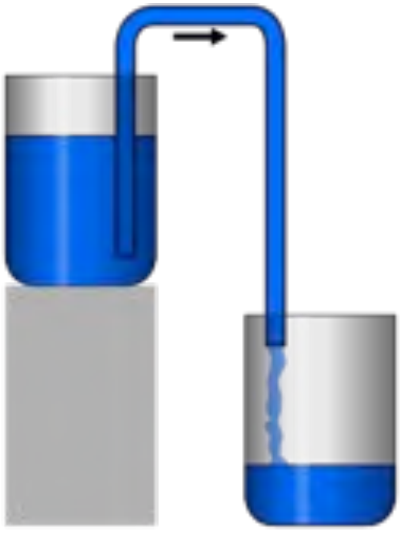
Japan Aquaponics DIY Aquaponics Guides
Autosiphons - Bell Siphons & Loop Siphons

One of the seemingly most mysterious components of an aquaponics system is the siphon. It seems to inspire confusion amongst newcomers, and frustration from more experienced aquaponicers.

At its simplest, a siphon is a mechanism for moving water from one reservoir to another, lower reservoir. The benefit of a siphon is that it is capable of raising water over a barrier – and this is what makes it distinctive, and of practical benefit to aquaponics.

The following diagram shows a simple experiment to demonstrate how a siphon works. Once the tube has been 'primed' – that is to say, all the air has bee removed inside the tube, then the water will flow up and over the edge of the beaker and into the lower beaker. This action will continue until the water in the top beaker reaches the bottom of the tube. At that point, air will enter the tube and the siphon action will be broken.



The mechanics of a siphon is relatively complicated, but we are really only concerned with the practical application of siphons to allow us to quickly empty a growbed into either a sump tank or fish tank using a simple mechanical method with no moving or electrical parts.

Suffice to say, siphons work largely because of hydrostatic pressure, i.e. the force that fluid molecules exert on each other because of the earth's gravitational pull. We can exploit small differences of pressure to enable us to move water around in aquaponics.

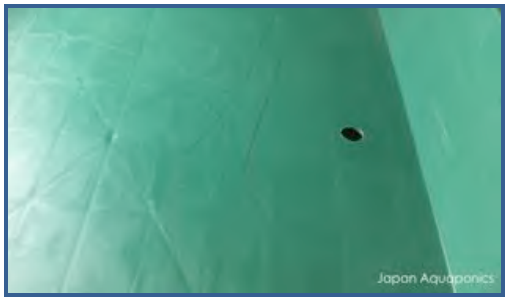
Hydrostatic pressure is what causes water to flow out of a hole in a cup – it forces fluid forwards or outwards.

You will hear the term, autosiphon used in aquaponics – an autosiphon is simply a siphon that can start and stop itself in response to changing water levels. This guide will look at two commonly used siphons:

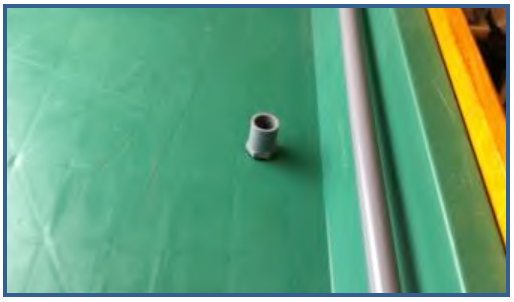
- Loop Siphon or U-Bend Siphon
- Bell Siphon

The Bulkhead and Standpipe

No matter which siphon we use, the first thing that we need to set up is the bulkhead, or through-pipe. With any growbed and siphon set up we will need to have some way of getting the water through the growbed – we usually do this by cutting a hole through the side or bottom of the tank:

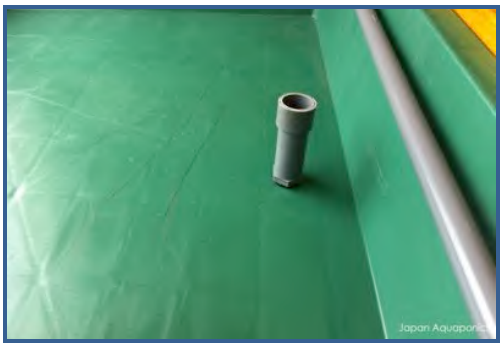


…. and the fitting that we then install to make this waterproof is called a bulkhead fitting (or a Uniseal could also be used):



We can see that in this case the bulkhead is about 2 inches high. When we use the loop siphon this means that there will always be 2 inches of water remaining in the bottom of the growbed – this is absolutely fine and is in fact recommended.

In the case of the bell siphon then we would add a straight piece of plumbing pipe into this bulkhead to form what is known as the standpipe. The height of the standpipe will be adjusted to determine the maximum height of the water in the growbed:



All of the components of the different siphons will come from bulkhead fitting, and so we are discussing first as a point of reference for the rest of the guide.

The following pictures are the top and bottom components of a typical bulkhead fitting at one of Japan Aquaponics' installations.

The fitting is a standard threaded fitting that can be purchased in just about any DIY store or Homestore: The threaded (male) section is put through the growbed from the top of the growbed, whilst the female fitting is coupled with it from below.

We generally used rubber washers on both the top and the bottom, although some will only place them on the underneath of the fitting.

Why do we use Siphons?

Research has shown that the slow flooding, and then rapid draining of the growbeds, provides for excellent access to nutrients for the plants, and high oxygenation for the plant roots.

The rapid draining draws oxygen down fully into the roots and this is vital for good growth.

Loop Siphons

Perhaps the simplest type of siphon we use is the loop siphon. This siphon can be used internally or externally – that is to say, it can be mounted inside, or outside the growbed. As the name would suggest this siphon is quite simply a loop of tubing.

However, it could also be made from solid pvc piping, in which case it may be called a U-Bend siphon.

The tubing comes out of the growbed and a loop is then formed. The top of the loop will determine the maximum height that the water rises to inside the growbed.

As the water rises inside the growbed it will also rise inside the tube until eventually it starts to trickle out. The flow of water will increase until eventually all the air has been expelled from the tube and at that point a siphon will have been formed and the water will start to rapidly drain. This will continue until the water level in the growbed drops enough to allow air to re-enter the tube and so stop the siphon.

The maximum level of water in the growbed can be easily changed by varying the height of the loop or the U-Bend. This makes the loop siphon a very flexible option for an aquaponics system and great for newcomers to and for use with smaller growbeds.

The tubing should be kept out of direct sunlight, or made from a dark material, otherwise algae will grow on the inside of the tube.

The tube diameter also needs to be varied according to the size of the growbed and the volume of water that needs to be drained. As a rule of thumb it should larger than the piping that brings the water to the growbed so that it can drain faster than the rate that the growbed is being filled.

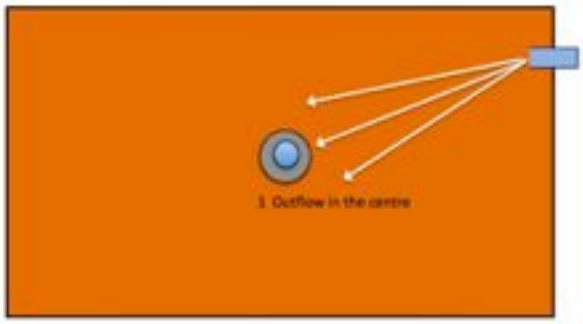
Bell Siphons

Bell siphons can elicit a large amount of consternation and frustration amongst aquaponics enthusiasts. They are ideal for using in an ebb & flow (flood & drain) system but there is no doubt that the beginner can find them tricky to set up and maintain.

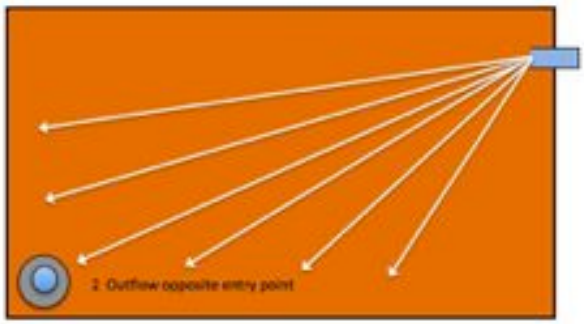
We hope that we can demystify the process a little bit and help you to put together an appropriately sized siphon and fine-tune it to get it running smoothly.

We start with the placement of the siphon. This was covered in a previous guide but you have to consider the siphon as part of the wider plumbing, and so place it where it is going to most effective and in relation to where your water inflow is placed:

In the first graphic the water enters the growbed at one single point and exits via the outflow pipe in the centre of the growbed. As you can see, with this set up there is the potential for solid waste to have limited movement within the growbed. This is still however one of the most common setups and will still be relatively successful. It is also very easy to set up.

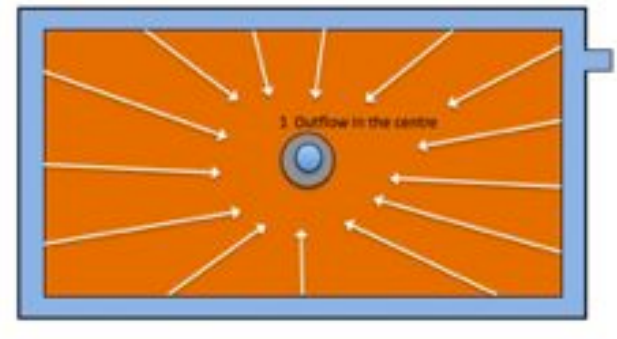


The second graphic is a slight modification, with the outflow placed opposite to the inflow. This means that the water will be dragged through the bed more ensuring better water flow and better movement of solid waste. This in turn will probably lead to less clogging and anaerobic (no oxygen) spots. This is also very easy to set up.



The final graphic shows the water entering the growbed via a piping grid. The grid runs all the way around the bed and has small holes drilled regularly around it. In this way the water is spread very evenly around the whole growbed and ensures maximum dispersal of solid waste and nutrients.

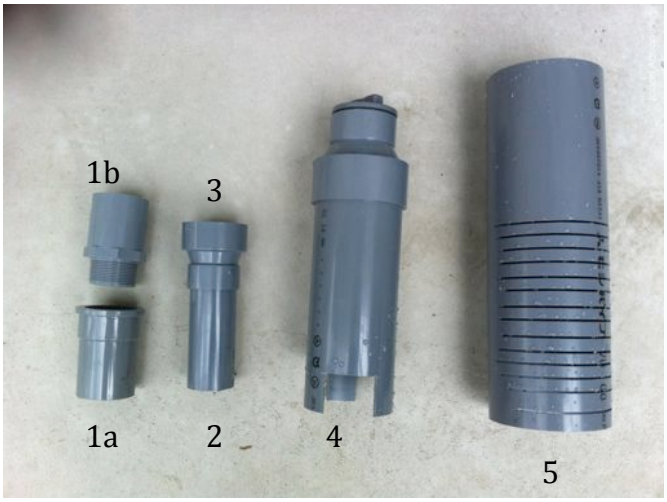
This is still relatively simple to plumb, but the holes will clog over time and so will need to be cleaned more regularly than the setups in examples 1 and 2. There is also an issue of the longer piping causing greater temperature fluctuations, and so you will have to decide if this method will be right for you.



Bell Siphon Components

Bell Siphons comprise of a few quite simple, and readily available components that can be purchased at most local hardware stores.

1. The Bulkhead
    a. Fits under the growbed
    b. Fits above the growbed
2. The Standpipe with:
3. Reducer on top
4. The Bell Siphon
5. The Media Guard



The assembly will also include the plumbing that fits into the Bulkhead underneath the growbed – these pipes fit specifically into part 1a of the photo above.

In this case it is just simple straight 40mm pipe with a 45-degree bend attached.

Bell Siphon Sizing Considerations

The first thing that we start with is the placement of your siphon in your growbed. Once this has been decided then you need to decide on the size of your siphon – what size pipe are you going to use?

Look at your plumbing bringing the water up from your growbed – a rule of thumb is that your main siphon components should be equal to or slightly greater than the water inflow components.

In a larger, say 500 litre growbed, you will need to be looking at filling and emptying approximately 200 litres of water in each cycle. Let's also assume that you will be using an 800-litre fish tank to support this growbed… you will need to circulate the entire contents of the fish tank every hour.

This means we are looking at approximately 4 cycles every hour… a flood and drain cycle of about 20mins. Your pump and your plumbing need to be able to handle this capacity.

We might choose in this case to use 40mm plumbing components to ensure that we have good water flow, minimize the chance of blockages and constrictions, and will also, in the event of a problem, be able to safely discharge the water flowing into the growbed.

Imagine if you have a high volume of water entering the growbed through a 40mm pipe… but your standpipe and outflow was only 20mm. The 20mm pipework would simply not be able to cope with the volume of water and so slowly but surely it would be overwhelmed and the growbed would overflow.

If you then reverse this situation, the 40mm outflow will be able to easily handle the amount of water that the 20mm pipe would be able to put into the growbed. It is exceptionally unlikely in this circumstance that the growbed would ever overflow.

So please consider the amounts of water flowing through your growbed, your pump capacity, how fast the water will be flowing, how many ebb & flow cycles you will need to do in an hour, and therefore what capacity you need your plumbing to be handle safely. This will guide you to your pipe sizes.

The following table shows maximum general water flow rate capacities of common diameters of PVC pipe, and of varying lengths. Nb. this is just for giving an idea of what is possible, but in your system the pump, and the head, will decide how much water can be pumped.

Pipe Length	Water Flow Rate, m^3/hr									
	Pipe Diameter , mm									
m	12	20	25	40	50	65	75	100	130	150
1	5.6	21.5	38.6	133.0	239.2	477.0	694.9	1481	2953	4302
2	3.9	14.8	26.6	91.5	164.5	328.1	478.0	1019	2031	2959
4	2.7	10.2	18.3	62.9	113.2	225.6	328.7	700.5	1396.7	2034.9
6	2.1	8.2	14.7	50.6	90.9	181.3	264.1	562.8	1122	1635
12	1.5	5.6	10.1	34.8	62.5	124.7	181.6	387.1	771.7	1124
30	0.9	3.4	6.2	21.2	38.1	76.0	110.7	236.0	470.5	685.5

Putting your Bell Siphon together

1. First, start with the hole in your growbed. Check and check again that you have the right sized drill bit for the PVC fittings (bulkhead) that you are using.

Even now we usually physically check on a scrap piece of plastic before we drill into the growbed itself. You really do not want to get this wrong!

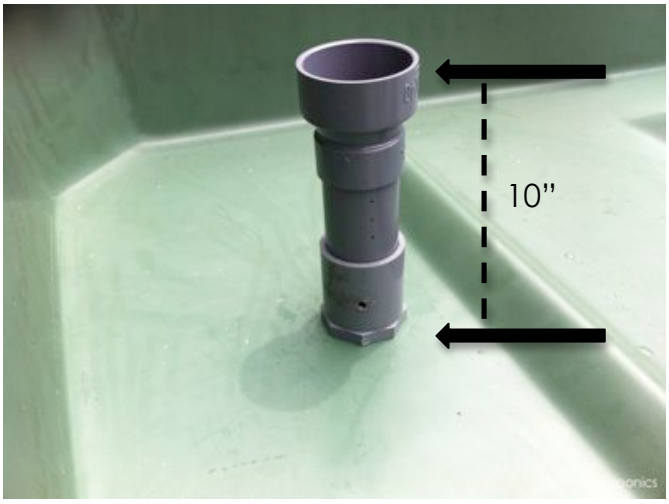
So drill the hole where you want it to go, and then place the bulkhead fitting above and below the hole. The male fitting (with the screw) should usually go through the top of the growbed so that you are left with something looking like this:

The underneath should look like this:

We use rubber washers on both sides of the fitting, but at a minimum they should be used on the underneath.

2. Now that we have the bulkhead in place we can add the standpipe. This is simply a length of pipe that fits into the bulkhead. The standpipe is cut to the appropriate size, meaning that it should be at the height that you want water to start draining from your growbed.

E.g. If your growbed is 12 inches deep then the top two inches you will want to remain dry. Therefore, the total height of your standpipe – from the bottom of the growbed to the top of the standpipe – should be 10" – as is this case in the picture below.



In this picture you can see that we also have a reducer fixed to the top of the pipe. The reducer is 50mm at the top lip and reduces to fix to the 40mm pipe. Experiments, particularly by a guy called Affnan, showed that the reducer helps to make the siphon more efficient and to work more regularly. We recommend using one if you can.

So in the case, from the bottom of the bulkhead shown in the photo, to the top of the reducer on the standpipe, the height is a total of 10".

In the photo above you will also notice a small hole about 1.5" up from the bottom of the bulkhead. This drip-hole will very slowly empty the growbed if the pump is stopped. This installation was in a built up urban area and so the client requested that the pump be turned off at night to reduce noise.

The drip-hole is not necessary at all, but is an option if you prefer it… or if you think that the pump may be turned off sometimes. The hole should not be placed right at the bottom as we would like to leave an inch or two of water in the bottom of the growbed at all times – so just place the hole at that height.

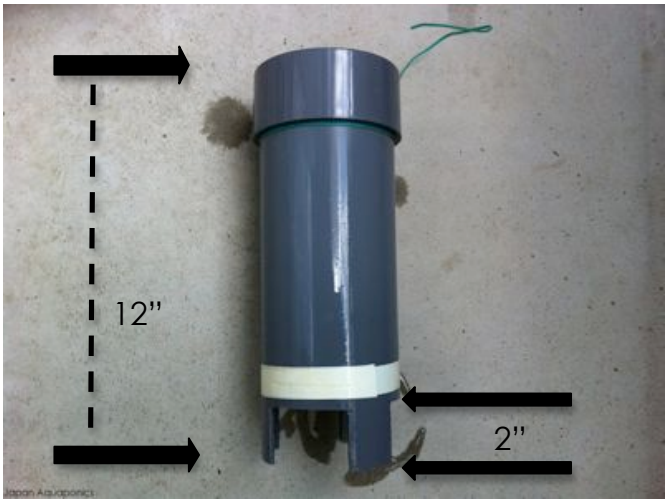
Affnan's Aquaponics is an excellent resource to see his many experiments with all sort of siphons. A general starting point is here:

http://affnan-aquaponics.blogspot.jp/2010/02/affnans-valve-detailed-explanations-of_9459.html

The idea of using the reducer on top of the standpipe was probably first used, or at least written about by Affnan, and so you may also see this referred to as the Affnan Bell Siphon.

Once we have the Standpipe in place then we can add the actual Bell Siphon to the set up. The Bell Siphon is simply the pipe that fits over the top of the Standpipe, but which enables an actual siphon to be formed.

The Bell Siphon needs to be airtight at the top and so will be sealed with some type of cap as shown below. It needs to allow water in at the bottom though and so it is usually cut out at the bottom as you can see in this photo. The water needs to flow freely and so these gaps at the bottom need to be big enough to allow for that.



The gap at the bottom should also be geared to how much water you would like to remain in your growbed at all times. If the gaps are 2" inches high, then you will also have at least 2" of water in the bottom of your growbed, because this is where the siphon will cut off and stop drawing up water. This depth is good for a 12" growbed, but you may want to reduce this height for a smaller growbed.

The Bell Siphon should also be sized according to your standpipe. In terms of width, there needs to be enough room between the side of the Standpipe and the side of the Bell Siphon, to allow water to flow smoothly and quickly. We recommend at least half as much again, and ideally twice as much as the Standpipe – so if you are using a 40mm Standpipe, you should use at least 60mm or 80mm diameter piping for the Bell Siphon.

The height of the Bell Siphon also needs to be appropriate for the size of your Standpipe. We recommend leaving between 1" and 2" between the top of the Standpipe and the top of the Bell Siphon.

These sizes are reflected in the sizings given in the two photos shown of the Standpipe and the Bell Siphon.

You will also notice in the photo of the Bell Siphon that there is a piece of wire attached around it and extending up from the top of the cap. Once the Media Guard is in place it can sometimes be a very tight fit between the guard and the Bell Siphon and so the wire is just there to be able to lift the Bell Siphon out easily.

So you should now have the upper half of the Bell Siphon set up – the Bulkhead, The Standpipe, The Bell Siphon and the Media Guard. We can now look at the lower half of the Bell Siphon – the part that goes under the growbed.

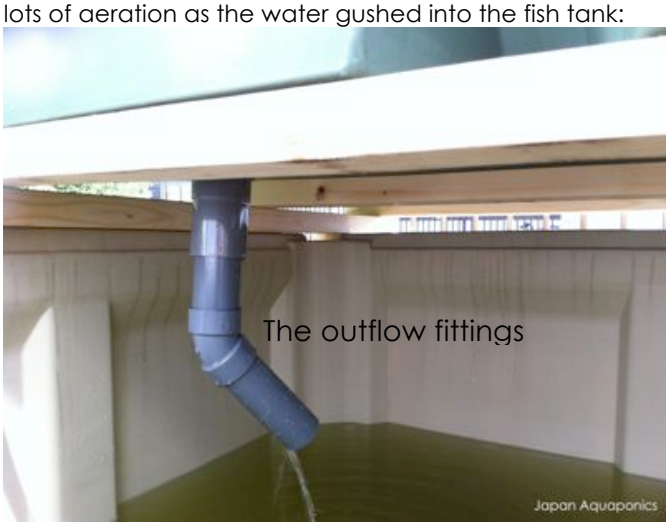
The lower part of the bell siphon is of equal importance to the upper part, as it will help to regulate the siphon and to influence how (or even IF) the siphon starts and stops.

We will show how this part goes together quickly, but we will move on to a discussion about how the bell siphon works in general and what makes it work – or fail to work.

Under the growbed we will see a couple of variations on the outflow fittings. Some of these will depend on how high your growbed is above the fish tank, whether you want the siphon to run quietly, whether you want it to help aerate your fish tank. But the basic configurations are as follows:

- A straight pipe of varying lengths (the length is important as it will determine how much backpressure there is to help start and stop the siphon.
- A pipe with one or two 45 or 90 degree elbows to provide backpressure, and to perhaps help aerate and swirl the water flowing back into the fish tank.
- A pipe with an aerator nozzle, or a venture to again help aerate the water in the fish tank.

Here with a simple 45-degree angled pipe that provided lots of aeration as the water gushed into the fish tank:



And here with a 90-degree angled pipe and a 45-degree fitting on the end angled upward slightly. This system needed increased backpressure to start the siphon smoothly, and it also helped to aerate the water.

Another common method is to use two sequential 90-degree elbows:

http://www.ctahr.hawaii.edu/oc/freepubs/pdf/BIO-10.pdf

So how do you set up the lower part of your bell siphon? In truth this will depend on how the siphon runs from the beginning and you are probably going to have to amend this part of the plumbing several times before you get it right, and your siphon is starting and stopping regularly every time.

So how does the Bell Siphon Work in practice?

There are a number of principles at play here, but very simply, as your growbed fills up with water the water will raise within the bell siphon until it reaches the top of the standpipe.

At that point the water will start flowing over the top of the standpipe and exiting the growbed. If there were no bell siphon this would just continue to overflow continuously and the water would stay at that height in the growbed. This is because the air pressure acting on the water in the growbed is equal across the whole system (i.e it is the same pressure in the growbed as it is in in the standpipe).

When we add the bell siphon over the standpipe, then something clever happens. As the water flows over the standpipe, if the siphon is set up properly then eventually all of the air will be sucked out of the bell siphon, and at that point, because of differences in air pressure acting on the water, a siphon will be formed and the water will be forced out of the growbed rapidly.

This will continue until the level of water in the growbed reaches down to the gaps at the bottom of the bell siphon and air will once again enter the bell siphon. This will cause the siphon to 'burp' and stop. You will quickly recognise the sounds that siphons make when this is happening!

Once the siphon has stopped then the growbed will simply fill up with water as before, until it reaches the top of the standpipe and the siphons automatically starts again. This process is repeated for as long as the water is entering the growbed.

This type of siphon is called an autosiphon, because as long as water is flowing into the growbed, the siphon will start and finish automagically!

So why do Bell Siphons fail?

There are only two things a siphon has to really do:

- Start
- Stop

It seems pretty obvious, but both of these functions require opposite actions and so setting and maintaining a balance so that they can do both, is sometimes the hardest part.

The siphon needs a build up of pressure to start – it needs to be able to expel the air inside it, and so if the flow is too small, or the pipes are too big, then it will always be able to suck up enough air to stop the siphon from starting.

Similarly, if there is too much pressure in the siphon then it will not be able to suck in air in order to stop. So if the water flow is too high, and the piping is too small, or with not enough restriction in the lower part – then it may never be able to suck in enough air to take the 'gulp' it needs to stop.

So balancing these two forces is what we need to do in order to make a siphon that will start and stop regularly, whilst at the same time moving the required amount of water through the growbed, and proving aeration and water movement in the fish tank if that is what we want it to do.

So what can we play with to tune the bell siphon?

- Water flow
- Pipe sizes (diameters and lengths)
- Restrictions to increase backpressure

Setting up the Bell Siphon at the beginning

First, start with your water flow.

- You need to work backwards from the fish tank volume of water. This volume needs to be recirculated at least once every hour. You can therefore work out the minimum setting for your pump – the setting that at a minimum will recirculate the entire volume of the fish tank.

- This setting will now give you the minimum amount of water that will be entering into your growbed(s) at any given time. You can increase this amount – but you **must not decrease it** – your siphon has to be able to start with this minimal amount of water coming into the growbed.

40% Rule. As a rule of thumb, if you have a growbed filled with media – the water will be about 40% of the volume of the growbed.

So if I am using a 500-litre growbed filled with gravel – then when full, the water will account for about 200 litres of the volume. Make an allowance for the actual height that the water rises to in the growbed and this will give you a more accurate figure.

Once you have your minimum water flow coming into the growbed you can test your siphon to see how it performs.

If you want the water coming from the siphon to help to swirl the water in the tank then add a 45-degree angle to the outflow pipe and point it around the edge of the tank.

If that is not a priority, then simply add a straight piece of pipe to the bottom of the bulkhead fitting. The pipe could be about 12" or so long to start with.

Start up your pump and let the growbed fill with water – as soon as the water reaches the top of the standpipe (you won't be able to see that of course, but you can see the water level rising and lowering between the bell siphon and the media guard) then it will start flowing over the top of the standpipe and out of the outflow pipe.

Wait for a short while to see if the siphon starts – there may be a couple of false starts, but hopefully fairly soon the water will come gushing out of the outflow pipe with real force – this is the siphon in action and is a great moment! The sound of the siphon in action is just fantastic and it is great when it works!

Slowly but surely the torrent of water will die down as the growbed empties and the water starts getting down to the level of the cut-outs in the bell siphon. If all is well, you will see a few spurts and false-stops and then you will hear the siphon 'burp' as it take a gulp of air, and the water will completely stop. The comparative silence that follows a successful siphon in action and then stopping, is very satisfying indeed!

If you manage to get it right on the first attempt, then congratulations… you are probably in a happy minority! For most other people there will be a little bit of tinkering to do in order to make it work properly… and like clockwork every time.

Troubleshooting your Siphon

There is likely to be one of only two real problems with your siphon:

- It won't start
- It won't stop

Beyond that, there are degrees of tinkering to make your siphon more efficient, quieter, starting and stopping more easily, adding maximum aeration etc… but these are all great issues to play around with…. once you can get your siphon working like clockwork and are comfortable with how it all works.

Bell Siphon will not START

If the bell siphon will not start (the water remain at a high level in the growbed) then it probably means that there is not enough backpressure in the system to expel all the air that we need in order for the siphon to start.

The first thing that we can check is the cap on top of the bell siphon – is this fitted snuggly? Could there be air entering through the top of the bell siphon? Check this first and make sure that there are no air leaks at the top of the bell siphon. Similarly make sure that there are no obstructions or media pieces in the bell siphon itself.

If that part of the bell siphon is ok then we can look at a few more things initially:

- Increase the amount of water flowing into the growbed. This is one method of getting the siphon to start, as the increased water volume will force the air out of the bell siphon causing it to start. You will have to experiment to see how much extra water flow is needed.

- Increase the backpressure in the siphon by adding a restrictor to the outflow pipe. This could be a simple reducer on the end of the down-pipe that helps to restrict the flow.

- Increase the backpressure in the siphon by adding a 90-degree elbow to the outflow pipe under the growbed. You may find that this is sufficient to create enough backpressure to kick-start the siphon.

- If this does not work, then try adding a second 45-degree or 90-degree elbow in sequence. This increases the pressure even more making it easier for the siphon to start. You can also vary the direction of this second elbow – downward / sideways or even pointing upwards – all these variations will change the backpressure in the siphon – so try a few different things.

- Some people have also reported success by using a different cap on the bell siphon. Sometimes a rounded, or domed cap can help the bell siphon to start and stop. Your own mileage might vary, but we have had some success using different caps on the siphon.

Between these measures you are likely to be able to solve the problem of the siphon not starting. If none of these measures work however, then you may have to look at the sizing of your pipes. It could be that your siphon is simply too big for the amount of water flowing through it and so you will need to downsize your siphon.

For most people though, the measures noted above should be sufficient to get the siphon to start.

Once you have got it to start, then you may well run into problem number 2:

Bell Siphon will not STOP

After the siphon has started then when it finishes it needs to be able to take a big gulp of air in order to stop the action of the siphon. If we have increased the backpressure too much, or the water is entering the growbed too fast, then it can be hard for the siphon to take in enough air to make that gasp, that burp that stops the siphon.

You will see this by the siphon outflow just continue to run at the same rate that water is entering the growbed. The water in the growbed will simply stay at the bottom level of the cutouts in the bell siphon.

The first that you can check is whether any media or anything else has gotten into the media guard and is blocking up the bell siphon cutouts. If this is the case then just clear the obstruction and see if this helps.

If this is not the case then you can try the following:

- Reduce the amount of water flowing into the growbed. This will make it easier for air to enter the bell siphon to stop it… but will of course also make it harder for the siphon to start. Please also make sure that you do not reduce the water flow so much that there is not enough water being pumped out of the fish tank. Remember that the volume of water in the fish tank should be recycled very hour.

- Next, you can look at reducing the backpressure in the system. Look at the outflow pipes under the growbed – can you remove a 90-degree elbow, or make a piece of pipe shorter? The less pipework there is in the outflow system, the easier it is for the siphon to gulp air.

- Some people have also reported success by using a different cap on the bell siphon. Sometimes a rounded, or domed cap can help the bell siphon to start and stop. Your own mileage might vary, but we have had some success using different caps on the siphon.

- Some people have reported success by increasing the height between the top of the standpipe and the top of the bell siphon. Increasing the height of the bell siphon may work, but again, your mileage may vary.

- You could also try adding a snorkel to your bell siphon. This is usually a rubber tube that is placed in the top of your bell siphon and which is then tied to the side of the outside of the bell siphon, and which is cut just above the top of the cutouts on the siphon. This breathing tube allows additional air to be sucked into the siphon at the appropriate time:

If none of these measures of work, then once again you may need to look at the sizing of your pipes and perhaps you may need to upsize the pipe diameters that you are currently using.

The Great Bell Siphon Balancing Act!

It should be clear from the notes previously, that what makes a siphon easier to start, makes it harder to stop… and vice versa. This means that we are left with a balancing act between these two measures.

If your pipe sizing is good then you will find the balance that you are looking for – it may take a few tries, but by varying the flow of water into the growbed, and then rearranging the combination of fittings on the outflow pipe you will come to an arrangement that will work. That will restrict flow enough to start the siphon every time – but which allows enough air into the system at the end of the cycle in order to stop the siphon.

So be patient when you are putting the siphon together, and we recommend playing around with a spare container and some pipe and fittings before you do your main growbed. Siphons can be made from a few odd fittings and soft drinks bottles, and so forth.

Check out a few videos on the web and you will see lots of variations and explanations. You can also find other tutorials, guides and links to aquaponics plumbing pages on the web. We have included some links for you at the end of this guide.

Don't be scared of playing around with your siphon – they are great fun and are an excellent way to get a flood and drain mechanism in your growbed that benefits your plants, your fish and your bacteria.

Aragon St-Charles
Japan Aquaponics

Our DIY Guides:
http://www.japan-aquaponics.com/diy-aquaponics.html

Other sources of information about bell siphons:

Affnan's Aquaponics – His Bell Siphon Design
http://affnan-aquaponics.blogspot.jp/2010/02/affnans-valve-detailed-explanations-of_9459.html

Aquaponics Wiki – Siphons Page
http://aquaponicswiki.com/index.php?title=Siphons

College of Tropical Agriculture Siphon Guide
http://www.ctahr.hawaii.edu/oc/freepubs/pdf/BIO-10.pdf