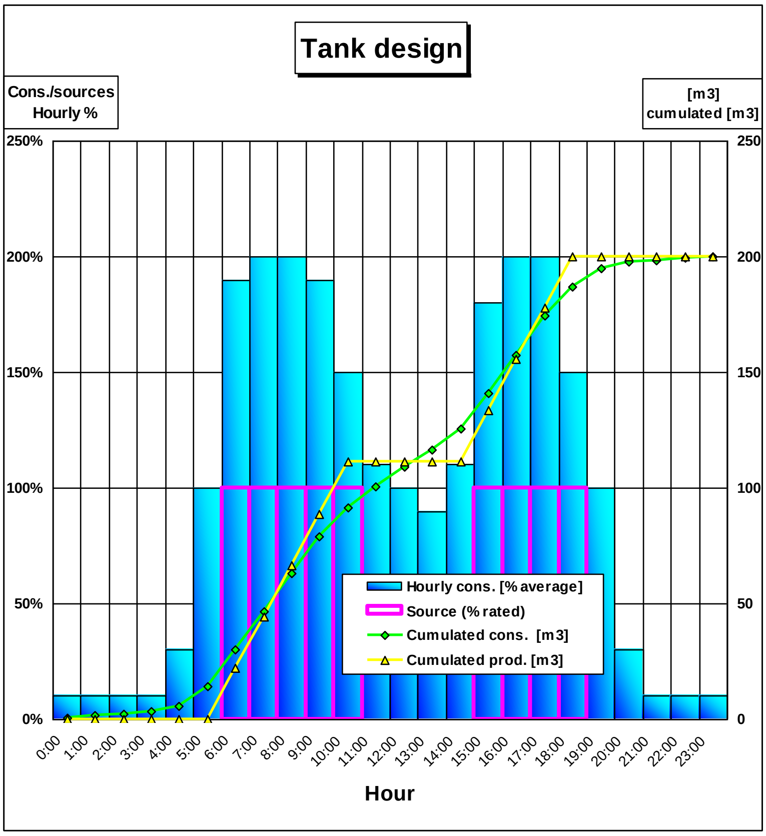
The purple empty bars are the hours in which water is pumped. For one hour, if the pump works the entire hour, the value of the bar will be 100% (to be read on the left axis); if it works only half an hour, its value will be 50% and so on. In this case, the pump works throughout the whole day (24 hours). The yellow line represents the added pumped volume (to be read on the right axis). Given that in this case the pump does not stop and pumps always the same volume, the slope of this line is constant. The volume of water pumped in one hour is calculated as follow: the total consumption in one day divided by the number of pumping hours. If it is chosen to make the pump work only a couple of hours, the pumped flow in one hour will be bigger and therefore the size of the pump and its power consumption will increase.

The following figure illustrates the filling of the tank with the scenario presented in the chart.

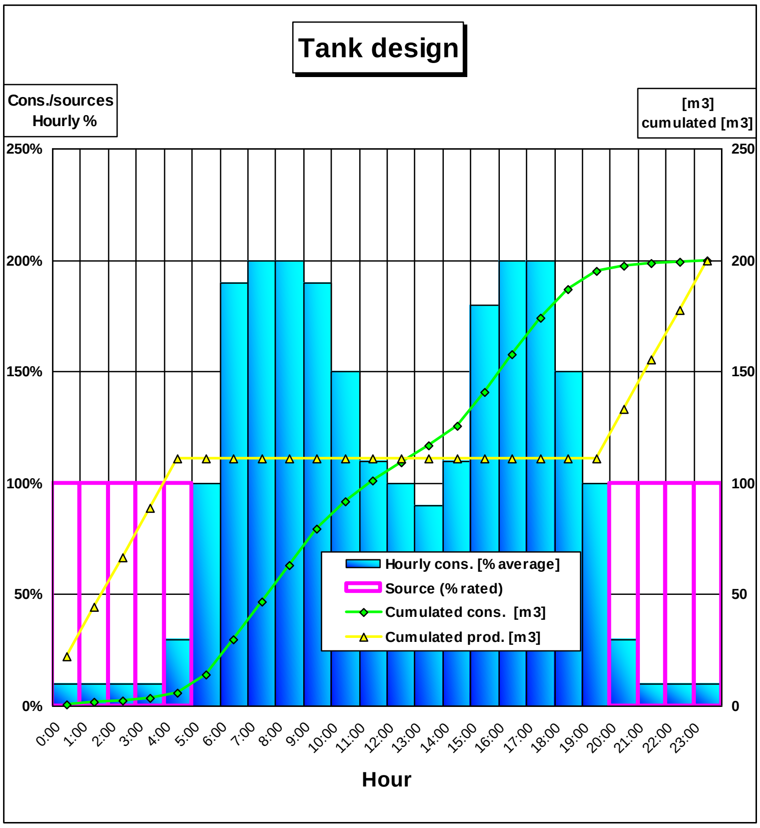
If the tank at midnight is half full: when the production is bigger than the consumption, the water level in the tank rises. When the production is lower than the consumption, the water level drops. If the production equals the consumption, the water level stays constant.



As can be seen, the critical points are at 5am, when the tank is full and at 7pm, when the tank is empty. The situation at 5am corresponds to the biggest negative difference between the added consumption and added production. It is the point where the green line is the most distant from the yellow line in the section where the green line is below the yellow one.
The situation at 7pm is where the biggest positive difference between the added consumption and added production occur. It is the point where the green line is the most distant from the yellow line in the section where the green line is above the yellow one. The size of the tank is the **sum** of these two values. In the chart, red arrows represent it. Therefore, for this example, the size of the tank would be:
size=($390m^3$-$330m^3$)+($90m^3$-$30m^3$)=$120m^3$. Given that the added consumption for one day is of $400m^3$, the relative size of the tank to the daily consumption is 32%



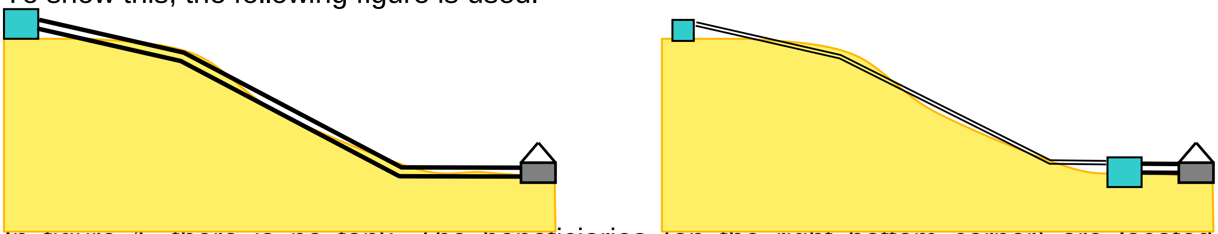
It should be noticed that the pumping hours could be adjusted to the peak hours, so that the size of the tank is reduced. This is illustrated in the following chart, where the pump works between 6am and 12am and between 3pm and 7pm.
This scenario would reduce the size of the tank to $70m^3$ (instead of $120m^3$). This number corresponds to 18% of the daily consumption.
It is true, the size of the tank has been reduce. Nevertheless, the flow needed by the pump has increased from 17 m^3/h to 44 m^3/h, since for the same volume to be pump, the pump has to do it over a smaller period of time. It will require a much more powerful pump to do this. As a result, it is not necessarily a good thing to want to reduce a maximum the size of the tank. Usually, it should be tried to reach a tank size of around 30% of the daily consumption. For the hourly pattern that has been used in this example, the case where the pump does not stop is certainly a good option. However, in some situations, it is wise to adjust the pumping hour with the hourly peak.



On the contrary, if the pumping hours are within periods of low water consumption (for example because electricity to run the pump is cheaper during the night), the size of the tank will increase and the required power of the pump will be as high as when it is adjusted with the peaks (if the numbers of pumping hours is the same). This case is illustrated in the following figure. In this case, the size of the tank should be of 362m^3, which is 90% of the daily consumption

Reduce pipes' diameter

When the source has a flow bigger than the hourly peak demand, there is no need to store water to balance the demand and the source. However, in some cases, tank can be built in order to reduce pipes' diameter.
To show this, the following figure is used.



In figure 1, there is no tank. The beneficiaries (on the right bottom corner) are located relatively far away from the source (at the left upper corner). In order to cover the peak flow with a velocity in the pipe not exceeding a critical threshold (usually 3 m/s), the pipes' diameter will be relatively big if the flow to be provided is big. In this situation, it might be wise to build a tank near the beneficiaries, so that a smaller pipes' diameter is needed between the source and the tank. Between the tank and the beneficiaries, the same diameter (as in the case without tank) is needed, but over a shorter distance.
This configuration is conceivable if the peak flow is important compared to the average flow (between 150% and 300%) and if the source is rather far away from the beneficiaries.

Storage in case of breakdown and maintenance

Another important role of a tank is to provide water during maintenance or breakdown. Maintenance is usually done once a year. The necessity of such a tank depends on the other sources. If a community depends on many sources, it might not be necessary, since if the device of one source breaks down, there still are the other sources that will provide water to the community.

The volume of water to be stored for this case will depend on the length of the duration of a breakdown/maintenance that we want to cover, but usually, it is at least one day (duration of common maintenance work).

Protection against fire

Another role of a tank is for the fight against fire. A supplementary volume is added to the tank for this reason.
An easy system exists to make sure that the tank is not empty when a fire breaks out (meaning that the consumption is bigger than estimated and the reserve for fire has been used):

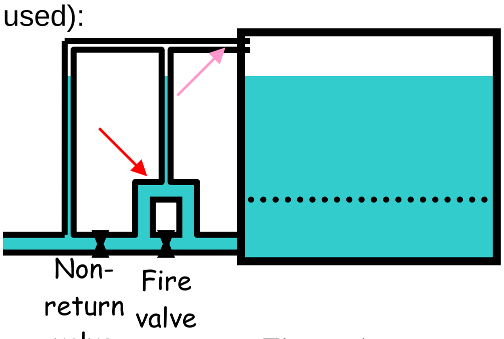


Figure 1

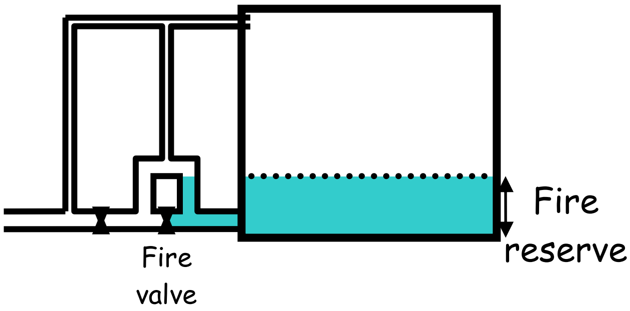


Figure 2

In figure one, the tank is full enough, and water flows in the pipe indicated by the red arrow and passing over the fire valve. In figure 2, the water remaining in the tank must be saved in case of fire. Given that the water level in the tank has dropped, and water cannot pass over the fire valve. There is no water in the pipe network and beneficiary cannot use water, but in case of fire, it can be fought back. In this case, the fire valve is open and water can be used to fight against fire.
The other valve drawn is a non-return valve allowing water from the tank to go into the pipe, but not the other way around. When the tank is full, water goes out from the pipe indicated by a pink arrow in order to avoid pressurization in the tank, and cannot come back to the tank.
This system can be seen as unnecessary, but it is usually during peak hours (when people are cooking) that a fire may start.

Action time of chlorine

If water must be biologically treated, one of the easiest and cheapest mean is chlorination. Chlorine is a chemical compound that will react and kill microorganisms in water. However, it does not kill every micro-organism in the water, since some of them are too resistant (as for example amoebae and spores). In order to be efficient, chlorine must be in contact with the water to be treated during at least 30 minutes. Residence time in the tank can be used to ensure that this time is reached. In this case, it should be checked that when the maximal flow is reached (peak hours of the peak daily demand), water stays at least 30 minutes in the tank.

3.2. Location of the tank

Beside the size of the tank, its location must also be designed wisely. Ideally, a tank should be in the geographical centre of the distribution, so that the length from the tank to the farthest beneficiary is minimized. This is because the biggest this distance will be, the more friction losses will happen in the pipe, the less pressure the farthest beneficiary will get.
The case where the tank cannot be placed in the middle of the distribution (no space available etc...) is illustrated in figure 1.

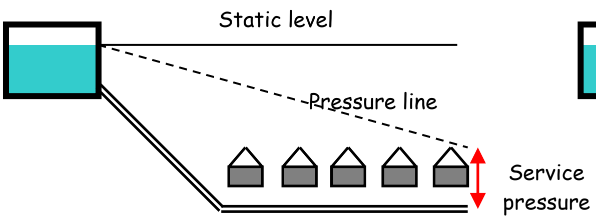


Figure 1

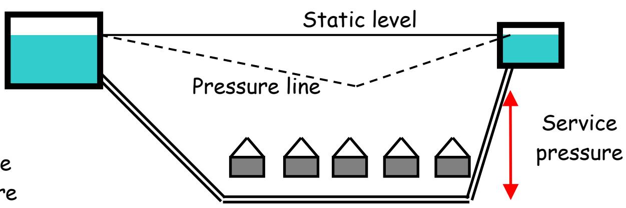


Figure 2

In this case, a balancing tank can be conceivable at the opposite side of the main tank (figure 2), so that the pressure line does not drop too much and reasonable pressure is ensured for all beneficiaries.

Conclusion

It is important to design correctly the storage, since both under and over design have bad consequences
Over design will cost money and time. Moreover, it will affect the quality of water, since if the water stays too long in the tank, it will decrease its quality.
Under design will make the service pressure decrease

4. Help to calculation: excel spreadsheet

In order to facilitate calculations, the following excel spreadsheet can be used. It calculates the needed size of the tank for the case where the tank balance the supply and the demand. To use this sheet, the daily pattern of the community must be known (to be done with the "demand pattern" excel sheet).

Exercises

1. What is the storage need for with 10 000 people (20 l/pers/day) with
   a. a permanent supply?
   b. a 12 hours supply?
   c. a 4 hours supply?
   d. a two-pump system?
2. In a system, we plan to have a ground storage tank with a pump in an elevated tank. Define the best sizes (cf Rumonge)