880 - Gallon Recycle Aquaculture System
Installation Guide

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Introduction

The design of this aquaculture/hydroponics system was prompted by the need for information by teachers interested in using aquaculture and hydroponics as a teaching tool for students. The system was developed to utilize current aquaculture technology, to be simple to operate, dependable and require a minimum of maintenance. A class of 10-25 students can operate it. Should you wish to occupy more students, it is modular and expandable. It has significant fish and vegetable production capabilities that should challenge the students' abilities in operating, marketing, and team management skills. It can be used in a small space (500 square feet) and has moderate monthly input (primarily feed) costs (< $250.00/month). It was designed for use with Tilapia.

Site Selection

The space that is selected should be carefully chosen. The aquaculture portion of the system will require about 160 ft^2 and will require the following:

- incoming water
- drains
- electricity
  - 120v
  - 240v
- adequate lighting
- good ventilation
- heat

Other considerations are:

- Can the floor support the weight of the tanks?
- Natural light can save on energy consumption.
- If the system is to be installed in a greenhouse, will they be using pesticides? Pesticides can kill fish.
- Room for the equipment and a class of students?
- The lab is a little noisy even without a class full of students.
- The floor should be able to withstand lots of water. It will most certainly get flooded.
- The system can produce some unpleasant odors.
- Large doors and easy access to vehicles help for loading fish or feed.
- Nearby storage for items such as: nets, chemicals, feed (refrigerated), equipment, books, etc.
- A telephoning alarm system can be invaluable (Is a phone line available?)
- Security.

The following may serve as spaces suitable for labs:

- Classrooms with sloped concrete floors with floor drains
- Greenhouses with gravel or concrete floors (or both)
- Converted storage buildings

Description of the System

Tanks - The two 440-gallon circular polyethylene tanks are designed to be "self-cleaning". Water should enter the tanks to create a circular water flow (counterclockwise). The standpipe (2 inch PVC well screen) in the center should be perforated throughout so that solids (not fish) may pass out of the tank. The tanks should have nets or screens that will prevent fish from jumping out of the tanks. These covers should be left on the tanks at all times except when work is being done. The actual volumes of the tanks can vary depending on whether the hydroponic unit is receiving water. It is recommended that you calculate the water volume for each of your tanks while water is circulating. You should also know the total volume of water in the entire system. This information will be useful.

Ebb and Flow Beds - The hydroponics portion of the lab consists of four 4' x 8' ebb and flow beds. The beds are constructed of wood, lined with plastic, and filled with gravel (the growing medium). Automated valves will alternately flood these beds every 8-20 minutes (you choose the cycle time). The beds will slowly fill (submerging all but the top inch of gravel), and then drain into a sump. High water levels in the sump (detected by a float switch) will trigger a pump to return the water to the culture tanks.

Circulation - The water is moved through the system with a 3/4 horsepower centrifugal pump capable of producing a 55-gallon-per-minute maximum flow rate. Water flow can be independently regulated for each tank. Flow rates are very important to the overall health of the system. The pump draws water directly from the tanks before pushing the water to the hydroponic beds. The water level should be checked and topped off daily. Operating the pump for prolonged periods with restricted water inflow may decrease it's lifespan. The pump will fail if allowed to run dry for any length of time. Restricting the flow of water on the supply side (not on the intake side) will pump less and save energy. The pump trap (if included) on the pump should be periodically checked for blockage. Do not allow foreign objects to be drawn into the pump.

Filtration - There are two types of filtration: 1) the removal of solid wastes such as scales, feces, uneaten feed, etc. (mechanical filtration, clarification); and 2) the removal of water soluble wastes (dissolved solids, dissolved organic material) such as ammonia and nitrites (biological filtration or biofiltration). Solid wastes come in many different forms: settleable solids, suspended solids, and floatable or fine solids.

Mechanical filtration. The bead filter is responsible for the mechanical filtration (clarification). Four cubic feet of small floating beads strain out unwanted solid wastes from the system (>20 microns). Each cubic foot of beads contains approximately 600,000 beads. As the amount of organic material trapped in the filter increases, the flow of water through the system is reduced. This buildup of organic material will begin to decay, causing deteriorating water quality. Therefore, periodic backwashing of the bead filter is required for constant flow rates and maintaining suitable water quality. The frequency of the backwashes depends on several variables. As the daily feed amounts are increased, it will become necessary to backwash the filter more frequently. Often a good indicator of the need to backwash is a reduction in the system's water flow rate. Other potential indicators are an increase in the turbidity of the water in the tanks or worsening water quality variables (declining pH and increasing total ammonia-nitrogen). At maximum feeding rates, the bead filters may have to be backwashed once or even twice a day. As each backwash utilizes 55 gallons of water, try not to backwash more than is necessary to maintain good water quality.

Biological filtration. Water-soluble wastes must also be removed from the system. Biofilters contain many different species of microorganisms, each utilizing different material in the wastewater. Of particular interest are the nitrifying bacteria that remove ammonia and nitrites from the water (ammonia and nitrites are both toxic to fish). Several factors influence the efficiency of the biofilters. Most important are the amount of surface area and the turnover times of the filters.

The bead filter provides a significant amount of biofiltration. The 400 square feet of surface area per cubic foot of beads serves as attachment sites for bacteria that help remove wastes. When the bead filter is backwashed, many of the bacteria are "washed off", thereby reducing the filter's effectiveness at biofiltration. Therefore the system has a supplemental biofilter - - the gravel in the hydroponic beds and the plants that grow in them (additional biofiltration is going on the interior surfaces of the pipes and tanks). As the water from the bead filter enters the gravel beds, a small amount of solids may accumulate in the gravel beds. The plants will use some of this organic material. Excessive buildup will cause the unused organic material to decay, causing deteriorating water quality and poor circulation. Therefore, you should monitor the organic buildup in these beds. Excessive buildup will cause anaerobic conditions that are not conducive to plant growth or good water quality for the fish. As the daily feed amounts are increased, it will become necessary to monitor the condition of the beds more carefully. Often a good indicator of excessive buildup is an increase in the turbidity of the water in the tanks or worsening water quality variables (declining pH and increasing total ammonia-nitrogen). Solids may also clog the gravel causing the beds to flood.

There are several factors that influence the efficiency of the biofilters. In order to maintain good water quality for the fish, it is as important to manage the bacterial populations on the biofilters as it is to manage the fish populations. As the fish grow, they require more feed. The bacteria will respond to the increased wastes by multiplying (the activity levels of the biofilters will increase). Drastic changes in water quality or feeding rates can adversely affect them. The biofilters must be "conditioned" before fish can be added to the system (see How the Biofilter Works). A sudden large harvest of vegetables or plants from the beds could cause problems.

<u>Air blowers/ aeration</u> - The most critical water quality parameter is the availability of dissolved oxygen provided through aeration. The tanks receive aeration from a 1/8 horsepower regenerative blower. The system is equipped with an additional blower should the primary blower fail. Without aeration, dissolved oxygen levels will quickly

drop to critical levels. Aeration not only provides fish with adequate dissolved oxygen levels, but also removes carbon dioxide and ammonia from the water (volatilization).

The blowers pressurize the overhead airlines (2-inch PVC) which release air into the "halos" that surround the edge of the tanks (1/2 inch polytubing). From here the air is released underwater in the tanks through the three-inch air stones that break the air into small bubbles to allow for more efficient diffusion of oxygen into the water. The deeper the airstones are underwater, the more aeration the water receives up to a point. This also causes the air blower to work harder, consuming more electricity. Airstones that are too deep will not release much air and should be moved closer to the surface of the water (they might need cleaning). A pressure relief assembly should be used to bleed off excess air. Open the relief valve as much as possible while still maintaining good airflow through all of the air stones. This should lower electrical costs.

<u>The blower should be able to maintain dissolved oxygen levels greater than 4 mg/l at all times. Since fish consume more oxygen just after feeding, dissolved oxygen levels should be checked after feeding.</u>

<u>Heaters</u> - The system can be heated either with a radiant heater (8,000-12,000 Btu) or with an electric bayonet-style immersion heater. The radiant heaters are suspended over the tank (18+ inches) and have thermostats that will maintain a constant water temperature. The electric heaters are floated in the tanks with styrofoam and require temperature controllers to maintain a constant temperature (an additional expense). The heaters should maintain the water temperature between 77 and 95°F.

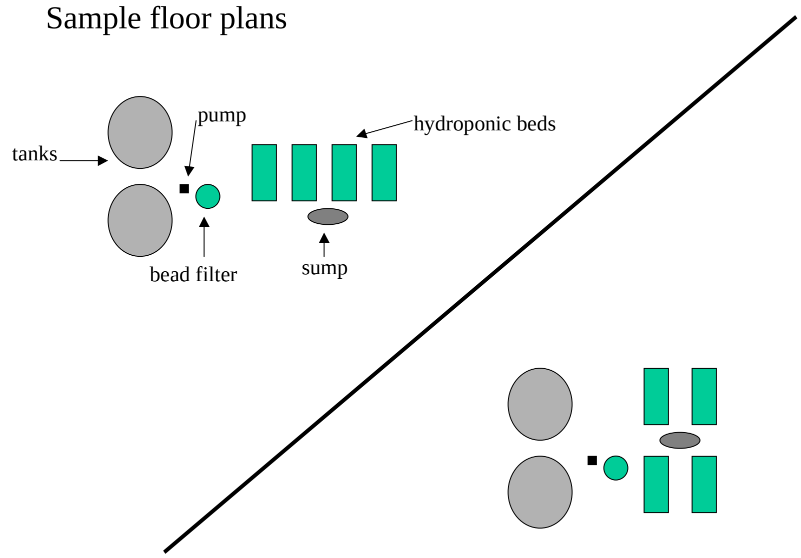
<u>It is important that the hot "zone" under the bayonet style heater is kept submerged and away from the sides of the tank at all times</u>. The radiant heater may also pose a danger if they are allowed to get too close to the tank sides or standpipe. Be careful not to get the heater or controller wet. <u>When working in the tanks, it is often a good idea to turn off and move the heaters out of the way first</u>.

<u>Emergency generator/ telephoning alarm/ emergency aeration</u> - You should have a contingency plan for emergency situations such as a power outage. You should consider an alarm system that will notify you in the event of an emergency. Many alarm systems will allow remote monitoring of the system (dissolved oxygen, temperature, etc). Once you have been notified of a power outage (the system will call you via telephone), you can start a backup electrical generator. The backup generator would be used primarily to operate the blowers to provide emergency aeration to the fish (the generator may be able to power the pump as well). Depending on how heavily the system is loaded with fish, it may be only a matter of minutes until dissolved oxygen levels drop dangerously low in the event of a power outage. You could also use a tank of oxygen to provide emergency aeration. Pressure sensitive switches will automatically supply oxygen should the blower fail or lose power. Whether you use a generator or oxygen to provide aeration, you need to be alerted to the problem with an alarm.

Installing the System

Once you have determined a space as a potential site, you should layout the tanks, beds, sump and bead filter into their exact positions (see Picture 1 and Diagram 1 for example layouts). Make sure that there is ample room for working around the tanks and beds (there should be at least a two-foot aisle between the hydroponic beds). A low ceiling will hamper efforts to net fish out of the tanks. The tanks, pump and bead filter should be clustered together and the hydroponic beds and sump also need to be clustered together. It is possible to have the tanks/bead filter/pump in one room and the beds/sump in another. This would require more plumbing and would make supervising a class of students more difficult, but space limitations may dictate some creative floor plans. Try to limit the areas where PVC pipe runs along the floor so they do not present a hazard to people walking through the lab. You might want to elevate the PVC pipes that run along the floor very slightly (you can slip a thin piece of wood underneath them) so they will not trap debris. This will allow you to keep the floor of the lab clean.

Sample floor plans



Picture 1 – Sample layout of fish tanks, beadfilter and gravel beads.

TOOLS

- Pocket knife or file
- Hacksaw
- Jigsaw
- PVC primer
- PVC cement
- Large pipewrench
- Teflon paste or tape
- Drill
- ½" Pipe tap
- ½" Drill bit
- 4" Cable ties

TIPS

Working with PVC - When you cut PVC use a miter and a hacksaw with a sharp blade for best results. Cut at a 90^0 angle across the pipe and be sure to cut all the way through before you separate the pieces. This will leave nice sharp edges on the cut pipes. Remove burrs or irregularities with a file or sharp knife. It's usually a good idea to "test" the more difficult sections that you are about to clean and glue together to make sure that you have cut the pipes the proper lengths. Do this before you clean with a primer (the primed pieces of pipe are difficult to get back apart). Clean all joints and pipe with a primer before gluing them (a colored primer will make sure you don't miss any). Once you have applied the PVC cement to both pieces being glued, you should quickly join the pieces (make sure they are fully seated), twist them ¼ turn to final position, and hold them firmly in place until the glue sets (there is a tendency for the joints to "back out" unless constant pressure is maintained for a few seconds). The glue sets quickly, you only have a few seconds to make any last minute corrections once you put the pieces together. All threaded PVC joints should be lubricated/sealed with teflon paste or tape. Take extra care when gluing ball valves so that glue will not accidentally get into the valve and cause it to malfunction. **Work in a well-ventilated area**.

Building tank platforms - Find the center of a tank. Lay the tank upright with it's center on the edge of a 3/4-1 inch 4x8 plywood sheet. Trace the outside edge of the tank onto the plywood. Use a jigsaw to cut the semicircular shape out of the plywood. Cut a smaller semicircle with a 6-inch radius from the center of the plywood shape (use a pencil on the end of a 6-inch string with a thumbtack in the center). Trace this shape to make three more identical halves out of plywood.

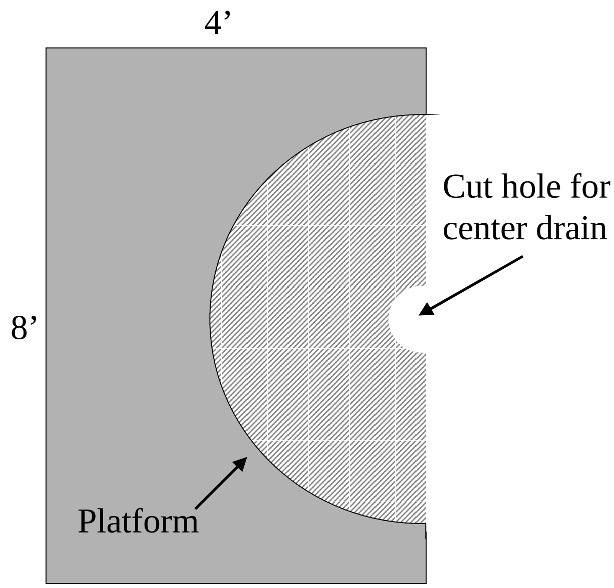


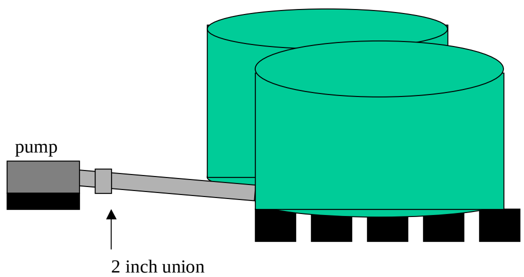
Diagram 1 - Cutting plywood base for tanks.

Preparing the tanks - Lay the tank on its side. Trace a circle that matches the insert (threaded) portion of the 2-inch bulkhead fitting in the center of the tank. Carefully cut out this portion (a drill can be used to start the hole and a jigsaw will be able to finish the job) - - if the hole is too big, the tank will leak. Insert the bulkhead fitting to be sure the fit is good. Smooth out burrs or rough edges in the hole then tightly secure the bulkhead fitting (use teflon paste or tape on all PVC threaded joints) in position with slip side up and fipt down. A light application of silicone on flat joining surfaces will ensure that the bulkhead fitting will not leak. Be sure rubber seal is in place. If the fitting is tightened too much, it will squeeze the rubber seal out of position. Screw the 2 inch male adapter (mnpt x slip) into the bottom portion of the bulkhead. Cut small sections of 2 inch PVC just long enough to join the male adapter and a 90^0 elbow. Clean and glue the 90^0 elbow onto the male adapter using the small 2-inch PVC section. Be careful not to damage the fittings once they are glued onto the tank. The tank should rest on its side until it is placed onto the platforms.

Setting up the tanks - The tanks are supported by 8-inch concrete blocks underneath the plywood tank platforms. Evenly space 10-12 concrete blocks underneath the platforms to provide support. Allow space for the drain lines of the two tanks to connect between the tanks.

Set the tanks onto the platforms being very careful not to damage the 90^0 elbows attached to them (the plywood semicircles can be pulled apart and pushed back together once the tank is in place). Rotate the tanks so the 90^0 elbows point towards each other and join them together with 2 inch PVC and a 2-inch tee. It is important to have already established the height of the pump prior to this so you may "aim" the horizontal angle of the tee to align with the pump location.

Diagram 2 - Alignment of the tank drain line to the pump



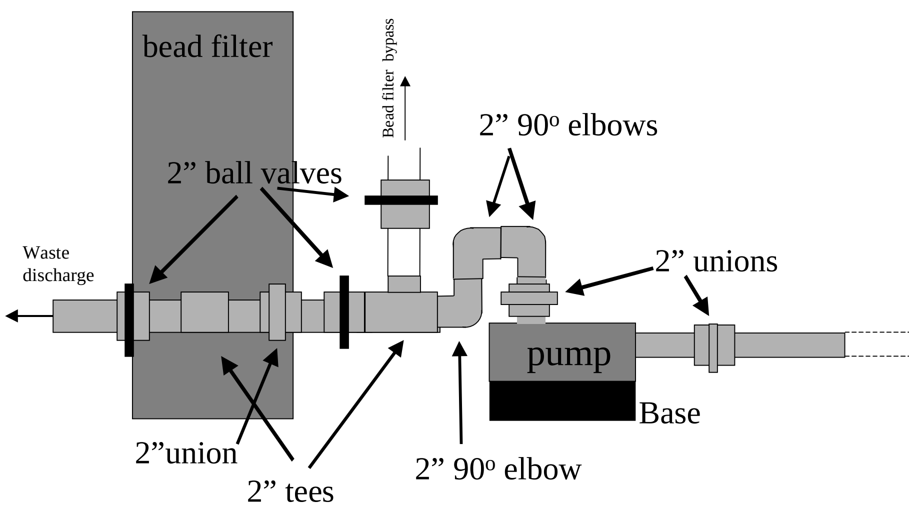
Glue a 2-inch section of PVC from the tee towards the pump. Use a union to join the drain line to the 2-inch PVC that leads to the pump (this will allow you to easily replace the pump when necessary).

Setting up the pump and bead filter - The pump should be elevated off the floor (at least a few inches) and covered to minimize water damage (a wood or concrete block works nicely). Make sure the pump inlet can be directly aligned with the drain line coming from the tanks (Picture 1). The inlet and outlet on your pump should be 1" mpt. Screw in the 1-1/2->2 inch male adapter reducing fittings (mnpt x slip) to the pump inlet and outlet. Use a short section of 2 inch PVC to glue in the 2 inch union on the male adapter fitting on the outlet side (on top) of the pump (this will allow you to easily replace the pump). You can use up to three 90^0 elbows to continue the supply line from the 2-inch union to the bead filter inlet. It's a little tricky, but by twisting a configuration of three 90^0 elbows, the elevation of the bead filter inlet can be matched so that no more turns are required (fit them all together before priming/gluing and make sure alignment is correct). (You can eliminate two elbows by placing the bead filter on a raised cement pad.) Try to minimize the number of turns necessary to join the bead filter and pump. The more turns there are in your water supply line, the more pressure loss because of friction. Once you have used the 90^0 elbows to match the inlet on the bead filter, you need to glue in the 2 inch tee with the bottom of the tee facing straight up (this will allow the water to bypass the bead filter when it is backwashed). Then glue in two- 2 inch ball valves (on top and beside the 2 inch tee - see diagram 3). The ball valve on the line to the bead filter is then followed immediately by a 2-inch union that will allow you to disconnect the bead filter if necessary. Now you can connect the union to the 2-inch tee that connects to the bead filter inlet (you don't need a check valve on the inlet side of the bead filter). Another 2-

inch ball valve (it should come with the bead filter) will be installed on the waste discharge line on the other side of the 2-inch tee that connects to the inlet of the bead filter.

Picture 1 – Installation of pump between fish tanks and beadfilter.

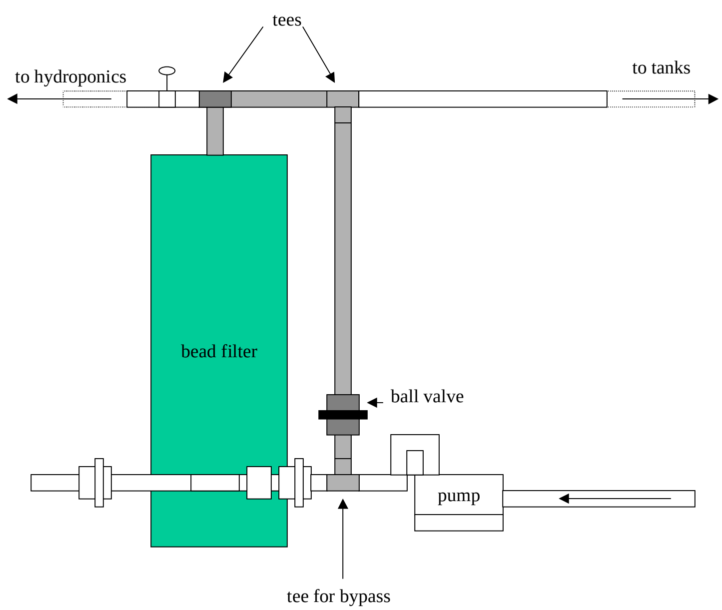
Diagram 3 - Plumbing between bead filter and pump.



When backwashing the bead filter, the 2 inch ball valve on the bead filter bypass should first be opened, then the 2 inch ball valve between the bypass and the bead filter should be closed (this will allow you to leave the pump running). You will then open the waste discharge ball valve and let the bead filter backwash. To resume filtration, close the waste discharge ball valve, open the ball valve between the bypass and the bead filter, and then close the ball valve on the bead filter bypass.

Water supply lines - The 2 inch 90^0 elbow that projects from the top of the bead filter should be turned so that it runs perpendicular toward the tank drain lines. Just after the 90^0 elbow, install a 2 inch union which should be immediately followed by a 2 inch check valve, and then a 2 inch tee that will connect to the bead filter bypass between the pump and bead filter. The bypass line should have a 2 inch ball valve (this ball valve will remain closed during normal operation and open when backwashing).

Diagram 4 - Side view of bead filter bypass



As the water supply line approaches the drain lines, you should use another 2-inch tee to split the supply line to the tanks and hydroponic beds. The line that supplies water to the hydroponic beds should include a 2-inch bronze gate valve so the hydroponics section of the lab can be shut off for maintenance (See Picture 2). If you do not plan to install the hydroponics portion of the lab, then you should cap this line for future use. The 2-inch water supply line for the aquaculture tanks should run straight towards the two tanks (in between them) preferably directly over the drain lines. A 90^0 elbow will turn the water supply line down when it reaches the point in between the two tanks and a 2-inch tee will split this line into two just above tank level. This water supply line may have to be supported from the ceiling (depending on how long it is) or it may be supported by resting the supply lines directly on the tanks and securing with cable ties to the tank rims. Insert the 2-> 1 1/2 inch reducer bushings (spig x slip) into the tee. Now cut a small section of 1 2 inch PVC just long enough to join the bushing and the 1-1/2 inch gate valves. Glue a section of 12 inch PVC just long enough to extend over the tank edge. Use a 45^0 elbow to make water enter the tank in a counterclockwise flow (this piece doesn't have to be glued).

Picture 2 – Return water line from top of beadfilter to tank and hydroponic growing beds. Note bronze gate valve for cutting off flow to hydroponic unit.

Diagram 5 - Water Supply Line

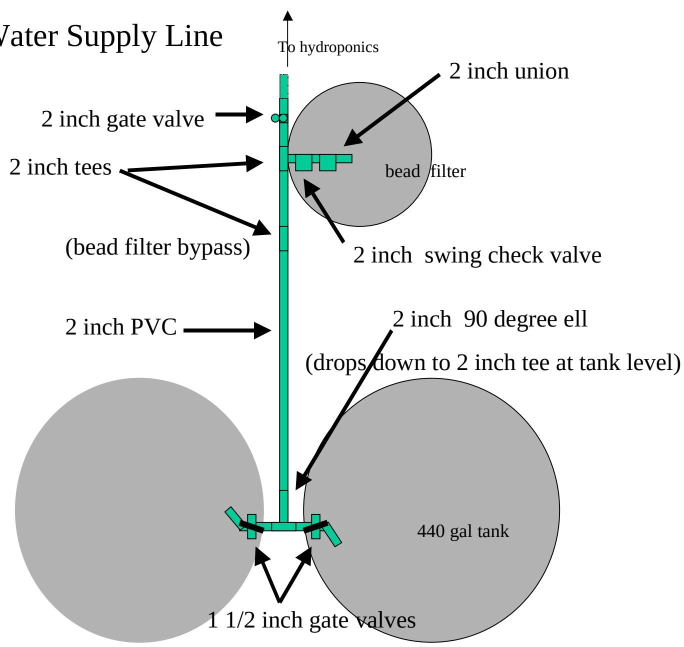
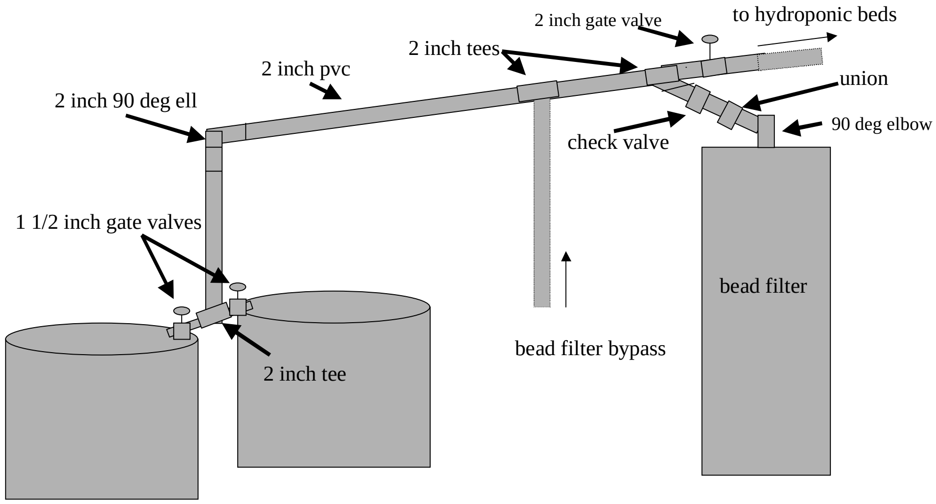


Diagram 6 - Supply Line Elevations



Blowers and air lines -

TIPS

- Before you pick a location to mount the blower, consider what kind of air the blower will be putting into your tanks. Clean fresh air that is not too cold or too hot is ideal.

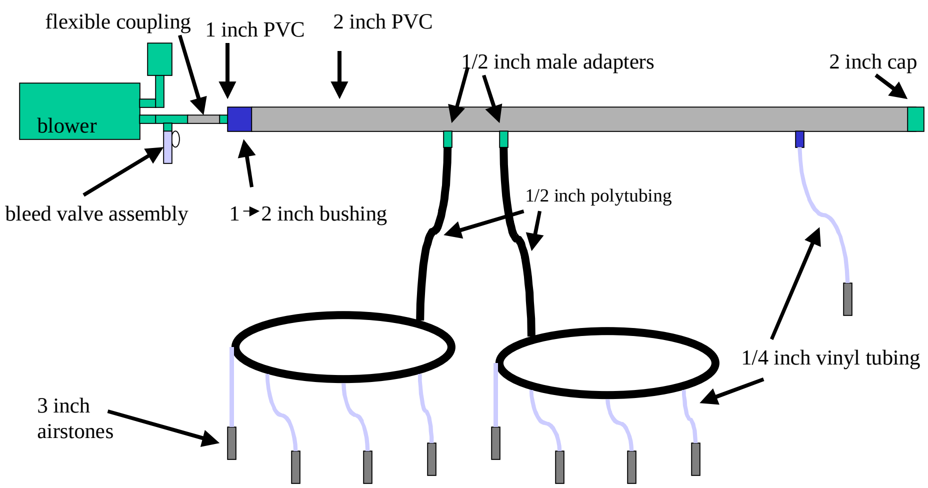
- After you have drilled and tapped all of the holes in the air line (and before you close the air line with the 2 inch cap), run the blower to eliminate the PVC shavings that may be in the air line. These shavings could cause some of the fittings to become clogged during operation.

- Wetting the vinyl or polytubing will make it slip onto the insert fittings more easily.

- Use the bleed valve assembly to bleed off excess air. The blower will run cooler and use less energy.

The regenerative blower may be mounted vertically onto a wall or horizontally onto a shelf. It should be located as close to the tanks as possible and should be mounted close to ceiling height (8-10 ft). Do not install the blower or airline below water level because water may be drawn into the airline and flood the blower. Mount the blower securely. Use the bleed valve assembly (it needs to be accessible), a short section of 1 inch PVC, and the 1-> 2 inch reducer bushing to enlarge the airline to 2 inch PVC. Run the 2-inch airline straight over the tanks (make sure the line is out of the way as possible). Depending on your layout, you may have to use one or more 90^0 elbows to get directly over the tanks. You will have to evenly support the airline with plumber's strap or pipe clamps. Over the inside rim of the two tanks, drill two holes (approximately 12 inches apart) into the bottom side of the 2 inch PVC air line using a 1/2 inch bit. Use the 1/2 inch pipe tap to thread the holes. You may want to install some additional male tubing adapters (1/2 inch mpt x 1/4 inch barb) into the 2 inch air line to allow for sources of aeration for activities such a sampling, holding fish, etc (the exact location of these airstones will depend on your particular layout - tubing flow valves should be used to regulate the air flow). Screw in the 1/2 inch polytubing male adapters (mipt x insert). Run ½ inch polytubing from the adapter down to the edge of the tank (the halo that you will install around the tank can sit on the inside lip or outside edge of the tank). Use a ½ inch tee to connect the polytubing to the halo. The 1/2 inch polytubing halo should have 6 – 1/2 inch tees (insert x insert x fnpt) spread evenly around the tank. You can drill small holes in the top of the tank edge and use small cable ties to secure the halo in position. If you elect to put the halo on the outside edge of the tank, you will have to drill holes to accommodate the male tubing adapters (1/2 inch mpt x 1/4 inch barb) that will be screwed into the 1/2 inch tees on the halo. Use the 1/4-inch clear vinyl tubing to join the 3-inch air stones with the male tubing adapters (1/2 inch mpt x 1/4-inch barb). The airstones should hang about 1 foot from the bottom of the tank.

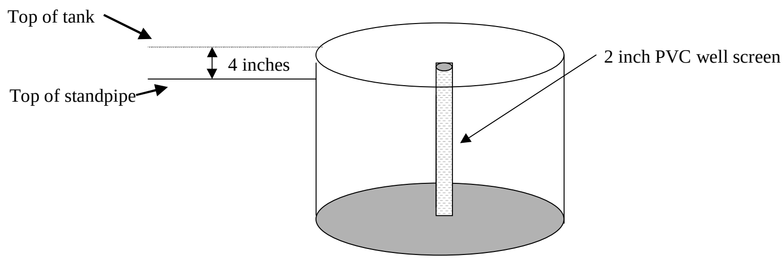
Diagram 7 - Air Line



Tank Standpipes

The 2-inch standpipes that sit inside the tank require holes that will allow all solids and no fish to pass through. A section of PVC well screen works nicely.

Diagram 8 - Relative elevations of standpipe and sleeve



The standpipe should be cut so that it stands at least 4 inches below the tank rim.

Parts List for 880 - System

Parts List - Aquaculture only

PVC primer
PVC glue
teflon paste or tape

Table 1. Estimated cost of tanks, pump and filter.

# Item	Item	$/item	Total Cost ($)
2	3/4 inch 4 x 8 ft plywood boards		
20	8 inch concrete blocks	$1.39	$27.80
2	440 gallon polyethylene tanks	$300.00	$600.00
1	3/4 hp centrifugal pump	$450.00	$450.00
1	> 4 ft^3 bead filter	$1300.00	$1300.00

Table 2. Estimated cost of alternative heating systems.

# Item	Item	$/item	Total Cost ($)
1	8,000-12,000 btu unvented gas radiant heater with thermostat, pilot, thermocouple	$180.00	$180.00
1	>4000 watt electric immersion heater with temperature controller	$690.00	$690.00

Table 3. Estimated cost of PVC piping and fittings.

# Item	Item	$/item	Total Cost ($)
2	2 inch bulkhead fittings (slip x fipt)	$20.00	$40.00
30-40	feet of 2 inch PVC		
< 1	feet of 1 inch PVC		
< 4	feet of 1-1/2 inch PVC		
2	2 inch male adapter (mnpt x slip)	$1.35	$2.70
3	2 inch ball valves	$28.00	$84.00
5	2 inch 90^0 ell (slip x slip)	$4.60	$23.00
5	2 inch tee (slip x slip x slip)	$2.70	$13.50
10?	pipe clamps to support water and air lines	$6.00	$6.00
2	1 ½ -> 2 inch male adapter reducing (mnpt x slip)	$2.90	$5.80
4	2 inch union (slip x slip)	$8.00	$24.00
2	2 inch sweeps (or 90^0 ells) (slip x slip)	$1.50	$3.00
2	2 -> 1 ½ inch reducer bushings (spig x slip)	$1.60	$3.20
2	1 ½ inch gate valves (slip x slip)*	$23.00	$46.00
2	1 1/2 inch 45^0 ells (slip x slip)	$2.00	$4.00

* use high quality gate valves

Table 4. Estimated cost of aeration system.

# Item	Item	$/item	Total Cost ($)
1	1/8 hp regenerative blower	$350.00	$350.00
1	Bleed valve assembly	$20.00	$20.00
1	1 -> 2 inch reducer bushing (spig x slip)	$1.55	$1.55
2	2 inch 90^0 ells (slip x slip)	$2.20	$4.40
1	2 inch cap (slip)	$1.10	$1.10
14	3 inch airstones	$4.00	$56.00
60	Ft 1/2 inch (ID) polytubing	$0.25/ft	$15.00
100	Ft 1/4 inch (ID) clear vinyl tubing	$14.00	$14.00
	POLYTUBING INSERT FITTINGS		
3	½ inch male adaptors (mipt x insert)	$0.50	$0.50
12	½ inch tee (insert x insert x fnpt)	$1.26	$15.12
14	male tubing adaptors (1/2 inch mpt x 1/4 inch barb)	$0.40	$5.60
3	½ inch tee (insert x insert x insert)	$1.13	$3.39

Additional Equipment

2 inch gate valve – this should be used to connect the water supply line to the hydroponic beds. It will allow you to shut down the hydroponics portion of the lab for maintenance.

large scales (for sampling fish) - should weigh up to 50 lbs +/- 1 lbs (approximate cost = $250.00)

small scales (for weighing feed amounts) - should weigh up to 10 lbs +/- 0.01 (approximate cost = $120.00)

aquaculture water quality kits - should contain tests for: alkalinity, ammonia, CO_2, nitrite, pH, temperature (approximate cost = $190.00)

dissolved oxygen meter - expensive, but necessary tool (approximate cost = $650.00)

monitoring/alarm system - invaluable when needed (approximate cost = $400.00 and up)

nets - large (3/4 inch+) and small (1/4 inch) mesh with removable 5 foot handles. Nets should have 12-18 inch bag depths (approximate cost = $150.00 and up)

discharge hose - a hard or soft discharge hose with quick connect fittings will facilitate backwashing the bead filter. Simply hook up one end to the bead filter and put the other end (use a 90^0 ell) in the drain/disposal. The hose can be stored when not in use.

garden hose and submersible pump – these are useful for pumping out tanks or adding fresh makeup water from a water storage tank.

roll-type tubing flow valves for ¼ inch clear vinyl tubing – if you add additional aeration stones to your overhead air supply line (for sampling or holding fish), you will probably need a few of these so you can regulate the flow of air (cost = $3.60 ea).