The Fish Farm™ II Operation Manual

(Part No. FF400)

PENTAIR

AQUATIC ECO-SYSTEMS™

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Contents

Introduction

The Fish Farm II can grow fresh, unpolluted fish throughout the year. Fish are one of the best sources of protein in the animal kingdom, low in both calories and saturated fats. Aquaculture is a fascinating hobby and the Fish Farm II will provide enjoyment for many years.

This guide describes how to grow up to 300 lbs of fish. The Fish Farm II recirculating aquaculture system is designed for both low energy and low water usage. It is a simple and economical system.

Until now, food fish culture has been limited to commercial facilities requiring large quantities of water and expertise. However, as natural water supplies are depleted or polluted, commercial operations are using more complex and expensive bioengineering designs. This modern technology has opened the door for a new approach to fish culture: growing your own fish. The Fish Farm II is a system of backyard fish culture as practical as home gardening for the combined benefits of relaxation, education and food production.

Description of the Fish Farm II

The Fish Farm II is a growing system for fish (as well as other aquatic animals and plants) that uses unique biofiltration and clarification devices that make the reuse, or recirculation, of water possible. The two culture tanks have a capacity of 450 gallons of water and each is capable of supporting up to 150 lbs of fish. Site selection could include a garage, patio or any other surface that can support the weight of 1,000 gallons of water (8,340 lbs), 300 lbs of fish and additional equipment necessary to support the Fish Farm.

Fish Culture Systems

The Fish Farm II is designed to operate with a minimum of technical knowledge. However, just as it is necessary to understand the fundamentals of gardening before attempting to grow your own food, there are fundamentals of fish culture that must be understood before proceeding. This manual will guide you every step of the way.

For fish to remain healthy and to grow at a favorable rate, they must be provided with a suitable environment. The environment is water, and water quality is something with which the beginner in aquaculture should be familiar. Following are ten rules that will help to make your first attempt at raising fish successful.

Operating Guidelines

1. Keep electricity and power cords away from the water. Wear safety glasses and gloves when pouring or handling strong chemicals. Keep chemicals out of children's reach.
2. Keep foreign chemicals away from the Fish Farm II. Insecticides, soaps, oil and grease, cleaning agents and bactericides can either kill fish directly or inhibit the operation of the system to the point that the fish could suffer.
3. Start the Fish Farm II by following the start-up procedures described in this manual under Biofilter Acclimation.
4. Never overfeed the fish. Give them only what they will eat at any one feeding. Uneaten food will place an undue burden on the water cleaning systems, degrade water quality, promote diseases and odors and discolor the water.
5. Make certain that water is always flowing through the clarifier and biofilter (besides cleaning).
6. Clean the clarifier and filter pad every day. The clarifier removes "settleable solids" (which are heavier than the water). If they are not removed daily, they will begin to float in the water (as a result of gas formation during decomposition) and will then pass through the clarifier, adding to the contamination of the water.
7. If ammonia gets too high, reduce it by either exchanging water or using zeolite. See Exchanging Water and Zeolite sections of this manual.
8. If nitrite gets too high, reduce it by exchanging water. If fish are already stressed, add 2 lbs of salt (noniodized) to the water to reduce the toxicity of nitrite. Stop feeding until nitrites are at a safe level. See Nitrite section.
9. Monitor and chart water quality daily (see Evaluation of Water Quality section for details). By charting, you will be able to foresee and thereby avoid problems. An example chart is found in Appendix A.
10. If there is a problem, call Aquatic Eco-Systems for guidance.

Chapter 1

Water Quality

Evaluation of Water Quality

Fish farmers should have some means of evaluating water quality in order to be aware of the health of the fish culture system. Water quality analysis kits are popular for this purpose because they are relatively inexpensive. Also, they provide cookbook-like directions, so little knowledge of chemistry is required. Test kits provide an adequate level of accuracy and reliability for most fish culture.

Because it is necessary to replace the reagents in these kits as they are used, it may be more economical to purchase a meter when large quantities of measurements are to be taken. Initially, meters are more expensive, but they are fast and convenient.

Water Quality Parameters

Temperature

One of the primary factors affecting fish growth is the temperature of the water in which they are cultured. For each species of fish, there is a wide temperature range that they tolerate and a smaller optimum temperature range for their optimum growth. In order to achieve the fastest and most efficient conversion of fish food to fish weight, the water temperature must be kept as close to this optimum value as possible (see Chapter 3).

Commercial aquaculture operations, because they use large quantities of water, must restrict their species choice to fish that grow well at the temperatures naturally occurring at their location. For instance, only operations with an abundant source of cool water grow trout. Catfish farmers (using outdoor ponds) are confined to geographic areas where the water remains warm enough for an adequate season of growth.

With recirculating tank culture, as in the Fish Farm II, temperature control is much more plausible. Recirculating culture systems reduce the quantity of heat (or cold) needed, as the heat can be conserved with insulation and very little new water is needed. It is recommended that the system be placed indoors where water temperature can be maintained more easily. Outdoors, season length is determined by the geographic location and the use of a cover. Solar energy can be collected to extend warm-water culture. A water chiller may be used to cool the water.

Oxygen

Oxygen is as necessary to fish as it is to us. However, oxygen is not as abundant in water as it is in air. The air we breathe is about 20% oxygen. The air in the water that fish breathe is only about .0001% oxygen. Very often, oxygen availability is one of the limiting factors to fish growth and survival. Oxygen (we'll refer to it as D.O., which stands for dissolved oxygen) enters the water in various ways, depending upon the body of water involved. In natural systems such as lakes and rivers, oxygen is provided mostly by absorption of oxygen from the air. Oxygen can also be added in significant amounts by plants and algae through photosynthesis (during nighttime hours, however, algae and plants will consume oxygen).

As the total weight of the fish increases, so does the amount of oxygen needed to sustain them. Without continual replenishment, the D.O. level becomes depleted, possibly resulting in a high degree of stress or asphyxiation of the fish. Some species have greater tolerance to low D.O. levels than others, but continued low levels stress the fish, resulting in less efficient food conversion and greater susceptibility to diseases. Frequent monitoring of D.O. is usually not as necessary in the Fish Farm II as it would be in pond culture, because continuous aeration is provided by an energy-efficient linear compressor. Compressed air is delivered to air diffusers, which produce small bubbles that add oxygen and remove carbon dioxide while circulating the water. If the oxygen level becomes low, stop feeding until it comes back up. (See Water Quality Tolerance chart.)

Chlorine

Chlorine kills fish and must be eliminated from water before adding fish. When filling the tank initially, add sodium thiosulfate (included) to the water. This will neutralize the chlorine. Also, when filling, it is best to spray the water in as this helps to degas. When refilling the clarifier, spraying the water in will degas it sufficiently because it is a small amount of water. (See Appendix F: Sodium Thiosulfate.)

Algae

Crystal clear water does not necessarily constitute good water quality. Some species prefer and may even require water green with algae. Trout production systems require clear water, but most outdoor fish culture systems are more likely to contain green water. Algae can have both positive and negative effects, but properly managed, a healthy algae population can offer some advantages. The Fish Farm II will operate equally well on both clear water and green water.

On a sunny day, the algae is capable of producing a large quantity of oxygen (through photosynthesis), while consuming carbon dioxide and ammonia. Algae uses both ammonia and nitrate as a food source, so their growth improves the water quality for the fish. When the algae is eaten by the fish (such as tilapia), these waste products become fish food. If not managed, however, algae can be dangerous. With the high levels of nutrients in a recirculating system, the algae population can become very thick (sometimes called an algae bloom). A "die-off" of such a large population of algae is where the problem comes in. Dead algae are fed upon by bacteria, which consume large quantities of oxygen, while producing ammonia. This additional ammonia can overload the biofilter, as it had been acclimated to low ammonia levels when the algae were alive.

The Fish Farm II provides good control of the algal community through mixing, aeration and clarification. As fish production levels increase during the early part of the season, the green algae become more abundant. The natural life/death cycle for algae is evenly spaced, and only a partial die-off takes place at any one time. Dead or unhealthy algae cells lump together and, if not removed in some way, they settle to the bottom of the tank and begin to decompose. The Fish Farm II sediment pick-up and clarifier system removes these clumps of dead cells, leaving the healthy, small, green algae to move through the system.

Nitrogenous Compounds

Nitrogen occurs in several forms in recirculating fish culture systems. Two of these, ammonia (NH_3) and nitrite (NO_2-) are toxic to fish and must be carefully monitored and controlled. This is especially important during start-up of the biofilter; during periods of maximum stocking densities; and in the event of some disruption of the system, such as disease, overfeeding or after a mechanical breakdown of the system. The third form of nitrogen, nitrate, is not toxic to fish. The Fish Farm II biofilter is designed to convert the ammonia produced by the fish into harmless nitrate.

Ammonia

Ammonia is probably the most important water quality parameter that needs to be monitored in the Fish Farm II (see Chapter 2, Acclimation of the Biofilter). Ammonia builds up in a fish culture system as a by-product of fish metabolism. The protein in the fish food is converted to both fish flesh and ammonia. In most aquaculture facilities, metabolites are controlled by varying the stocking and feeding rates or by adjusting the amount of water exchange. In a natural body of water, such as a pond, ammonia produced by the relatively small fish population is diluted by the water and is ultimately consumed by algae and other plants.

In the more densely populated situation of a recirculating system, ammonia can be partially removed by the algal population (in well-lighted situations), but high production levels require a biological filter (see the Water Quality Tolerance chart for safe levels of ammonia for each species).

Even though pH is not as critical as some other factors, it is extremely important to measure and take it into consideration when determining the toxicity of ammonia. The higher the pH, the more toxic the ammonia. Ammonia in water occurs in two states: ionized (NH_4+) and un-ionized (NH_3). It is un-ionized ammonia that is toxic to fish. The proportion of un-ionized ammonia in water is directly related to the pH and the temperature of the water. The higher the pH, the higher the proportion of toxic NH_3.

The following chart illustrates the relationship of the ammonia equilibrium as a function of pH and temperature. Most water quality tests for ammonia-nitrogen provide a value for the total ammonia (NH_3 + NH_4+) present. If the pH and temperature of the water are known, this chart will give the actual percentage of toxic (un-ionized) ammonia.

The Water Quality Tolerance chart uses un-ionized ammonia, so reference to this chart is always required when testing for ammonia. To determine toxic levels, measure total ammonia, pH and temperature of the fish culture water. Find the percentage of toxic ammonia at the measured pH and temperature from the chart. Move the decimal of the percentage two places to the left and multiply this value by the value measured for total ammonia.

Example:

Fish Farm II water is measured at pH 8.0 and temperature 86ºF. The chart indicates that 8% of the total ammonia levels is the toxic NH_3. If total ammonia levels are measured at .18 ppm, the un-ionized portion is .18 x .08 = .014 ppm. If the toxicity of the un-ionized ammonia (NH_3) is considered detrimental at levels above .03 ppm (for your species) then .014 should not be dangerous to the fish.

The biofilter produces acid as it removes the ammonia, so the pH of your culture water should drop throughout the production cycle. When the pH drops below the desired level, add sodium bicarbonate to return the pH to the desired level.

Percentage of Un-Ionized Ammonia in Water at Different pH Levels & Temperatures

Temp	Temp	pH							
(°F)	(°C)	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5
50	10	0.02	0.1	0.2	0.6	2	6	16	37
59	15	0.03	0.1	0.3	0.9	3	8	22	46
68	20	0.04	0.2	0.4	1	4	11	28	56
77	25	0.06	0.2	0.6	2	5	15	36	64
86	30	0.1	0.3	0.8	3	8	20	45	72

Example:

The ammonia test kit has indicated that the ammonia level is 1 ppm. The pH kit measures 7.0 and the water temperature is 68ºF. Multiply the ammonia measured (1 ppm in this example) by the percentage shown on the chart (.4% in this example) 1 x .004 = .004 ppm un-ionized ammonia. Remember that the bold numbers on the chart are percentages, so the decimal must be moved two places to the left in all calculations.

Nitrite

Nitrite could be the second most important parameter to monitor, especially while acclimating the biofilter. Nitrite (NO_2-) is the intermediate product of biological nitrification resulting from the oxidation of ammonia by *Nitrosomonas* bacteria. Nitrite may sometimes reach toxic levels during the early stages of filter acclimation or following overfeeding. Nitrites are absorbed through the fish gills and interfere with their ability to absorb oxygen. Fish affected by high nitrite levels appear to suffer from oxygen depletion. The toxicity of nitrite can be reduced by adding 2 lbs of noniodized salt (included) to the Fish Farm II water. In a properly functioning system, nitrite should not be present at toxic levels. The nitrite is oxidized by *Nitrobacter* bacteria, also growing on the biofilter, and changed to nitrate (NO_3-), which is not toxic to fish. If potentially toxic nitrite levels do not start coming down after two days, begin water exchange and/or add salt as described above.

Nitrate

Since nitrate is not toxic to fish even in high concentrations, it is a relatively safe end product of nitrification and can be allowed to accumulate in the Fish Farm's water. When the Fish Farm is located where it receives sunlight, nitrate becomes a nutrient source for the algal population. In combination with algae-eating fish, this provides for an efficient recycling of nitrogen, with the original waste from the fish converted into a food source.

pH

Technically, the pH of water is a measure of its hydrogen ion (H+) concentration. In general, water with a pH less than 7 is called acidic and with a pH greater than 7, basic. A pH of 7 is neutral. Fish can tolerate a fairly wide range of pH, but optimum values are usually from 7.0 to 7.6 (see Water Quality Tolerance chart). pH can be raised using sodium bicarbonate (50 lbs is supplied with the Fish Farm II). It can be lowered by the addition of hydrochloric acid (also known as muriatic acid), but the water may need to be buffered by the addition of sodium bicarbonate first, if the alkalinity is too low. Change pH levels slowly. Do not change more than 0.2 pH units per hour, or more than 1.0 units in 24 hours. (See Water Quality Tolerance chart and Sodium Bicarbonate in Appendix.)

Alkalinity

Alkalinity is a measure of the quantity of compounds that shift the pH to the alkaline side (above 7) of neutrality. This measure is mostly influenced by bicarbonates, carbonates and hydroxides, and less frequently by borate, silicate and phosphates. Alkalinity is important to the fish farmer because it buffers (slows rate of reaction) pH changes that occur naturally during photosynthetic cycles and pH changes that are caused by other factors, such as the addition of acid. For most fish species, total alkalinity should range between 50–200 ppm $CaCO_3$. Alkalinity can be increased by the addition of sodium bicarbonate (see Sodium Bicarbonate in Appendix E).

Hardness

Hardness is a measure of dissolved metallic ions and is commonly measured in mg/L (ppm) or grains per gallon (multiply grains per gallon x 14.2 to get ppm). Typically, calcium and magnesium dominate the ion concentration but iron, strontium and manganese ions can also be found. Since bicarbonates generally are measured as alkalinity, the hardness (carbonate hardness) usually is considered equal to the alkalinity; therefore, hardness should also range between 50–200 ppm $CaCO_3$. Hardness and alkalinity can be used interchangeably in some cases; however, in other situations they are not at all the same, so be aware of the difference when doing chemical analysis.

Clarification

As control of ammonia and nitrite is achieved, fish production increases. However, this in turn leads to increased feeding levels and increased solid waste material within the system. The control of these suspended (particles that do not sink) and settleable (particles that will sink if given time) organic waste materials is as important to the health of the fish as the control of the parameters discussed previously. It has been demonstrated that in small-scale recirculating systems, without a means of effectively removing suspended organic material, production capacity is severely limited.

The solids in a fish culture system are comprised of fecal wastes, uneaten food, fines (dust material from the food too small to be eaten) and, in outdoor systems, dead algae. Their concentration, both in the water and on the tank bottom, can affect the health of the fish and the carrying capacity of the system. Through bacterial decomposition of this organic material, oxygen levels decrease and secondary ammonia levels increase. Increased turbidity reduces light penetration and, in a system with algae, decreases the oxygen made available through photosynthesis. The suspended solids in the water can also directly affect the fish through gill damage, as well as by reducing their ability to locate the food.

The Fish Farm II uses a unique clarified resigned for its effectiveness, ease of maintenance and low energy requirements. This system provides stable water quality conditions and good dissolved oxygen levels, and helps maintain the health of the fish. The Fish Farm II clarifier and filter pad should be cleaned daily.

Biofiltration

A recirculating aquaculture system is very dependent on its water cleansing systems. In the Fish Farm II, solid waste (particulates) is removed by sedimentation and filtration, which takes place in the clarifier. The liquid waste (dissolved) is removed by bacteria growing on the surfaces of the biofilter packing (Kaldnes® media), as well as all other submerged surfaces.

Plants and algae may be present if the Fish Farm II is in a well-lighted location. Plants and algae will also remove liquid waste.

Biofiltration is a natural, two-step process that changes ammonia first to nitrites and then to harmless nitrates. The process is performed by two species of nitrifying bacteria (*Nitrosomonas* and *Nitrobacter*), which are found naturally in the soil, air and water. These bacteria attach themselves to solid surfaces, forming what feels like a slime.

In the Fish Farm II, ammonia builds up more quickly than it can be removed by the algal population. More of the nitrifying bacteria are needed to remove ammonia than are naturally supported on the surface areas of the tank. The biofiltering system provides greatly increased surface area to support a large, active population of bacteria.

Water Exchange

Water should be sprayed or aerated when filling the culture tanks. This allows the chlorine to bubble off as a gas. If the water supply is from a municipal system, it will contain chlorine. If the water supply contains chlorine, add sodium thiosulfate if animals will be placed in the tanks within 24 hours of filling (see Appendix F). Chlorine may also be removed by allowing the system to run for 24 hours.

When adding small amounts of water while cleaning the suspended solids filter or the clarifier, dechlorinate the water beforehand. When cleaning the filter, the 15 gallons of water removed must be dechlorinated and replaced after cleaning. Be sure that the water is dechlorinated before adding to the system. When cleaning the clarifier, make sure that the 10 gallons of replacement water is dechlorinated before adding it to the system.

Zeolite

Ammonia can also be removed from water through the use of zeolite, also known as clinoptilolite. Like activated carbon, zeolite can also remove color and organic matter.

Some recirculating fish culture systems have been built to use zeolite in place of a biological filter but, commonly, zeolite is used to augment the biofilter during periods of acclimation, recovery or overload. Keep some on hand as an alternate to a water exchange for ammonia reduction. To expand the Fish Farm II growing capacity well beyond the capacity of the biofilter, use zeolite to control ammonia levels and/or exchange water.

Zeolite traps ammonia in its pores. When all pores are filled, it must be replaced or recharged. One gram of zeolite will trap up to 3 mg of ammonia (total ammonia). To remove one mg/L (ppm) of ammonia from the Fish Farm II, a minimum of one kilogram (2.2 lbs) of zeolite is needed (10 lbs is included with system).

Zeolite may be used in conjunction with chloramine neutralizer to eliminate ammonia after it is freed from its bond with chlorine. The amount of zeolite to use (and its frequency) will be determined by the brand of zeolite, the particle size and the number of times it has been recharged.

Circulation of water through the zeolite is required for the ammonia to come in contact with the microscopic trapping pores. We recommend that mesh bags of zeolite be hung from the tank walls.

Recharge the zeolite by submerging it in a salt solution, 45 ppt or greater (one gallon of water with 1/2 lb salt works well) for about 8 hours. Rinse with fresh water, then reuse (be careful not to pour waste salt water on intolerant plants). Another recharge method is air drying for several days, preferably in a warm, dry climate. The effectiveness of recharging diminishes approximately 10% per recharge cycle.

Summary

While all of the information provided in this introductory chapter may seem overwhelming for beginners, the actual management of the Fish Farm II is relatively simple. For instance, by correctly following the procedures outlined in Chapter 2, water quality remains acceptable throughout the season. A careful feeding schedule results in rapid and efficient fish growth. Choosing the correct species of fish provides the least expensive and most productive harvest possible.

While experience is the best teacher for making these management decisions, the following step-by-step instructions provide a safe and effective method for obtaining a profitable harvest from the very first year.

Chapter 2

Operation and Maintenance

As described in Chapter 1, the Fish Farm II is a complex living system with interacting physical, chemical and biological variables. No matter how carefully monitored and controlled, unforeseen problems can always occur. Management requirements for the Fish Farm II have been greatly reduced through its almost foolproof design to reduce the possibility of a catastrophe (see Maintenance).

Fish Farm II Components

Fish Culture Tanks

Each polyethylene tank holds sufficient water to grow a population of fish whose total weight can be as high as 150 lbs. The tanks are adapted for integration with other system components to provide for necessary water quality control. The tanks should be located on a solid, flat surface with a minimum of bumps and protrusions. A floor that will support 180 lbs per square foot or 1.25 lbs per square inch is acceptable. Both tanks must be installed at the same height, so that the water will be of equal depth in each tank. If one tank is situated higher than the other, they will have an unequal depth of water and the system will not operate properly.

Heavier solids exit the tanks through the drains (see Figure 8). As water and heavier solids leave the tanks, they flow through the smaller of the two pipes and through an isolation valve to the clear tubing at the clarifier. Total flow through the clarifier from each tank should be about 3 gallons per minute. At this slow rate, solids are given time to settle at the bottom of the clarifier. A pre-filter pad is located at the weir to catch any floating debris. Water exiting the clarifier is mixed with water exiting the biofilter (see Figure 1) and returned to either tank through isolation valves and lines to their respective airlifts.

The suspended solids leave the tanks through the standpipes (see Figure 7) and travel through the larger of the two lines and associated isolation valves to the bottom of the suspended solids filter. Water enters the filter through the standpipe and the filtering process begins. Water and suspended solids travel to a series of filter pads (see Figure 3) at the bottom of the tank and the solids are deposited on the pads. The filtered water exits through the three-position ball valve at the bottom of the tank to the biofilter. Diffusers circulate the cleaned water from the suspended solids filter inside the biofilter (see Figure 5). The bacteria in the biofilter convert ammonia to nitrates. Over time, these small pieces of media will change color from a bright white to a dirty white as the bacteria establish themselves.

The treated water exits the biofilter and is mixed with water that has exited the clarifier. The water then enters a common line and is returned to both tanks via the airlifts.

Biological Filter

The biofilter is prebuilt for ease of installation and provides the necessary surface area for the growth of nitrifying bacteria. These bacteria work more effectively at temperatures above 55ºF. Once in position, all that is necessary is to start the air compressor, and the filter will begin to flow with water. However, before it can function properly, the filter must go through a period of acclimation. This means that a bacterial population must grow to a sufficient size on the filter media (initially it is a slimy film, eventually building to a thick, brown slime). After proper acclimation, it will be possible to follow the filtration process using water quality tests for ammonia, nitrites and nitrates. It may take up to 8 weeks to establish a healthy bacteria population. In Chapter 2, we describe how to pre-acclimate your filter so that it is actively working even before fish are added to the system.

Clarifier

The clarifier moves settleable wastes from the water and returns clarified water to the tank by means of an airlift. The water returns free of the settleable solids and lower in dissolved nutrients. The clarifier is cleaned daily to remove the settled wastes. A filter pad is used to "magnetically" attract and remove other nonsettleable particles before they pass into the biofilter.

Suspended Solids Filter

The purpose of this filter is to remove fine particles of uneaten food, dust and other waste. It is designed to handle 80% of the water flow through the system.

Aeration System

Because of its innovative design, the Fish Farm II can utilize a very low-energy air compressor to provide the pumping, biofilter and aeration functions of the system. The output of the air pump is routed to the air manifold and distributed to the airlifts and diffusers throughout the system. Water and air are mixed in the airlifts, resulting in a lifting effect that circulates and drives the water through the filtering system and returns it to the tanks. The diffusers provide oxygenated air to the tanks and the bacteria.

Management of the Fish Farm II

The Fish Farm II is designed to maintain water quality for the production of up to 300 lbs of fish. The limiting factor in achieving this production level is the time given to the fish, optimal temperatures for their growth and management of the input of feed.

The most important defense against mishap, and the greatest assurance for the fast and efficient growth of the fish, is careful management of water quality within the system. This requires a thorough understanding of the system and its everyday health. How are the fish eating? Is there a healthy algal bloom? Are the filter and clarifier working properly? Most importantly, is fish feed being added in the proper amounts?

This chapter provides the guidelines for daily, weekly and seasonal management practices. As increased levels of fish are produced, the culturist must accommodate new pressures on the system, changing feed rates, checking on oxygen levels at different times of the day and carefully monitoring the system for ammonia and nitrite levels.

Testing the Water Source

The first step in preparation for fish culture is determining the suitability of available water sources. Surface waters such as streams, ponds or lakes should be avoided, since they can introduce disease organisms; however, if known to be free of such pathogens, as well as the other environmental contaminants, it is possible to use such water sources.

On the other hand, any potable water (drinking water) source is usable, since so little water is replaced in the system. It is possible to precondition even chlorinated city water in a separate container by aeration or by adding sodium thiosulfate (included) to rid the water of chlorine. By aerating water for 24 hours, chlorine is removed and temperatures are brought up to the ambient levels in the tank. It is important to remember that aeration alone will not rid chloramines from the water and the sodium thiosulfate should be used as prescribed (see Appendix F).

The pH of the water should be between 6.5 and 8.5. Take the pH reading after aerating the water, as it may change. The action of the biofilter will tend to bring the pH down over the course of the production cycle. To acclimate the biofilter initially, when the pH is too high, use pH Down liquid, or muriatic acid poured slowly into the airlift side of the clarifier. Be very careful when pouring acid. Always use eye protection against splashing. If any acid splashes on skin or clothing, rinse immediately with water.

Levels of oxygen may be very low in the water put into the tank, but the Fish Farm II aeration system will quickly raise it up to the required levels.

If the Fish Farm II is filled from a good source of water, there should not be any PCBs, heavy metals, herbicides, pesticides or other contaminants in the water used for fish culture. Insecticides (bug spray, etc.) can be very toxic to fish even in very low levels.

Biofilter Acclimation

The biofilter must be acclimated with the necessary bacteria before it will function properly. A clean, new filter, or one that has been dry for any length of time, will not remove ammonia from the water. A population of nitrifying bacteria must be cultured before the fish can be cultured.

One way to acclimate the filter is to stock low densities of fish, and feed them small amounts of feed. The little ammonia that is produced acclimates the biofilter slowly without harming the fish. After the filter is seen to be changing the ammonia to nitrates, increasingly more fish and/or feed can be added.

The bacteria (*Nitrosomonas* and *Nitrobacter*) that accumulate on the filter are present naturally in the air and in the water of the culture system. However, in order to acclimate the filter quickly, the bacteria should be introduced from sources where they are found in higher concentrations. This is called "seeding" the biofilter.

A concentrated population of the nitrifying bacteria (Bacta-Pur®) is included with the Fish Farm II and will insure that the bacteria are present for the acclimation of the biofilter. Also, previously acclimated filters (such as aquarium filters), or the soil or sediments from a shallow pond area, are good sources of *Nitrosomonas* and *Nitrobacter*. If soil is used, it must be free of pesticide or herbicide residues. If pond sediment is used, it should be removed from a clean, well-oxygenated pond. The substrate is then placed into a fine-mesh cloth sack and hung in the fish culture tank.

In order for the seeded bacteria to multiply and colonize the biofilter, they must be supplied with ammonia. If the tank is not to be partially stocked at this time, small quantities of household ammonia (non-detergent) can be added to the water in the culture system. This creates a situation similar to that caused by feeding a small population of fish. When total ammonia concentrations rise above 2 ppm, the *Nitrosomonas* population will increase. Periodic checks with an ammonia test kit show that simple aeration and evaporation dilute the ammonia concentration over time. Add ammonia to keep the concentration above 2 ppm.

As *Nitrosomonas* bacteria grow on the filter, they change some of the ammonia (NH_3) into nitrites (NO_2). This can be observed with a nitrite test kit. As the concentration of nitrites begins to increase, the filter is halfway acclimated. The presence of nitrites stimulates the reproduction and buildup of *Nitrobacter* on the filter plates.

Nitrites are changed into nitrates (NO_3) by the *Nitrobacter* bacteria. Watch the nitrite levels carefully. When the nitrites are removed as fast as they are produced and concentrations have dropped to less than 0.5 ppm, the filter is acclimated and fish can be stocked safely. If ammonia is added at this time, it should very quickly disappear from the culture water, with nitrates as the end result. In outdoor situations, as nitrates accumulate in the system, the water in the tank may begin to turn green with algae. This is a good sign and signals the readiness of the tank to accommodate fish. Heavier concentrations of algae may not appear until the fish population is stocked and growing.

Aeration

The compressor will provide the necessary flow of air, directed to the airstones, which are placed in position on the tank wall near the bottom of the tank. Depending upon the pH of the water, it is possible that airstones will need cleaning every six months. This can be done by soaking the airstones in muriatic acid for a couple of hours. Always use caution when using acid and wash hands thoroughly when finished.

Clarifier

It is very important to correctly establish the siphoning and airlift pumping systems, to provide for the flow of water into the clarifier and back into the culture tank. If the clarifier is not cleaned, the waste will start to break down and can possibly float over the weir and into the biofilter, causing an adverse effect on the water quality.

Fish Transfer

Note: If ammonia is used to acclimate the biofilter, fish should not be added to the Fish Farm II until the ammonia and nitrites have been reduced to safe levels by the biofilter. The fish may be delivered in oxygen-charged bags of water. Problems can arise during the fish-acclimation procedure when the fish are released from the bags too quickly. Usually this is due to thermal shock from differing temperatures. If the temperature difference is more than 10ºF, it is best to float the bags in the water for an hour, allowing the temperatures to equalize. Open the bags and add small amounts of the Fish Farm II water to the bagged fish over a period of about 10 minutes. This will slowly condition the fish to the varying chemical conditions (especially the pH) of their new environment. The fish can then be released into the tank. They should quickly become comfortable in the tank and begin to take food within 24 hours.

Feeding

Fish Foods

Feed costs are the single greatest expense in raising fish. When possible, this expenditure should be reduced by utilizing those species of fish whose nutritional requirements are easily met because they feed low on the food chain. These may include such examples as carp (an omnivorous fish that efficiently converts many forms of feeds) and tilapia (an herbivorous fish that eats algae and several forms of vegetation). However, in most situations at least some commercial feed is necessary for optimum feed conversion. The proportion of food needed to produce a corresponding fish weight is usually expressed as a ratio, such as 1.2:1 (1.2 lbs of food are required to raise the weight of fish by one lb).

Many years of nutritional research to determine the requirements of trout, salmon and catfish have resulted in the development of commercially available feeds. These rations provide the necessary proportions of protein, carbohydrates, fat, minerals and vitamin levels for that species of fish. Other fish species may accept these foods, but their nutritional requirements may not be met completely. Therefore, try to use the best feeds available for your species.

Feeding Techniques

An accurate determination of the amount of food to add to a closed culture system is critical. Underfeeding results in poor growth and overfeeding can have devastating results on water quality.

To estimate the proper amount of feed to offer, several parameters must be considered. Most important is an accurate estimate of the "standing crop," which is the weight of live fish present in the culture system. Depending upon the nutritional quality of the feed, the amount to add can be determined by taking a percentage of this standing crop. Under proper conditions of temperature and good water quality, fish consume at least 3% of their body weight daily. A method for determining the proper feed weight is described in Chapter 2.

Some species feed best at a certain time of day or night. Research the habits of the species being raised.

Example:

The standing crop has been determined to be a total of 10 lbs (4.5 kg) of fish that need to be fed six times daily:

1. The proper feeding rate has been determined to be 5% of body weight per day (5% of 10 lbs is 0.5 lbs (227 grams).
2. Divide the 0.5 lbs (227 grams) of food into six portions. Feed all six portions in 24 hours, trying to feed at those times of the day when feeding is most active.
3. After finding the best feeding times, use an automatic feeder, set to dispense the proper amounts at the proper times. Note: A demand feeder (one which allows the fish to feed themselves) may not be a good choice for use with the Fish Farm II, because fish will often "play" with it, resulting in overfeeding, wasting feed or polluting the water.
4. At least once a day, observe the fish while they feed. If they become sick, it will show up as a reduction in feeding activity. Reduce the amount of feed whenever they are not eating it.
5. Larger and more aggressive fish will outcompete the smaller and more timid fish for food. See that all the fish have an opportunity to eat.

When the fish are stocked, their weight can be obtained directly. This can be done by placing all or some of the fish in a bucket of water, whose weight was predetermined. The additional weight of the fish is obtained by subtracting the weight of the water without the fish. Once the weight is known, feeding should commence at a level of 3% daily. With fingerlings, levels as high as 6% can be given, if it is known for certain that the biofilter is properly acclimated. This is determined by frequent testing of the water for ammonia and nitrite in the first few weeks of feeding.

Since the fish are constantly growing, a re-estimate of the fish and new feed weights must be made weekly. Sampling the population could provide an accurate idea of the growth of the fish, but this can be stressful and may put the fish off feed for a period of time.

A theoretical determination of the growth can be made by assuming that the fish are converting the fish food into fish weight at a particular rate. This "feed conversion" value is usually estimated to average around 1.5:1. This means that 1.5 lbs of feed will result in the growth of one lb of fish. Many fish, especially tilapia, will do better than this, but it is better to underestimate growth than to overfeed the system. One or two samples over the growth cycle will serve to provide a correction for any variation of growth due to estimations.

Formula for Determination of Feed Conversion:

$$S = \frac{\text{Feed added (lbs)}}{\text{Net fish production (lbs)}}$$

By using the following formulas, it will be possible to readjust the feed weights on a weekly basis:

Fish weight x 3% (.03) = Feed weight
Feed weight x Feeding days per week = Weekly feed weight
Weekly feed weight/1.5 = Net fish production
Net fish production + Previous week's fish weight = New fish weight

Feed Management

By observing the feeding behavior, it can be decided whether the correct amount of feed is being provided by the above method. Floating feed pellets can be a great management tool by clearly demonstrating the feeding levels of the fish. The feed should be added to the tank several times a day if possible, so that the fish can eat it over the entire light cycle. If this is not possible, it is even more important to use a floating feed that will not be removed by the clarifier siphon.

If there is feed floating at the end of the day, the fish are being fed too much, and the amount should be reduced. If the fish are consuming all of the rations within minutes of its being added, it is recommended to provide more feed, while carefully watching that the water quality is remaining good.

As the standing crop of fish increases to levels near the holding capacity of the system (50 lbs) or if water quality conditions deteriorate (high or low temperatures, high ammonia or low oxygen levels), it may be better to reduce feed and continue culturing rather than harvest the fish. Or, if any differential growth occurred, there may be fish of harvestable size to remove, allowing for continued growth of the remaining stocks.

The normal feeding routine involves a 3% feeding for 6 or 7 days each week. A day without feed, especially when the standing crop is large, is often very helpful to the overall health of the system. There may be a "slingshot effect" if feeding is resumed at higher levels than the previous week, after giving the system a day or more without feed. Ammonia levels could shoot up for a day or two before the filter re-acclimates at the higher feeding levels. In these cases, it is often helpful to either use a lower daily feed percentage or gradually increase the feed percentage through the week. For instance, after not feeding on Sunday, feed 1% on Monday, 2% on Tuesday and 3 or 4% for the remainder of the week.

With such alternative feeding regimes, as food weight increases to very high daily levels, ammonia production should increase more steadily, rather than erratically. By this time the fish are quite large and should be receiving a lower daily percentage of feed. Through proper management of the feed level and feeding methods, it will be possible to maximize the growth of the fish and use as much of the system capacity as possible.

Maintenance and Cleaning

Feeding

The most obvious daily maintenance requirement of the Fish Farm is the feeding of the fish. The feed weight for the week should be computed and the ration weighed out. When the fish are small, they may receive up to 6% of their body weight; when they reach 1/4 to 1/3 lb, this should be reduced to 2–3% per day.

The daily feed weight should be added in 2 or 3 feedings to increase the growth rates of the fish and to provide for more efficient water quality maintenance by the biofilter, clarifier and aeration systems.

Water Quality

Initially, it is necessary to watch ammonia and nitrite levels very carefully. If the filter is properly acclimated, the levels should remain low as feeding commences. If the levels rise above that shown in the Species Tolerance chart, feeding should be discontinued until they come back down. Temperature and oxygen levels should be noted frequently in the first two or three weeks of growth as well. As the fish, the system and management techniques become harmonized, these parameters need only be checked 1 or 2 times a week until production levels are much higher.

As feeding levels increase to over 12 ounces (340 g) per day, the frequency of water quality checks should be increased. Dissolved oxygen levels, in particular, provide an accurate determination of the success of your feed management techniques, and the pressure being exerted on all of the system components. Usually, unless acute problems occur that require immediate measures to save the fish, an adjustment of feed weights will rectify any problem that is occurring with water quality.

We suggest that a thorough record of feeding, temperature, oxygen, ammonia, pH and nitrite levels be kept. It is usually possible to see problems beginning to occur well before they become threatening to the fish. An example log is provided in Appendix A of this manual. You can make your own logbook or make copies of this one.

Clarifier Cleaning

It may be necessary to increase the frequency of the cleaning process as feed levels increase, or as algal blooms tend to increase or die off. In general, the clarifier and its filter pad should be cleaned at least every 24 hours (see Chapter 3 for cleaning procedure).

Harvesting

As long as the water temperature within the Fish Farm II remains within the optimal levels for the growth of the fish species being raised, and the capacity of the system has not been reached, feeding and growth of the fish can continue. After temperatures drop below optimal, feed will be wasted if continually added, since the fish will convert it less and less efficiently.

Also, as temperatures drop, the filter does not function as well, and the algal population is less healthy. During the later portion of the growing season in temperate climates, the temperature may fluctuate a great deal, unless some form of covering is applied to the tank.

After the feed levels are at their maximum for daily input without causing water quality problems, it is possible to continue for a period without increasing these levels. The fish will continue to grow and possibly exceed the system capacity. Once the feeding is discontinued, harvest operations can proceed.

There may be some concern about off-flavor from such intensive culture of fish. This can arise from the existence of some blue-green algae species as well as a certain species of bacteria that can grow on the walls of the tanks. If this occurs, it is best to hold the fish in clean water for a few days. This will remove the off-flavor, and the fish will be ready to eat. Because of this possibility, it is imperative to understand the importance of keeping the system as clean as possible at all times. Keeping the system very clean is important not only for controlling the off-flavor problem, but also so that the fish are not allowed to deteriorate. If emphasis is given to periodically scrubbing the liner and keeping the pipes and clarifier clean, no such problem should occur.

In some cases, all of the fish will be removed at one time for processing and, possibly, freezing. Holding facilities and ice should be on hand and processing should occur immediately following harvest.

If fish are to be kept alive, a secondary holding tank is handy. The Fish Farm II can be used after harvest to continue to hold fish, even at sub-optimal temperatures, so that fresh harvests can be made. If temperatures remain above 55ºF, or if the system is inside, it is possible to continue to remove the fish until the system is to be restocked. As they are removed, it is possible to resume feeding, even at reduced levels, to minimize weight loss.

Chapter 3

Fish Species

Fish Species Used in Small-Scale Systems

Species Selection

A choice must be made concerning the type, size and number of fish to be stocked in the Fish Farm II. The different species of fingerlings available at startup is likely to influence this decision. Do not acquire the fingerling fish before the system is ready. The *Buyers' Guide*, published annually by *Aquaculture Magazine*, lists distributors for several varieties of fish. Local or state aquaculture extension agents should be able to provide a local source of fingerlings.

In order to determine the number of fish needed to start, decide how many lbs of fish you want to harvest at the end of the season. For example, assuming each fish grows to about a one-lb size, it may be advisable to stock only 50 the first season. This will result in something less than 50 lbs of production (assuming few will die or be eaten by the others) and will provide an opportunity to learn management techniques with a wider margin for error.

We recommend using fingerlings between 2" to 3" in length. This size fingerling can reach a harvestable size in 6 months. However, everyone's situation is different. Sometimes, smaller, less expensive fish fry can be obtained. The shipping cost would be reduced; however, it will take up to 2 more months of growth to produce harvestable-sized fish. If the warm water season is short, the fish may be too small to harvest at the end. Larger fingerlings maybe more expensive initially, and more difficult to ship, but the increased harvest size could more than pay for the added expense and inconvenience.

The environmental characteristics of the aquaculture system determine the type of fish (warm or cold water species) to be raised. The most important consideration is water temperature. Temperature may be most easily controlled indoors, since climate throughout the growing season must be considered for outside systems. In addition, the tolerance of the fish to stress and water quality are important considerations.

Many of the warmwater fish species have the greatest potential for recirculating systems. These fish are capable of more efficient food conversion and may accept less expensive supplementary or substitute feeds, such as algae, detritus or aquatic vegetation. The following describes a few of the species that may be considered in this category, and some of their qualities.

Tilapia

The earliest record of man harvesting a cultured fish exists as a frieze on an Egyptian tomb dated 2,500 B.C. The fish depicted is a tilapia and, since that time, species of this family of fish have become the most widely cultured in the world. From its origins in the near East and Africa, tilapia has been introduced into Japan, Russia, India, Europe, Latin America, South America and the United States. Because they are easy to breed and tolerate a wide range of water quality conditions, they can make a home in practically any body of water, from drainage ditches to brackish ponds.

The more than two dozen separate species of tilapia occupy various niches in the food chain. This has made them popular in subsistence aquaculture where high-quality commercial foods are not available. Some species have adapted to feed on plankton, while others prefer larger aquatic vegetation.

Tilapia have varying degrees of temperature tolerance, but none survive below 50ºF for long periods of time. This has limited their natural range to tropical and subtropical areas. In temperate regions, this may be an advantage to small-scale aquaculture interests, since there is no danger of escaped tilapia surviving the winter and displacing the native fish species. In parts of southern Florida, Louisiana, Texas and California, populations of tilapia have established themselves. Since they have excellent culinary characteristics of taste and texture, they should be seriously considered for culture in the Fish Farm II.

As small-scale or backyard culture species, the many tilapia varieties provide several advantages. In addition to those already mentioned, they are a forgiving fish and tolerate low oxygen, high ammonia and the generally eutrophic conditions that are lethal to many other cultured species. There is a distinct advantage in using fish that survive poor water quality when you are a novice in aquaculture.

As tilapia become more widely cultured in both research and commercial situations, their availability is increasing. The purchase of fry and the requirements for their transport from the hatchery may be costly for most people. However, the reproductive ability of this extraordinary fish is excellent and breeding your own fish for restocking is not unreasonable.

Oxygen: Tilapia survive with oxygen levels as low as .5 ppm, partly because of their unique ability to breathe oxygen from the surface layers of water.

Temperature: Tilapia live in water from 64° to 94°F, but the best growth rate is around 75° to 85°F. From 61° to 50°F they can survive, but they are lethargic, do not feed and become more susceptible to disease. They die at temperatures below 50°F.

Ammonia: Tilapia tolerate high levels, surviving in ponds with large amounts of organic matter.

Hardness: Tilapia are highly resistant to both disease and parasites and thrive even with poor water quality.

Feeds: Some tilapia (*T. zillii*) prefer larger aquatic plants (or even garden wastes or grass clippings), while others, like blue tilapia (*T. aurea*) are adapted to feed on plankton. Java tilapia feed mainly on plankton, but also eat all kinds of plants and vegetable feeds such as soybean or grain meal. For fastest growth, pelleted feeds are readily accepted, with natural feeds available for supplementation.

Stocking: Java and Nile tilapia can be raised successfully with channel catfish or carp. Since carp and catfish have different feed requirements than tilapia, polycultures (two or more species in the same body of water) using these species provide increased growth.

Growth Rates: This varies with stocking densities, available food and water quality. Under proper conditions, the tilapia can grow extremely fast, reaching harvest size from 1" (2 cm) fingerlings in one season (6 months).

Availability: Tilapia are most commonly raised by commercial dealers in Alabama, Arkansas, California, Idaho, Oklahoma and Florida. They are easily spawned and kept indoors through winter. Aquarium dealers often obtain tilapia species, which are then spawned by the culturists to provide the required number for stocking. Since it is illegal to culture tilapia in some states, check with your state fish commission before purchasing. Even though tilapia may be more difficult to obtain initially, they have favorable qualifications for backyard fish culture. Once an initial population is established, the fish provide the fry necessary to stock the Fish Farm II year after year. It may be possible to buy fingerlings from dealers in Florida or other southern states and have them shipped by air in containers with oxygen. This means bigger fish can be obtained, which will reach a harvestable size easily.

Spawning Tilapia

Several large specimens (3 inches or more) can often be obtained from an aquarium store. These fish should spawn and provide enough fish to stock the entire system. This method of stocking is the least expensive, but requires more patience and an understanding of the reproductive techniques of the fish. In areas with a long growing season, the broodstock (a few spawning individuals) can be allowed to reproduce in open ponds (if permitted by state laws). The fry will appear in a school on the surface, and can be removed to a separate growout tank, or allowed to grow within the pond. At this time, the larger fingerlings will begin to consume smaller fry that continue to be spawned, unless they are removed. It may be possible, with a long enough growing season, to bring these newly hatched fry to table size the first summer. If they are too small for harvest, overwintering them inside provides large fish for stocking the following year. In this way, a two-year season yields a very productive harvest.

Aquarium Spawning

If a small pond is not available, or if temperate region temperatures are too low most of the year (tilapia spawn at 80ºF), tilapia may be spawned in an aquarium over the winter. The aquarium can be as small as 30 gallons, but spawning occurs more easily in a larger tank. Fine gravel on the bottom of the aquarium stimulates spawning activity and a small box filter will maintain water quality. The temperature should be kept between 78º to 82ºF with an aquarium heater. Also, sufficient light should be provided for 12 to 18 hours daily. With this setup, successful tilapia spawning can occur continuously throughout the year.

Large numbers of fry can be produced by two methods. In the first method, a male tilapia and 4 or 5 females (broodstock of about $^1/_4$ to $^1/_3$ lb size are the easiest to use) are introduced in to the aquarium. When spawning is initiated by two individuals (usually marked by the building of a nest), remove all fish except for the pair. When eggs are observed in the female's mouth, the male should be removed and the female allowed to brood the eggs and fry. When the fry begin swimming in a school, the female is removed to protect the growing fry from being eaten. The second method encourages a more continuous production of juvenile tilapia. A "family" of tilapia is established in a larger aquarium or tank. As free-swimming fry appear, they should be removed. This method works best in larger aquariums or tanks (over 100 gallons), because the spawning pair must constantly defend the nest from other individuals that wish to spawn.

Aquarium-spawned fry can be raised indoors in aquariums and small tanks over the winter. By raising twice the number of fry required, enough fish for stocking is virtually assured. However, fry should be sorted according to age groups to prevent cannibalism. Newly hatched fry are the most vulnerable. The fry should be fed a fine, protein-rich meal, which can be obtained by pulverizing pelleted feed or buying aquarium fish food. Algae growing in the aquarium provides additional food and increased growth.

Catfish

Channel catfish are prime candidate for small-scale fish farming due to their qualities as warmwater, domestic, farm-raised fish and the vast amount of research that has been carried out on them. Their nutritional requirements have been exactingly determined and can be provided by pelleted commercial feeds. Catfish have fast growth and exceptional quality as a food fish, and can tolerate a lower temperature than the tilapia.

Channel Catfish (*Ictalurus punctatus*)
Brown Bullhead Catfish (*I. nebulosus*)
Black Bullhead Catfish (*I. melas*)
Yellow Bullhead Catfish (*I. natalis*)

Oxygen: Catfish grow well with more than 4 ppm of oxygen. At less than that, they may not eat and become less resistant to disease and parasites.

Temperature: They grow most efficiently between 80º to 85ºF. Below 60ºF, growth stops, but the fish are not particularly stressed.

Ammonia: Keep un-ionized ammonia below 1 ppm.

Nitrite: Keep nitrite below .5 ppm.

Hardiness: Catfish can contract bacterial infections, viruses or parasitic diseases if oxygen, ammonia and temperature levels are not maintained.
Under controlled conditions, the catfish is very hardy and resistant to disease or parasite problems.

Feeds: Their natural diet includes aquatic insects, crayfish, bluegills and other small fish, frogs and some filamentous algae. For rapid growth in a culture system, commercial pelleted fish feeds are necessary.

Feed Utilization: In intensive culture, catfish may convert feed as efficiently as 1.5 lbs of feed to 1 lb of fish.

Growth Rate: Catfish fingerlings (3 inches to 6 inches) can reach harvestable size in 6 months, under optimal culture conditions.

Availabillty: Unless a pond is available to breed your own fingerlings, catfish have to be acquired from a commercial dealer each year. They are generally more available than tilapia and can often be purchased through local fish farmers. The state fish commission can provide a list of dealers in your area. Catfish can be purchased in most states in the south and several in the north, generally in the spring. The dealer usually bags the fish for transport if the fingerlings are small and only 100 to 200 are ordered. A transport tank may be necessary for larger fingerlings. In both cases, the supplier makes sure there is enough water and oxygen to transport the fish. It is also possible to have small fingerlings air-shipped from greater distances.

Other Species

Species such as trout, hybrid striped bass, yellow perch and carp can also be grown in the Fish Farm II. It is important to learn as much as possible about the fish you wish to raise and to determine whether the necessary water quality required can be provided for a season long enough to assure their growth to harvestable size.

To be considered for aquaculture, a fish species must be available as fry or fingerlings, and must be trained to take commercial feeds. If these requirements are met, it is only necessary to provide whatever additional water quality and management needs are demanded by that fish.

Freshwater prawns (*Macrobracium Rosenbergii*) can be raised along with warm water fish such as tilapia. Polyculture is a more advanced culture exercise, as feeding, predation and harvesting become more difficult.

Afterword

As you enter into this backyard fish farming venture, you can anticipate the enjoyment that will come with growing a tankful of fresh, healthy fish. With the Fish Farm II and the enclosed information, you should be able to make aquaculture as useful as gardening for providing food for your table. You will add a measure of self-sufficiency to your life and enjoyment and satisfaction to your leisure time.

Just as home gardening has become one of the nation's widest practiced hobbies (gardening is the number one hobby in the world), small-scale fish farming can make a significant contribution to your family's food requirements. You will have the satisfaction of knowing that the fish you are eating is the freshest and purest available.

Good luck and happy harvests.

—Aquatic Eco-Systems Inc.

This manual was prepared with the cooperation of Steven Van Gorder for Aquatic Eco-Systems Inc. and incorporates years of scientific research as well as practical experience in the art and science of small-scale fish production.

Maintenance
There are three main areas of maintenance:

Clarifier

The clarifier must be cleaned daily. If the fish waste is not removed every day, it will begin to decompose and float to the surface of the water. Cleaning the clarifier is a simple procedure and shouldn't' take more than 5 to 10 minutes.

a. Close the air to the clarifier lifts.

b. Drain the ten gallons of water from the clarifier.

c. Use the squeegee to remove the solids.

d. Remove and spray the pre-filter pad to remove debris.

e. Make sure the ten gallons of replacement water is dechlorinated before adding it to the system.

Suspended Solids Filter

Cleaning the suspended solids filter will require the temporary installation of the cap on the standpipe. This cap prevents water from entering when the tank is drained and the filters are cleaned. Be sure to position the 3-position valve so that water from the biofilter does not backflow into the suspended solids tank. The tank may be used as a sink during filter pad cleaning. The pads can be hosed down to remove particulates. The 15 gallons of water removed must be dechlorinated and replaced after cleaning the filter. Be sure that the water is dechlorinated before adding it to the system.

Air Diffusers

Air diffusers will build up a growth of bacteria (feels like slime) and calcium carbonate. Clean by first removing them from the fish tank, then brushing, rinsing and, if necessary, immersing them in hydrochloric acid (also knows as muriatic acid).

a. Safety first. Have water available to rinse skin, clothing and other material in the event that acid is spilled or splashed.

b. Wear glasses to prevent eye injury.

c. Use acid in a well-ventilated area only.

d. Follow all safety precautions on the acid label.

e. To reduce the amount of acid used, select a tall acid-compatible container that is slightly larger than the diffusers being cleaned. Pour in sufficient acid so the diffusers will be covered.

f. Connect at least 2 feet of air line to the air diffuser, blow out the water held in the diffuser pores and immerse the diffuser in the acid. Acid will enter the diffuser and flow into the air line, backwashing the diffuser. Foam and gases will be given off as the acid reacts with the diffuser fouling materials. Note: Cleaning should not be left unattended because of the possibility of acid back-siphoning out of the container due to foam production.

g. Leave the diffusers in the acid for a few minutes (acid will not damage them even if left for hours), lift them above the acid level to allow the acid to drain and either pour water into the tubing or use air to force out the acid.

h. Rinse and put the diffusers back into service for "like new" performance.

Appendix A

Daily Water Quality Data
(sample form)

Date	Air Temperature	Water Temperature	pH	Total Ammonia	Un-Ionized Ammonia*	Feed Fed	Standing Crop
5/24	78	72	8	7	.35	1.5	50
5/25	80	74	8	7.5	.37	1.52	50.75
5/26	85	78	7.4	5.5	.072	1.54	51.51
5/27	83	76	7.4	6.0	.078	1.57	52.28
5/28	85	76	7.6	6.0	0.78	1.59	53.06
5/29	90	79	7.6	3.0	.062	1.61	53.86
5/30	87	79	7.6	1.0	<.02	1.64	54.67
5/31	90	76	8.0	<1	0	1.66	55.49
6/1	95	79	7.6	<1	0	1.69	56.32
6/2	95	79	7.6	<1	0	1.71	57.16
6/3	91	80	7.6	<1	0	1.74	58.02
6/4	88	79	7.6	<1	0	1.77	58.89
6/5	88	79	7.8	<1	0	1.79	59.77
6/6	90	80	7.8	<1	0	1.82	60.66
6/7	92	81	7.8	<1	0	1.85	61.57
6/8	92	81	8.0	<1	0	1.87	62.49
6/9	88	80	8.0	<1	0	1.90	63.43
6/10	90	81	7.9	<1	0	1.93	64.38
6/11	90	81	7.9	<1	0	1.96	65.34
6/12	91	81	7.8	<1	0	1.99	66.32

*To be calculated using un-ionized ammonia chart in Appendix B.

Worksheet designed by Annandale Fisheries & Manufacturing Co., St. Paul, MN.

Daily Water Quality Data

Date	***Air Temperature***	***Water Temperature***	***pH***	***Total Ammonia***	***Un-Ionized Ammonia****	***Feed Fed***	***Standing Crop***

*To be calculated using un-ionized ammonia chart in Appendix B.

Worksheet designed by Annandale Fisheries & Manufacturing Co., St. Paul, MN.

Appendix B
Un-Ionized Ammonia Measurement

Materials needed: pH test kit
Total ammonia test kit
Thermometer
Percent un-ionized ammonia chart

Method:

1. Measure and record the pH and temperature.
2. Sample and determine "total ammonia" levels (using test kit).
3. Using data from steps 1 and 2, refer to the "Percentage of un-ionized ammonia" chart below and determine the percentage of un-ionized ammonia for a particular pH and temperature.
4. Use the following equation to determine the concentration (ppm) of un-ionized ammonia.

$$\text{ppm unionized ammonia} = \frac{\text{(ppm total ammonia) x (percent un-ionized ammonia)}}{100}$$

Example: pH = 8
Temp = 15°C
Total ammonia measurement = 1 ppm
Percent un-ionized ammonia (from chart) = 3

$$\text{ppm un-ionized ammonia} = \frac{10 \text{ x } 3}{100} = .03 \text{ ppm}$$

Percentage of un-ionized ammonia in water at different pH levels and temperatures

Temp (°F)	Temp (°C)	pH 6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5
50	10	.02	.1	02	.6	2	6	16	37
59	15	.03	.1	.3	.9	3	8	22	46
68	20	.04	.2	.4	1	4	11	28	56
77	25	.06	.2	.6	2	5	15	36	64
86	30	.1	.3	.8	3	8	20	45	72

Appendix C

Water Quality Tolerance Chart

By keeping water quality within the ranges shown, the fish should remain free of stress, eat well and grow at a good rate.

	Temp °F	D.O. mg/l	pH Units	Alkalinity mg/l	CO_2 mg/l	*Ammonia %	Nitrite mg/l	Hardness mg/l	Chloride mg/l	Salinity ppt
Trout/Salmon	45–68	5–12	6–8	50–250	0–20	0–.03	0–.6	50–350	0–1,500	0–3
Walleye/Perch	50–65	5–10	6–8	50–250	0–25	0–.03	0–.6	50–350	0–2,500	0–5
Sunfishes	60–80	4–10	6–8	50–250	0–25	0–.03	0–.6	50–350	0–2,000	0–4
Hybrid Striped Bass	70–85	4–10	6.8	50–250	0–25	0–.03	0–.6	50–350	0–1,500	0–3
Tilapia	75–94	3–10	6–8	50–250	0–30	0–.03	0–.7	50–350	0–5,000	0–10
Catfish/Carp	65–80	3–10	6–8	50–250	0–25	0–.03	0–.7	50–350	0–4,000	0–8
Goldfish/Koi	65–75	4–10	6–8	50–250	0–25	0–.03	0–.6	50–350	0–2,000	0–4
Minnows/Shiners	60–75	4–10	6–8	50–250	0–25	0–.03	0–.6	50–350	0–2,500	0–5
Shrimp (Freshwater)	68–80	4–10	6.5–9	60–100	0–20	0–.05	0–.9	60–250	0–1,500	0–3
Shrimp (Saltwater)	60–75	4–10	6–8	50–250	0–15	0–.01	0–.1	50–350	13,000–18,000	25–35
Mussels (Freshwater)	40–50	4–10	6–8	50–250	0–20	0–.02	0–.3	50–350	0–500	0–1
Sturgeon	50–70	4–10	6–8	50–250	0–25	0–.03	0–.6	50–350	0–2,000	0–4
Tropical Fish	68–84	4–10	6–8	50–250	0–20	0–.03	0–.5	50–350	0–2,500	0–5
Snails	60–80	3–8	6–8	50–250	0–20	0–.02	0–.6	50–350	0–2,000	0–4
Fresh H_2O	60–65	3–6	6–7	25–150	—	0–2	0–.5	25–150	0–50	0–.5

***Un-ionized Ammonia—See page 18 for the method of calculation.**

To convert to °C use the following formula: $\frac{5(°F-32)}{9} = °C.$

Appendix D

Troubleshooting Guide

Careful management of the Fish Farm II can result in trouble-free production, but good management depends on the ability to recognize potential problems as they develop and respond quickly with the proper course of action. The following chart describes possible problems that may occur and the management techniques necessary to rectify them.

Problem	*Possible Cause*
Compressor stops running.	No power to compressor.
Reduced diffuser flow.	Kink in air line. Diffusers need cleaning. Check valve adjustment at manifold.
Reduced water flow through airlift return.	Fish tank water low. Siphon is not working. Siphon assembly tubes need cleaning. Clarifier filter pad needs cleaning. Check air lines. Biofilter clogged. Check valve adjustment at manifold.
Fish not feeding.	Check water quality.

Appendix E

Sodium Bicarbonate

Adjusting pH and Alkalinity Using Sodium Bicarbonate

Sodium bicarbonate (baking soda) can be used to buffer against sudden pH changes and increase total alkalinity in a fish culture system. Typically, recirculating systems require weekly or biweekly dosages. We advise maintaining a pH between 6.5 and 8.5 depending on the species and a total alkalinity between 50 and 200 mg/L. If pH and alkalinity are lower than the suggested range, they may be corrected by the addition of sodium bicarbonate. To accurately calculate the minimum amount needed for a given change, test a sample of the water to be adjusted by following the following steps:

1. Collect 5 gallons of sample water to be adjusted.
2. Test pH and total alkalinity.
3. Dissolve 1/4 teaspoon of sodium bicarbonate into the sample.
4. Retest pH and alkalinity.* If desired results are achieved, the dosage rate is set at 1/4 teaspoon of sodium bicarbonate per every 5 gallons of water in the system.
5. If desired results are not achieved, dissolve another 1/4 teaspoon sodium bicarbonate into the sample and retest to determine change. Continue to add sodium bicarbonate in 1/4 teaspoon increments, testing each sample after sodium bicarbonate has completely dissolved, until desired results are achieved.

*Note: pH should not be adjusted more than 1 unit every 24 hours. Alkalinity should not be adjusted more than 50 mg/l every 24 hours.

Example: After 1/4 teaspoon of sodium bicarbonate is dissolved into a 5-gallon sample of water collected from a 780-gallon system, the pH increases .5 units. If this is a desired result (it could be, as it keeps with the rule of limiting change in pH to less than one unit in a 24-hour period), then the dosage has been determined to be 1/4 teaspoon sodium bicarbonate per 5 gallons of water in the system. The rest is simple arithmetic: Divide 780 gallons by 5 to yield the number of 1/4 teaspoon dosages, which is 156. Then multiply 156 by .25 teaspoons, which equals 39 teaspoons (1 cup = 48 teaspoons).

Note: It is better to add small amounts of sodium bicarbonate daily rather than a large amount once a week.

Appendix F

Sodium Thiosulfate

Removing Chlorine Using Sodium Thiosulfate

Sodium thiosulfate is the main comlb in most chlorine/chloramine removers. When municipal water is used for aquaculture, use sodium thiosulfate for instant neutralization of chlorine. Dosage rates vary with the pH of the water; however, rates between 1.6 to 2.6 parts sodium thiosulfate per one part chlorine should be adequate. To calculate the minimum amount needed for a given change, test a sample of the water to be adjusted.

1. Collect 5 gallons of water to be adjusted.
2. Test chlorine levels.
3. Dissolve 1/4 teaspoon sodium thiosulfate into sample.
4. Retest total chlorine levels. If chlorine is not detected, your dosage rate is 1/4 teaspoon sodium thiosulfate per 5 gallons of water in system.
5. If desired results are not achieved, dissolve another 1/4 teaspoon of sodium thiosulfate and retest to determine change. Continue to add sodium thiosulfate in 1/4 teaspoon increments, testing sample after sodium thiosulfate is completely dissolved, until desired results are achieved.

Example: After 1/4 teaspoon sodium thiosulfate is dissolved into a 5-gallon sample of water collected from a 780-gallon system, the chlorine level drops to 0 ppm. The dosage has been determined to be 1/4 teaspoon sodium thiosulfate per 5 gallons of water in the system. The rest is simple arithmetic: Divide 780 gallons by 5 to yield the number of 1/4 teaspoon dosages, which is 156. Then multiply 156 by .25 teaspoons, which equals 39 teaspoons (1 cup = 48 teaspoons).

Remember: pH will affect dosage rates, so adjust the pH of subsequent treatments to match the pH of the past treatment from which the dosage was derived, or retest using the above procedures. Excess sodium thiosulfate up to 100 ppm will not harm fish.

Appendix G

NaCl (Noniodized Salt)

Salt is used as a nitrite stress reducer that inhibits the occurrence of "brown blood" disease in catfish. We recommend using 2 lbs of salt in the system to raise chloride levels. It is the chlorides in the salt (60%) that help the fish to maintain oxygen levels in their blood. See Nitrite.

Zeolite (Clinoptolite)

Zeolite is a naturally occurring clay-type product that is used to absorb ammonia. It can be recharged overnight using a saltwater bath. This will recharge it to 85% of its original capacity. Zeolite can only be used in fresh water. To remove one ppm of ammonia from the Fish Farm II, 5 lbs of zeolite should be put in a mesh bag and placed in the tank. This is usually used as a backup if the biofilter crashes and/or ammonia rises to unacceptable levels.

Appendix H

Calcium Chloride

Adjusting Hardness Using Calcium Chloride

Depending upon water's buffering capacity, calcium chloride may raise or lower the pH. Normal calcium hardness levels in recirculating aquaculture systems should be maintained between 100 to 250 mg/L, depending upon the species. Fast dissolving pellets are 1/8" to 1/4" in size.

Caution: Avoid contact with eyes, skin or clothing. Avoid breathing dust or mist. Use good personal hygiene and housekeeping.

Disposal: Dissolve in water. Use care—solution can get very hot. Flush to sewer with plenty of water only if permitted by applicable disposal regulations. If the calcium hardness is lower than the suggested range of 100 to 250 mg/L (depending upon species), it may be corrected with the addition of calcium chloride. To calculate the minimum amount needed for a given change, test sample of the water to be adjusted.

1. Collect 12 gallons of water to be adjusted.
2. Test pH, total alkalinity and calcium hardness. Calcium chloride will change pH and alkalinity. Note that pH should not be adjusted more than one unit every 24 hours. Alkalinity should not be adjusted more than 50 mg/L every 25 hours in water containing fish.
3. Dissolve 6 grams (about one teaspoon) of calcium chloride into the sample.
4. Retest sample for hardness, pH and alkalinity. If desired results are achieved, the dosage rate is determined to be 6 grams calcium chloride per 12 gallons of water in the system.
5. If desired results are not achieved, dissolve another 6 grams of calcium chloride into sample and retest to determine change. Continue to add calcium chloride in 6-gram increments, testing sample after calcium chloride has totally dissolved, until desired results are achieved.

Example: After one teaspoon calcium chloride is dissolved in a 12-gallon sample of water collected from a 780-gallon system, the hardness increases to 150 ppm. If this is the desired result, the dosage has been determined to be one teaspoon calcium chloride per 12 gallons of water in the system. The rest is simple arithmetic: Divide 780 gallons by 12 to yield the number of one-teaspoon dosages, which is 65 (1 cup = 48 teaspoons).

Note: Dissolve determined amount of calcium chloride in a bucket of water before adding to system. **Caution**: Mixture will become very hot. Add slurry to system slowly. Test system to verify that desired results are achieved.

Appendix I
Fish Farm II Inventory
Part No. FF400

Tanks
1. Floor Drain (2)
2. Standpipe (2)
3. Pre-Assembled Boil Baffle Diffusers (2)
4. Airstone Diffusers (4)
5. Pre-Assembled Airlifts (2)
6. Culture Tanks (2)

Chemicals
1. Sodium Chloride (5 lbs)
2. Sodium Thiosulfate (5 lbs)
3. Calcium Chloride (5 lbs)
4. Bacta-Pur® (5 lbs)

Heavy Solids Filter System
Clarifier
1. Pre-Assembled Clarifier Stand (1)
2. Pre-Assembled Clarifier (1)
3. Pre-Assembled Clarifier Airlifts (2)
4. Pre-Filter Pad(1)
5. Squeegee (1)

Suspended Solids Filter
1. Standpipe (1)
2. Standpipe Cap (1)
3. Filter Pads (2)
4. Pre-Assembled Suspended Solids Filter Tank Assembly (1)

Biofilter
1. Pre-Assembled PVC Diffuser Piping (1)
2. Air Diffusers (2)
3. Bio Media
4. Pre-Assembled Biofilter Tank Assembly (1)

Air Distribution System
1. Pre-Assembled Air Manifold (1)
2. Air Lines
3. Check Valve (1)
4. Air Pump (1)

Miscellaneous
1. Pre-Assembled Interconnecting Flex PVC Pipe (4 sections)

Appendix J
Setting Up the Fish Farm II

Tools needed: Flathead Screwdriver, Level
Note: Reading the directions and watching the video before assembling will make the assembly faster and easier.

Instructions

The Fish Farm II will arrive on one pallet with all components packed inside tanks.

Tank Placement

Each of the two culture tanks has a capacity of 450 gallons of water and each is capable of supporting up to 150 lbs of fish. Site selection can be a garage, patio or any surface that can support the weight of 1,000 gallons of water (8,340 lbs), 300 lbs of fish and the additional equipment that supports the Fish Farm. The site should be solid and flat, with minimal bumps and protrusions. A floor that will support 180 lbs per square foot or 1.25 lbs per square inch is acceptable. An important point to remember is that both tanks are to be installed at the same height. The water in the system will balance itself and be of equal depth in each tank. If one tank is placed on a higher surface than the other, the depth in each will be unequal and the system will not operate properly.

Site Preparation

The ground should be level. If the ground is uneven (more than one inch from one side to the other), place a two-inch bed of sand, level it and place the tanks on top. It is important that the system be level to ensure good water flow dynamics when in production. Note: Do not use shims to level the tanks, as the weight of the tanks will cause them to bend around the shims. Use a four-foot carpenter's level to ensure that the tanks are level. Place the level on the lip of the tanks in several locations. Use sand to fill in the low spots under the tanks if they are located on a natural surface.

Filter Placement

Make sure that there is enough ground clearance to gain access to all the joint connections and valves. No external equipment or support not associated with the Fish Farm should interfere with the ability to tighten or loosen a union or retaining ring when the system is in operation. It may be necessary to shim the legs of the clarifier stand and the suspended solids filter to gain an acceptable clearance.

Setup

Unpack and lay out each component. Become familiar with each piece, as this will make installation easier.

Culture Tanks

The tanks come with no assembly required. If the tanks have windows (optional), position them for optimal viewing.

Clarifier Stand

The stand arrangement should be about 14.5 inches from the lip of the tank nearest the stand. Some slight repositioning may be necessary to connect the clarifier airlifts with the flex PVC pipe. Place the clarifier on its stand and place the pre-filter pad over the drain at the weir (see Figure 4). Connect the clarifier airlifts to the clarifier and lay out the small diameter precut flex PVC between both tanks. Inspect unions for O-rings and connect to tanks. Hand-tighten connections.

Tank Component Placement

Attach air diffusers to each boil baffle assembly and secure the assembly to the lip of the tank. Place the pre-assembled airlifts in a manner so that the discharge is directed between the boil baffle diffuser and the tank wall. Attach each airlift to the wall of its respective tank. Install the floor drains and standpipes at their respective locations in each tank.

Plumbing Lines and O-Rings at Unions

Inspect each connection for the required rubber O-ring during assembly, as they may become dislodge during shipping. It is important that they are seated properly before installing them in the system. All pipe connections require only hand-tightening.

Biofilter

The biofilter comes pre-assembled. The PVC piping and connections between the biofilter, suspended solids filter and the clarifier will dictate the exact position of the biofilter. Hand-tighten the connections to the suspended solids filter and the output of the clarifier. Assemble the air diffusers and install them in the biofilter tank. Add the biofilter media after the diffusers have been installed. The tank should only be half-full of the media (see Figure 1). Add half of the required media to the filter tank and add the remaining half after the biofilter begins to "boil," which may take a few days.

Suspended Solids Filter

This filter should be positioned about 16.5 inches from the tank as a starting point for the connection of the large-diameter flexible PVC. Lay out flex PVC piping, inspect for proper seating of O-rings, and hand-tighten connections.

Airlifts

Attach airlifts to the clarifier and tanks using tubing and clamps provided (see Figures 2 and 8). Be sure tubing covers both pipes evenly and clamps are tight. Note: Use only water as lubrication, as any other substance could foul water.

Boil Baffle Diffusers

Using attached clips, hang this assembly on the inside of the tank wall near the mid-line of the clarifier. With air diffuser suspended off the bottom. Be sure to remove cardboard from diffusers before installation.

Air Pump Installation with Check Valves

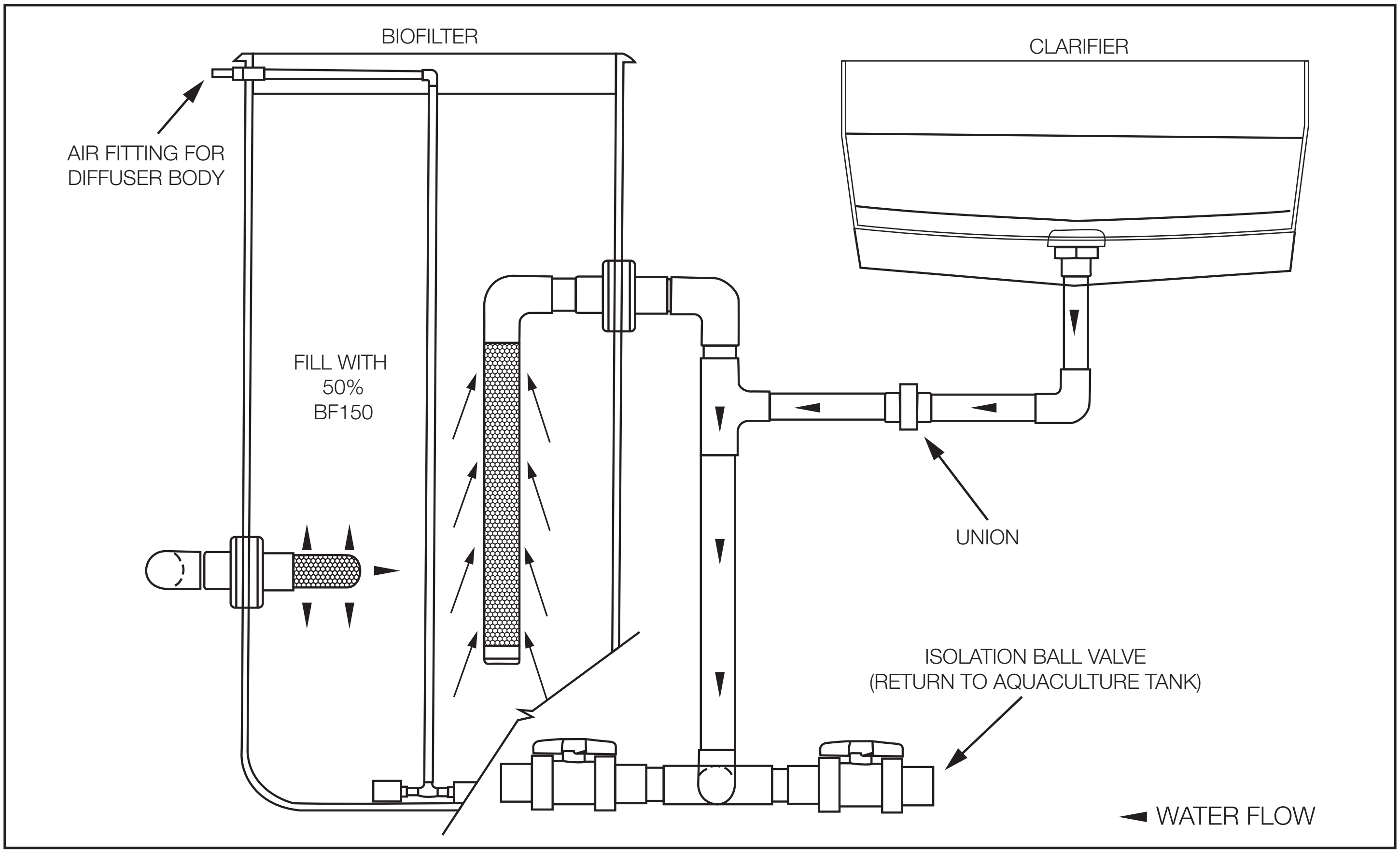
The air pump should be located above the tank waterline if at all possible. The air pump comes with a check valve that must be installed in the supply line to the air manifold. The check valve will prevent water backflowing into the pump. The air pump can be placed on the lower shelf of the clarifier stand and the air manifold can be hung anyplace that is convenient. Be sure to route the lines in a manner that they will not be bumped into or stepped on.

Air Manifold Balancing

The key to operating the Fish Farm II system is balancing the air manifold. When the system is full of water and all the air lines have been connected to the air manifold, balancing may begin. The valves on the air manifold have a wide range of operation, but only a small portion of this range is used. A key point to remember is that any adjustment to any of the valves will affect the air passing through all the remaining valves. As one output is adjusted for the desired result, each of the previous outputs must be checked to see how they have been affected.

Initial setup of the air manifold is with the tanks full of water and the air pump running. All water supply and return valves are open from the tanks and the filter system.

1. Close all valves on the air manifold, with the exception of the supply valve from the air pump.
2. Slightly open the two valves for the clarifier airlifts and adjust for water to enter the clarifier and spill over the weir.
3. Slightly open the valve supplying air to one of the airlifts that returns water to the tanks and adjust until water flow is obtained. To establish the 3-gpm flowrate, use a 5-gallon bucket, a container that will hold 1.5 gallons of water and a stopwatch. Place the empty bucket at the airlift discharge to the tank and time the discharge into the bucket for 30 seconds. Measure the contents of the bucket for the required 1.5 gallons and adjust the airflow to the airlifts to increase or decrease the flowrate until the 3-gpm rate is reached.
4. Repeat Step 3 for the remaining airlift.
5. Check the flow at the clarifier to ensure that flow has not weakened and adjust accordingly.
6. Slightly open the valve for the biofilter. The boiling action of the biofilter cannot be monitored if all of the media has been used. It will take about a week for the entire media load to begin to "boil." As the bacteria grow on the media, it will require less airflow. Adjust over time as required.
7. Check the flow on both clarifier airlifts and both tank airlifts and adjust accordingly.
8. Slightly open the valve for one of the boil baffle diffuser assemblies. Adjust for moderate airflow and check for airflow at the airlifts and the action at the biofilter.
9. Slightly open the valve for the remaining boil baffle diffuser. Adjust for a good but moderate airflow and check the flow on the four airlifts. Check the action at the biofilter and the flow at the other boil baffle diffuser and adjust accordingly.


BIOFILTER
CLARIFIER
AIR FITTING FOR
DIFFUSER BODY
FILL WITH
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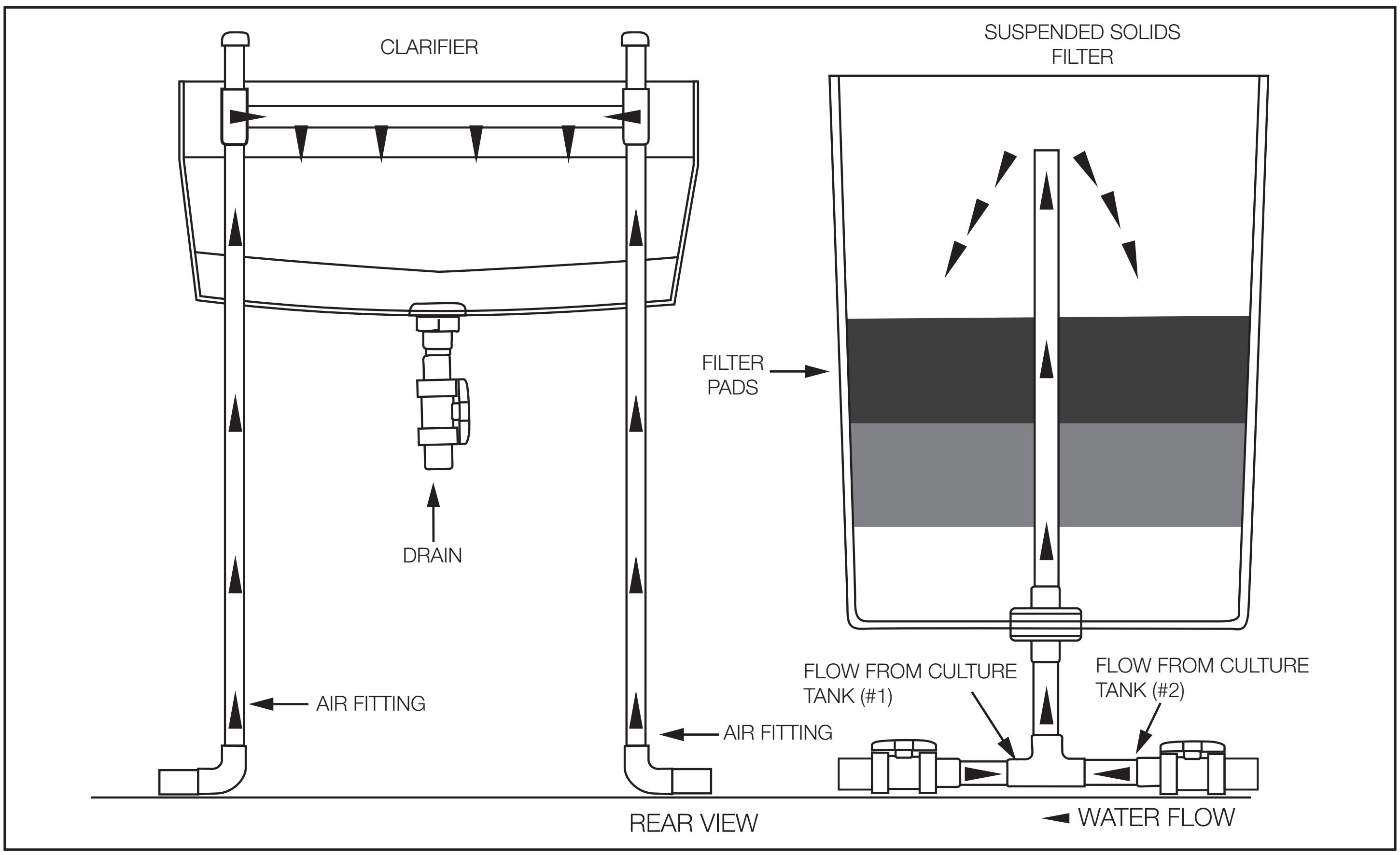
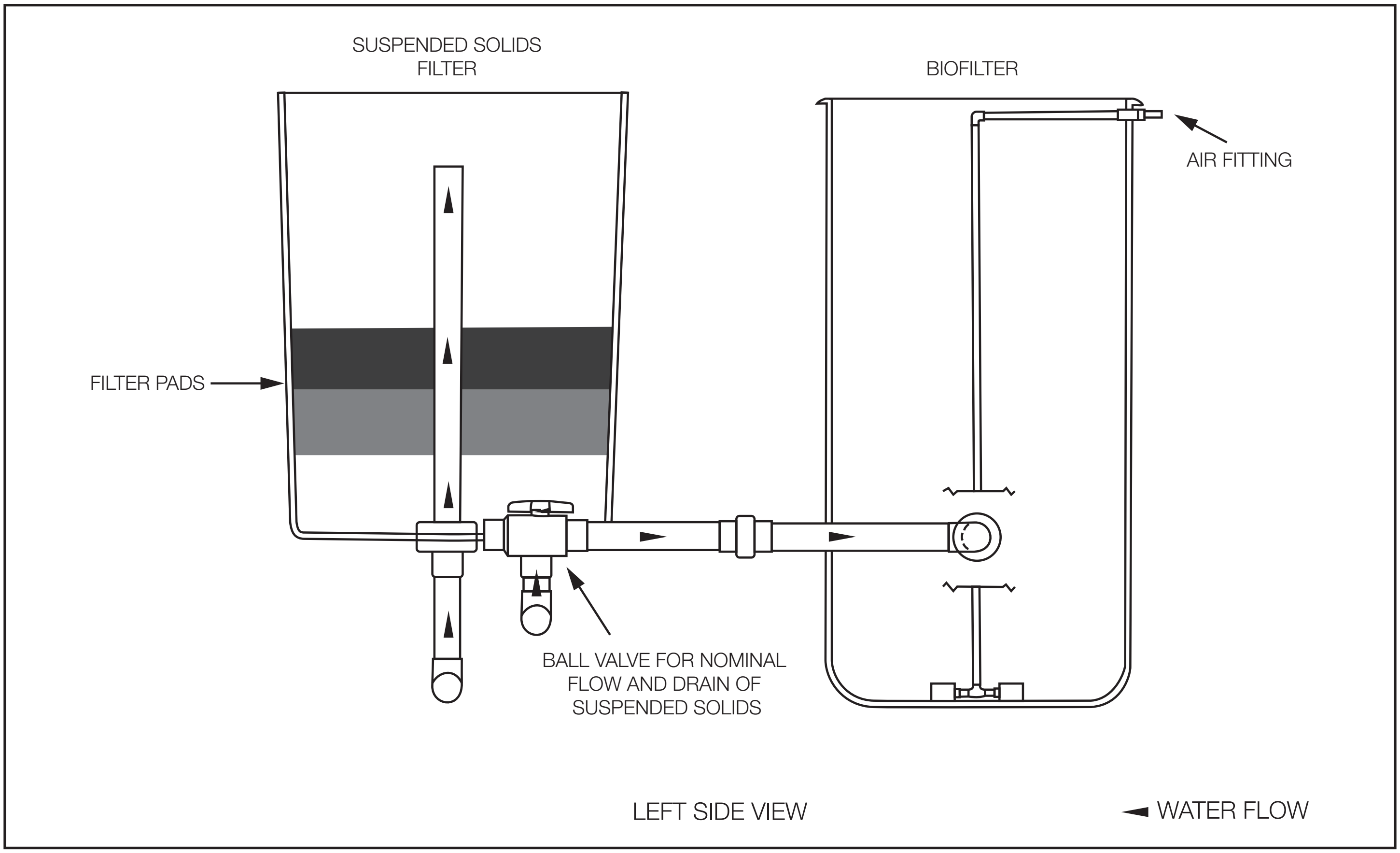
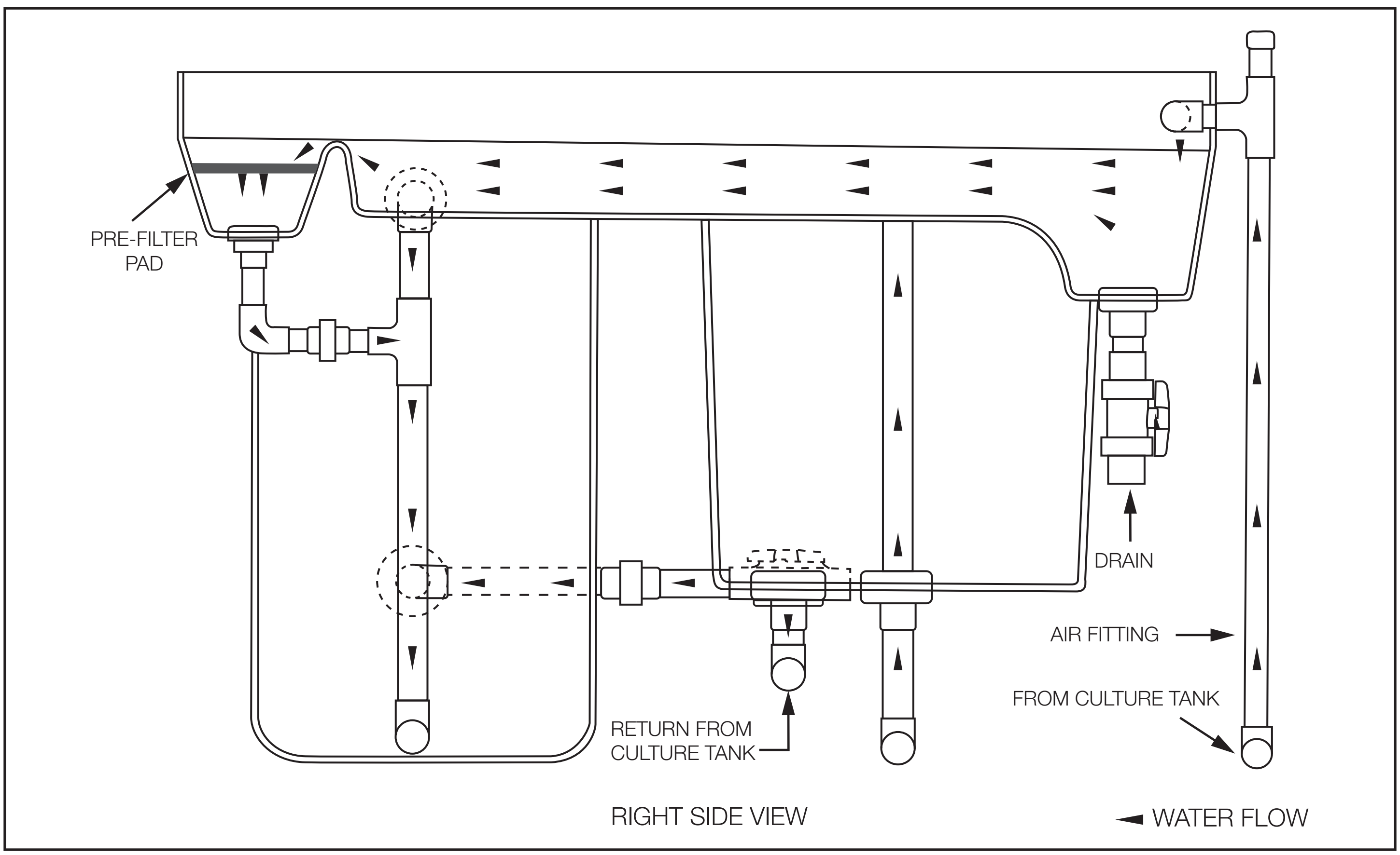
BF150
UNION
ISOLATION BALL VALVE
(RETURN TO AQUACULTURE TANK)
WATER FLOW


CLARIFIER
SUSPENDED SOLIDS
FILTER
FILTER
PADS
DRAIN
AIR FITTING
AIR FITTING
FLOW FROM CULTURE
TANK (#1)
FLOW FROM CULTURE
TANK (#2)
REAR VIEW
WATER FLOW


SUSPENDED SOLIDS FILTER
BIOFILTER
AIR FITTING
FILTER PADS
BALL VALVE FOR NOMINAL FLOW AND DRAIN OF SUSPENDED SOLIDS
LEFT SIDE VIEW
WATER FLOW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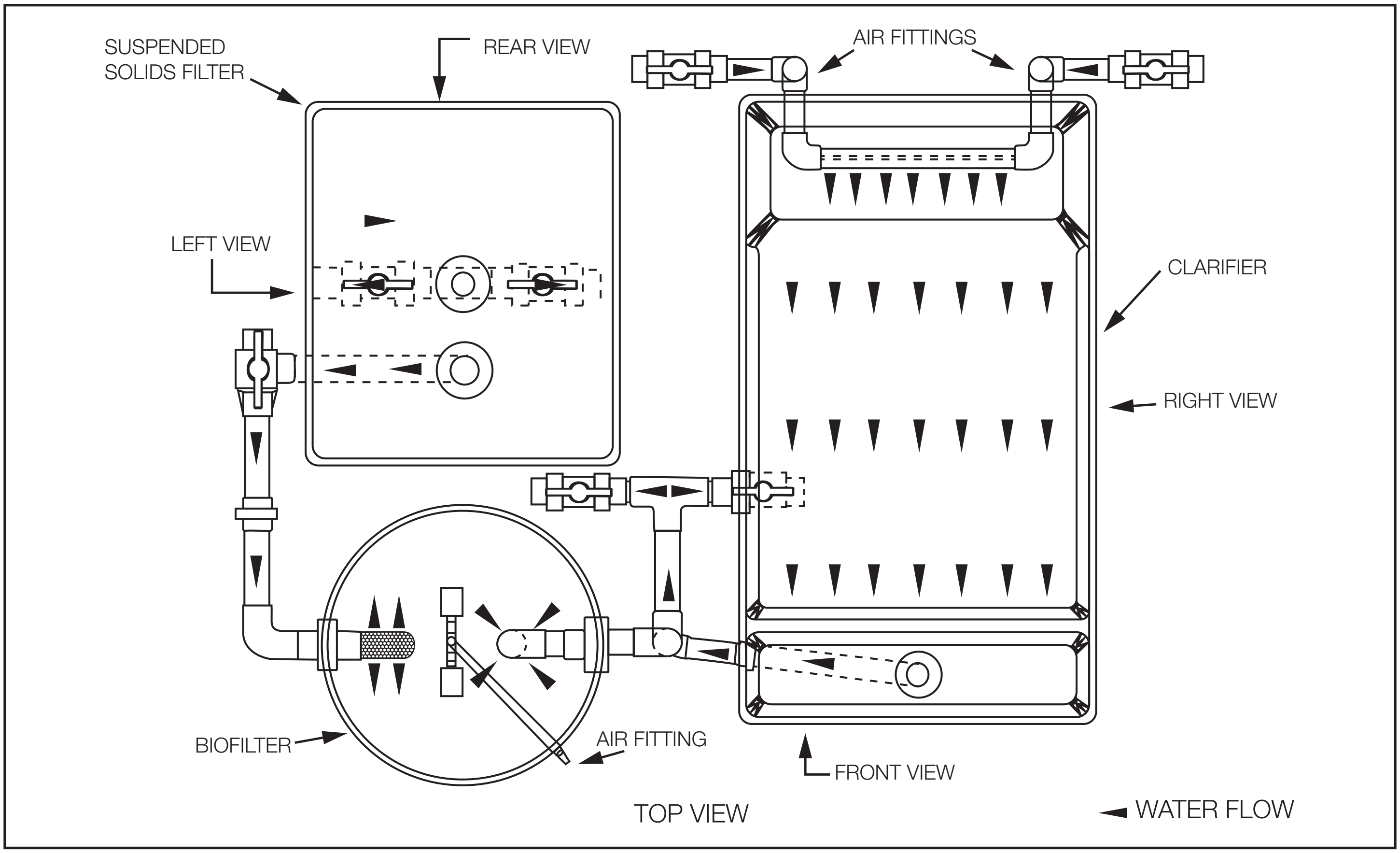
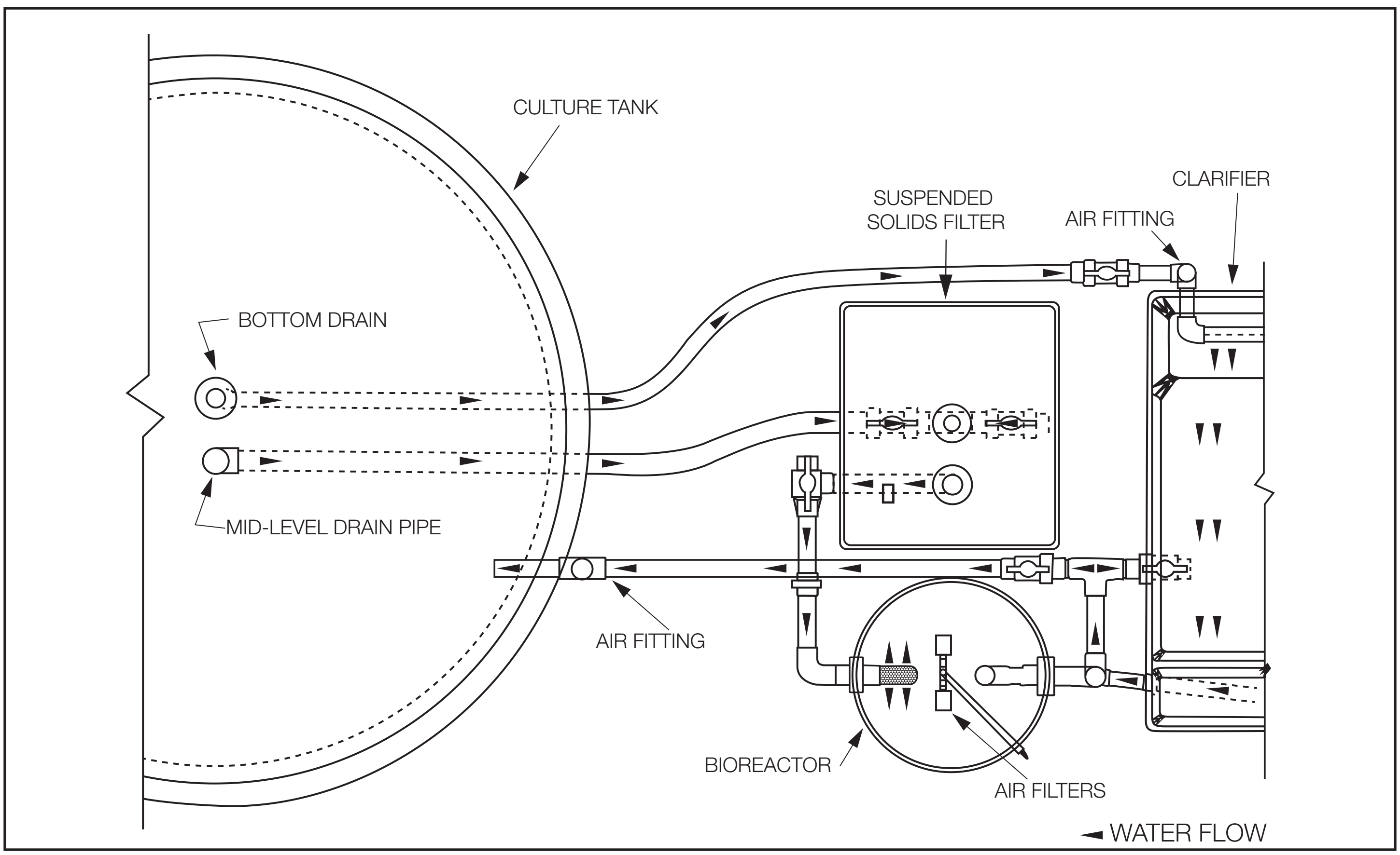
DRAIN
AIR FITTING
FROM CULTURE TANK
RETURN FROM CULTURE TANK
RIGHT SIDE VIEW
WATER FLOW


SUSPENDED
SOLIDS FILTER
REAR VIEW
AIR FITTINGS
LEFT VIEW
CLARIFIER
RIGHT VIEW
BIOFILTER
AIR FITTING
FRONT VIEW
TOP VIEW
WATER FLOW


CULTURE TANK
CLARIFIER
SUSPENDED
SOLIDS FILTER
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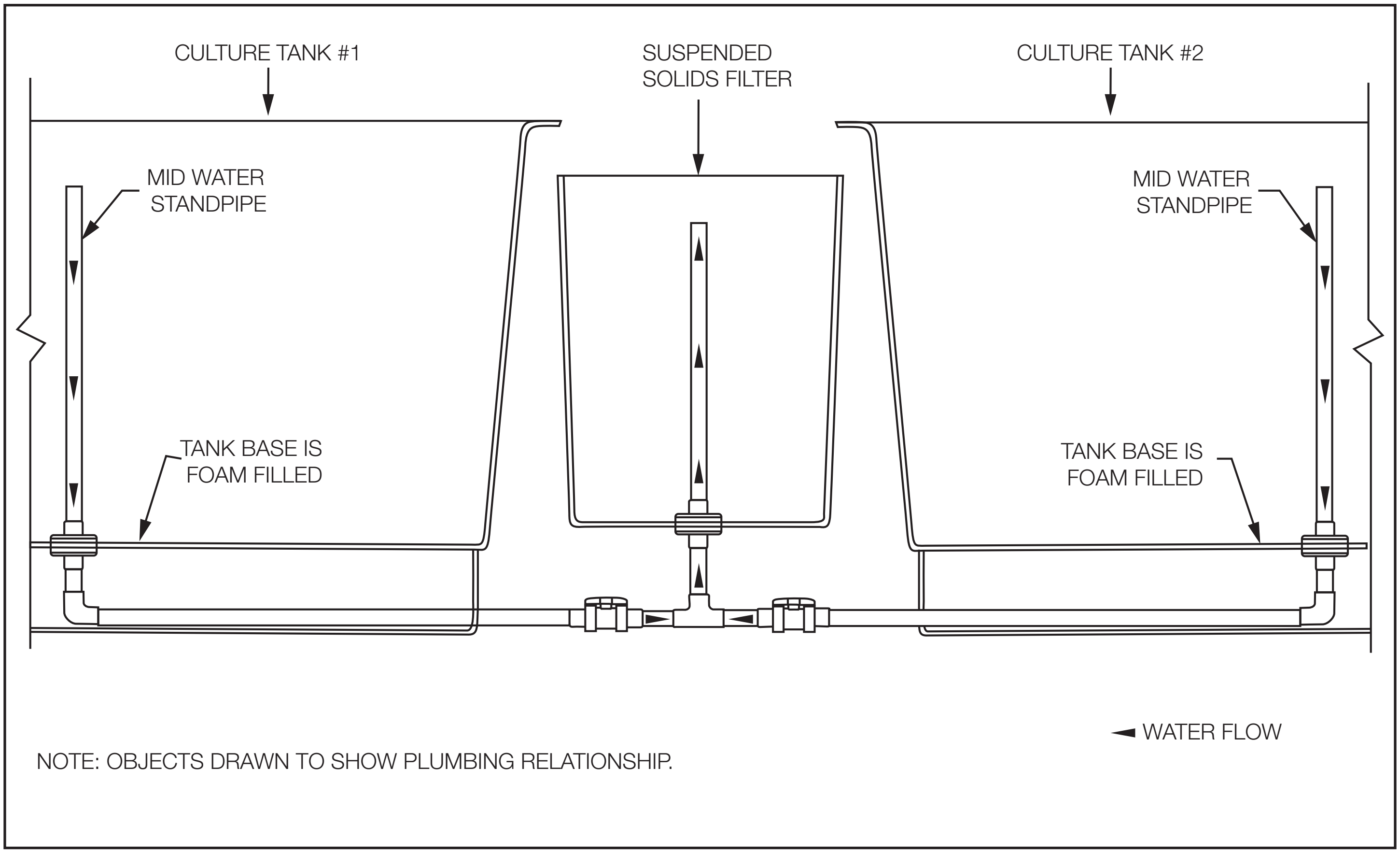
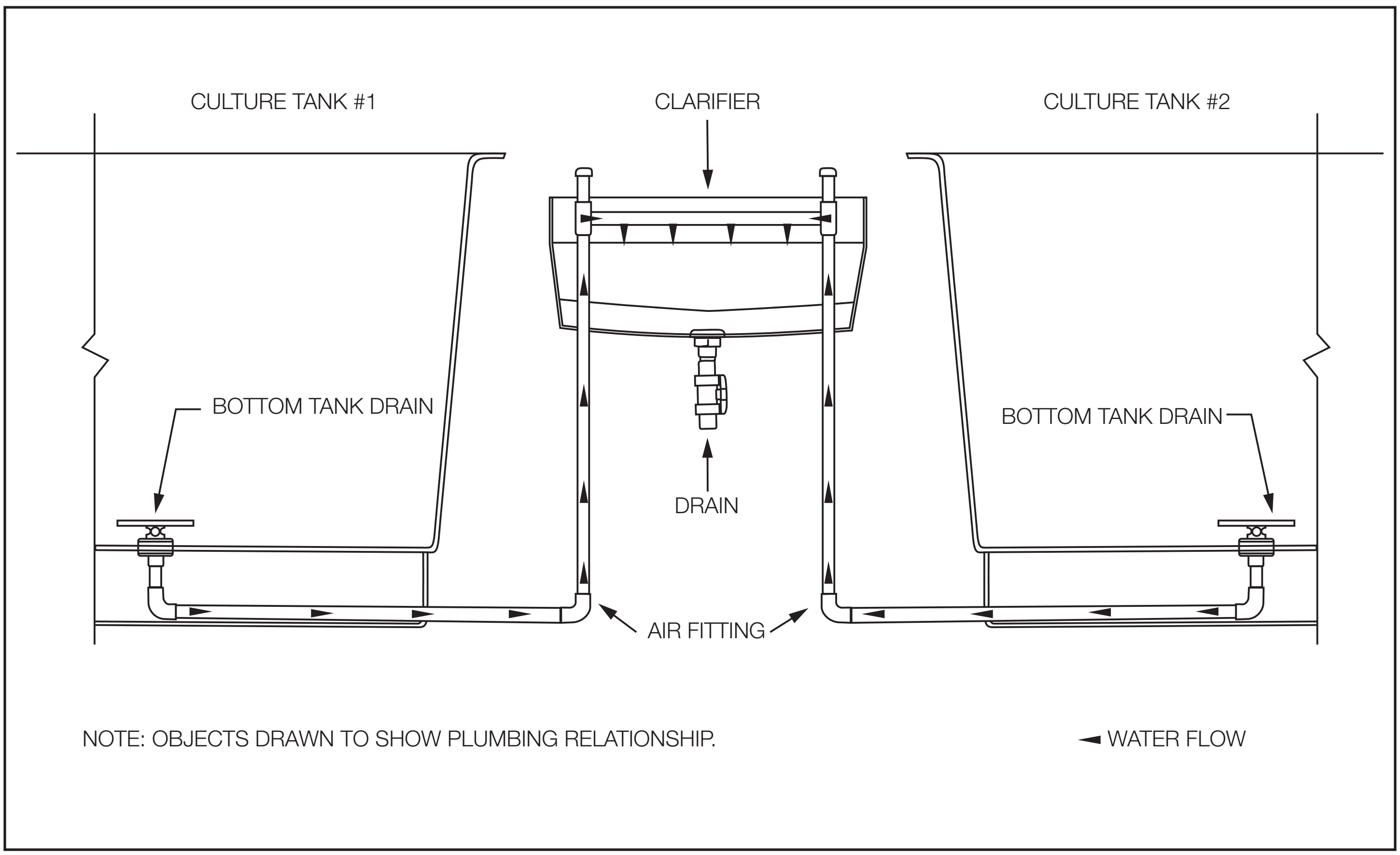
BOTTOM DRAIN
MID-LEVEL DRAIN PIPE
AIR FITTING
BIOREACTOR
AIR FILTERS
WATER FLOW


CULTURE TANK #1
SUSPENDED SOLIDS FILTER
CULTURE TANK #2
MID WATER STANDPIPE
MID WATER STANDPIPE
TANK BASE IS FOAM FILLED
TANK BASE IS FOAM FILLED
WATER FLOW
NOTE: OBJECTS DRAWN TO SHOW PLUMBING RELATIONSHIP.


CULTURE TANK #1
CLARIFIER
CULTURE TANK #2
BOTTOM TANK DRAIN
BOTTOM TANK DRAIN
DRAIN
AIR FITTING
NOTE: OBJECTS DRAWN TO SHOW PLUMBING RELATIONSHIP.
WATER FLOW

Notes