

# An Operator's Manual for the CP&L / EPRI Fish Barn

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October 1999

## **Introduction**

Since 1990, the North Carolina Fish Barn, located at North Carolina State University, has been operated as a demonstration project for the development and evaluation of water reuse technology suitable for conducting commercial aquaculture in the water-limited Piedmont of North Carolina. Various combinations of equipment and management techniques have been evaluated and demonstrated with a wide range of success. With the successful “marriage” of foreign and domestic technologies, water reuse systems have been built and operated at the Fish Barn, as well as by private operators. The equipment and techniques presented in this manual are based upon those systems, which continue to be improved in order to develop a more efficient, cost-effective technology.

## **System Overview**

The system that will be described is based upon experience in the construction and operation of similar systems utilizing technology developed by North Carolina State University and AquaOptima AS (Kjellermannsgata 35, 7011 Trondheim, Norway). The basis for effective solids removal in this system is the ECO-TRAP particle trap and associated components developed by AquaOptima AS. The particle trap is available in three sizes, each of which is suitable for a specific maximum tank diameter. At the beginning of the project, these devices were designated by the manufacturer as the ECO-TRAP models 100, 200 and 300, which are the models installed in tanks at the CP&L / EPRI Fish Barn. Newer models have since been developed, utilizing more cost-effective materials and manufacturing methods. Construction techniques have been developed that are applicable to the installation of all models.

## **Biosecurity**

In the confinement and commercial production of nearly all animal species, the prevention and control of pathogens must be addressed in order to continue to operate profitably. The CP&L / EPRI Fish Barn is set up to address biosecurity issues by isolating newly arrived stock for two 6-week stages before introduction into the main growout room. Each of the quarantine rooms is equipped with separate water treatment systems so that culture water is not mixed with that of other systems in the facility. This design represents significant additional capital cost. This added cost, however, yields significant returns in the form of control and the increased probability of a continuing production schedule.

In the successful implementation of a biosecurity plan, a few basic rules should be established and adhered to, as follows:

- Visitors, if allowed inside the operation at all, should be excluded from all quarantine areas. The fewer the personnel entering, the better.
- Dedicated equipment such as dip nets should be purchased for exclusive use in their assigned quarantine area, and should be clearly identified.
- Daily routines such as manual temperature and dissolved oxygen readings should be sequenced so that quarantined areas are entered last.

- Equipment such as dissolved oxygen meters, which are expensive and therefore difficult to dedicate to exclusive quarantine area use, should be cleaned after each use in a quarantined area.
- Personnel working in quarantined areas should wash hands and arms with anti-bacterial soap when returning and before entering other areas.
- Foot baths or disinfecting mats should be provided at the entrance of each quarantine area. A suitable disinfectant solution, such as quaternary ammonia based solution, should be utilized and replaced regularly. Indicator strips for testing active ingredient concentration are available and should be used regularly to assure effectiveness of the solution.

The CP&L / EPRI Fish Barn is organized to provide six weeks of isolation in Quarantine 1 (Q1), and six additional weeks of isolation in Quarantine 2 (Q2). Stock should be examined regularly, as well as immediately prior to transfer to the next stage. Operators should be able to carry out a cursory examination to determine the general health status of stock. A general scan should include examination of the following areas:

- **Color and condition of gills:** Should be uniformly rich red in color, no mucous coating nor bleached areas, and no gaps between gill filaments. Look for possible presence of gill parasites
- **Presence and condition of slime coat:** Mucous should be clear, uniform, and moderately heavy.
- **Condition of scales:** Should lie flat against body, evenly spaced, not missing.
- **Condition of fins:** Take note of any fraying and/or erosion of soft tissue and fin rays. Pelvic fins may show evidence of erosion from contact with concrete tank floor (not necessarily cause for alarm).
- **Appearance of eyes:** Should be clear with no swelling or bulging.
- **Abdominal area:** Should show some bulging even if feed has been withheld, should not be concave or sunken.
- **General vigor:** Fish should exhibit good avoidance response and should be lively and jumping.

Review the mortality records of each cohort before transfer to determine if extraordinary mortality has occurred. If health is questionable or the presence of pathogens is suspected, contact your Cooperative Extension Service or personnel trained in aquatic animal health. Moving stock forward in the system may not only spread any contamination into other systems, it may also be a waste of production time and money. Treatment, if required, is more easily accomplished in systems with smaller volumes. With smaller volumes, there is better control in creating the proper concentration of the treatment in the tank, and smaller quantities of the therapeutant are needed.

## System Startup

In the operation of a commercial facility, startup strategy can be approached from different perspectives. Recognizing that there are combinations of the following general options, the obvious options are:

1. **Partial Startup.** Starting and operating each tank system as its construction is completed, beginning with quarantine and nursery tanks, and progressing to growout or finishing tanks. This option gives the operator the opportunity to handle stock in phases and move fish through the systems as they grow. In starting with smaller, more manageable quarantine or nursery systems, the inexperienced operator is able to learn about the system, water quality, particular strains of fish stock, and the challenges of operations under specific local conditions. This startup method also has the advantage of producing cash flow earlier. In this business, in which there will be no saleable product for at least five to seven months after initial stocking, this head start can be significant. The disadvantage of this startup option is that operation of systems must be conducted while construction in other areas of the facility is continuing. Interruptions of labor, routine maintenance, and utilities (electric power and water service) may occur as construction continues.
2. **Full Startup.** Beginning startup of systems after construction of the facility is complete. This method can also be phased, with a starter cohort of fish transferred through each phase of the system and new cohorts stocked as the starter fish are harvested and transferred forward. All tanks can be stocked simultaneously. Even larger growout tanks can be stocked at low density in anticipation of reaching a final growout density. This method has the inherent disadvantage of inefficient use of resources, however. It may be necessary to operate oversized pumps and filters even for a lightly loaded system. Sufficient tank space must be held available for those cohorts of fish advancing through the nursery system. Their growth rates will be retarded if tank space is unavailable at the time when they are to be transferred and their densities reduced.

With the system fully constructed, startup and operation without fish allows the new operator to get a “feel” for the system and its operation without the risk of losing a crop. Although the challenges posed by water quality issues will be absent, the physical operation of pumps, solids filters, and water flows can be practiced. It is possible to become familiar with such things as flow characteristics, water levels, and the sights and sounds of a properly operating system. Experienced operators find that variations in sounds produced by the working system are often the first clue that something requires attention.

### **System Filling**

Before filling the system, it is important to complete several tasks that will allow for better operation of the system. It is considerably easier to complete these tasks before filling than to try to accomplish them later with the tank filled or partially filled.

1. **Provide a depth scale within the tank.** By providing visible reference marks, the operator can quickly determine the status of flow within the system at any time in the cycle. Communication among personnel can also be facilitated if there is a measurement system. Under normal operations, an increased water level in the tank may indicate increased pump flow or a restriction in the effluent pipes of the tank. In

the latter case, this restriction may signal the need for cleaning of the system pipes. The scale can also be a quick reference to be used during drain down in preparation for harvesting or sampling. One of the simplest scales is a series of marks with an indelible marker on the tank wall, or a ruler or scale affixed to the tank wall or the vertical manifold pipe, using the tank floor as the zero reference point. Units should be in one centimeter increments, or every half inch if desired. The scale should be made sufficiently durable to withstand cleaning by hand scrubbing from time to time.

2. **Adjust the top plate of the particle trap.** This plate should be adjusted so that the space under the plate at the outer edge is sufficiently large to allow entrance of the largest waste solids and uneaten feed that will be used in the cycle, while at the same time small enough to exclude the smallest fish that will be stocked at the beginning of the cycle. Laterally compressed fish such as *tilapia* can slip under the plate on their sides and can cause considerable problems in solids removal if they become lodged under the outer perimeter of the plate or in the flexible pipe leading to the sludge collector. In order to avoid having to get into the tank and re-adjust the plate under water during the growout cycle, it is prudent to adjust the plate correctly at the start of the cycle. Trial and error and the experience of numerous cycles have yielded guidelines for particle trap top plate spacing shown in Table 1. These are meant as guidelines only and may need to be modified to fit local conditions or particular strains of fish.

Table 1. Suggested Spacing for Top Plate of AquaOptima Particle Trap.

Particle Trap Model	Fish Size @ Stocking	Fish Size @ Harvest	Smallest Feed Size	Largest Feed Size	Top Plate Spacing
ECO-TRAP 100	0.5 grams	20 grams	#2 Crumble	1.5 mm (1/16 inch)	3.0 mm (1/8 inch)
ECO-TRAP 200	20 grams	100 grams	1.5 mm (1/16 inch)	3.0 mm (1/8 inch)	10 mm (3/8 inch)
ECO-TRAP 300	100 grams	600 grams	3.0 mm (1/8 inch)	4.5 mm (3/16 inch)	16 mm (5/8 inch)

3. **Prepare the tank surfaces for filling.** Attention should be paid to the materials composing the wetted surfaces of the system. These wetted surfaces of a new system, depending upon their composition, can contain substances that may be toxic to the cultured fish and thus, should be rinsed or allowed to leach these substances before stock is added. For example, while it may not be necessary or even desirable to coat concrete to seal the surface, it is prudent to flood these surfaces and allow leaching of the surface lime. By rinsing surfaces and discarding the rinse water, it is possible to remove very fine solids that may become suspended and difficult to remove later by filtration. The tank should be filled or at least partially filled and the system should be allowed to circulate before this water is drained and discarded. This allows the operator to monitor the tank and piping for possible leaks or malfunctions that can be repaired more easily at this time. If there are doubts about materials in contact with the culture water, obtain manufacturer recommendations about possible contaminants. A general rule of thumb that can be used is that materials recognized by the United States Food and Drug Administration (FDA) as safe for food contact or for holding potable water usually will be safe for use in fish culture systems.

4. **Allow sufficient time for system filling and conditioning.** The time required to fill a system in preparation for startup may vary, depending upon the specific water supply and the system capacity, among other factors. A removable standpipe should be placed in the standpipe well and adjusted later, if necessary, to maintain the proper culture tank operating level. As the tank fills and water begins to overflow the standpipe and fill the biosump, the level of the water in the biosump should be monitored. The biosump should receive sufficient water to cover the pump intake pipe and to allow pump operation without entraining air into the intake. Priming of pumps (adding water to the pump and suction pipes) should be carried out to avoid operating pumps in a “dry” condition. Proper placement of check valves and a priming port can make pump startup much easier.

With the current layout of the growout systems at the CP&L / EPRI Fish Barn, each of the main systems is provided with a priming pump. The high efficiency main pumps of the system are not self-priming. In addition, pump intakes were not fitted with check valves or foot valves. This was done for several reasons: 1) to reduce friction loss created by the valves 2) to remove a potential maintenance item which would be difficult to access in the biosump 3) difficulty in sourcing affordable, reliable check valves in a 3-inch size. Priming of the systems for initial startup is accomplished by first starting the self-priming auxiliary or priming pump. The discharge of this pump is connected to the intake side of one of the main pumps, allowing the main pump suction to be filled prior to starting.

Startup of a filled system and operation for “shakedown” purposes may provide slightly different operational characteristics than will be encountered when the tank is fully stocked and operating. A good example of this is the formation of a standing wave in the tank. In a system with no aeration and development of a center vortex, it is possible to develop a wave that sweeps the wall of the tank, threatening the tank wall with flexure and possible failure. This wave can be broken up and its formation prevented by adding objects that create resistance to normal flow within the tank. A foam block, biofilter media, netting, or even sections of PVC pipe and fittings can be suspended in the tank to create this resistance. Care should be taken to position the items so that damage to tank walls will not occur as the items move in the water current. This condition is rarely seen after stocking of fish, since the fish create sufficient resistance to inhibit the development of the standing wave.

5. **Adjust standpipes to maintain proper water levels.** The top elevation of the external standpipe should be adjusted to maintain proper water level within the tank, as well as proper flow through the sludge collector. The system is highly dynamic, and slight changes in inlet water flow and external standpipe elevations can affect operating water level. The external standpipes at the CP&L / EPRI Fish Barn are arranged so that there is a minimum height standpipe approximately 90 cm (35 inches) tall fitted into the standpipe well base. A PVC coupling is fitted on top of this pipe, and smaller sections of PVC pipe are fitted into the coupling to provide for the

proper tank water elevation at a given flow rate. An inventory of these sections of pipe in 2.5 cm (1 inch) increments can be used to replace the top section if tank water level adjustments are necessary, i.e., a 15 cm (6 inch) section can replace a 12.5 cm (5 inch) section to raise the tank water level slightly. All sections should be marked for easy identification and should be “dry fit” without glue or sealant for easy removal and replacement. Further adjustment of the tank water level can be done by seating the top section of pipe deeper or shallower in the top coupling as needed.

After adjusting flows and standpipe elevations to achieve the desired operating level within the tank, the sludge collector elevation should be adjusted to maintain the proper rate of flow. Since water flow through the sludge collector is by gravity, the unit is attached to a bracket that allows for fine adjustment up or down to regulate water flow. Recommended flow for proper removal of solids varies with the model of sludge collector used. Currently, two sizes of sludge collectors are produced by AquaOptima for use with the three sizes of particle traps that they sell. Table 2 is a summary of the recommended flow rates for each of the sludge collectors.

Table 2. Recommended flow rates for AquaOptima sludge collectors.

Particle Trap Model	Sludge Collector Size	Recommended Flow Rate
ECO-TRAP 100	17 liters / 4.5 gallons	6-10 liters per minute
ECO-TRAP 200	70 liters / 18.5 gallons	20-30 liters per minute / 5.3-7.9 gallons per minute
ECO-TRAP 300	70 liters / 18.5 gallons	20-30 liters per minute / 5.3-7.9 gallons per minute

Allow the tank level to reach normal operating condition. This usually will take about two hours to stabilize after an adjustment in flow is made, since movement of the entire mass of water and formation of the vortex at the center of the tank must be established. Once the tank water level has become established, measure the flow rate of water from the discharge side of the sludge collector. If necessary, empty the sludge collector by temporarily plugging the inlet on the inside of the collector, drain the collector, and lower it or raise it as needed to increase or decrease the rate of flow. Allow the sludge collector to refill completely and re-measure discharge flow rate. Repeat as necessary until the proper flow rate is attained.

6. **Prepare tank water for receiving stock.** Preparation for stocking should be carried out keeping in mind the conditions that are desirable for the fish at time of stocking. Sufficient time should be allowed, for example, to bring the system water to the proper temperature in time for receiving fish. Most wells will provide water at a near-constant temperature year round. Seasonal variations in supply water temperature may occur depending upon the distance the water is transported to the facility in shallow piping or above-ground piping. Supply water piping enters the CP&L / EPRI Fish Barn at one end and is located close to the ceiling along one wall. This placement allows incoming water passing through the supply piping to be warmed passively by the warmer air near the ceiling.

Bringing the entire volume of water to an acceptable temperature may require several days or longer, depending upon a variety of factors, including the system volume, incoming water temperature, heating or cooling capacity, and the building environment. The operator should match the system temperature to anticipated transport water temperature. Because of reduced metabolic processes, most fish will transport more easily and for greater distances if transport water is cooled. Since transported fish are subjected to numerous stressors such as crowding, handling, elevated ammonia levels, deprivation of feed, elevated CO<sub>2</sub> levels, and pH fluctuation, matching system water temperature to transport water temperature can significantly reduce the amount of stress that the new fish undergo. The system can be brought to the proper operating temperature after fish have arrived and have become acclimated. Operating the tank with a lower water level and a reduced volume and topping up the system after stocking may be an acceptable alternative if time is a constraining factor.

### **Biofilter Conditioning**

Operating without stock also will allow for conditioning of the biofilter media, the establishment of a “seed” population of nitrifying bacteria. Commercially produced bacterial preparations are available and may be safer to use than inoculating bacteria—and possible disease organisms—from an operating system. The decision of whether or not to inoculate bacteria from an operating system should be based upon the health of the stock from the system providing the inoculum, and from evaluation of production scheduling. Generally, if initial biomass and corresponding feed additions are expected to be quite low, pre-activation of the biofilter using a bacterial inoculation may not be necessary or desirable. If enough time is allowed, a natural population of bacteria will become established in a new system. Each operator should determine his/her own “level of comfort” in risking contamination. If pre-activation of the biofilter is desired, adjustment of specific water quality parameters to promote the growth of nitrifying bacteria is necessary. The most critical of these parameters are pH and alkalinity. With the addition of sodium bicarbonate, pH will be buffered and carbonate will be available for use by the rapidly growing populations of nitrifying bacteria. Optimum pH range for these bacteria is roughly 7.0 to 8.0. Total alkalinity, the measure of carbonate (CO<sub>3</sub><sup>2-</sup>) and bicarbonate (HCO<sub>3</sub><sup>-</sup>) ions, should be maintained between 100 and 200 milligrams per liter (mg/l). Daily additions of sodium bicarbonate may be necessary to maintain this concentration during startup and operation. Nutrient levels will need to be maintained in the new system to provide nutrition for growing bacteria. Recipes for nutrient mixes are available (Masser, 1992) and can be used. Small quantities of feed can also be added to the system to provide some available nutrients for the bacteria.

Establishment of both *Nitrosomonas* and *Nitrobacter* bacteria can be monitored by testing for concentrations of ammonia and nitrite as the biofilter “matures.” If ammonia concentrations are monitored over a number of days during startup, a decline in ammonia concentration signals that *Nitrosomonas* bacteria are becoming established within the biofilter. This is assuming that nutrient input, whether it is by chemical addition or by

addition of feed, is constant. It is possible that new water addition can dilute ammonia within the system, causing concentrations to decline from day to day, and therefore giving the impression that nitrification is occurring. This is an additional piece of information that the operator must interpret as part of daily system management. Once *Nitrosomonas* bacteria begin converting ammonia to nitrite, conditions become more favorable for the development of *Nitrobacter* bacteria. With an increasing level of nitrite to support *Nitrobacter* development these bacteria will begin to multiply rapidly and become established. As a result, nitrite will begin to be oxidized to nitrate. As cell density increases in the biofilter media, nitrifying capacity of the biofilter will increase and both ammonia and nitrite will decline to stable levels. During the development of bacterial populations when growth is occurring rapidly, alkalinity can plunge rapidly, and the operator must be prepared to quickly adjust the rate of application of sodium bicarbonate in order to keep up with its removal and use by the bacteria.

## **System Stocking**

### **Sourcing and Purchasing Stock**

The quality and health of the incoming stock is of utmost importance. One of the most important factors in procuring quality fish stock is to buy from reputable, established hatcheries. Sellers of hatchery products should be prepared to provide recent documentation from qualified veterinarians regarding the health of their products. Purchasing from hatcheries with a poor track record, even at heavily discounted prices, can mean the beginning of the end for a growout operation. Once introduced, disease organisms can be extremely difficult to eradicate or control, requiring breakdown of the system components for disinfecting and drying. Realizing that even small crevices can harbor disease organisms if they are not disinfected properly, one can see the importance of avoiding disease contamination.

Having selected suitable fish stock, preparations for stocking should focus on providing an environment as near stress-free as possible. Whether arriving from an on-site hatchery, live-haul transport, or air cargo, each lot of new stock will have undergone some degree of stress as a result of handling and transportation. It is usually good practice to provide some level of chloride (Cl<sup>-</sup>) ion in the transport water and the receiving system water to alleviate stress. While chloride levels are generally maintained at around 200 to 300 milligrams per liter (mg/l) during the culture cycle, this level can be more than doubled for receiving stock, and then allowed to decline to operating levels as new water is added to the system. Chloride can be added as sodium chloride (non-iodized NaCl or rock salt) or calcium chloride (CaCl<sub>2</sub>), the latter being preferred if additional calcium hardness is desired. Each form is sufficiently soluble to allow it to be dissolved in a container and then added as a solution to the system, avoiding loss through solids filtration or ingestion by the fish. Alternatively, a screen or mesh bag or perforated container can be suspended in the tank or in the flow stream exiting the tank and the solid will dissolve and be mixed gradually throughout the system water. Without fish in the

system, salt and soda can obviously be added without concern of the impact upon the fish. However, experience from several operations has shown that once fish are stocked, chemical additions can cause the population to refuse feed for a short time. In production situations, therefore, in which it is important to keep the population feeding, chemical additions should be made with as little impact as possible on the fish. This means adding any salt or soda slowly and in a part of the system other than application directly to the tank.

The desired form of chloride used in the system is usually a question of cost. Operators should choose the form that is more cost effective to acquire, store, and apply in their system and at their location.

### **General Stocking Procedures**

The general sequence of events for preparation and system stocking should be as follows:

1. **Secure necessary permits.** This can usually be accomplished early in the project's timetable. Failure to provide copies of permits to fingerling suppliers can result in shipment cancellations or delays.
2. **Prepare the tank and system.** Adjust flows and install screens on the culture tank outlets suitable for the anticipated size of incoming stock. If possible, adjust physical parameters such as temperature, salinity or chloride ion concentration, and pH to match transport conditions.
3. **Organize personnel.** Schedule work for sufficient personnel to allow the transfer and system stocking to be accomplished in minimum time. Plan for extra personnel if size sampling or counting of new fingerlings is planned.
4. **Organize equipment.** Clean and repair equipment such as dip nets, buckets, and scales or balances.
5. **Expect delays.** Organize personnel and facility in anticipation of delays or cancellations. Expect the unexpected and plan alternate strategies. Be aware of weather conditions that could affect transportation.
6. **Maintain contact with supplier.** Last minute changes could result in cancellation of the delivery. Mutually acceptable compromises may be necessary.
7. **Move quickly.** Delays can result in loss of fingerlings. Organization of resources will allow for more efficient accomplishment of tasks.
8. **Check condition of transport medium.** Knowing temperature, dissolved oxygen levels, and pH could determine the urgency of introducing the stock to the system. If dissolved oxygen level in the shipping bags or live haul tanks has fallen dangerously low, it may be wise to forego or accelerate tempering. In the case of new stock arriving in shipping bags, check all bags to make sure they are inflated. Deflated bags are a sign that dissolved oxygen levels may be dangerously low. These bags may require special attention and should be checked immediately.
9. **Temper incoming stock to local conditions.** Temperature is most easily adjusted by floating shipping bags in the receiving tank. In the case of live haul transport, exchanging transport water with system water will gradually introduce fish to new conditions. For recurring operations, invest in a small pump and hoses to slowly

transfer water from the receiving system to the transport tank if it must remain on the transport vehicle. For transport bags, adding small volumes of water to the bag will gradually adjust conditions. Do not add transport water to your system.

10. **Note any observed mortality.** Provide accurate feedback to the supplier to promote better service in the future. Better service may result simply from the fact that the supplier knows that the purchaser is observant and conscientious. Checking and recording dissolved oxygen concentration, pH, ammonia-nitrogen and nitrite-nitrogen concentration in the shipping water can provide important information if fish losses are apparent in the incoming shipment. In the case of greater than anticipated mortality, it may be necessary to stock additional fish quickly to avoid growth disparity between the stocking cohorts.
11. **Reduce the velocity of water flow within the tank.** In order to provide a calmer environment for fingerlings that may be stressed due to transport, reduce or eliminate flow into the tank. This can be done by shutting down the main pump or closing down the inlet water valve at the tank. A better setup is to provide for a bypass around the tank which allows flow through the biofilter and the solids filter, without discharging this full flow into the culture tank. Reduced current will avoid overwhelming weaker fish and sweeping them toward the center vortex over the particle trap. As newly stocked fish begin feeding and recover their strength flow can be increased slowly over a period of days after stocking.
12. **Release fingerlings gently.** Minimum handling will result in improved survival. Size sampling can usually be accomplished by sampling about 10 percent of the population. Avoid transfer of shipping water. This necessitates net handling of fish. Handle fish in batches that are sufficiently small to keep them in good condition. If cold weather conditions exist, protect fish being transferred from exposure to cold air.
13. **Observe post-stocking mortality.** Losses that occur after stocking may be due to unusual shipping conditions or delays and may be the responsibility of the supplier or the carrier. Estimates of replacement stock will be more meaningful if post-stocking observed mortality is recorded. Accurate population estimates will result in more efficient use of feed resources and better planning for harvest and marketing.
14. **Begin feeding as soon as fish will accept feed.** Most fish transport involves starvation of fish for one day to one week prior to transporting. Fish generally arrive at their destination very hungry. Cannibalism of weaker fish can result. Offering small amounts of feed by hand can give an additional piece of information about the condition of newly received stock. Fish that accept feed readily after stocking are generally in good condition and have a better chance of surviving in their new system.

Observing these general rules can significantly improve survival of one's stock. Operator experience with local conditions could result in modification of many of the above rules, and can be the most significant factor in tailoring procedures to a particular production situation.

## Size Sampling at Time of Stocking

Size sampling at the time of stocking new fish can provide important operational information. In addition to verifying information provided by the supplier, an accurate assessment of average size and stocking number can allow for better adjustment of feeding rates and thus, more efficient utilization of feed, one of the most important items of the operating budget.

Size sampling of approximately 10 percent of the population will generally provide statistically valid information for operational purposes. Samples should be randomly selected, such as randomly setting aside boxes or bags of arriving fish, or capturing by dip netting in several tank locations or from multiple tanks in the case of live haul transportation. Samples can be weighed in a known volume or weight of water, or quickly weighed after being allowed to drain of excess water in a dip net or container. In the case of weighing in water, use system water, not bag or live haul transport tank water. After weighing, fish should be quickly returned to a bucket of water and individually counted by gently pouring them into the receiving tank or dipping them out with a cupped hand and gently setting them in the receiving tank. The following simple formulas can be used to calculate individual average weight and total tank biomass.

### Average weight:

Gross weight of sample - tare weight of container = net weight of sample

Net weight of sample ÷ number of fish in sample = average weight of fish

### Total biomass:

Average weight of fish x total number of fish = total biomass

## Adjustment of Flow for Newly Stocked Fish

The system for solid waste removal developed by AquaOptima, consisting of the particle trap and the sludge collector, relies upon the circular flow pattern created within the tank to move solids to the center of the tank where they are removed. The velocity of this flow should be adjusted so that fish are not overwhelmed by the water current. Greater than normal velocity of flow can result in more energy expended by the fish to swim against the current, causing poorer feed conversion.

The Q1 system of the CP&L / EPRI Fish Barn has a single main pump to provide circulation through the system. When newly arrived fingerlings are stocked, the main pump is shut down and emergency oxygen is used. After stocking, the main pump is started and a small flow is restored. Only a portion of the pump output is routed to the tank. The balance of the pump output is diverted before entering the tank and sent directly to the standpipe well. This reduces the velocity of the current within the tank, while still providing flow through the solids filter and the biofilter. As fish grow and biomass increases, flow is gradually increased through the tank.

Main growout tanks and the Q2 tank utilize two main pumps to provide circulation of system water through the tank, biofilter and oxygenation equipment. This redundancy

allows for a backup in case one pump fails and also allows for more efficient use of energy during the early part of a growout cycle, when total tank biomass is low and less biofiltration capacity and oxygen addition is required.

Recommendations are provided by AquaOptima for placement of the ECOFLOW vertical manifolds in order to achieve movement of solid wastes to the center particle trap. Reduction in the velocity of the current in the culture tank can be further affected by changing the direction of inflowing water from the ECOFLOW vertical manifold. In a situation in which there is greater velocity of current within the tank than is desired, the vertical pipe of the manifold can be rotated so as to direct the discharge toward the tank wall. This reduces the component of force that moves tangential to the perimeter of the tank and slows the water current without reducing total flow. In tanks that have two vertical manifolds, it is usually best to vary the direction of the discharge of only one manifold, allowing the discharge of the other to create the force required to establish and maintain the circular flow pattern.

AquaOptima has developed guidelines for water exchange through tanks of various sizes based upon hydraulic retention times. These guidelines should be followed in order to achieve efficient solids removal. In operation of the larger tanks (56.7 cubic meters/15,000 gallons) at the CP&L / EPRI Fish Barn, measurements of the velocity of the circular flow pattern were checked on several occasions, and were found to be between approximately 0.24 meters per second and 0.42 meters per second. This flow was measured at a point about 30 to 40 centimeters in from the perimeter of the 6.4-meter diameter tank. A medium-sized orange makes a good flow indicator, since it floats partially submerged in the water and creates sufficient resistance to be carried along by the current. It is also highly visible and is unaffected by air currents at the tank surface.

## **Feeds and Feeding**

The system described herein employs an advanced method of solid waste removal to allow capture of solids and uneaten feed before they deteriorate and add to the biological load on the system. For this reason, the use of slowly sinking feeds is preferred. Should feed not be consumed immediately by the fish, it becomes a settleable solid that migrates to the bottom center of the tank and enters the particle trap, to be settled in the sludge collector and removed from the system. Slow-sinking or floating feeds may be used as required, if feeding behavior of the fish is slower and more time is required for them to consume a feed application. These feed types tend to remain in the tank for longer periods of time if not consumed by the fish.

A distinct advantage of this system is the ability of the operator to monitor and adjust feed rates to avoid inefficient feed application. By monitoring the amount of feed entering the sludge collector, feeding can be reduced or suspended if feed is not being consumed by the fish. With feed representing one of the largest line items in an operating budget, it is essential to use it wisely.

The size of the fish being stocked is an important consideration in selecting starter feeds. Table 3 is a suggested schedule of feed types and sizes, with operator discretion encouraged in selecting feed types and in scheduling changes of feed sizes.

Table 3. Suggested schedule of feed types and sizes for *tilapia* growout in water reuse systems.

Feed Type	Feed Size	Range of Average Weights of Fish
#2 Fingerling Crumble	#16-#20 mesh (1.19-0.84 mm)	0.5 gram to 5 grams
#3 Fingerling Crumble	#10-#16 mesh (2.00-1.19 mm)	5 grams to 15 grams
#4 Fingerling Crumble or 1/16" Pellet	#6-#10 mesh (3.36-2.00 mm)	15 grams to 100 grams
Grower	1/8 inch Extruded (3.2 mm)	75 grams to market
Grower	3/16 inch Extruded (4.8 mm)	300 grams to market (optional)

Consult with your feed supplier or your Cooperative Extension Service about the selection and use of feeds available in your area.

Delivery of feeds can be accomplished in a variety of ways. The overall goal in feed delivery should be to offer feed uniformly to the entire tank population. This minimizes behavioral factors that contribute to competition for feed, thus yielding more even growth rates across the population. The task of feed application changes dramatically during the growout cycle, with typical daily feed amounts being modest at the beginning of the cycle and progressing to increasingly greater quantities just before harvest.

A uniform, timed application of feed throughout the day will cause a more stable oxygen demand pattern. In the absence of automatic control of oxygen input, dissolved oxygen levels will rise and fall if feed is given on an intermittent basis. Depending upon personnel availability and staffing of the facility, feeding by hand may be a good option. Hand feeding allows the operator to monitor the feeding activity of the fish and is an interaction that gives the operator significant information about the state of the fish population. Feed rates can be adjusted up or down depending upon the reaction of the fish when feed is offered. This can result in better feed conversion ratios (FCR) and more efficient use of this significant item in the operating budget.

## Daily Maintenance Routine

Time requirements for completing daily maintenance depend upon the facility size and stocking condition at that time. The daily routine consists of activities in the following areas, ranked in the order in which they should be accomplished as the day begins:

1. **Check in** – as the operator enters the facility, there should be a quick check of each system, visually checking the condition of the stock in each tank, listening for unusual or extraordinary sounds; water levels in each tank should be noted, along with the flow of water into and out of each tank; the floor around each tank should be quickly scanned for any fish which have jumped out and may be returned to the tank alive; electronic monitoring of dissolved oxygen levels should be quickly checked for each system.
2. **Water quality testing** – if necessary, grab samples of water should be taken from those systems that require testing. This should be done before any conditions are disturbed by further activity in the tanks. Tests for parameters that must be tested immediately after sample collection, such as dissolved carbon dioxide, should be completed. For systems that will require the test results to determine the day's feed ration, these tests should be completed as soon as possible.
3. **Feed preparation** – feeders should be filled with the required ration and activated so that feeding can begin.
4. **Completion of water quality testing** – tests for parameters that are less sensitive to the time lag between sample collection and sample analysis should be completed next. These are tests such as measurement of alkalinity and chloride levels, if required.
5. **Chemical additions** – addition of sodium bicarbonate (or alternative source of alkalinity) and rock salt (or alternative source of chloride) should be completed.
6. **System cleaning/maintenance** – cleaning of gravity flow pipes from particle traps, based upon observations of tank water levels; cleaning of pump strainer baskets, if fitted; miscellaneous maintenance as needed.
7. **Afternoon feed additions** – evaluation of dissolved oxygen conditions and decisions about additional feeding.
8. **Check out** – verifying that systems are operating normally, alarm system is activated, and operator can leave. A written list of items that can be checked off as they are verified is strongly recommended.

### **Water Quality Testing**

The extent of testing for each system will vary depending upon a number of factors, including:

- species being cultured
- operator background and experience
- feeding rate and feed type
- tank biomass
- health condition of the fish stock
- changes in production strategy

Operators should become intimately familiar with water quality conditions as they relate to the operating system. As a new facility is started up, more frequent data should be collected as the operators become familiar with the interactions of feed rates, new water additions, and water quality parameters. As operators successfully complete growout cycles, their knowledge base and experience should increase to allow for a greater level of comfort in daily operations. The amount of testing required should be sufficient to give the operator that level of comfort needed to result in a profitable operation.

A guide in the measurement of various water quality parameters is presented in Table 4.

Table 4. Water quality parameters requiring monitoring, methods, frequency of monitoring, and alarm requirement.

Parameter	Monitoring Method	Frequency	Alarm
Dissolved Oxygen	D.O. Meter	Continuous	+
pH	pH Meter	Daily	-
Carbon Dioxide	Wet Chem./pH Meter	As needed	-
Alkalinity	Wet Chemistry	Every other day	-
Temperature	Thermocouple	Continuous	+/-
Total Ammonia Nitrogen	Wet Chemistry	Daily	-
Nitrite (NO <sub>2</sub> )	Wet Chemistry	Daily	-
Nitrate (NO <sub>3</sub> )	Wet Chemistry	Weekly	-
Tank Water Level	Mech. / Elect.	Continuous	+/-
Recycle Water Flow	Mech. / Elect.	Continuous	+/-

+ = requires automated alarming; - = does not require alarming; +/- = optional  
(Source: Losordo, 1997)

### Operation of Downflow Oxygen Saturators

Increasing feed inputs to any of the systems will create greater oxygen demands. As fish grow and biomass increases, feeding rates increase. Oxygen inputs to downflow oxygen saturators should be checked daily to assure that dissolved oxygen concentrations are sufficient for the fish to efficiently convert feed. With new systems generally requiring lower oxygen inputs, a new operator will have a chance to become accustomed to the gradual adjustment of the downflow oxygen saturators to provide the oxygenation needs of the systems.

The basic rule to remember in operation of the downflow oxygen saturator is that all oxygen that goes in must equal the sum of the dissolved and undissolved oxygen bubbles that come out. If there is an imbalance such that greater quantities of oxygen are being input than that which is carried out of the saturator (dissolved and undissolved combined) by the effluent water, a surplus of gaseous oxygen within the saturator will occur. This condition can be recognized by a large section of the saturator appearing to be hollow, either visually (for saturators constructed of clear or translucent pipe) or by sounding hollow when tapped with the hand or when the ear is held against it. By checking the saturator at 20 to 30 minute intervals after adjusting the influent oxygen, the experienced

operator can determine whether the “hollow” area is increasing or remaining about the same. Check the saturator by listening or tapping on the upper part and progressively moving downward until reaching the point at which it appears filled with water. Note this level, and recheck again at a later time. If the hollow section is larger, one of three possible actions must be taken to alleviate the developing surplus oxygen situation that may be occurring: 1) Reduce oxygen input 2) Increase water flow 3) Combination of both 1 and 2.

When approaching difficulties in maintaining tank dissolved oxygen concentrations, it is helpful to increase the pressure under which the saturator is operating. This can be done most effectively by partially closing the valve at the farthest point from the oxygen saturator, thus placing the entire length of pipe from the saturator to the valve under greater pressure and improving conditions for dissolving the oxygen bubbles. Check the surface of the tank near the discharge of the vertical manifolds for bubbles surfacing. These bubbles are undissolved oxygen and are being lost to the atmosphere. Since liquid oxygen is an operating expense, it is an expense which should not be wasted.

### **System Cleaning**

Because of the smaller pressure differentials, more frequent cleaning of gravity flow piping is required than for pumped flows. Frequency of cleaning varies, depending upon the operating temperature and nutrient loading of the system. In growth trials at the North Carolina Fish Barn and with a private commercial operator, at water temperatures of 26° to 28° Celsius, cleaning of pipes was required about every four days beginning in the third month of the 6 to 7-month *tilapia* growout trial. Less frequent pipe cleaning was required before the third month of operation. In comparison, in a coolwater system at the North Carolina Fish Barn operating at 15° C, pipe cleaning was required at intervals of about 10 to 12 days.

With the AquaOptima ECO-TRAP system, regular cleaning of two primary pipes is required. These pipes are the main discharge pipe exiting the particle trap, and the smaller sludge collector flexible hose leading from the particle trap to the sludge collector (See Figure 1).

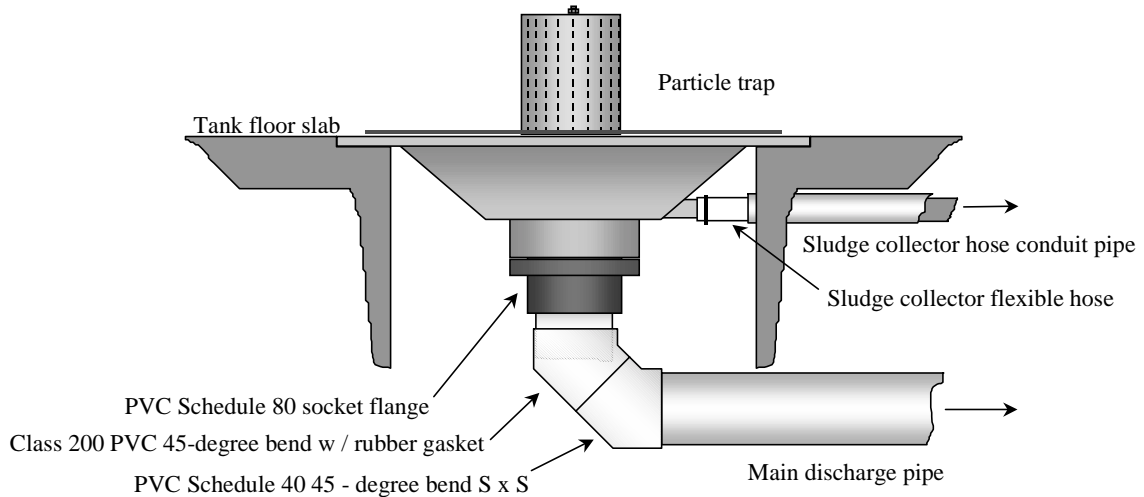


Figure 1. General layout of installed ECO-TRAP particle trap.

If proper velocity of flow is maintained in these pipes, settling of solids within these pipes is not a problem. As mentioned previously, however, the growth of bacteria on the inner surfaces of these two pipes can cause reduced flow area that can significantly reduce flow.

As the system is started up and operated, flow into and out of the culture tank will equalize so that the tank water level stabilizes. Given that the flow returning from the biological filter to the culture tank remains constant, even a slight decrease in flow out of the culture tank is manifested by an increase in water level. This increased water elevation has become necessary to overcome the increased friction losses caused by bacterial fouling inside the piping. By checking the depth scale within the culture tank, the operator can easily determine that the tank water level is rising and that effluent pipes need cleaning.

In the case with the private operator previously mentioned, as with the systems operating at the North Carolina Fish Barn, cleaning of tank effluent piping could usually be accomplished in 10 to 15 minutes. Cleaning equipment can be of two types—brushes, or pressurized water spray. Most effective, although not as easily used, are brushes with cylindrical shapes, such as properly sized bottle brushes, which are attached to the end of a plumber's snake purchased from a local hardware store. This provides sufficient flexibility to negotiate the bends and changes of direction within the pipes, while at the same time providing the rigidity necessary to allow the brush to be alternately pushed and pulled through the pipes from the standpipe well, outside the tank. Cleaning of pipes is most often done with the system operating, so that dislodged material is flushed from the pipes and the flow pattern and tank water levels are more quickly re-established.

Pressurized water from a garden hose with a straight spray type nozzle also can be used to scour the inside of the piping. It is important to tape or otherwise wrap the hose fittings to avoid snagging the hose fittings inside the piping. With practice, any operator can

become adept at cleaning with these methods. A more sophisticated method uses a high pressure washer with a hose attachment and a specialized spray tip. The type used for cleaning boiler tubes which sprays against the sides of the pipe and backwards, causing it to propel itself forward, is very effective and easy to use in regular cleaning.

Other critical areas requiring cleaning attention in the system are the inlet and outlet of the sludge collector, the waste line leading from the sludge collector, and piping associated with the drum screen filter (See Figure 2).

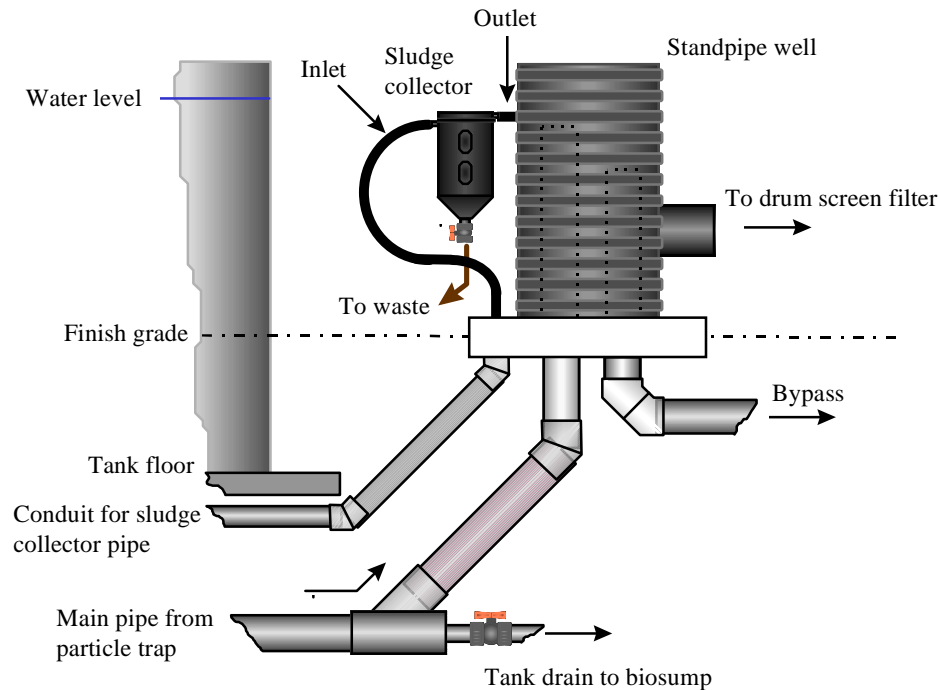


Figure 2. Detail of sludge collector and standpipe well piping

The sludge collectors must continue to receive proper flow from the particle trap located in the tank. Cleaning of tank effluent piping has been described in the preceding paragraphs. It is an equally simple task to clean the settleable solids pipe from the particle trap to the influent side of the sludge collector. Since this is usually installed as a flexible PVC pipe from the particle trap, under the tank slab, and up to the inlet side of the sludge collector, it is a smooth, continuous pipe, without traditional pipe fittings for the changes in direction. This makes the inner surface much easier to clean by brushing with a bottle brush or pressure washer and flexible hose, as described previously. The elevation of the sludge collector should be adjusted to an elevation lower than the main tank water level, to provide for gravity flow of the flow stream containing settleable solids into the sludge collector. Manufacturer's recommendations should be followed in adjusting this flow.

It is important to keep the effluent or discharge pipe of the sludge collector flowing freely so that clarified water can free fall over the inner circular weir and thus allow a constant rate of flow into the collector (See Figure 3).

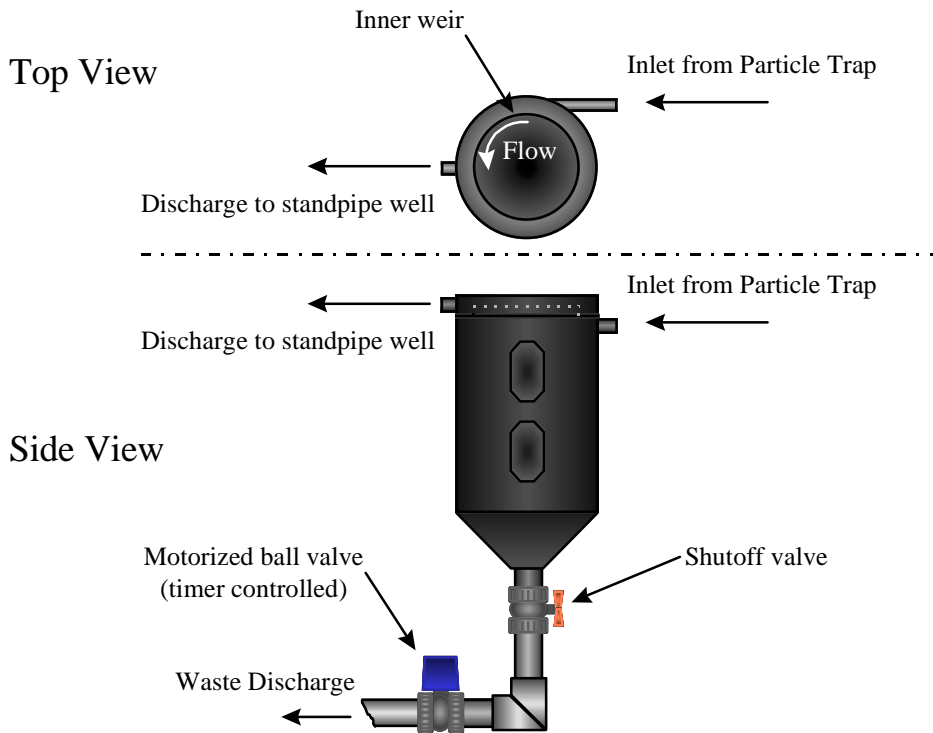


Figure 3. Detail of sludge collector setup

As solids settle and are collected in the conical bottom collector, they are periodically drained through a motorized ball valve connected to the waste discharge pipe. Periodic cleaning of the conical bottom of the sludge collector and the discharge pipe ensures that solids do not bridge and block the pipe. Due to bacterial activity on the solids, and the generation of gases within the sludge, the solids must be drained from the sludge collector at regular intervals to avoid re-floatation. This regular draining is accomplished by operating the motorized ball valve with a timer to drain the solids before they have the chance to be re-floated and lost over the inner weir of the sludge collector, out of the discharge pipe and back into the system. At system temperatures of 28° C this draining process must be done at a minimum of every three to four hours. A complete description of materials and construction of the controller can be found in Ebeling, 1994.

## Record Keeping

The importance of maintaining various types of data can be addressed from several standpoints. Throughout the development of the daily operational plan, a balance must be

struck between necessary and useful data collection, and the generation of data that may never be used. The following goals are offered:

- **Education** – for the beginning operator, organizing records and notes can be the basis of an important educational process in learning how to operate the facility. Accurate note taking allows the operator to determine the effects of various operational changes on the performance of the systems.
- **Budget analysis** – Tracking operating costs, and recognizing and addressing problem areas in an operating budget, can be the difference between profitable and unprofitable operations.
- **Production improvement** – more cost effective equipment and procedures should always be sought, as well as maximizing production through improved water quality conditions, improved survival, more efficient feed utilization, and faster growth rates.
- **Communication** – very few facilities of commercial size are strictly single-person operations. Promoting exchange of information between operators can avoid duplication of efforts, or at the extreme, avoid dangerous conditions for the stock or the operators.
- **Investor relations** – operations that include investors need a basis for educating and informing them about progress.
- **Lending institution education** – bankers and personnel from lending institutions generally do not have good background information about aquaculture. Providing that information, as well as specific performance information about your operation to your lending institution, will promote a better understanding of the industry and can foster financial support at critical points in the development of your business.

Each operation brings with it slight differences based upon size, geographical location, market conditions, climate, water supply, and a host of other criteria. Suggested minimum data to be collected are:

- Feed additions and type
- Chemical additions; i.e., sodium bicarbonate, rock salt, etc.
- Water use
- Electricity use
- Tank populations (stocking, sampling, harvesting, observed mortality)

Format of data sheets is not critical, however, organization for later retrieval and analysis could be very important. A daily operational log is essential in making operational comments, changes, strategies, and maintenance issues available to other employees who may have to share weekend or emergency on-call duties. The following examples of data collection sheets are attached as Appendices to this paper:

- Daily Log – daily operational notes
- Daily Water Quality – dissolved oxygen and chemical parameters, chemical additions
- Feed Record – feed type(s) and quantity added on a daily basis
- Water Record – daily water meter reading, total new water addition by system
- Stock Record – stock movement transactions, stocking, sampling, harvesting, and observed mortality.

## **Size Sampling**

Size sampling of the population during the growout cycle can provide valuable information about growth rates, feed requirements, feed conversion, general fish health, and production scheduling. While sampling may interrupt the daily routine and feeding schedule of the fish, it is a valuable tool that can be used at the discretion of the operator to provide essential data.

If flow is to be reduced during the sampling procedure, preparation for size sampling should begin by withholding feed for 12 to 24 hours before sampling. This allows filtration of system water without new feed additions and reduces oxygen demand. Normal oxygenation capacity will be reduced when pumps are shut down, and emergency oxygenation with diffusers will be necessary. If diffuser oxygenation is attempted without reducing the oxygen demand of the system water, it may not be possible to maintain sufficiently high dissolved oxygen levels during the sampling procedure. Pay close attention to dissolved oxygen levels during the preparation and sampling procedure. Fish that are stressed by low dissolved oxygen levels may not fully recover. Recovery is dependent upon several factors, such as the general condition of the fish, the degree and duration of low dissolved oxygen, and the amount of handling that the fish receive.

Diffuser oxygenation is considerably less efficient at oxygenating the tank water, and significant amounts of oxygen can be used in a short time. The time during which emergency oxygenation is used, therefore, should be minimized. Sampling is best done early in the day so that feeding can resume for the remainder of the day if the fish will accept it, and if the operator will be on hand to observe the fish and the system. There are two basic options which can be followed to conduct a sampling operation: (1) Sampling while the tank is operating at full water depth (2) Reducing water depth to concentrate the population for easier capture.

For the first option, all that is necessary is to begin dip netting. Smaller tanks such as Q1 and Q2 can usually be sampled by this method due to the population density and the smaller, more manageable size of the tanks. Dip netting should be done at random positions around the tank in order to capture a representative sample of the population. Larger fish may tend to crowd into protected areas around the tank, such as the area at the base of the tank wall. For this reason, it is important to capture fish from the deep areas near the tank floor as well as from the water column. Experience has shown that if tank density is sufficiently high, it should be possible to capture about 5% to 10% of the population by scooping with dip nets. If partial harvesting of the tank has previously been done and the tank population has been reduced, dip netting in a tank at full depth

may capture too few fish, and the time and effort required to collect a representative sample will be prohibitively high.

The second option, reducing the tank water level by draining, is done relatively easily with the CP&L / EPRI Fish Barn systems. The biosumps serve as reservoirs for system water and provide storage capacity when tank water level need to be reduced temporarily. By not having to waste water in order to lower the level to a workable depth, the expense of having to replace and reheat wasted water is avoided. With two biosumps for each two-tank system filled to within six inches of the top of the biofilter media, it is possible to store approximately 30% of the tank volume temporarily without loss of water from the system. By adding taller sections of standpipe to the adjacent tank on the system, an additional 5% to 6% of water can be transferred and stored. When storing water in the biosumps, take care not to overfill and cause the biofiltration media to float.

Begin draining the tank to be sampled or harvested about one hour before starting the sampling or harvesting procedure. In the case of harvesting product for market, it may be necessary to closely coordinate activities in order to be ready for the transport truck arrival. Reduce water level by removing top sections of the standpipe and monitoring the tank water level and dissolved oxygen conditions. Draining should be done in stages. If the entire standpipe for the tank is removed, draining may occur too rapidly for the drum screen filter to accommodate the increased flow. At a high flow rate the level switch that controls the backwashing cycle of the filter may not reset the controller, and backwashing will cease. Flow from the tanks within the standpipe well will divert to the bypass pipe and solids filtration will not occur. To be able to safely and comfortably work in the tank, water depth should be reduced to about 140 cm (56 in) or less. At this depth, the Crowder / Grader assembly (Lance Industries, Bayboro, NC) can be lowered into the tank and its setup can begin. This operation requires a minimum of two persons. Due to the danger posed by jumping fish as they are crowded into a decreasing volume of water, eye protection, head protection, and flotation vests are required for all personnel working in the tank. As with any maintenance or procedure requiring a person to be in the tank, at no time should this be done alone.

Figure 4 represents the placement and subsequent movement and manipulation of the Crowder / Grader assembly. This apparatus consists of a center cage which fits over the ECO-TRAP and can be moved from side to side. Attached to opposite sides of the center cage are panels that are pivoted from the starting position, spanning the width of the tank and folding together to finally crowd the fish population opposite the starting position. If grading of fish is desired, the grader panel can be fitted with vertical bar grader panels to allow smaller fish to escape capture during the crowding process. For sampling, screen panels should be used in order to capture all size fish so that grab samples are not biased for size by the smaller escaped fish.

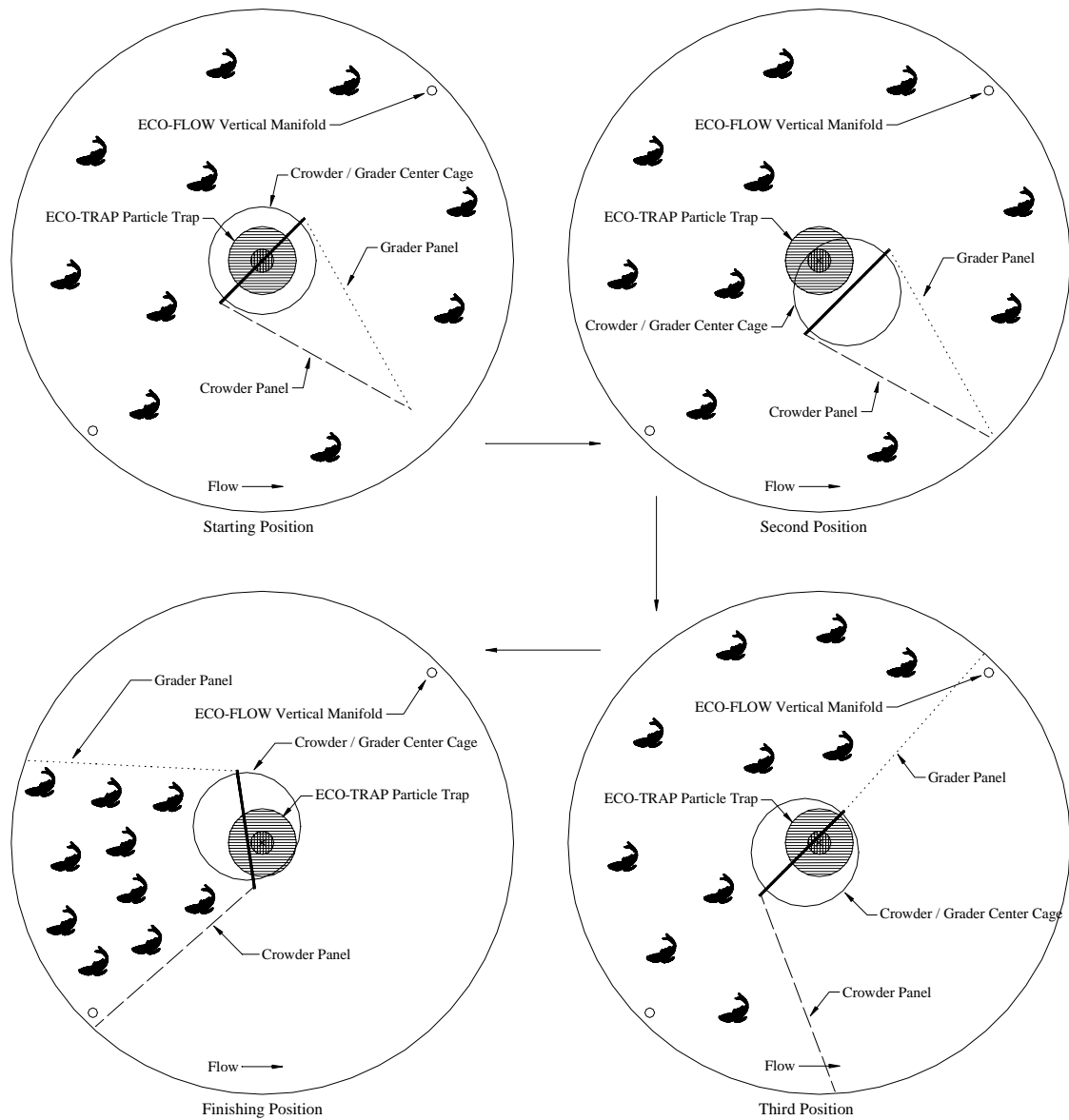


Figure 4. Tank Crowder / Grader setup and operation sequence.

Grab samples should be allowed to drain of excess water and then should be consolidated into a clean container of sufficient depth to avoid loss of jumping fish. Plastic seafood baskets work well for holding samples. After recording the gross weight of the container and fish, these fish can be counted and returned to a temporary holding cage in the tank. Holding these fish temporarily will assure that they are not recaptured during subsequent sampling. If the Crowder / Grader has been used, a temporary holding cage is not necessary. Sampled fish can be returned to the area behind the crowder and grader panels. The tare weight of the empty container, preferably wet with fish slime and water, is subtracted from the gross weight previously obtained to give a net weight of the

counted fish. By dividing the total net weight of the fish by the total number of fish, an average individual fish weight is obtained.

Sampling should continue until about 5% to 10% of the estimated population has been weighed and counted. An example of numbers generated during a sampling procedure is shown in Table 5. As each basket of fish is weighed and counted, note that there is some variation of average weight among baskets.

Table 5. Sampling Data for growout Tank 4, October 13, 1999.

BASKET NO.	GROSS WT. (KG)	TARE WT. (KG)	NET WT. (KG)	NO. OF FISH	AVG. WT. (GRAMS)	OVERALL AVG. WT. (GRAMS)
1	27.42	1.68	25.74	68	378.5	-----
2	25.74	1.68	24.06	61	394.4	386.0
3	27.08	1.68	25.40	67	379.1	383.7
4	20.76	1.68	19.08	49	389.4	384.8
<b>Totals</b>	<b>101.00</b>	<b>6.72</b>	<b>94.28</b>	<b>245</b>	<b>384.8</b>	<b>384.8</b>

In the example above, a total of 245 fish were weighed and counted. This represented about 6.6% of the estimated tank population, as the following calculation shows:

$$245 \text{ fish sampled} \div 3,686 \text{ fish estimated} = 0.06647 \times 100\% = 6.6\% \text{ of population}$$

These data are not presented as an exercise in statistics—that subject could be exhausted elsewhere. Rather, the data are presented to illustrate that there can be variability in sample average weights. A valid sample, therefore, should consist of a number of sub-samples to achieve a reasonable representation of the average weight for purposes of making production decisions.

### **Purging and Testing for Off-flavors**

Preparation for harvesting depends upon the intended market for the product. Fish that will be live-hauled or sold as live product need to be “purged,” or held without feeding for a period of at least two to three days before harvest. This will allow the fish to empty their digestive systems and will greatly improve the water quality of live-hauling containers. Purging, for purposes of eliminating off-flavors, should be done based upon each facility’s requirements. Although not completely understood, off-flavor is characterized as a muddy or musty taste that can occur in cultured fish. In water reuse aquaculture, off-flavors are thought to be caused by bacteria growing within the systems, as well as the brand of feed and feed ingredients. Off-flavors can usually be lessened or eliminated by holding fish—without feeding—in clearer water conditions or with significant (> 25 percent of tank volume per day) exchange of new water. The time required for proper purging is dependent upon a number of factors and should be determined on a tank-by-tank basis.

Testing for off-flavor consists of cooking a freshly caught and prepared fish without added seasoning or spices and tasting skinless cooked samples, noting any objectionable

flavor. This analysis can be done by wrapping the prepared fish in a damp paper towels, placing it in a partially sealed “ziploc” type bag, and cooking in a microwave oven. Cooking times will vary depending upon the type of microwave oven and the size of the fish. For a market-size fish such as *tilapia* of about 570 grams (1.25 pounds), begin by cooking for three minutes on high, turning the fish over, and cooking an additional three minutes. Adjust cooking times as needed to assure complete cooking through the thickest part of the fish. Upon opening the bag and taking care to avoid the escaping steam, the odor of the off-flavor—if present—can be detected. Some individuals appear to possess more discriminating senses and can more readily identify the presence of off-flavor. It is important to sample from different areas of the fish flesh, since it appears that some areas may have more flavor than others. Darker meat and the areas nearer the belly of the fish are usually stronger in flavor. If objectionable flavor is present, a course of action should be determined. Individuals in some markets have reported that they actually prefer that a routinely bland fish such as *tilapia* have some flavor. Based upon the expected market and the degree of off-flavor present, therefore, harvesting and sale of an affected population may be possible. For more serious off-flavor problems, water exchange should begin, and withholding of feed can continue until such time as further samples show improvement.

## **Harvesting**

After completing any required purging and taste-testing of sample fish, preparations for harvesting should generally follow those previously described for size sampling. Tanks should be drained down to a comfortable working depth, and fish should be crowded quickly and efficiently to minimize stress. Set up and operate the Crowder / Grader as previously described in the discussion of sampling. The use of the grading function continues to evolve at the CP&L / EPRI Fish Barn. Grading is a difficult operation to accomplish due to the need for small fish to efficiently move through the grader bars and essentially grade themselves. Fish such as *tilapia*, which do not naturally exhibit strong schooling behavior, cannot be forced—only encouraged, persuaded, and assisted in moving themselves through the grader bars. Efficient grading most likely involves the proper combination of fish density, direction of water current, and timing.

Continue movement of the individual crowder and grader panels as represented in Figure 3, until the population becomes more crowded. Jumping behavior of fish is an indicator of the density and degree of crowding. As jumping of fish begins, cease any further crowding and allow the population to become redistributed and more comfortable with their confinement. Excessive jumping causes damage and scarring of fish, mortality, and inferior product, and should be avoided.

At the suitable density between the crowder / grader panels, sample scoops with the dip net should yield good catches and full nets. If the density is thin and fish are not sufficiently crowded, excessive passes of the dip net will be needed and may result in rougher treatment of the fish and more damage. Begin filling baskets or the lift net and begin weighing and recording net (as opposed to gross) weights as fish are transferred out

of the tank to waiting bins or tanks. Although all product should be handled with care to assure high quality, fish which are to be transported alive should be handled with extra care.

## **Emergency Operations**

Due to the fact that recirculating aquaculture operations are generally located in indoor, enclosed areas, there is considerable protection from the elements built into the operation. This does not mean, however, that these operations are immune from the affects of weather or accidents. Since there is a heavy reliance upon electrical power for the operation of the facility, planning for emergency situations is essential. Certain types of electrical power outages may be expected and more predictable. These outages would be those caused by predictable severe weather such as electrical storms, hurricanes, and ice storms. Other situations, however, such as the loss of power poles due to traffic accidents, are completely unpredictable and may occur at any time of the day or night.

Each facility should be equipped with suitable monitoring equipment to alert facility personnel in the event of loss of power. Employees should be encouraged to be on alert and available on rotating schedules to be able to respond to emergency situations.

During periods of predictable severe weather such as hurricanes, it is prudent to begin preparation well ahead of the anticipated arrival of severe weather conditions. If tank systems are being heavily fed, it may become difficult to maintain dissolved oxygen conditions during a prolonged power outage. For this reason, and recognizing that advance information of impending severe weather conditions continues to improve, preparations should begin well in advance. Supplies of items which will be needed during a prolonged outage, such as emergency oxygen, generator fuel and lubricants, and flashlight batteries, should be checked and procured well in advance of their needed time. Liquid oxygen is a product that is commonly used by hospitals and health facilities. Service to these facilities will be a priority for supplier companies during emergencies, so the prudent operator should make arrangements for delivery and filling of storage tanks as quickly as possible when severe conditions are predicted.

Testing of emergency oxygenation should be a part of regular facility operation. An extra testing session of the system, as well as the alarm system, should occur before an anticipated power outage.

Prior to anticipated severe weather, equipment located outside the facility should be inspected and secured against wind damage or movement. Feed addition to systems should cease at least 24 hours prior to arrival of severe weather conditions. This allows the oxygen demand of the system water to decline so that emergency oxygenation will be more effective in maintaining dissolved oxygen concentrations. Withholding feed will also result in lower ammonia levels within the system after possible loss of pumping and biofiltration functions.

## Procedure for Changeover to Generator Power

This procedure provides step by step instructions for connecting and operating emergency generator service during times of power outages. These procedures assume that safe conditions exist in the facility and that conditions that created the emergency, such as severe weather, do not threaten the safety of the operator or assisting personnel. Personal safety should be the top priority.

Upon arrival at the facility, responding personnel should respond with hand held flashlights or obtain flashlights immediately upon entering the facility. Flashlights are located just inside all main exterior doors. Even if power outages occur during daylight hours, the lack of windows in the facility results in dark conditions during power outages. It may be necessary for the operator to retrieve any individual fish that have jumped out of tanks as a result of being startled by the automatic operation of the emergency oxygen service. These fish may be in walkway areas.

These general procedures should be followed upon entering the facility:

1. Turn on the portable dissolved oxygen meter in preparation for later use. This meter requires a ten to fifteen minute “warm up” time to polarize the probe. Proceed with calibration.
2. Determine that emergency oxygen flow has commenced in all tanks containing stock. This should be determined by visual examination of all tanks, beginning with growout tanks and progressing through quarantine rooms. Vigorous bubbling of oxygen from individual diffusers should be occurring in each tank. Replace any individual fish that may have jumped out of tanks during the startup of emergency oxygen flow.
3. Notify the electric utility about power outage. In many situations in which Fish Barn personnel quickly respond to power outages, the electric utility may be unaware of the specific location of an outage, and other customers within the affected service area may assume that notification has been made. It is important to begin notification promptly so that, as outage reporting telephone lines become occupied, wait time for reporting of the problem will be minimized. Prompt notification of the outage will result in faster resolution of the problem and quicker return to normal service. The telephone to be used in the event of a power outage should be of a type that will allow operation without AC power. For this reason, a “standby” phone, operable under outage conditions, should be available as backup to an electronic system. In the event that telephone service has also been affected and is unavailable, proceed with next step.

**Carolina Power and Light Outage Reporting : 800 419-6356**  
**Customer Account Number: 758-306-1283**

1. Turn off all circuit breakers in “Main Panel”, main electrical panel located inside southwest corner of main building.
2. In “Main Panel”, turn on circuit breakers labeled “Aisle Lights” and “Tank Lights”.
3. Position tractor and generator near connection area. Main service disconnect and generator cable connections are located on outside wall at southwest corner of main

- building. There are three cabinets to be located. Facing the southwest wall of the building, locate the cabinets labeled “Main Service Disconnect”, “Main Transfer Switch”, and “Generator Connection Cables”. The generator should be positioned within approximately fifteen feet of these cabinets—distance from the panel connection is not critical. It is more important however, to locate the tractor so that the long axes of the generator and tractor are aligned, providing for less strain on the universal joints of the tractor power takeoff (PTO) shaft. Tractor and generator should also be positioned so that there is clear access around both the tractor and generator for service and inspection. The tractor parking brake should be firmly set.
4. Connect PTO shaft to rear power takeoff of tractor, checking that PTO shaft is locked in position on tractor PTO driving shaft and that shaft is clear of obstacles which may become entangled.
  5. Connect power cables to generator. Remove cables from storage box labeled “Generator Connection Cables”, uncoil, and connect four-position connector to corresponding outlet side of generator. Connect separate ground cable to ground cable provided on generator frame.
  6. TURN OFF circuit breaker located on side of generator housing.
  7. Start tractor and engage rear PTO smoothly.
  8. Accelerate tractor engine with hand throttle to PTO speed (2700 rpm). Check to see that green indicator light on front of generator is lit. If either of the red indicator lights is on, indicating a PTO speed either higher or lower than optimal for generator operation, adjust tractor throttle until the center green light stays on.
  9. Move handle of “Main Transfer Switch” from upper position to center position, and then down to lower engaged position.
  10. Turn on circuit breaker located on side of generator housing. Power should now be applied to main electrical panel of the building, and lighting should now be available for safe movement within the building.
  11. Prepare growout systems in main gallery for startup on generator power. In equipment rooms 12 and 34, locate circuit breaker panels labeled “Sub Panel 12” and “Sub Panel 34”, respectively. Turn off all circuit breakers with the exception of the breaker labeled “Lights”. This circuit breaker should be left on.
  12. In “Main Panel”, turn on circuit breakers for “Sub Panel 12” and “Sub Panel 34”.
  13. Begin startup of facility depending upon each system’s need. Choose the first system for startup based upon the age and density of the stock, as well as the current feed rates. Systems with older stock, higher densities, and higher current feed rates generally represent greater risk of loss and greater oxygen demands, and thus, should be attended to first.
  14. In either Equipment Room 12 or Equipment Room 34, close valves on both inlet and discharge sides of main pumps. Remove fused electrical disconnect at pump for all pumps.
  15. Open valve on inlet side of priming pump. Open valve on discharge (outlet) side of priming pump and all valves on the pipe which enters the intake pipe of Pump 2 for Tank 1 (or Tank 3 if System 34 is being started first).
  16. Close the crossover valve between the overhead discharge pipes from Pump 1 and Pump 2 for each of the tanks.

17. Locate the fused disconnect for the priming pump and verify that the disconnect is engaged for pump operation.
18. In circuit breaker panel marked "Sub Panel 12" (or "Sub Panel 34 " if System 34 is being started first), turn on the breaker labeled "Priming Pump". The priming pump should now be operating and, since it is a self-priming pump, will begin filling the intake pipe of Pump 2 as soon as it becomes primed.
19. Allow the priming pump to operate for 3 to 5 minutes after becoming primed, so that any air in the intake pipe of Pump 2 will become entrained and expelled.
20. In circuit breaker panel marked "Sub Panel 12" (or "Sub Panel 34 " if System 34 is being started first), turn on circuit breaker labelled "Tank 1 Pumps" (or "Tank 3 Pumps" if System 34 is being started first).
21. In the electrical disconnect box for the pump being primed, re-install the fused disconnect and restore power to the pump. With the pump operating, open the valve on the intake side of the pump smoothly and slowly.
22. While listening for the rush of water through the pump discharge pipe, open the valve on the discharge side of the pump slightly. Maintain a restricted flow from the pump discharge until most of the air has been discharged and less turbulent flow is heard, then open the discharge fully.
23. Close the valve leading from the priming pump to the pump just started, and disconnect power to the priming pump.
24. Adjust oxygen flow to the downflow oxygen saturator which has just had flow restored. Check and adjust flow from the corresponding valve at the tank.
25. Repeat the pump priming procedure and restoration of flow for the adjacent tank on the system, and then move to the other systems and restore this limited flow and oxygenation.

Restoration of flow to Quarantine rooms Q1 and Q2 are much simpler and should be accomplished as soon as possible after restoring flow to the main systems. In the case of system Q2, only one of the two pumps should be started. If dissolved oxygen concentrations cannot be maintained at satisfactory levels with one pump operating, continue to operate the emergency oxygenation by diffusers in combination with the downflow oxygen saturator.

When normal power returns, shut down each of the operating pumps, turn off the breaker on the emergency generator, shut down PTO generator and the tractor, and restore power to the facility by returning the handle of the main transfer switch from the lower position to the center position, and then to the upper position. Begin priming and restarting all main pumps as described before in the previous procedures.

Once conditions have returned to normal, water is flowing, and tank water levels have risen to their normal levels, it is a good idea to remove the flexible hoses from the sludge collectors and flush any accumulated solids from these hoses. During times when flow or water level is reduced, solids may settle out in these flexible pipes, and it is important to clear them once again.

## References and Suggested Reading

Ebeling, J. M. 1994. Monitoring and control. Pages 307 - 323 *in* M. B. Timmons and T. M. Losordo, editors. Aquaculture water reuse systems: Engineering, design and management. Developments in Aquaculture and Fisheries Sciences (27), Elsevier Scientific Publishing Company, Amsterdam, The Netherlands.

Jensen, G.L., 1990. Transportation of Warmwater Fish, Procedures and Loading Rates. Publication No. 392, United States Department of Agriculture, Southern Regional Aquaculture Center, Stoneville, Mississippi, USA.

Losordo, T. M., M. P. Masser, and J. Rakocy. 1992. Recirculating aquaculture tank production systems: An overview of critical considerations. Publication No. 451, United States Department of Agriculture, Southern Regional Aquaculture Center, Stoneville, Mississippi, USA.

Losordo, T. M., J. E. Rakocy, and M. P. Masser. 1992. Recirculating aquaculture tank production systems: Component options. Publication No. 453, United States Department of Agriculture, Southern Regional Aquaculture Center, Stoneville, Mississippi, USA.

Losordo T. M. and P. W. Westerman. 1994. An analysis of the biological, economic and engineering factors affecting the cost of fish production in recirculating aquaculture systems. Journal of the World Aquaculture Society (25)2:193-203, Baton Rouge, Louisiana, USA.

Masser, M.P., and J.W. Jensen. 1991. Calculating the Area and Volume of Ponds and Tanks. Publication No. 103, United States Department of Agriculture, Southern Regional Aquaculture Center, Stoneville, Mississippi, USA.

Masser, M.P., J. Rakocy and T.M. Losordo. 1992. Recirculating aquaculture tank production systems: Management of recirculating systems. Publication No. 452, United States Department of Agriculture, Southern Regional Aquaculture Center, Stoneville, Mississippi, USA.

Timmons M. B. and T. M. Losordo editors. 1994. Aquaculture water reuse systems: Engineering, design and management. Developments in Aquaculture and Fisheries Sciences (27), Elsevier Scientific Publishing Company, Amsterdam, The Netherlands.

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Appendix 1. Sample Forms for CP&L / EPRI Fish Barn