Well Water System

1. The Well Pump

A 7.5 horsepower submersible pump supplies water from a 185-ft well. The pump is capable of supplying 378.54 Liters/minute (Lpm) (100 gallons/minute (gpm)) or more, but when more than about 265 Liters/minute (70 gpm) are pumped the water contains too much sediment. The pump switch is located on a gray control box on the east wall just inside the back room near the egg trays. This gray control box also controls a heat tape that runs inside the 5.08 cm (2-in) supply pipe from the pump (Figure 1). A green indicator light on the control box indicates the amount of current flowing through the heat tape.

The volume of water pumped is regulated by a valve inside the pump enclosure (Figure 2) located outside the hydro plant. The valve is located on a 1-in bypass line that returns a portion of the pumped water back into the well. No flow meter is currently in the system, but a pressure gauge (Figure?) reads about 50 pounds per square inch (psi) when the pump is producing about 265 Liters/minute (70 gpm) (when the filters for the well water are being backwashed the reading on the pressure gauge will be lower). There is a value that restricts the water flow to 265 Lpm (70 gpm). The flow meter was removed because it was clogged with iron. The general plumbing system for the well water is shown in Figure 4. Well water was only used for the egg trays and the inside raceways or aquariums.

2. The Filtration System

The chemical characteristics of the well water are:

Iron……………………………. .5 ppm

Total hardness……………….. 289 ppm

PH……………………………… 7.3

Total gas saturation (P)……. >400 mm

The well has not been used at the lab since 1994. The filter system did not last more then two years. The well is very high in iron. The iron is very tough on equipment and fish. With out filtering the well water before the fish are expose to can kill fish due to iron precipitating out on equipment. If the unfiltered (raw) well water used in eggs trays it will eventually clog up the screens, not allowing water to cicurlate evening through the eggs trays, in turns not giving the eggs enough of water to survive on. The iron will also kill eggs and newly hatched sac-fry, by either coating the egg or clogging the gills. Also, the iron would coat the kock rings in our degassing columns, making the column ineffective in removing high N2 from the water. The filter system once used was not sized properly and could be back washed. It is not longer used.

The River Water System

1. Gravity-flow supply lines.

Two intake lines from the turbine penstocks supply gravity-flow water from the forebay of the Hydro Plant. The water enters the power canal from Lake Superior at Ashman Bay. It sometimes contains some organic and inorganic particulates, especially after heavy winds and rains and in the spring with the snow melt runoffs. The particulates have caused high mortality in young fish, especially Atlantic salmon. Once the fish have grown to about two inches they survive well in the river water. A well was drilled in fall, 1991, to provide cleaner and warmer water for the early rearing period.

An 8-in line from penstock 2 supplies rearing containers in the back room. A 12-in line supply line from penstocks 2 and 5 supply the outside rearing tanks and raceways (Figure 6). Normally the valves on the 12-in line are open where the line leaves each penstock so that water comes from both penstocks However, penstocks are periodically drained by Edison for maintenance; this requires that the valve be temporarily closed at that penstock. A back-up pumps is necessary to supply river water in winter because gravity-flow lines can become obstructed with anchor ice (see following section on pumps).

2. Raceway degassing columns.

Degassing columns are used in summer on the raceways to lower nitrogen gas levels, and supplement oxygen to the fish if fish are crowded. Year-around monitoring of nitrogen in river water has shown that nitrogen exceeds

100% saturation from about late May, when water begins to warm, until November (Figure 7). Oxygen injection of 1 1pm should be enough to lower nitrogen gas to acceptable levels, but we have used up to 4 1pm when the fish are crowded.

Pumps

1. **Description of pumps.**

During winter, anchor ice can block all water from the gravity lines. A back-up pump located near the water heater, supplies water to all rearing tanks. It pumps water up from the river beneath the floor. This pump runs continuously all winter (from January until April). Anchor ice can happen anytime during this period so that rearing containers receive both gravity-flow lines, the fish will receive enough water from the pump, but the water levels in the raceways may drop and set off the low water alarms. The outside standpipe of the raceways may need to be raised to bring the water level up. Other pumps are located near the water heater that pumps river water up from beneath the floor.

PUMP	Location of Switch	Location of Circuit Breaker
1. Well Pump (3-Phase)	In back room on gray panel on east wall	In 3-phase panel behind office door
2. Back-up Pump (220 volts) (Sludge Pump)	On gray panel by pump with green (on) light and red (off) light	Under steps by raceway 1
3. Back-wash Pump (220 volts)	On gray panel by turbine 4	Under steps by raceway 1
4. "New" back-up pump	On gray panel for pump	In 3-phase panel behind office door
5. Aspirator Pump for large degassing column (110 volts)	Wall switch near pump with red (on) light	In panel behind office door
6. Aspirator Pump for small degassing column and sinks (110 volts)	Near pump with red (on) light	In panel by sink in front room downstairs
7. Water Heater pump (110) volts	On east side of water heater	Under steps by raceway 1
8. "Bug Room" Pump	In bug room	In panel in bug room

The Degassing Columns

1. The Large Degassing Column.

Well water enters the top of the large degassing column via a 2-in supply line (Figure 8). This water has passed through the filters which should have removed most of the iron an H_2S gas. The degassing column is necessary to remove excess N_2 gas. Oxygen is injected into the top of the degassing column at the rate of 3-8 liters per minute (1pm). Water enters the column through a spray head and flows through Koch rings to provide increased surface area for gas exchange (diffusion of oxygen into the water and diffusion of nitrogen out). A _ -in exhauster (aspirator) vacuums gases from, the column. A _ -HP shallow well pump pumps river water through the aspirator at the rate of approximately 6gpm. A sight tube on the outside of the column indicates the water level inside the column which is normally about the same level as the aspirator. The aspirator creates a vacuum inside the column. A vacuum gauge above the sink (left side in gray box) in the office shows this vacuum which normally is 3 inches Hg. The vacuum gauge line runs from the top of the degassing column. The vacuum inside the column can be changed by changing the position of the head tank (or head tank standpipe), however this should not be necessary once conditions have been set.

Water from the head tank exits via three 1.5 –in lines to inside tanks and the water heater. Water from the standpipe flows into the raceways or directly into the river. A low-water alarm is located in the head tank.

The large degassing column is only used for well water. The system is often shut down most of the summer. When the well water is to be used the system should be started at least several days in advance to make sure everything is working properly. The level of oxygen injection can be determined by trial-and-error while monitoring the N_2 gas level and total gas saturation of water leaving the degassing column. The less oxygen that is needed, the lower the cost and the lower the demand on the compressor. During the summer, when the large degassing column is not in use, it should be taken down for cleaning. The Koch rings should be removed and soaked in bleach or some other solution to loosen any iron or algae.

2. The Small Degassing Column.

This column is needed to lower nitrogen gas saturation in water from the water heater. When heated, water cannot hold as much gas and nitrogen can then become superstaturated, (oxygen also may become supersaturated, but is not harmful to the fish). The small degassing column is basically a smaller version of the large one. The pump that supplies the sinks supplies water for the aspirator. Oxygen is normally injected at about 1 1pm and the vacuum is normally 2 inches of Hg. The oxygen flow meter and vacuum gauge for this column are above the sink in the office on the right side of the gray box (Figure 9). The overflow from the standpipe for the head tank flows into raceway 1. The pipes exiting the bottom of the head tank serve as rearing containers inside both rooms on the ground floor.

The Alarm System

The alarm control is located immediately to the left of the doorway next to the desk in the office. A list of the sensing devices or alarms is posted under the control box and shown her on page ?. The alarms include low water alarms on some of the rearing containers and head tanks of the degassing columns, a temperature alarm in the small degassing column, and alarms for the compressor and xorbox oxygen generators. The complete operation manual for the alarm control is in another binder, but the basics are given below.

When an alarm sounds a bell rings at the control box for 2 minutes. Downstairs, a high-pitched sound is emitted from a source between raceways 2 and 3. A bell also rings and a light goes on at the control center for the hydro plant I the center of the building. They then telephone the lab manager (or other people if they can't get the manager) depending on the list of numbers they were given. If no action is taken by the Edison control center, the system automatically calls the alarm company in Wisconsin and they call the LSSU Physical Plant. The physical plant also has a list of individuals to call.

<u>To arm the alarm system</u>

1) Press ∆under LEAVE.
2) The screen will display the zones that are not ready. For each of these zones be sure they are not being used. If they aren't in use press

Δ under next. Bypass each zone that is not being used. Note: If the display indicates a zone that is in use, but isn't ready, be sure to check and see why it isn't ready and fix the problem before continuing to arm the alarm system.

3) When all not-ready zones are bypassed enter 1949 into the key pad.
4) The alarm will beep for one minute and then be armed

To shut off an alarm

1) Press Δ under SILENCE
2) Enter 1949 in keypad (this disarms the system)
3) Press Δ under display
4) Hold in Δ under TIME (this will tell you when the alarm went off)
5) Press Δ under QUIT to deactivate alarms in the system

To check when an alarm went off

1) Press the key with a delta and a line under it.
2) Press Δ under alarm history.
3) Press and hold Δ under time.

To deactivate a zone (alarm) from the system

Sometimes an alarm can freeze or otherwise become nonfunctional. To deactivate the zone first disarm the system then press the # key (lower right corner of keypad) and then the number of the alarm (see the alarm master list (p. ? for alarm numbers).

Emptying Raceways for flushing

If raceways or other tanks with alarms are drained, the alarm system must be deactivated first.

NUMBER	SCREEN DISPLAY WHEN	LOCATION OF ALARM
	ALARM GOES OFF	SENSOR (S)
01	ROOM 1	INCOMING WELL WATER
	(PRESSURE SWITCH)	
02	OLD RACEWAYS	IN RACEWAYS AND TANK 4 1
	(4 OLD RACEWAYS + TANK 4)	
03	NEW RACEWAYS	IN RACEWAYS
04	SMOKE ALARM	IN ALARM (S)
05	HEAT ALARM	IN ALARM (S)
06		
07	ASPIRATOR	PRESSURE TO ASPIRATOR ON
		LARGE DEGASSING COLUMN
08	LOW TEMP	TEMPERATURE SENSOR IN
		SMALL DEGASSING COLUMN
09	SMALL HOLDING TANK	WATER LEVEL IN BIG
		DEGASSING COLUMN
10	WELL OXYGEN SECURE	OXYGEN PRESSURE SWITCH
		ABOVE SINK IN OFFICE
11	VACUUM SECURE	VACUUM SENSOR IN BIG
		DEGASSING COLUMN
12	AIR COMPRESSOR	AIR COMPRESSOR
13	OXYGEN TANK 1	1ST XORBOX
14	OXYGEN TANK 2	2ND XORBOX
15	LG HOLDING TANK	WATER LEVEL IN HEAD TANK
		OF BIG DEGASSING COLUMN
16		
17		
18		

To see if all of the alarm sensors (zones are in use as indicated above, or are bypassed, press the delta with a line under it. Then press Δ under zone status, enter 1949, and continue to press Δ uner next to observe the status of each zone. Press Δ under quit when finished.

The Air Compressor

A new air compressor was installed early in 1994. This compressor is situated on the main floor across from the outside raceways. It has two motors that alternate and an air storage tank beneath the motors. It also uses the storage tank from our old compressor located in the room with the Xorbox oxygen generators. Proper functioning of the air compressor is vital to the operation of the Xorbox units. The new compressor is identical to other air compressors on campus, and the LSSU maintenance staff can service the unit. They should be called in an emergency. Pressure gauges on the two tanks normally read just under 100 psi. A site tube shows the oil level for the unit. The two motors alternate every few minutes on the new compressor and if one motor should fail, the other motor will take over. If only one motor is running, the LSSU maintenance department should be contacted.

THE XORBOX OXYGEN GENERATORS

We have two model X-75 Xorbox units. Each is capable of producing about 36 1pm of oxygen that is 90% pure (plus or minus 5%). We normally run only one of the units, saving the other for back-up. They are designed to accept air from the air compressor passes through filters that remove dirt, water, and oil. The filters need to be changed and cleaned periodically. After passing through the filters, the air pressure is lowered to about 67 psi and the air passes through one of two adsorbers that remove nitrogen and allow the oxygen to pass through. While one adsorber is adsorbing nitrogen the other is being purged. They alternate about every 40 seconds. The oxygen is sent to a pressure tank located behind outside raceways 1 and 2. The pressure tank is normally set at about 60 psi. It is necessary to maintain this pressure higher than our water pressure. Otherwise, when oxygen is injected into a water line, water flows back into the oxygen line instead.

The Xorbox manual should be consulted for information on care and servicing of the Xorbox units. Two filters should be replace every six months. A videotape is available that shows cleaning and replacement of these filters, and other aspects of maintenance. <u>If oxygen to the degassing column is lost because of failure of the Xorbox units or compressor, bottled oxygen is kept in the feed room behind raceway 4.</u> The bottled oxygen must be plumbed into the main oxygen line and the pressure is maintained at about 60 psi. At 8 1pm one bottle of oxygen lasts about 16 hr. Oxygen flow meters to the large and small degassing columns are located above the sink in the office (Figure ?) We normally use 1 1pm for the small degassing column. Oxygen flow meters to regulate oxygen to inside rearing containers are located on the east wall of room 1 and the west wall of the back room. Oxygen flow meters to the outside raceways. The gray fiberglass raceways are usually supplied with 2 1pm, and the new concrete raceways 3 1pm. We only inject oxygen into these raceways in summer when gas supersaturation can be a problem.

The Water Heater

The water heater is rated at 90 KW and has 15 6-KW heating elements. The main switch is located in the 3-phase panel behind the office door. Fuses for the heating elements are in a fuse panel on the north side of the heater (Figure ?). A relay and thermostat are accessible at this panel (Figure ?). We purchased the thermostat in about 1989 when the heater wasn't working properly, but the problem turned out to be the relay. The relay was replaced; we should still have the extra thermostat. The thermostat turns the heater off at a temperature of 32 °C. The desired temperature at each rearing container is set by mixing cold and hot water at that container. However, the heated water warms the cold water, which contains high gas levels, and the resulting mixture may have supersaturated gas levels. A degassing column with oxygen injection may be necessary to lower gas levels.

The capacity of the heater to produce water at a given temperature can be calculated from the KW rating of the heater and the fact that it requires 0.07 KW to heat 1 1pm 1 °C. Our heater can produce 40 1pm at 32 °C if the incoming water is 0 °C, or 53.5 1 pm of 32 °C water when incoming water is well water at 8 °C. The capacity is the sum of heated plus unheated water mixed to achieve the desired temperature. The following box gives a formula for calculating the 1pm of heated water for any conditions.

To calculate the total 1pm that can be obtained at a given temperature, the following formula can be used to first see how much unheated water we will need to mix with the heated water to get the desired temperature:

$$\text{1pm of unheated} = \frac{(32 - \text{Desired Temp}) * (\text{1pm of heated water})}{\text{Desired temp} - \text{Temp of unheated water}}$$

Example 1. We want to rear fish at 15 °C. We are heating well water, which is 8 °C. The heater can produce 53.5 1pm of heated well water at 32 °C. The 1pm of unheated water we will need to mix is:

$$\frac{(32 - 15) * (53.5)}{15 - 8} = 130 \text{ 1pm of 8 °C}$$

The **total 1pm we have for rearing** is 130 (unheated) + 53.5 (heated) = 183.5 1pm

Example 2. We want to rear fish at 15 °C. We are heating river water which is at 0 °C. The heater can produce 40 1pm at 32 °C. The 1pm of 0 °C we need for mixing is:

$$\frac{(32 - 15) * 40}{15 - 0} = 45 \text{ 1pm of 0 °C water}$$

The **total 1pm for rearing** is 45 + 40 = 85 1pm

The following table gives the capacity of heated water (1pm) for temperatures

from 9-20 °C.

Desired Temperature ° C	Total 1pm capacity if well water at 8 °C is heated	Total capacity uf river water at 0 °C is heated
9	1284	142
10	642	128
11	428	116
12	321	107
13	257	98
14	214	91
15	183	85
16	161	80
17	143	75
18	128	71
19	117	67
20	107	64

Dissolved Gases

1. Background.

Air is a mixture of gases. About 80% of air is nitrogen, and 20% oxygen. Other gases, e.g. carbon dioxide and argon, make up a very small portion of air. Gases in air exert pressure. The sum of the pressures exerted by all gases (but mostly nitrogen and oxygen) is measured as barometric pressure which averages 760 mm of mercury (Hg) at sea level. Roughly 80% (about 600 mm at sea level) is from nitrogen, and 20% (about 160 mm) from oxygen.

Gases become dissolved in water when molecules move from air into water by diffusion. Molecules move in both directions and when the same number move in as out, an equilibrium is reached (Figure?). Molecules of dissolved gases in water also exert pressure. This pressure can be measured with a saturomenter. A reading of zero on the saturometer gauge (this is the ΔP value) indicates equilibrium or 100% saturation. A positive reading of delta P means that gases in water are supersaturated. Supersaturation is usually due to excess nitrogen. Excess gas in water can cause bubbles to form in body fluids of fish and lead to gas bubble disease. Safe levels of gas supersaturation depend on species and age of fish. To be conservative it is best not to have total gases or nitrogen at levels above 103% saturation. A recent study on lake trout (Krise 1993 Prog. Fish-Cult.) showed that ΔP above 58 can cause mortality, and ΔP over 17 could afffect growth.

To measure nitrogen saturation it is necessary to measure ΔP with a saturometer (the Weiss saturometer or the Common Sensing gas monitor) and also measure dissolved oxygen. We use a BASIC computer program to calculate nitrogen saturation from ΔP, dissolved oxygen, water temperature, and barometric pressure (see Appendix A for program named “SATUR.BAS”). Saturation values for oxygen range from a high of 14.6 ppm at 0 °C to 9.1 at 20 °C. Fish should have at least 6 ppm.

Oxygen injection is an effective method of lowering nitrogen gas levels. Nitrogen molecules in water diffuse into the bubbles of pure oxygen gas, and oxygen molecules diffuse into the water. The net effect is less nitrogen, but more oxygen in the water (Figure ?).

2. The common sensing total dissolved gas monitor.

This meter measures the following:

BAR = Barometric pressure

Temp = Temperature

P_T =Total Gas Pressure (mm Hg)

PO_2 = Oxygen Pressure (mm Hg)

ΔP = Delta P = difference between gas pressure in water and barometric (air) pressure

$P_T – PO_2$ = Total Gas Pressure – oxygen pressure

= nitogen + argon + H_20 vapor or roughly nitrogen pressure

%SATN P_2 =% saturation, total gases

%SATN O_2 = % saturation, oxygen

This instrument is easy to use and has given very good results. Barometric pressure is measured with the probe in the air. This measurement should be very close to (+ or – 2 mm Hg) to the reading taken from the barometer in room 1 downstairs. With the probe in water all of the above gas measurements can be made. The probe should be moved from side-to-side until a stable reading is obtained. The P_T – PO_2 reading <u>approximates</u> N_2 pressure, but includes water vapor pressure. A more accurate measure of N_2 pressure is obtained by running the BASIC program "SATUR.BAS". The program calculates water vapor pressure and subtracts it out to estimate N_2 pressure.

3. The Weiss Saturometer

The Weiss saturometer contains 200 ft. (7300 in^2) of dimethylsilicone rubber tubing. Gases can pass through the tubing, but not water. The tubing is wound onto frames and protected by steel mesh. Puncture of the tubing destroys the functioning of the instrument. A gauge on the saturometer records the total gas pressure under water relative to the current barometric or air pressure. The reading ΔP can be positive or negative.

a) Use of the saturometer

A video is available for learning how to use the saturometer. Be sure you understand where the <u>water pump handle</u> and <u>pressure value</u> are located on the instrument. Immerse the base of the instrument into the tank and move it back and forth. Be sure the pressure valve is open. If the pressure goes up the water is supersaturated and you will need to use the water pump. If the pressure goes down, gas bubbles can't form on the tubing, and you don't have to use the water pump. Agitation, by moving the bottom of the saturometer back and forth, and pumping if the reading is positive, should be done frequently until a stable reading is reached. The purpose of the water pump is to flush gas bubbles away from the surface of the tubing so that equilibration can occur more rapidly. Time needed for equilibration may be 15 min or longer—check with the lab manager. Dirty tubing and cold water temperature are two factors that slow equilibration time.

b) Testing and care of the Weiss saturometer

Leaks in the tubing or leaks in the fittings will result in erroneous readings. Leaks in the tubing may allow gas to pass through the tubing in only one direction. Two tests are necessary to check for these leaks.

Vacuum leak test. Apply mouth suction to the pressure valve until the gauge reads –150. (Do this with the instrument in air; otherwise water could enter the tubing if a leak is present.) With the valve closed record the time in seconds that it takes for the gauge to go from –100 to –50. This time should be between 50 and 200 seconds. If the time is <50, a leak is indicated. If the time is >200, an obstruction is indicated; the tubing may be pinched too tightly at one of the fittings.

Pressure leak test. Apply pressure at the valve opening with a syringe or pump to bring the gauge reading to +500. This test should be done in water. Close the valve and measure the time for the gauge to go from

+400 to +300. Again, this should be 50 to 200 seconds. If this test is done in an aquarium, gas bubbles should be evident at the site of any leak.

Leaks at fittings. These leaks should be detectable with soapy water. If necessary, the pressure gauge dial plate can be removed and the entire instrument submerged, with pressure appied, to look for bubbles.

Cleaning the tubing. Periodic cleaning of the tubing by immersion in a detergent solution is recommended.

4. Oxygen measurement with the YSI meters.

Oxygen meters have probes attached by cables to the meter. The probe contains an electrolyte (KC1 solution) covered by a thin membrane. Water cannot pass through the membrane, but oxygen can. Oxygen diffusing into the probe generates an electrical current that is measured by the meter and displayed as mg/L or % saturation of oxygen. The probe should not be allowed to dry out. It should always be stored in a tight-fitting plastic bottle that contains a damp sponge.

Calibration of the Model 50 YSI meter

a) Place the probe in a constant oxygen environment (e.g. in a tight-fitting plastic bottle containing a sponge saturated with water. The probe should not touch the sponge).

b) Set the function switch to the TEMP °C position. The meter will make a sound and test itself. The display should be as shown on pg.2 of the manual and should disappear in about 7 seconds when a second sound occurs. After this the temperature will be displayed. Wait until it stabilizes. This could take up to five minutes.

c) Set the switch to mg/L and allow 15 min for the system to stabilize. Only turn the meter off at the end of the day.

d) Set the meter to TEMP °C. The probe should be in the plastic botle.

e) Determine the air saturation value for the current barometric pressure. Get a barometric pressure reading and adjust the table saturation value, which is based on 760 mm Hg, to the actual barometric pressure. For example, at 20 °C (air temperture) the table reads 9.09 mg/L. If the saturation value is 730 mm, the adjusted oxygen saturation value is lower: (730/760) ∗ 9.09 = 8.73. If the barometric pressure is 770 m, the adjusted value is higher:

(770/760) ∗ 9.09 = 9.21.

f) Set the meter to mg/L CAL. Using the key pads calibrate the meter to the adjusted air saturation value. Set the meter to mg/L. “CAL” will appear on the display followed by one or two sounds. If the meter drifts more than 2 or 3 digits in the next 3 min it may not have had enough warm-up time.

<u>Calibration of the Model 51 B YSI meter.</u>

a) This instrument has 3 operation positions: flat, upright, or tilted. It should always be used in the same position. Changing the position can affect the readings.

b) In the OFF position adjust the meter to zero, if necessary, with the screw in the center of the meter panel. Switch to ZERO and adjust to zero. Switch to FULL SCALE and adjust to 15 mg/L. Allow 15 minutes warm-up before calibration. Have the probe in a calibration bottle during the warm-up period. The calibration bottle is a tight-fitting plastic bottle containing a damp sponge. The probe should not touch the sponge.

c) Switch to CALIBO 2 and adjust the meter pointer to an altitude of 600 ft (our elevation). Allow a few minutes for calibration.

Oxygen Measurement – YSI meters.

a) Model 50. Place the probe in water and move it continuously (about 1 ft per sec). Set the meter to mg/L or %. Allow 3-5 minutes for the probe to reach the water temperature (this could be done first). Read the meter when the value has stabilized.

b) Model 51B. Place the probe in the water container and allow five minutes to reach the water temperature Switch to TEMP and read the temperature. Turn the oxygen SOLUBILITY FACTOR dial to the temperature of the water. Switch to READ oxygen and read the mg/L of oxygen.

Maintenance of the YSI meters

If the meters are operating properly, the only routine maintenance should be replacement of batteries and membranes. For membrane replacement see the manual for the instrument. Both meters utilize the same probe.

Feeds and Feeding

Feed sources and storage.

Feed for Atlantic salmon is furnished by the Michigan DNR. It must be ordered at least three weeks in advance and is normally delivered about the 15th of each month. Quantities of at least 500 pounds are delivered to us directly. Smaller quantities are dropped off at the Mackinac Bridge and we must pick them up (usually the same day or the next day). Nancy Cummings, Fisheries Division office of the MDNR in Lansing, handles the feed orders (517) 373-1280. Swim-up fry are often started on a semi-moist pellet from BioProducts, Inc. A limited selection of trout chow, (Purina Co.) is available from Huyck's Feed Service, Pickford, Michigan (sizes No. 4 and No. 5).

Semi-moist feeds (e.g. Biodiet) should be kept frozen until used. They are kept in the walk in freezer in Crawford Hall. Dry diets are stored at the Aquatic Lab. Feed bags should be handled gently to avoid breaking the feed into "fines". The fines collect in the gills of the fish and contribute to bacterial gill disease. Feeds should be used within 90 days to prevent loss of vitamins and breakdown of fats.

2. **Feed Sizes**

The approximate length of trout for switching to pellets of larger size is given in Fish Hatcher Management. We normally feed larger sizes to our Atlantic salmon to prevent fouling their gills.

The table below gives both sizes. Atlantic salmon can be started on Biodiet, but we have had better success with Atlantic salmon diet (ASD). They should only be fed No. 1 for a week or two, and then switch to No. 2. The small feed sizes contribute to gill disease.

Pellet Size	Switch trout to this size at (in)	Switch Atlantics to ASD at this size (in)
No. 1	1.1	
No.2	1.5	
No.3	2.2	1.6
No. 4	2.9	2.2
1/8 inch	4.4	2.9
3/16 inch	6.3	4.3

3. **Calculation of feeding level.**

A table for the amout of dry feed to feed rainbow trout is given in Fish Hatchery Management pp. 240-241. We normally use the following modification of the feeding equation (see p. 224 in the same reference for the general feeding equation).

$$\text{\% Body weight to feed daily} = \frac{\text{Feed Conversion} * \text{TUGR (mm/TU)} * b * 100 * \text{Temp}}{\text{Length (mm)}}$$

In this formula Feed Conversion and TUGR (mm/TU) are the expected values, b is the slope of the length weight equation, and Temp is the water temperature in °C. The denominator is the current average length of the fish. This equation is utilized in the BASIC program named "FEED.BAS" (see Appendix A, page 5). Values for feed conversion and TUGR should be based on the best judgement of the lab manager.

MONITORING GROWTH, BIOMASS, AND FEED CONVERSIONS

1. Growth calculations.

Growth rates of fish in hatcheries are usually expressed as temperature unit growth rates (TUGR). A temperature unit can be defined in °F as in the book Fish Hatchery Management, or in °C. For example, if the water temperature averages 8 °C, 8 temerature units accumulate for that day. We normally calculate TUGR's for a group or lot of fish it is necessary to measure a representative sample of fish periodically (e.g. biweekly). We normally measure and weigh 100 fish every two weeks. Relatively large samples are necessary to get accurate estimates of length and weight. The lengths and weights are entered into the BASIC program named "MEANS.BAS" (see Appendix A) which orders the lengths from lowest to highest and calculates the mean variance of lengths and weights. The program also calculates condition factors by the formula

$$K = \frac{\text{Weight (grams)} \times 10^6}{(\text{Length in mm})^3}$$

The program checks the condition factors as they are calculated for unreasonable values, and indicates an error if the values are too high of too low. Extreme values probably indicate erroneous measurements or recording of the data.

The change in average length over a period of time is divided by the temperature units for the same time period yields the TUGR for that period:

$$\text{TUGR (mm/TU)} = \frac{\text{Length increase (mm)}}{\text{Temperture units (°C)}}$$

The temperature units should be counted for the beginning day or the ending day of the period, but not both days.   A TUGR of 0.05 (mm/TU) is a “good” growth rate, but we have recorded values of 0.1 on occasion.

2. Biomass calculations.

It is necessary to have current estimates of the total weight or biomass of a lot of fish to calculate feeding levels. The number of fish present should be updated biweekly by subtraction of the biweekly mortatlities to update the number of survivors. Often, when eggs are shipped they have been cencused before shipment and we don’t have to recencus (see Fish Hatchery Management for methods of cencusing eggs and fish or video). We sometimes hand-count our fish and the average weight of the fish:

Biomass = No. of fish x Average weight
(g or kg)   (g or kg)

Daily feeding amounts are calculated by multiplying the % body weight to feed per day times the total biomass. (Sometimes it is difficult to know if our estimates of the number of fish are accurate. Bad estimates can result in improper feeding levels – see section on feeding).

3. Calculations of feed conversions.

The feed conversion for a time period, or feed/gain ratio, is the total amount of feed fed to all fish for the period divided by the increase in biomass of all fish over the same time period.

$$\text{Feed Conversion} = \frac{\text{Weight of feed fed (kg)}}{\text{Increase in biomass (kg)}}$$

A good feed conversion is 1.0, but we have recorded values as low as 0.05 (lower is better). The increase in biomass should be calculated only for the average number of fish present during the time period, or erroneous estimates of feed conversion wil ressult for periods of high mortality. The best formula for calculation of biomass is:

Biomass increase = increase in ave. wt. X Geometric mean no. of fish

The geometric mean number of fish is:

Geometric mean no. = SQR (Beginning no. X ending number)

For example, if 10,000 fish are present at the beginning of a period at an average of 20g and only 5,000 survive to the end of the period at an average weight of 25g the change in biomass is

$$5 \text{ g} \times (10{,}000 \times 5{,}000)^{1/2} = 35.35 \text{ kg}$$

Note the beginning biomass was 10,000 X 20 g =200 kg and the ending biomass was 5,000 X 25 g =125 kg. Calculating the change in biomass by subtraction gives –75 kg, a much different estimate and a negative value (this is a bad estimate because many fish grew and converted feed during the period, but died during the period). If the fish were fed 67.2 kg during the period (about 3% body weight for 14 days) the feed conversion would be:

$$\text{Feed Conversion} = 67.2 / 35.35 = 1.90$$

Poor fed conversions could indicate:

1) You are overestimating the actual number of fish present.
2) You are overfeeding for reasons other than 1) above
3) The fish are sick and either not eating or not converting.
4) The fish aren't accepting the diet. Many hatcheries start-feed species like chinooks on semi-moist diets and wait until the fish are two inches or so before switching to cheaper dry diets. The small fish can starve if they won't accept the diet.
5) You are feeding "too much too fast". Fish often won't eat the feed once it hits the bottom.

CARRYING CAPACITY

1. The density index.

The simplest approach to carrying capacity is the density index first proposed by Piper for rainbow trout:

$$\text{Density Index (lbs / ft}^3\text{)} = 0.5 * \text{Length (in)}$$

The carrying capacity is directly proportional to the size of the fish. Because small fish have a higher metabolic rate, and are fed proportionally more than large fish, they they use more oxygen. The density index does not directly take oxygen into account, but does require more rearing space for small fish. However, it does not adjust for temperature, and fish eat more and use more oxygen at higher temperatures. The density index should be used with caution at high rearing temperatures, because <u>it may overestimate capacity at high temperatures.</u> At low temperature, with abundant oxygen, it is too conservative.

2. Capacity calculations based on oxygen.

Formulas based on oxygen as the limiting factor for carrying capacity include Westers' formula and the flow index. Westers; formula for <u>loading</u> (i.e. the weight of fish that can be supported per unit <u>flow</u> of water) is:

$$\text{Loading (kg / 1pm)} = \frac{\text{Available Oxygen (ppm)}}{2 * \text{\% Body Weight Fed}}$$

Available oxygen is the incoming oxygen in ppm (this value depends on the saturation level, usually 90 – 100%) minus the 6ppm (the minimum allowable in Westers' method). Loading can be converted to density and vice versa if the number of water changes per hour (R) is known for the rearing container:

Density (kg/m^3) = 16.67 $*$ R $*$ Loading (kg/1pm)

or Loading (kg/1pm) = (0.06 / R) $*$ Density (kg/m^3)

To convert densities from English to metric units or vice versa:

1 lb/ft^3 = 16.07 kg/m^3 or 1 kg/m^3 = 0.0622 lb/ft^3

Some workers feel that, even with sufficient oxygen, fish should not be crowded as much as Westers' formula allows. Some hatcheries do not want the density index constant to exceed 0.25 for Atlantic salmon (instead of the 0.5 proposed by Piper for rainbow trout). However we have successfully reared Atlantics (e.g. 1993) for prolonged periods at a density index of 1.0 or greater.

The flow index is also based on oxygen as a limiting factor (see pp. 67-71 in Fish Hatchery Management). It sets a minimum oxygen level of 5 ppm and assumes incoming water is 100% saturated. You would expect this method to give results similar to Westers', and sometimes it does. But it is derived from the experimentation whereas Westers' formula is derived from the assumption that fish utilize 200 g of oxygen to metabolize each kg of feed; therefore the two methods have different starting points and sometimes give very different results.

3. Examples

For comparison of the three methods two examples are given below. In these examples the % body weight feeding level is based on the feeding table in Fish Hatchery Management pp. 240-241.

Example 1. 1000 3-in fish, 36 °F, fed 1.3% body weight

	Carrying capacity (kg/m^3)
Density Index	23.7
Westers' (100% O_2)	192
Flow Index	75.7

Example 2. 100 3-in fish, 68 °F, fed 5.5% body weight

	Carrying capacity (kg/m^3)
Density index	23.7
Westers' (100% O2)	17.6
Flow Index	26.3

Note that the density index doesn't change with temperature or feeding level. Westers' formula gives a much higher capacity for the cold temperature and a lower capacity than the density index for the warm temperature. Carrying capacity by the flow index falls between the other two methods.

The BASIC program "LODE.BAS" (Appendix A) gives carrying capacity calculations by these and other methods. If in doubt whether fish are too crowded one should monitor oxygen at the outlet of the rearing container. It should be at least 5 ppm, and will probably be at its lowest level of the day about 1 hr after feeding.

Production Planning

The hatchery manager must plan ahead to order proper quantities and sizes of feed, and to determine when fish must be thinned and moved to larger containers to avoid exceeding carrying capacities. The BASIC program "ATSKIP3.BAS" (see Appendix A) is designed to help in such planning. Also the BASIC programs "LOADING.BAS" and "LOADTABL.BAS" are specifically designed to plan future capacity needs.

1. **Feed Planning**

   The length of the fish for switching to bigger feed sizes is given in the section on feeds and feeding. Fish weights corresponding to these lengths can be used to predict feed needs based on the number of fish and the expected feed conversio. For example, Atlantic salmon are fed #3 granules of ASD between the lengths of 1.6 and 2.2 inches. The expected weight gain of a salmonid between 1.6 and 2.2 inches is about 1.15 g. Each 1,000 fish would gain 1,150 g or 2.53 lbs. If you are rearing 60,000 fish, the expected weight gain is 60 X 2.53 = 152 lbs. If the expected feed conversion is 1.0 you need to order 152 pounds of #3 granules. However, for fish this size you should expect more waste than for larger fish. An expected feed conversion of 1.8 may be more realistic; you would then order 273 lbs (1.8 X 152) or 6 50-lb bags of #3. The following table will help make these calculations for some feed sizes

EXPECTED WEIGHT GAIN OF 1000 FISH FOR SEVERAL FEED SIZES (e.g. ATLANTIC SALMON ARE FED #3 GRANULES FROM LENGTHS OF 1.6 TO 2.2 INCHES)			
Length (in) to switch feed size	Average weight of a fish (g)	Weight of 1000 fish (lbs)	expected weight gain of 1000 fish (lbs)
1.6	0.75	1.65	
	FEED #3 GRANULES		2.54 lbs
2.2	1.9	4.19	
	FEED #4 GRANULES		5.72 lbs
2.9	4.5	9.91	
	FEED 1 / 8 - INCH PELLETS		23.35 lbs
4.3	15.1	33.26	

One must also know when feed of different sizes will be needed. Remember, feed should not be stored more than 3 months. The BASIC program "ATSKIP3.BAS" can be used to make projections of fish sizes and feed needs. It uses temperature unit growth rates based on actual data from past years (mostly rainbow trout) for fish reared at the Aquatic Lab. The feed needs in this program are based on feeding tables in Trout and Salmon Culture by Leitritz and Lewis (this is the same table that has been reproduced in Fish Hatchery Management); the program might give somewhat different results than calculations based on the above table.

2. Planning carrying capacities

The BASIC program "ATSKIP3.BAS" also gives capacity needs based on Westers' capacity formula. To plan capacity needs one must project expected fish size by TUGR's and consider rearing container sizes and

R values. Crowding stresses the fish and can lead to higher losses from disease such as bacterial gill desease and furunculosis. The following table gives the capacity of all rearing containers as of February, 1994.

Rearing Container	Capacity (cubic meters)
Fry Raceways A & B	0.56 each
Fry Raceways C & D	0.58 each
Fry Raceways E & F	with 10" standpipe 0.35 each
	with 16" standpipe 0.55 each
Fry Raceways G & H	0.28 each
4- foot Round Tanks	0.74
Fry inserts for 4- foot Tanks	0.312
6- foot Round Tank	1.73
21-foot Fiberglass Raceways	6.204

Diseases

1. **History of diseases at the Aquatic Lab.**

   John Hnath, fish pathologist for the MDNR has done inspections in 1986,87,88,92, and 93. We have a history of furunculsis in our Atlantic salmon, similar to other hatcheries. The following pathogens have been problems at our hatchery:

   -*Ichthyophthirius.* This pathogen was only a problem in 1983 when water temperature was very high. We were only rearing rainbow trout at that time.

   -*Aeromonas salmonicida* (furunculosis). This has been a problem every year in Atlantic salmon.

   -*Aeromonas hydrophila* (motile Aeromonas septicemia). This common pathogen has been found but is not normally a problem.

   -Bacterial gill disease. This is always a problem, but a clean rearing environment minimizes its effects.

2. **Disease prevention and treatment.**

   Bacterial gill disease is always a potential problem, and is usually the result of particulates in the water that irritate and clog the gills of small fish. Fish wastes, when fish are crowded, including feces and ammonia, also exacerbate the problem. We had a well drilled primarily to counter the problem with particulates in river water. Feeding too small a feed size and dirty raceways also contribute to the problem.

The preferred treatment for bacterial gill disease is 10-20 ppm Chloramine-T in constant flow treatment for 1 hr. We normally use about 12 ppm, but have used 17 ppm for larger fish. Hyamine or Roccal (quaternary ammonia compounds) can also be used at 2 ppm active ingredient for 1 hr, but the margin of safety is narrower for these chemicals. Fish are more tolerant to Chloramine-T. These chemicals can be used as a preventative measure (e.g. treating for 2 or 3 consecutive days if mortalities begin to rise), or to treat acute conditions. When the gills of the fish are badly clogged the chemicals can't get to the bacteria; the fish should first be dipped in 3% NaCl before treatment with Chloramine-T or hyamine. A BASIC program "CONFLOW.BAS" (see Appendix A) simplifies the calculations necessary to do a constant flow treatment.

Furunculosis is common in Atlantic salmon. We normally do not have problems with it ntil the river water warms up, usually not before July. Any factor stressing the fish can make them vulnerable to acute cases, and it can cause heavy losses if left unchecked. We installed degassing columns on the large raceways in 1992, and have had less problems with furunculosis since then. Apparently the elevated nitrogen gas level stressed the fish sufficiently in former years to make them less resistant to furunculosis. The preferred treatment is Romet 30 mixed in the feed at a dose of 50 mg active ingredient per kg of fish (live weight) for 5-10 days. Romet 30 is only 30% active so each kg of fish should receive 167 mg of Romet 30. If fish are being fed 2% of their body weight, they are fed 20 g of feed per kg. If the 20 g contains 167 mg of

Romet 30, it contains 0.835% Romet 30. Feed suppliers, but fish should be treated without delay if an acute outbreak of furunculosis occurs. The hatchery manager should order an appropriate quantity and size of feed in advance to be ready to treat at a moment's notice. It is easiest to order the same concentration as the MDNR orders for its hatcheries since our feed orders go through the MDNR. Romet can be purchased seperately and mixed into feed with corn oil or gelatin, but we do not have a permit to do this legally.