Guide for Fish Containment

In Land-Based Aquaculture Facilities

March 20, 2002

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BACKGROUND

With the decline in wild fisheries world-wide, aquaculture has expanded in recent years to supply the ever increasing demand for fish and fish products. Many Countries have a well-established aquaculture industry, which may date back many centuries.

In most Canadian Provinces, in comparison to other Countries, the land-based aquaculture industry is still developing.

To establish an environmentally friendly aquaculture industry many concerns have to be addressed by regulators, the general public and fish farmers. A first and very important step in this direction was taken in the year 2000. A paper was drafted, which in general terms describes guidelines in the context of a conduct for a responsible aquaculture industry in Canada. The title of this manual will be "National codes of practice for freshwater aquaculture".

To compliment this manual and describe in a more detailed fashion the prevention of escapement or mitigation of fish from a land-based aquaculture facility this manual has been devised.

This manual presents an initiative to prepare facility security guidelines for land-based aquaculture across Canada. It is being co-championed by the Ontario Aquaculture Association and the New Brunswick Trout Farmers Association and is supported by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and the Ontario Ministry of Natural Resources (OMNR) and Office of the Commission for Aquaculture Development (OCAD).

A lack of facility security standards and guidelines has constrained development of the Canadian freshwater aquaculture industry and has often resulted in disagreement and conflict among government regulators, environmental lobby groups and fish farm operators. Development of a consistent set of standards for security measures would be invaluable for all stakeholder groups.

Keeping fish contained within the culture system is a primary goal of all fish producers. Farmed fish are valuable private property and any escape ultimately reduces farm profitability. However, damage to the surrounding aquatic ecosystem must also be a consideration. In the past, assessing the risk that a fish farm poses on the surrounding watershed and appropriate security measures, has been done on an inconsistent basis. Well-defined facility security guidelines have never before been developed for land-based aquaculture facilities in Canada.

For example, in Ontario issuance of a license to culture a particular species of fish is contingent on the applicant submitting a risk analysis, which describes the ecological risk the cultured species poses to the receiving aquatic ecosystem and facility security requirements to address the risk factors.

This licensing process has proven difficult for both the aquaculture industry and Ontario Ministry of Natural Resources field staff responsible for risk analysis assessment. This difficulty can be attributed to the fact there are no supporting implementation guidelines at a level of detail required by field offices to ensure predictable, consistent facility classification.

Industry frustration has arisen from inconsistent application of the policies across administrative boundaries. The absence of facility security guidelines has hindered the aquaculture industry's business planning ability, since costs required to implement facility security with acceptable levels of risk can not be reliably determined. In the absence of defined security standards and guidelines, regulating agencies often shift towards a lower level of risk.

Escapement of cultured fish from land-based aquaculture facilities often poses an ecological concern to resource managers, regulatory authorities and stakeholder groups across Canada. Sustainable growth and development of the aquaculture industry depends upon ensuring risks are managed and kept to acceptable levels. It is clearly in the interest of fish farmers to minimize or eliminate losses to valuable stocks and ensure that their activities are not detrimental to the integrity of the receiving aquatic ecosystems. The environmental lobby is also aware of the lack of facility security standards and guidelines and often questions government about their ability to adequately assess the escapement associated with applications for new aquaculture operations.

This manual will provide guidelines for determining risk and appropriate security measures for land-based aquaculture operations in Canada.

OBJECTIVE

The objective of this manual is to provide clear methods and information to identify security concerns and address these concerns, to a suitable level, to avoid losses and escapement of fish from land-based fish farm operations.

The Risk Assessment process will examine:

- Ecosystem Compatibility Risks
- Water Management Concerns
- Flooding Risks

The Mitigation Section Will Examine:

- Security Level Classification
- Inflow Protection
- Outflow Protection
- Flood Proofing
- Genetics / Exotic
- Disease / Other factors

Evaluation of Fish Farm Security

There are many parameters that need to be examined to determine the risk a fish farm poses to the receiving watershed. The main items to consider are:

- Effects of escaped fish in the surrounding ecosystem
- Risk of Flooding

Effects of escaped fish in the surrounding ecosystem

A major concern of aquaculture is the potential to change the natural balance of an ecosystem through introducing new species or strains of fish into the receiving body of water by accident.

To minimize this type of problem the species of fish raised in a facility must be carefully considered. It must first be determined what the effect of this fish species might be in the ecosystem of the receiving body of water. If the risk of damage to the ecosystem is high; then the species should either not be raised in that facility or a very high level of security should be put in place to eliminate the chance of fish escaping into the surrounding water body.

If a fish species poses a little risk to the surrounding environment then the approval process should be easier. Also, the fish farmer will be allowed to operate with a lower level of security where loss of some fish may occasionally happen by mistake.

An aquaculture license should be evaluated for each species on an individual basis and if the security levels are acceptable, a fish species will be approved with a corresponding level of security required. If the species is a threat to the local ecosystem that cannot be mitigated by increased security measures, the species should not be licensed for that particular fish farm location.

Concerns

To consider an application for a license by a fish farmer to raise a specific fish species in a watershed, it should be established how escaping fish might interact with indigenous or naturalized fish fauna.

- Genetic strains may be changed with interbreeding with escaped fish
- Non-native species may compete with existing species
- Can the fish survive in the receiving water body

A checklist will help identify fish species interaction concerns

Species compatibility security level analysis

Fish Species	Present in Watershed	Not Present	Indigenous	Naturalized	Specific Genetics	Low Risk	Medium Risk	High Risk
A	X		X	X		X		
B	X				X		X	
C		X						X
D		X				X		

Situation A
When a species of fish that is indigenous and/or naturalized in the watershed is farmed there is very low risk of damage to the surrounding watershed unless there is a concern with the specific strain of fish being raised.

Situation B
If a species is being raised in an aquaculture facility that is a different strain from the indigenous fish in the watershed there is a medium risk factor. More efforts should be made to eliminate the chances of escapement from the facility into the receiving waters.

Situation C
Raising a species not present in the watershed creates a higher risk of damage to the receiving water's ecosystem. This is especially true if this species could compete with species in the existing ecosystem. To raise a species in this situation the facility must comply with high security guidelines.

Situation D
If a species of fish is being raised that will not survive in the surrounding watershed there is lower risk. Tilapia is an example of this, if there are physical constraints that will not allow all life stages of a species to survive there is a lower risk factor.

RISK OF FLOODING

Flooding has the potential to do considerable damage to the fish farmer's profitability and the surrounding environment's ecosystem. If a facility is located in a flood plain or flood prone area this should be a consideration in establishing the facilities security level or existence. Generally, if a facility is prone to flooding, only fish of low or medium risk should be considered. However, there are measures that can be taken to reduce the risk of the facility flooding.

Even small streams can carry very large volumes of water at certain times of the year and excessive rainfall can often trigger flooding. To some extent it can be estimated what the high water flow is in a normal year. To do so one should estimate the drainage area upstream from the facility and the average rainfall in the area. To a certain extent the size of culvert running under a road can help determine the maximum expected flow that a stream receives.

A berm was constructed around the rearing areas above the level of the 100 year flood

Ideally, a fish farm should be located outside of the flood plain, however, this is not always possible as rivers and streams often provide the source of water for aquaculture facilities.

Concerns

A flooding event can release large numbers of fish into the surrounding watershed. The risk of flooding will determine what type of security rating a facility can have. If a facility cannot be flood proofed then a "high security" rating is not possible. However, sites that might be prone to flooding can be flood proofed with appropriate measures that will vary from site to site.

Flood Prone

Any area that lies in the flood plain or a low lying area that is connecteed to a watershed should be considered flood prone. A combination of heavy rain, snow melt or other flushes of water have the potential to flood the facility and allow fish to escape uncontrolled by the operator. Flood prone sites can often be made flood proof by installing appropriate dykes or berms.

Flood Proof

To be considered flood proof, a facility must be situated out of the flood plain or have a dyke / berm system that will protect the site from high-water events. Additional features within the site must also be in place to control the water flowing out of the facility.

There are methods that can be used to significantly decrease the chance of facility flooding. Each individual site will have its own constraints, but it is possible to reduce the risk of flooding through:

- Rerouting the stream
- Building a berm around the facility
- Using a by pass system to pump water directly into the rearing system
- Using a by-pass system to divert water into a header pond and distribute to the facility from this water source.

FACILITY SITE RISK ASSESSEMENT

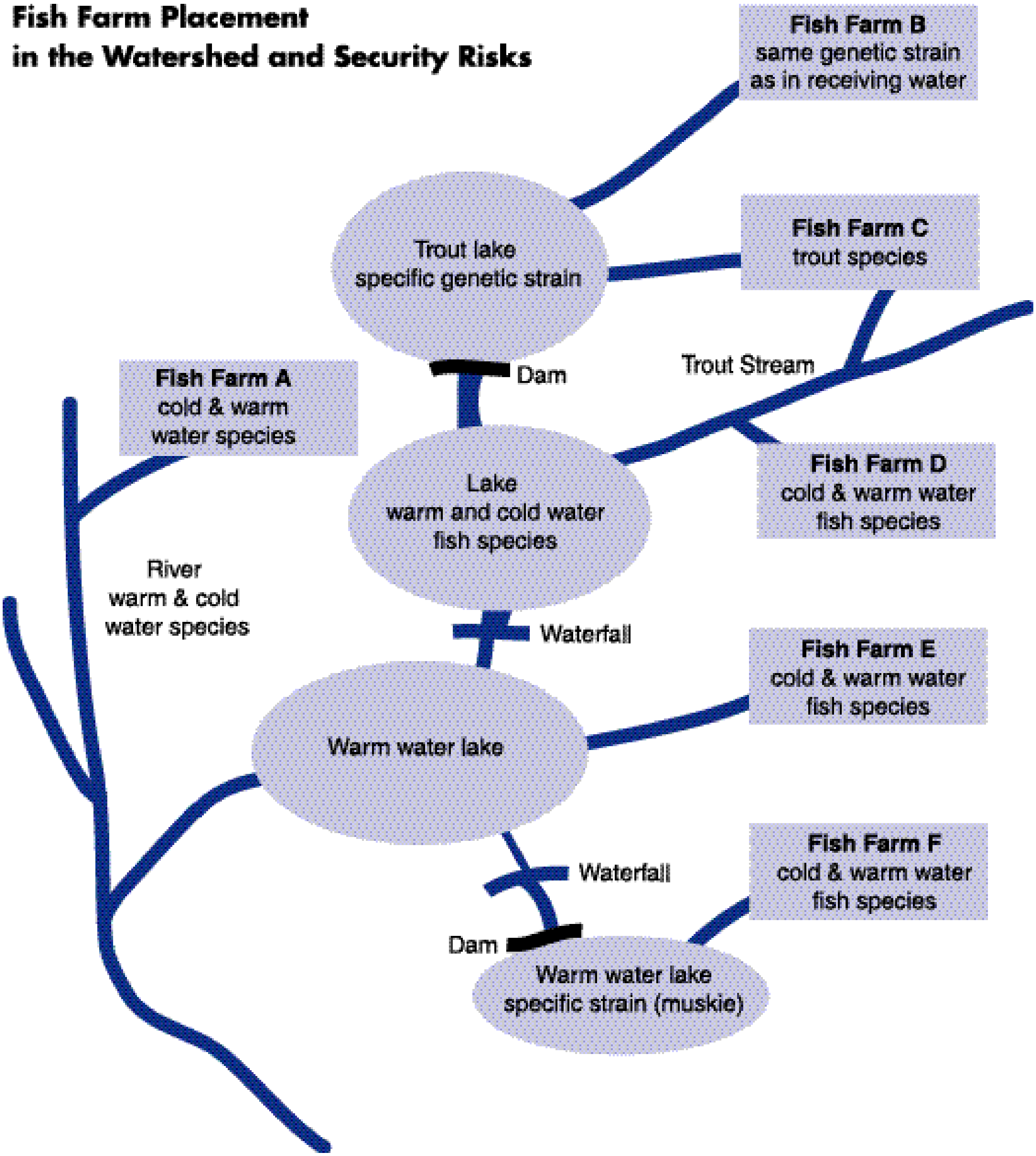
If a facility is flood proof then the facility has the potential to be designed to high security standards where no escapement of fish from the facility is possible. If a facility is not flood proof, but there is a very low likelihood of flooding, medium security standards are possible (very low expected losses of fish). If a facility is flood prone, then measures should be taken to reduce the risk of flooding and only species of low risk to the surrounding ecosystem should be considered, as some losses of fish are probable.

OVERFLOW PATHWAY CATASTROPHIC EVENTS

The overflow pathway is essentially the path that water takes if one or more rearing unit/areas were to overflow or collapse. Often, rearing units are constructed with an overflow screen as a backup in the event the primary outflow screen on an individual unit fails. Facility flooding is often related to seasonal events where inflows cannot be controlled (e.g. runoff ponds without berms or in stream ponds) failure of outflow structures (plugged screen/clogged outflow) or outflow backing up (e.g. by beaver dams ice jams downstream causing flooding via the outflow).

Variable Category	Variable	Overall Risk of Loss	Risk of Loss Into Adjacent Ecosystems
Facility Location	Location in flood plain	Increases as vertical distance to creek/stream/river decreases	Increases as vertical distance to creek/stream/decreases
	Upslope catchments area	Decreases with decreasing upslope catchment areas	Decreases with decreasing upslope catchment area
	Terrain characteristics	Complicated interaction of topography, soil types, vegetation cover, ground water levels and flow, soil moisture levels, and land use etc.	Complicated interaction of topography, soil types, vegetation cover, ground water levels and flow, soil moisture levels, and land use etc.
Inflow Source	Ground water	Lower risk - less likely to contain screen fouling debris	Lower risk - less likely to contain screen fouling debris
	Surface water	Higher risk since more likely to contain screen fouling debris, often seasonal	Higher risk since more likely to contain screen fouling debris, often seasonal
Maintenance	Staffing level	Risk increases as staffing level/monitoring decreases	Risk increases as staffing level/monitoring decreases
Time	Duration of overflow event	The longer the time period of the overflow, the greater the risk of loss from rearing units/areas	The longer the time period of the overflow, the greater the risk of loss from rearing units/areas

Fish Farm Placement in the Watershed and Security Risks



Fish Farm A

Cold & Warm water fish on a River System. In this situation there are similar fish in the ecosystem to the one's being cultured in the facility. There is a low risk factor in this situation unless there are extremely large numbers of fish being produced. If competing species are not present in the river then those particular species should be allowed only if High Security Containment procedures are put in place.

Fish Farm B

Same Genetic Strain Connected to Trout Lake. Trout of a specific genetic strain are present in the receiving water. For this reason the trout raised in the hatchery connected to this water should be of the same genetic strain to avoid damage to natural stocks.

Fish Farm C

Trout Farm Connected to river linked to lake with Warm water Fish. Trout pose a low level of risk to a warm water fish community. Escaped fish have a marginal chance of survival. There is little security risk in this situation except to the trout stream flowing into the lake. Medium risk guidelines are recommended here.

Fish Farm D

Warm & cold water fish linked to Warm & Cold Water species lake. This fish farm should be able to rear all species present in the receiving body of water with low security guidelines. Species not present in the watershed should be considered on an individual basis to determine if they should be considered for culture or cultured under high security guidelines.

Fish Farm E

Cold & Warm water fish farm connected to warm water lake. Cold water fish should be able to be produced with low security guidelines and warm water species should be considered under low or medium security guidelines if they are present in the lake and high security guidelines if they are not present.

Fish Farm F

Cold & Warm water lake connected to lake with specific strain of fish. Cold water species should be considered under medium security guidelines and warm water species considered on a n individual basis and approval would be dependent on determining that this species poses little or no threat to the specific strain of fish found in the receiving lake.

Salmonid Culture

Type of Salmonid Aquaculture Facilities and Security

Coldwater fish (salmonids) are mainly cultured in three systems or a combination of these three types of facilities. Each of these systems have their own particular security concerns and methods of addressing the concerns. The systems to be examined include:

a] Flow through concrete raceways

b] Tanks

c] Ponds

Flow through - raceways are the choice when large amounts of suitable water are available. Raceways allow intensive cold-water fish culture. High densities of fish can be kept with aeration and high water exchanges per hour.

A typical Concrete Raceway

It can be a challenge to prevent escapement from a raceway operation. Fish tend to try to escape when attracted by fresh water entering the raceway and water flowing out of the raceway. Inflows and outflows are the two main points where losses might occur if the appropriate measures are not taken. Different techniques are required depending on the size and species of fish being cultured as well as the plumbing configuration of inflows and outflows.

Raceway Inflow Security
Medium Security
(some losses anticipated)
To mitigate fish losses at the point where water enters the raceway screens of a size appropriate for the size of the fish to be contained has to be properly installed. Two screens are recommended. One screen should have larger holes or bar spacing, which prevent them from clogging with debris. To prevent fish from jumping towards inflowing water and over the screen extent one screen upwards. A larger size screen will prevent clogging and a smaller screen to prevent fish escapement effectively. To prevent jumping fish from escaping extend the screen upwards.

Double screen system on the inflow is useful where surface water sources may carry substantial amounts of debris

If water enters the raceway via a pipe a wire basket of some design should be fashioned around the pipe to prevent fish from jumping into it and escaping.

Galvanized screen basket catches fish from upstream and blocks jumping into inflow

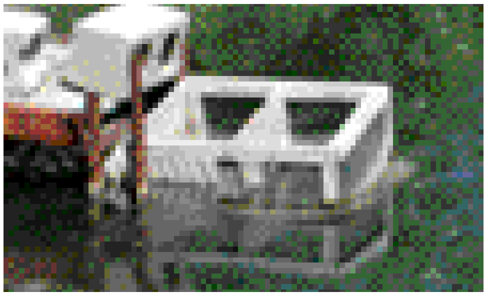
Although a vertical drop such as this may be a deterrent to upstream movement, there is still a risk that suitably sized salmonids could jump up and into the pipe

The inflow coming into this raceway drops sufficiently to make an extremely effective barrier to upstream movement through the inflow

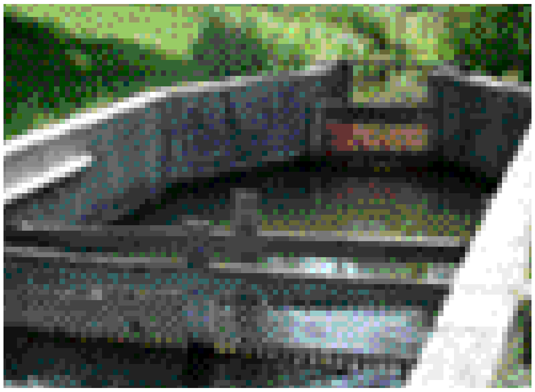
Raceway outflow security

To secure the raceway outflow requires two screens securely installed and of a size which will prevent fish escaping. To preventing losses from jumping the screens should be extended upwards.

Raceway partitioning should be considered because partitions not only spread out fish, but reduces the risk of a total loss in case outlet screens fail.



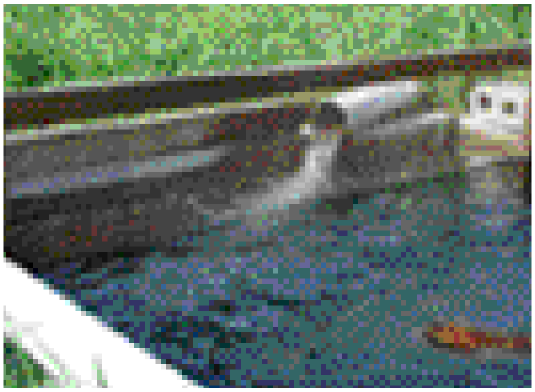
A box type screen installed on rearing pond outflow increases the surface area of the outflow pipe



Four screens have been used in series to contain valuable broodstock

Screen held in place by wooden wedge

Outflow screen held in place by cement block could be knocked over

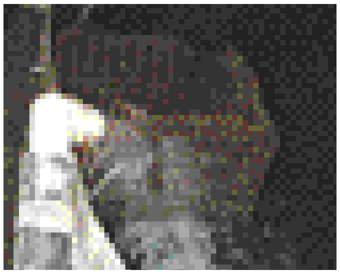


Muskrat do not chew through wire mesh screens

Dividers along the raceway spread out fish and reduce the risk of total loss if overflow ocurrs.

Screening over raceways

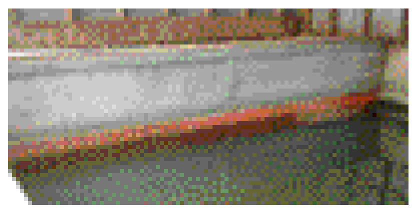
Screening over top of tanks provides protection from fish being removed from the facility by birds and mammals that eat fish. It can also prevent fish from jumping out of the tanks. These loses may not endanger the surrounding water body, but they can reduce farm profitability.



Galvanized screen basket catches fish from upstream and blocks jumping into inflow

Commercially available bird deterrents like these "Scare-Eyes" must be targeted to the appropriate problem bird species.

Simple attachment of angled boards to block jumping



Board attached to outflow screen prevents fish jumping out of the raceway

Herons must be able to wade or perch close to the water to fish effectively. The side of this raceway is too high from the water for the heron to reach the fish

High security raceway

No losses from this type of facility is anticipated. All high security facilities must be flood proof. The inflow to a raceway must be via a pipe. A pipe can be more easily screened and the water flow regulated than in a more open concept.

The outlet should be comprised of two pipes twice the capacity of the inlet pipe. These outflow pipes should be installed as vertical stand -pipes.

One or two screens should be placed in the raceway in front of the outlet pipes. The outlet pipes should be screened around the pipe. but the opening at the top is to be left open, so in case the screen plugs up, water can still run over the top into the pipe. To regulate the water level in the raceway, pipes of different length should be available.

Before the outflow water from the rearing system enters the receiving water outside the aquaculture facility as an additional security measure a flow through gravel box should be used.

a] Larger fish

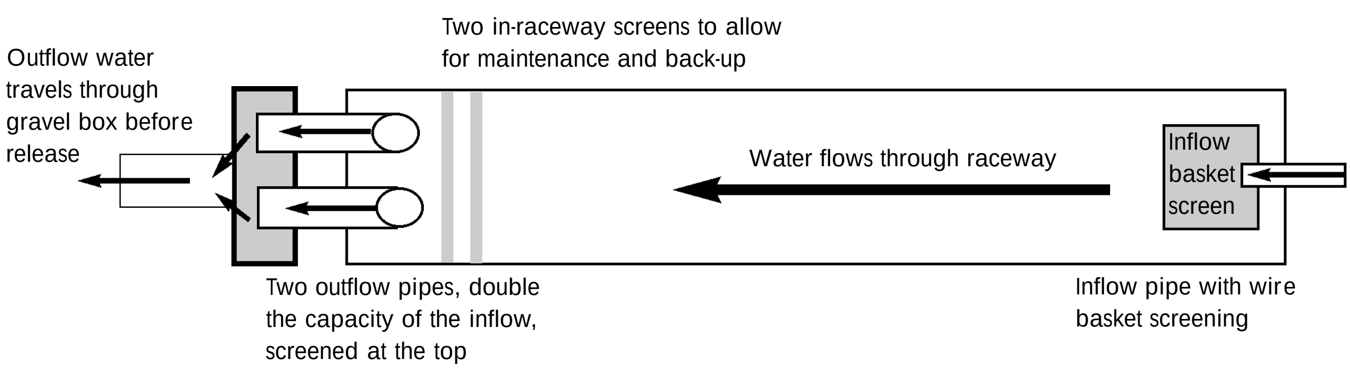
The outlet pipes should end up outside the raceway in a fully screened box which is above the outflow water level so that any fish that escape up to this point will be trapped and perish.

b] Smaller fish

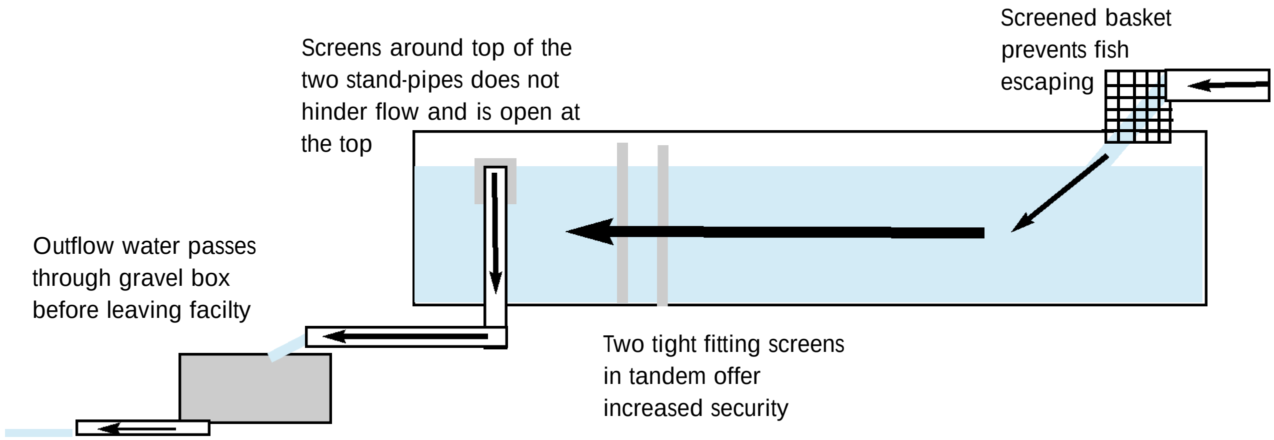
The outlet pipes should end up outside the raceway in a square box [wood, steel concrete etc.] with a screen at the bottom made of strong, long lasting material. This screen should be covered with at least three inches of gravel or crushed limestone. If maintenance is a problem an additional box can be connected via an overflow. The boxes should be covered to prevent trapped fish to jump out and also to prevent excessive algae growth.

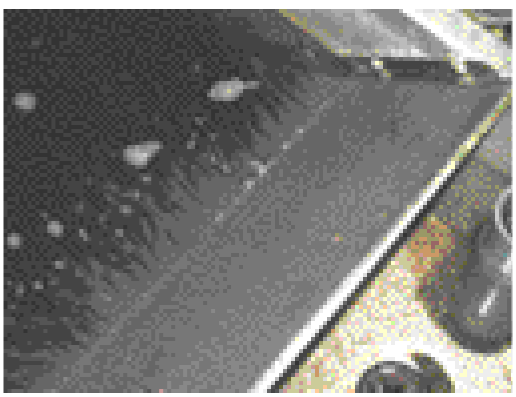
If fish have access to receiving waters when jumping out of a raceway then netting other means have to be employed to prevent this type of escape.

High Security Raceway Design (Top View)



High Security Raceway Design (Side View)





This angles outflow screen will allow debris to pass with less clogging than vertical screens

The slots in this vertical stand-pipe provide a barrier for fish and debris

Low security raceway

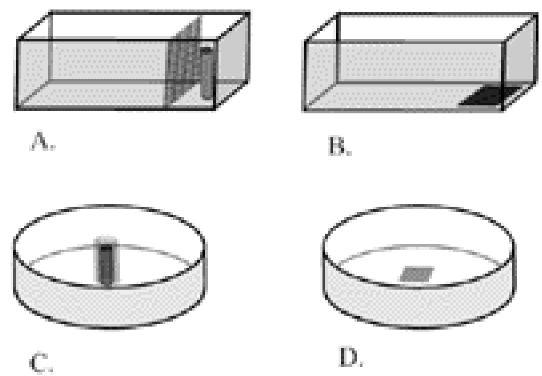
In this type of raceway operation there is the expectation that some fish may escape. It is also posible that a flooding event could allow all of the fish in the facility to escape. Raceways in low security risk situations pose very little risk to the surrounding ecosystem. Escaped fish are not a concern to the environment, however if large numbers of fish are lost recovery via electro-shocking or netting should be considered. To prevent financial loses fish farmers should incorporate security measures outlined in the medium security level description.

Tanks of all sizes and shapes are used in an aquaculture facility. They are made of a variety of materials, but mainly of fiberglass, steel or concrete. Tank culture is popular because of its convenience and efficiency. Benefits of tanks are numerous.

Tanks offer many benefits for fish farmers

Benefits of culturing fish in tanks:

- Tanks are durable.
- Tanks are easy to clean and maintain.
- Less water is required in comparison to a raceway operation to culture an equivalent amount of fish per cubic meter of water.
- Fish can be easily observed.
- Fish treatment can be done efficiently.
- Sorting fish for size prior to shipping is easy.
- Tanks can be used to hold fish prior to spawning
- Tanks can be used indoors or outdoors.



Common outflow screen configurations for different rearing unit types and plumbing arrangements. A. Vertical screen in raceway with internal standpipe. B. Horizontal screen in raceway with external standpipe. C. Vertical screen enclosing internal standpipe in circular unit. D. Horizontal screen in circular with external standpipe.

Low / Medium Risk Operation

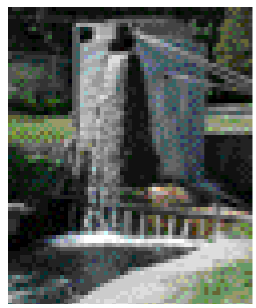
In a normal tank culture operation no massive losses of fish are to be anticipated. Most tanks have two screens to prevent fish from escaping, one covers the bottom outlet and the other one is usually at the high water level. Both screens should be of a size to contain the smallest fish in the tank. The upper screen prevents the tank from overflowing in case the bottom one plugs up due to dead fish or fish waste.

Water should be fed into the tank via a pipe. The inlet pipe is arranged in such a way that the inflow water creates a counter clockwise current in the tank. This will discourage fish from jumping.

To prevent fish from jumping in to the inlet pipe an elbow or a tee is recommended. If an inflow pipe goes straight into a tank screens are a must. [This arrangement should be discouraged because fish get injured when they jump and hit the screen.]

Although a vertical drop such as this may be a deterrent to upstream movement, there is still a risk that suitably sized salmonids could jump up and into the pipe

By placing netting over the tank losses of fish from jumping out can be prevented. Netting also protects outside tanks from fish eating birds.



The vertical drop of this inflow is sufficent to prevent fish escaping through this inflow device

The inflow water is angled to prevent fish from being able to jump into the inflow pipes.

High security operation

To upgrade a tank operation to this level, the facility must be flood proof.

Before the outflow water from the tank culture system enters the receiving waters outside the aquaculture facility as an additional security measure the following devises can be installed.

a] For larger fish

The outlet water should flow through screened box before it is discharged into the receiving waters. The box should be above the receiving water, so that trapped fish will perish quickly. The mesh size has to be such, so that the smallest fish in the system will be trapped.

b] For smaller fish

The outlet water should drain into a square box before entering the receiving waters outside the aquaculture facility. The box may be made of wood, steel or concrete and have a screened bottom of made of strong and durable material. The screen should be covered with at least three inches of gravel or crushed limestone. More than one box can be connected via an over flow if water volumes change. The boxes should be covered to prevent trapped fish from jumping out.

If required, system A and B can be incorporated in tandem for extra security.

In the past it was more common to culture salmonids in ponds than today. With the ready availability of manufactured fish feed; salmonids can be more intensively reared in tanks and raceways than in ponds.

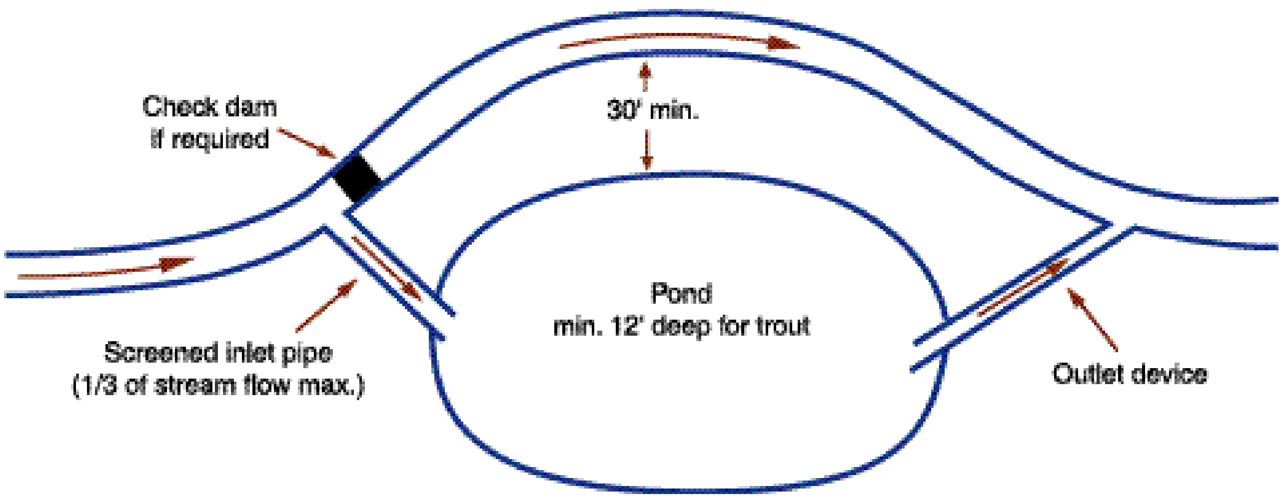
Ponds do not have to be large to be productive fish rearing sites

Ponds are still widely in use for many reasons:

- Ponds may be utilized because they have been build in the past.
- Ponds are relatively inexpensive to a build in comparison to other fish culture operations.
- Ponds are in use at many smaller fish farms on an extensive fish culture basis.
- Pond cultured fish are of a better quality for stocking purposes. They adapt better to a new environment and have no fin wear that would distinguish them from wild fish.

Water sources for operating ponds are commonly derived by using:

- Artesian springs
- Pumped water from deep wells
- Bypass water from a cold stream
- Deep excavation into ground water
- Excavation in low lying areas filled with surface runoff



Ponds can be created by using water from an existing stream as the water source for a constructed pond. However, security is more challenging when this type of water source is used.

Low risk pond culture

There are many situations where ponds cannot offer high levels of security against fish escaping into the surrounding water bodies. Any pond that has the following characteristics must be considered a low security situation

- If a pond is built by damming up a stream.
- If a pond is built in a common flood plain and not protected by a dyke.
- If a pond is in a remote area.
- If a pond can't be supervised on a daily or routine basis.
- If a concrete spillway is in a condition of repair that failure of the structure may be a possibility.
- If an outlet pipe is improperly installed and due to frost heaving, out flowing water under the pipe may cause the pond to drain uncontrolled.

To mitigate losses the inlet source of water and the outlet should be screened off with a size of material to contain the smallest fish being cultured in the pond.

Fish species to be raised in ponds that fall under the above descriptions must be compatible with the surrounding waterbody.

It is expected that a flooding event could result in the complete loss of the fish in the facility to the surrounding watershed.

Medium security pond operation

In a medium security pond operation there is the possibility that some fish may escape, but these losses will be minimal. A medium security operation in contrast to a low security operation is often similar to a raceway operation but it instead uses rectangular ponds. This system also uses large quantities of water and with aeration it is capable to produce an appreciable amount of fish per cubic meter of water.

If containment measures fail it could mean the loss of all fish.

To mitigate the above possibility certain containment devices have to be installed which are practical and easy to maintain.

The water inlet should be screened so that fish can't jump or swim out of the pond. The use of a pipe is preferred as an inlet since it is easier to screen and the water flow can be better regulated.

The outlet of a pond may be a concrete spillway, a pipe assembly or of steel or concrete open device.

Spillway

A spillway is an opening made of concrete in the side of a dam. It has groves for stop logs to control the water level and groves for screens to contain fish.

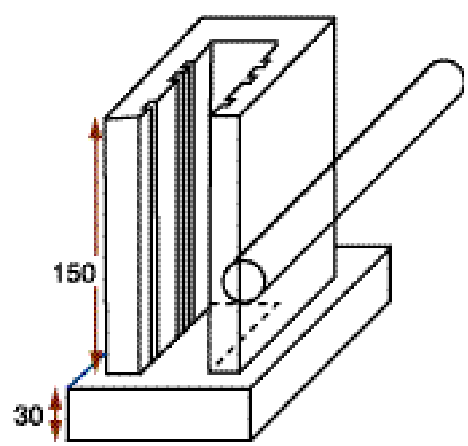
Pipe Assembly

One pipe of an appropriate dimension is horizontally installed on the bottom of the pond through the dam. On the inside of the pond a pipe is vertically connected to the outgoing pipe. The vertical pipe controls the water level in the pond. When removing this pipe the pond can be drained. A round screen can be affixed to this pipe to prevent escapement of fish.

Steel/Concrete Open Device

The steel version consists of a vertical U shaped section and is set in concrete on the pond bottom. Square bars or channel irons are welded to the opposite sites, so that stop logs and screens can be inserted. A pipe is connected horizontally to the bottom of the upright and leads through the dam.

The concrete devise is the same in principal, except only the horizontal pipe is made of steel.



Monch Device

This fixture allows fish farmers to change stop logs and screens with ease to manage outflow and screening for various sizes of fish.

High security pond operation

In a high security facility no losses of fish are anticipated. To upgrade a medium risk pond to a high-risk pond additional security measures are required.

To better manage the inflow of water the inflow should be through a pipe to have better control over water flow. This inflow should also be screened appropriately for the species of fish and size of fish being reared.

Outflow devise either pipe assembly or Steel/concrete open devise. This Monch device or a similar device should have the ability to double screen the outflow and regulate the water level without compromising security.

As a further security measure the outflow pipe should drain water through a screened box and or gravel box. This will ensure that fish that do pass the double screening cannot escape to a surrounding water body or the receiving water.

Top of dam should be 6 to 8 feet wide. So that it reduces the risk of failure or overflow can be monitored.

Top of dam should be 18 inches above water level so that even under extreme situations where the outflow is plugged, there is sufficient capacity that the problem can be solved before water flows over the top of the dam uncontrolled.

Dam might have to be protected from burrowing animals [muskrats]. Excessive burrowing through the dam could compromise its integrity and create leaks or a dam failure, either of which can result in losses of fish into the surrounding water.

Pond must be flood proof. This can be accomplished by locating the pond outside of a flood plain area or through berms around the facility that are designed to protect the facility against unusually high flows.

Early rearing of salmonids

Salmonids are usually cultured in the early stages from egg to fingerling size in buildings designed for that purpose. There is lower risk with these operations due to the smaller size and lack of mobility that smaller salmonids have.

Egg stage

Eggs are usually hatched in one of three arrangements.

1. Heath Trays
   Heath tray systems are often preferred because of the compact design; high capacity of egg space, relatively low water demand, efficient treatment against fungus, etc. The eggs can be well observed and dead eggs be removed. Newly hatched sack-fry can stay for some time in the heath tray incubator before they are moved to a larger container.

2. Screen Baskets
   Screen baskets that sit in troughs with water flow through them are also common. This system is more labor intensive; needs more space and water flow.

3. Jars
   Eggs are also incubated in jars or other vessels.

Security of eggs

Low or Medium Security Facility

If reasonable care is taken to prevent losses of eggs they pose little threat of survival in the receiving waterbody. The overflow or flooding of an early rearing building is the only way that numbers of eggs could escape if proper measures are taken to contain the eggs. Unless fertilized eggs are discarded into the receiving water body.

High Security Facility

Hatchery buildings in a high security facility should be contained in a building that can be locked. As with all other high security facilities the facility should be flood proof. Also, all out flowing water should pass through a fine- screened box to catch any eggs that wash out of an incubator. If water from the early rearing facility passes through a settling tank or septic tank eggs will settle on the bottom and perish.

Sac fry stage

Newly hatched salmonids are transferred from the incubators to a trough or a tank. They are very poor swimmers at this stage and sit mostly motionless on the bottom. It will take several weeks, depending on the water temperature, before they have absorbed the yolk-sack and become free swimming [swim up stage] and start feeding. Security for this life-stage is the same as for eggs.

Swim up stage

These small free-swimming fish are not overly mobile, but their small size increase the risk of escape. Fine screen arrangements are required to contain these fish.

Low and medium security

If salmonids are held from the swim up stage to fingerling size [2 inches] in troughs than there should be a screen of adequately small size in front of the outflow pipe to prevent fish from escaping. The inflow should consist of a pipe and so installed that fish can't swim nor jump into it.

If salmonids are held from swim up stage to fingerling size in tanks the inflow pipe should be installed so that fish can't swim nor jump into it. The outlet drain is usually on the bottom of a tank and covered with a screen of a size that prevents any escapement. An extra safety screen is installed at the high water mark of the tank to prevent over flowing in case the bottom screen plugs up.

High security

To prevent any losses of fish if a trough is used then there should be two screens installed in front of the outflow pipe. The second screen should be somewhat higher to prevent fish from jumping out.

Tanks should have screens that contain the smallest fish in them.

The inflow must be installed so that fish can't swim nor jump into it.

All water leaving the facility should drain through a screen box or a gravel/ sand box to catch any escaped fish. It may be necessary to make this arrangement for different life stages at several locations in the facility.

Warm Water

Warm water fish species thrive under conditions that differ from cold water or salmonid culture. This varied group of species have their own security concerns. Many of these species have very small free-swimming larvae that can be challenging to contain and culture often takes place in ponds that offer unique challenges to effective fish containment.

Warm water fish will tolerate a wider range from 1 degree to 30 degree Celsius. Temperatures that exceed around 30 to 35 degree Celsius can be fatal to these fish. The optimum temperature to culture most warm water fish is between 18 degree and 25 degree Celsius.

In contrast, cold water fish tolerate a temperature range between 1degree and less than 20 degree Celsius. Temperatures around 25 degrees Celsius are fatal for their survival.

Spawning methods of warm water fish

Artificial

Artificially removing eggs and milt from warm water fish and fertilizing these fertilized eggs are incubated in jars, heath incubators, troughs etc... can be very practical and provide a higher success rate in comparison to natural spawning. The hatching success rate is more predictable and the eggs can be better observed and treated against fungus if needed. The water temperature can often be manipulated to advance or delay hatching.

Natural

Warm water fish, in contrast to coldwater fish, can be easily induced to spawn naturally in specially prepared ponds. Fish will spawn if the right substrata and water temperature for a specific fish species is provided in a pond. This method is less reliable, but in some cases unavoidable. Brood fish might have to be removed to avoid predation on newly hatched fish larvae.

The early rearing and containment of warm water fish is more complex and differs in many ways from cold water fish culture.

Key considerations in rearing warm water species are spawning water temperature, how many times a season fish spawn, the size and mobility of fry and the type of substrate spawning fish require.

There are a wide variety of warm water fish that are cultured in Canada. The fish farmer should know various characteristics about the species they wish to raise. The temperature that these fish spawn at, the mobility of their larvae or fry, the substrate that the fish spawn on and how many times each season that the fish may spawn are all important considerations that will affect the ability of the farmer to raise these fish.

Some warm water fish spawn annually, others spawn several times during the summer. It is important to know if you have a multiple generation spawner because the adults may eat newly hathced fish or water released from the pond at the incorrect time may release unknown fish larvae into the receiving water.

Spawning temperature is also important to know. Knowing when the smaller life stages of fish are present or likely to be present is essential to know how water should be managed throughout the season.

Perch, walleye, pike etc...start spawning when the water temperature reaches 7 to 10 degree Celsius.

Muskellunge, suckers, catfish etc... start spawning when the temperature reaches 10 to 15 degree Celsius.

Carp, bass etc... start spawning when the temperature reaches 18 to 22 degree Celsius.

Most cyprinids and the sunfish family will spawn several times during the summer as long as the water temperature stays above 20 degree Celsius.

Other fish culture books can identify these characteristics to a level required for fish culture purposes.

Low-medium

When eggs of species of fish that have free-swimming larvae are incubated in jars only the smallest screens will prevent losses. Screens on jars are often impractical because they easily clog up with fry and eggshells. This might cause the jar to over flow and subsequently a total loss of fry may occur. To mitigate this situation fry should be allowed to drift into a larger tank that can be better screened to avoid losses. In some cases fry can drift from jars directly into rearing ponds.

If eggs are incubated in modified Heath Incubators, or by similar methods, newly hatched fry sometimes stay in them for a short time before being released into a rearing pond.

High Security

Whenever warm water fish eggs are incubated artificially some losses may occur. The fry larvae are very small and if accidentally spilled are very hard to recover and may escape into natural waters and cause problems.

To prevent escapement all water leaving a hatchery building or any other location, which is used for incubating eggs, must be safeguarded. Before released water enters a water flow, connected to a natural ecosystem all waters should first drain through a gravel box and secondly through an upwelling box with small grained gravel or sand to remove live eggs or fry.

High security facilities must also be flood proof.

Containment of warm water larvae

The containment of newly hatched warm water fish larvae can be quite challenging and great care, must be taken to avoid losses. The size of newly hatched fry is in general very small and their initial behavior differs from species to species.

Some fry are free swimming immediately [walleye]. Some fry attach themselves on an object until the yolk sack is absorbed and they become free swimmers. [carp, pike]. Some fry crowd on the bottom until yolk sack absorption and then become free swimming. [suckers, bass]

Small. Free-swimming fry or larvae can be challenging to contain. Very fine screening is required to prevent escape and if a facility is to be secured filtering of the water may be required to prevent live fry or larvae from escaping to the receiving body of water.

FRY FINGERLING STAGE

High Security

In general warm water fish fry are stocked and cultured to fingerling size in specially prepared ponds. These ponds can have the inflow and outflow completely closed off. This serves two purposes. First, the tiny fry have no escape route and secondly all the nutrients that create a zooplankton growth in the pond to feed the fry are contained. Fresh water is only added to compensate for seepage and evaporation.

As long as the culturing method is adhered to as described above and the pond is flood proof no escapement is to be anticipated.

This pond culture method and stage can be classified as High Security.

FINGERLING TO ADULT STAGE

Once warm water fish reach fingerling size and are trained on prepared fish feed a water supply of a minimum of 20 gal. /min. per hectare pond size is required. Depending on the stocking rate either aeration is applied and/or the water supply may have to be increased.

Ponds, which have no in or out flow of water have lower production rate unless extra aeration is be supplied.

The behavior of warm water fish compared to salmonids in a culture system is different. Whereas salmonids try to jump towards inflowing and out flowing water; warm water fish tend more to swim towards flowing water. With decreasing water temperature warm water fish will also become less active and seek out deeper water in a pond.

Three main types of ponds are in use to culture warm water fish, they are:

a] If a water flow is dammed up and a water body is created.

b] If a pond is excavated on a property where the ground water table is high or artesian springs are present.

c] If a pond is build by impounding an area with four dams and filling the area with water.

Dams have to be properly designed and maintained and the top should be at least ten feet wide. The dam top should also extend at least 18 inches above the high water mark. There should be no trees on a dam, because wind action may cause the roots to loosen the soil and extensive seepage may occur that may entail the washout of the whole dam.

To discourage mammals [muskrats, beavers, otters etc.] from burrowing into a dam the pond side of a dam should have no high vegetation [cattails, bushes etc] and for an extra safety precaution wire mesh can be buried along the dam extending two feet above and below the high water mark.

In a pond system there are two main avenues where losses can be anticipated; they are the in and out flow unless the pond has neither one.

Warmwater Pond Security

High Security

A facility that cultures warm water fish in ponds under a high security rating implies that no escape or losses are anticipated. Most mature warm water fish will reproduce in ponds during the season. The escapement of fry from ponds that contain adult populations of fish can be prevented if the pond:

a) is isolated with neither an inflow or outflow
b) has a recycling water system
c) has inflows and outflows that can be completely closed off.
d) is one in a series of ponds that can have the inflow and outflow completely closed off.

Immature warm water fish can be contained in ponds if secured as prescribed int eh medium security section, except an open spillway outflow should be avoided. Culturing warmwater fishin raceways is comparable to culturing salmonids and the same security measures apply.

Ponds with no inflow or outflow or with double screens of appropriate size can be classified as high security as long as the facility is flood proof and outflow water passes through a gravel and sand box filter before entering the receiving body of water.

Medium Security

Ponds with proper screening that are flood proof but lack the filter system can be classed as medium security.

Low Security

Ponds that are flood prone or lack proper screening and the gravel box filter of outflow water must be classified as low security.

Pond inflow

When ever possible it should be avoided to let a natural stream flow directly through a pond [flow through], unless the stream is a very small headwater stream. If the stream is fish habitat the migration of fish should not be unnecessarily inhibited.

A bypass system is more desirable. Diverting part of the stream into the pond or ponds provides a water source, but should not interrupt all water flow in the stream.

When a bypass system is used the water from the stream should feed into a header pond and from there be distributed into rearing ponds. If feasible, a screen may be placed between bypass and header pond to prevent mainly larger wild fish from entering the facility.

A pipe best controls the water flow between a header pond and the rearing pond. The maximum capacity of a pipe if water is free flowing [not under pressure] can be mathematically established. This data is also valuable when designing the outflow. (See Appendix)

To prevent fish from escaping through the inlet pipe a tube screen or a screened box [screen size according to smallest fish in the system] should be installed where the pipe enters the pond.

When an open spillway is between the header pond and rearing pond the spillway may be constructed from concrete, wood or metal. The spillway should have grooves so that stop logs and screens of an appropriate size can be installed to prevent fish from escaping.

When water is pumped into a pond and discharged through a screen no escapement can be anticipated.

When water from a small headwater stream is used that originates on the property screening may be installed to prevent fish moving up the stream and become easy prey for birds in shallow water.

Note: Most mature warm water fish will spawn and reproduce uncontrolled in a pond in season. To prevent that the fry escapes through the out flow it will be a necessity to completely close the in and out flow of the pond until the fry reaches a size large enough so that they can be contained by screening with a suitable mesh size on the in and out flow.

Pond outflow

The outflow of a pond is about the most important part and at the same time the weakest link of a pond. If not properly designed and installed to be able to drain all excess water from a pond, the pond may flow over at the lowest part of the dam and may cause the same to wash out. This may cause considerable damage in the pathway of the out- flowing water and the loss of all fish in the pond.

Frost heaving and seepage around the out flow installation may also cause a wash out of the dam.

The outlet of a pond may be a concrete spillway, made up of a pipe assembly or of a steel or concrete open devise.

Spillway

A spillway is an opening made of concrete in the side of a dam. It has grooves for stop logs to control the water level and grooves for screens to contain fish.

Pipe assembly

One pipe of an appropriate dimension is horizontally installed on the bottom of the pond through the dam. On the inside of the pond a pipe is vertically connected to a tee section on the outgoing pipe. The vertical pipe controls the water level in the pond. The open end of the tee is closed with a plug, which can be removed if the pond is to be drained. A round screen can be affixed to the vertical pipe to prevent escapement of fish.

Steel/Concrete open devise

The steel version consists of a vertical U shaped section and is set in concrete on the pond bottom. Square bars or channel irons are welded to the opposite sides, so that stop logs and screens can be inserted. A pipe is connected horizontally to the bottom of the upright and leads through the dam. The concrete devise is the same in principal, except only the horizontal pipe is made of concrete.

Eel Culture

Eels are an anadrome fish species their spawning ground is in the South Atlantic Ocean [Sargasso Sea]. From this area the young [glass eel] drift north with the Gulf Stream. In the North Atlantic the eels split up and some travel towards the European coast and others the North American coast line.

They enter rivers and migrate inland until they find suitable habitat. They will spend the next 8 to 10 years in temperate fresh water until they mature. When this stage is reached they will migrate back to the Sargasso Sea to spawn and die.

The escapement of eels from a fish culture facility does's not constituted a permanent ecological problem, but they require special efforts to contain them. The eel will avoid cold water [salmonid habitat] and seek out warm water streams and lakes for the duration it lives in fresh water. Due to their spawning habits, they will not be a long-term threat to any body of freshwater.

The containment of eels needs special attention. Eels are cultured in recycling systems [tanks] and ponds. Heavy financial losses for the culturist may occur if the ability of eels to escape is not considered.

To contain eels in tanks a smooth barrier sloping inwards must surround the tank; the height of this barrier should be 18" to 24" otherwise the eels will be able to climb out. Screens must be of a size so that they can't squeeze through them.

If eels are cultured in a pond that has no iflow or outflow of water it is necessary to surround the pond with barrier as described for tanks. They can crawl on land for considerable distances. They can also climb rough textured barriers.

To prevent escapement of eels from ponds, which have water flowing in and out, then the same security measures have to be installed as described for tanks.

Eels will try to escape from ponds on rainy days and nights and can slide through wet grass for a considerable distance. If preventive measures are not taken, most if not all eels can disappear from a pond.

Guidelines
Applicants should be aware that each proposal will be reviewed on a case-by-case basis and that, in cases where containment of the fish is warranted, the following minimum guidelines should be considered in establishing containment procedures for introduced or transferred fish :

1. The facility cannot be located within the floodplain of a river as determined by the New Brunswick Department of Environment and Local Government Environmental Quality Branch

2. Physical enclosure of the facility with adequate security. The enclosure will include a locked entrance.

3. Admission to the facility will be controlled by the project manager and will be restricted to designated persons.

4. Holding units for introduced or transferred fish will be constructed and plumbed in such a way, and with materials, that minimise the possibility of structural failure.

5. The facility will be constructed so that all of the fish held in holding units within the facility can be contained within the facility in the event of a catastrophic failure, or flooding, of all holding units.

6. Prior to release from the facility, effluent from all fish holding units must go to effluent treatment systems, which have overflow protection and effluent screening. Depending on the fish and life stages involved and on the assessed 'risk' that escape might pose, this may require mesh screening, sand filtration, chemical filtration or other 'screening' judged by NB I&TC as appropriate to the situation

7. Disposal, or transfer, of introduced fish, or their gametes must be done in a NB I&TC-approved manner which poses no genetic, ecological or fish health threat to wild aquatic resources or aquaculture in New Brunswick.

8. Detailed records must be maintained, for the duration of the containment, on events occurring in the containment facility. These would include inventory numbers, treatment (of introduced or transferred fish or effluent) records, and equipment failure records as well as any other records deemed appropriate by NB I&TC.

Possible Additional Requirements Related to Fish Health

Although these guidelines are aimed at the containment of the actual transferred or introduced fish themselves, applicants should also be aware that Canadian Fish Health Protection Regulations (FHPR) and/or regional or provincial fish health programs may require that additional 'isolation' or 'quarantine' conditions be applied to their containment facilities to prevent the release of fish pathogens. These may include (but may not be limited to) the following:

1. Disinfection of influent water

2. Disinfection of effluent water.

3. Disinfectant footbath and handwash facilities at entrances to be used when entering and when leaving the unit.

4. All protective garments such as rubber boots, gloves, coveralls, lab coats, etc. used within the facility to remain there. (If protective garments must be removed, e.g., for laundering, disinfection procedures prior to removal will be required and defined.)

5. All equipment (lab equipment, nets, etc.) to be used in the facility should remain within the facility and should be disinfected between uses.

All solid wastes (paper, plastic, wood, fabric, etc.), from the facility, must be disinfected, using a DFO Fish Health Unit-approved method, (chemical disinfection, autoclaving, incineration, etc.) prior to disposal.

Ministry of Natural Resources Policy (FisPp.9.2.5 Jan. 2000). Key to Facility Classification

OMNR identifies three classes of aquaculture facilities based on the risk of escape from the facility. They are as follows:

1) F1 - High Security Facility
A high security facility must have a low risk of escapement at all times and meet all of the following security criteria:

- physically secure (i.e. fence and/or wall around facility;
- at least three levels of escape prevention involving different methods (e.g., a combination of screens, certain pump types, de-watering, effluent filtration or treatment);
- at least one method of escape prevention must be passive (i.e. not dependent on a power supply);
- located above the regional flood plain.

2) F2 - Medium Security Facility
A medium security facility must have a low to moderate risk of escapement and meet the following security criteria:

- at least two levels of escape prevention involving two different methods (e.g. a combination of screens, certain pump types, de-watering, effluent filtration or treatment
- at least one method of escape prevention must be passive (i.e. not dependent on a power supply);

Most existing Ontario trout farms are currently F2 facilities. F2 facilities can occur on a regional flood plain, provided that there is adequate flood proofing.

3) Low Security Facility
Low security facilities, which pose a high risk of escapement such as those connected to Ontario waters, or located in a lake or on a regional flood plain (e.g. earth ponds and floating cages) A facility situated on a regional flood plain cannot be classified as F1 unless it is adequately flood-proofed.

Fish Length		Fish Weight		Required Screen Spacing	
mm	inches	grams	ounces	mm	inches
51	2	1.5	.05	5	3/16
76	3	5	.17	10	3/8
127	5	28	1	13	1/2
203	8	114	4	19	3/4
305	12	284	10	25	1
381	1	681	24	35	1 3/8

TABLE 1: from "Screening your Fish Pond", Alberta Agriculture Food and Rural Affairs Agri-fax (Agdex 485/87-1), April 1999

Size (salmonids)	Screen Type	Screen Opening size
Fry -< 2.36 inches (60.0 mm)	Perforated plate	<=3/32 inches (2.38 mm)
	Profile bar screen	< 0.0689 inches (1.75 mm) in the narrow direction
	Woven wire screen	<3/32 inches (2.38 mm) in the narrow direction (e.g. 6-14 mesh)
Fingerlings > 2.36 inches (60 mm)	Perforated plate	<1/4 inches (6.35 mm)
	Profile bar screen	<1/4 (6.35 mm) in the narrow direction
	Woven wire screen	1/4 (6.35 mm) in the narrow direction

TABLE 2: from JUVENILE FISH SCREEN CRITERIA, National Marine Fisheries Service Environmental & Technical Services Division, Portland, Oregon, Revised February 16, 1995

Fish Weight (grams)	Slot Size	MM	(inches)
Up to 0.45	3.175	1.5875	1/8 - 1/16
0.45-2.27	6.35	3.175	1/4 - 1/8
2.27-15.15	12.7	6.35	1/2 - 1/4
Over 15.15	19.05	12.7	3/4 - 1/2

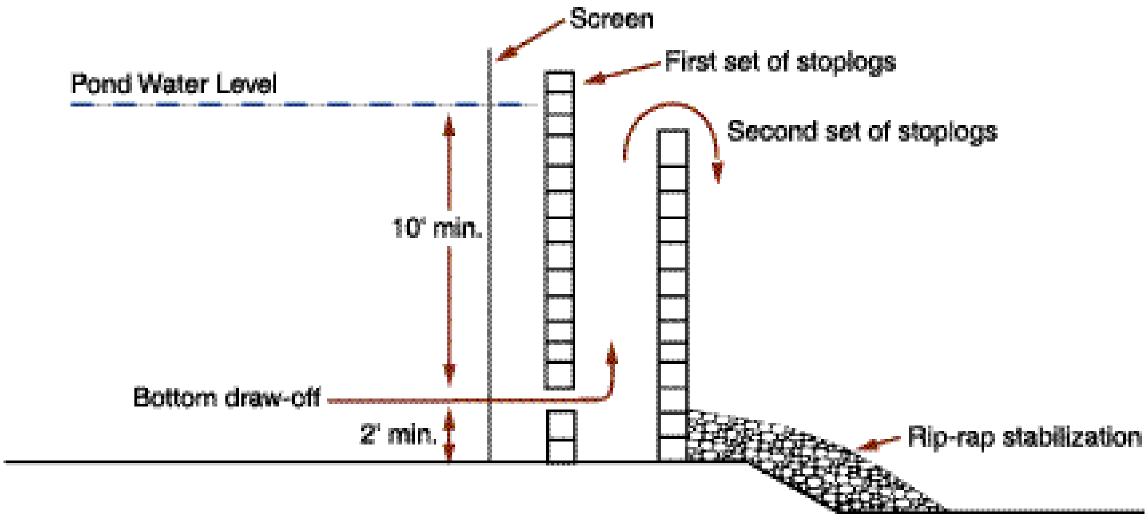
Screen Material	Relative Cost	Durability and Strength	Notes
Galvanized hardware cloth	Low	Low	• Resists chewing • Corrosion can be a problem • Widely available in many sizes
Plastic (roll)	Low	Low	• May deteriorate in sunlight • Widely Available in many sizes • Subject to chewing or tearing
Aluminum	Med.	Excellent	• Preferred in smaller raceway troughs and circular units with bottom draw • May be difficult to cut
Stainless Steel	High	Excellent	• Preferred in smaller raceway troughs and circular units with bottom draw • May be difficult to cut
Plastic (rigid) PVC	Med.	Moderate	• May become brittle in the cold • Can be cut using common hand tools

Vertacl distance CM	Diameter of pipe 10	20	30	40	50	60	Length of pipe M
5	6	23	54	98	155	225	
10	8	34	80	138	220	320	
20	11	45	115	196	310	450	
30	14	55	134	239	435	635	
40	16	65	156	280	435	635	
50	18	74	174	310	485	705	2
60	20	81	192	340	535	775	
70	22	87	206	370	575	835	
80	24	96	220	395	620	895	
90	25	105	232	420	650	950	
100	26	114	244	440	690	1000	
5	4	18	46	85	140	200	
10	6	26	64	125	195	285	
20	8	36	93	175	280	410	
30	10	46	115	215	340	500	
40	12	53	134	250	390	580	
50	13	60	150	280	440	650	10
60	14	66	165	310	480	715	
70	16	70	178	330	525	770	
80	18	76	190	355	565	840	
90	19	80	203	375	595	875	
100	20	86	215	390	630	935	
5	3	6	30	65	100	170	
10	4	9	46	99	160	240	
20	5	13	74	140	230	340	
30	6	15	90	170	285	425	
40	7	17	104	200	325	490	
50	8	19	116	225	370	550	30
60	9	22	128	245	405	610	
70	10	25	140	270	435	660	
80	11	27	150	290	470	710	
90	12	30	160	305	500	750	
100	13	33	170	320	525	790	

Most salmonid production systems have facilities for settling solid wastes. Settled solids are periodically removed by gravity (waste lines plumbed into units, siphoning), or pumped into waste ponds. The waste pathway includes the apparatus used to remove fish wastes from culture areas including storage areas. Losses through the waste pathway will tend to be small. Most fish entering into the waste pathway will not survive long, since the concentrated waste holding areas are not generally suitable for fish life and the effluent is normally spread into a non-aquatic environment.

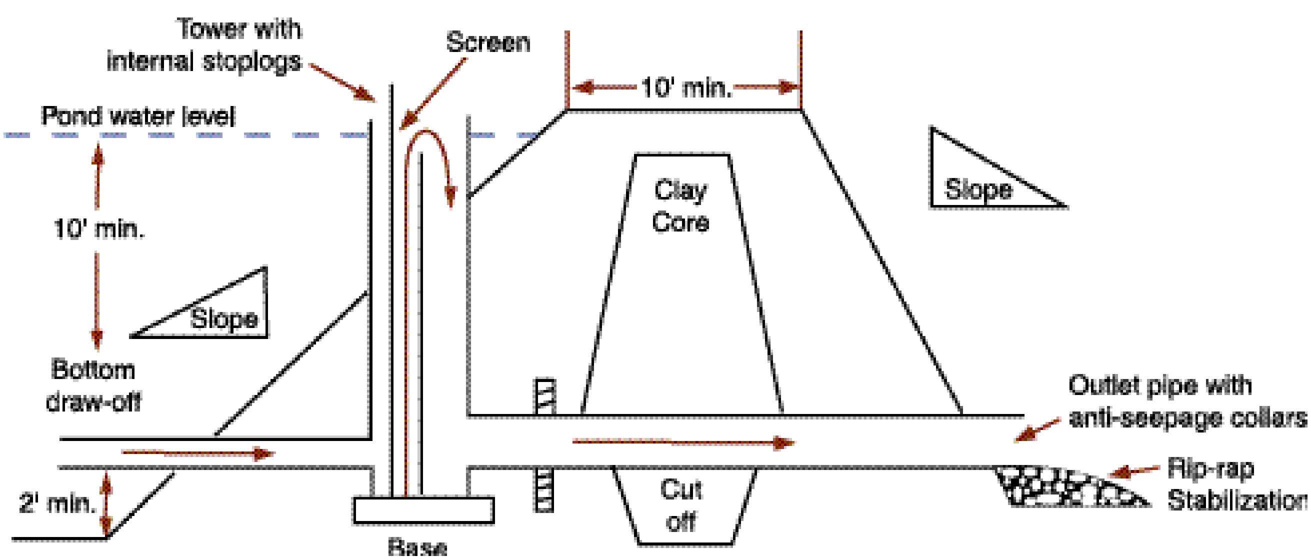
Variable Category	Variable	Overall Risk of Loss	Risk of Loss Into Adjacent Ecosystems
Waste Destination Type	Waste pond/holding area with no outflow	Low-Moderate	None-Low
	Waste pond/holding area with outflow	Low-moderate	Low
	Pumped/Siphoned onto field/soil	Low-Moderate	None-Low

Double Stoplog Draw-off Device



The double stop log draw-off device allows screening and water-level modifications to be controled easily and effectively.

Tower Draw-Off Device



A tower draw-off devise allows control over a pond outflow. Screening can be changed and stop logs can be easily modified to change water levels.