Barrier Management

WHAT IS BARRIER MANAGEMENT?

Barrier management incorporates the environmental effects of natural and man-made obstructions on the health of our rivers and streams. Obstructions in rivers can be vertical structures or water velocity barriers. Permanent natural barriers include geological formations such as waterfalls, chutes and gorges. Man-made barriers include dams, weirs, locks, culverts, pipes and channelizations.

The physical form of our rivers is produced by the surface geology of the watershed. Life in the river has evolved over thousands of years to adapt to natural barriers. Likewise, the animals in a river are adapted to natural disturbances such as beaver dams or logjams. These short-lived barriers have negligible long-term environmental effects on riverine ecology.

Dams and locks are structures that have the ability to control a volume of water behind them.

Unnatural barriers take the form of dams, weirs, locks, drop structures and culverts. Dams and locks are structures that have the ability to control a volume of water behind them. Typically, small dams are less than 5 metres high and have an impoundment, or on-line pond, less that 40 hectares. Large dams include those used for generating electricity, or for supplying water to our towns and cities. Locks allow for ships and boats to move through a waterway such as the Trent Severn canal system. Drop structures are used for gradient control where the stream has been channelized; they also provide energy dissipation of fast flowing water. Culverts are steel or concrete pipes used to convey water under a road or highway. The physical footprint of unnatural barriers is short-lived, with most structures typically having a life expectancy of 50 years.

Some barriers are beneficial to society, while others are functionally obsolete. Regardless of the function of existing barriers, many of these water control structures fail to adequately mitigate the physical, chemical and biological impacts on the forbearing river. It is the manufactured barriers that create significant long-term environmental effects on a river's biological integrity. In relation to rivers and streams of Ontario, our rehabilitation efforts need to focus on reversing the harm of unnatural barriers. We need to look closely at how we manage man-made barriers and take sensible actions that revitalize our rivers and streams.

A HISTORY OF CHANGE

The last ice age retreated from Laurentian Great Lakes over 10,000 years ago. Human colonization of North America is thought to have occurred around 9,000 B.C. From the initial colonization to about 1600 A.D., the Native peoples of Ontario lived in harmony with nature, using rivers as travel corridors for trading goods and as a source of food and water. Fish, wildlife and plants were plentiful and harvested from the river valleys, prairies and forests to sustain their lives.

Weirs have a static volume of water behind them and are typically used for irrigation, monitoring river flows or inhibiting sea lamprey migration.

Europeans first ventured to North America in the early 1600's and came into contact with Ontario Iroquois and the Algonquin speaking people. The rivers were used as trade routes supplying furs to the European markets. As the European influence dominated more and more of the Ontario landscape, new diseases from Europe, exhausted food resources and dwindling territories, overwhelmed the Native peoples.

By the late 1700's, pioneers from Europe were moving into Ontario to conquer the landscape. Parcels of Native land were traded for goods and purchased by early settlers. Once acquired, lands were harvested for timber and cleared for farms and roads. The first man-made barriers of the Industrial Revolution were dams, built to harness the power of rivers, for milling lumber and grinding grains or to provide water for logging operations, irrigating crops and livestock. The first dam on record was built in 1782 on the Cataraqui River near Kingston. These early dams were commonly built of elm and pine cribs filled with rock. By the 1860s, dozens of mills existed in the Moira, Ganaraska, Credit, Don, Humber, and Rouge rivers of Upper Canada. 90 mills were in operation on the Humber by 1860. Communities formed around mills as more settlers came to Ontario from Europe. The dam and pond associated with the mill were important to the livelihood of community because they were the basis of prosperity.

"Dams are not like the pyramids of Egypt that stand for eternity. They are instruments that should be judged by the health of the river to which they belong"

US Secretary of the Interior Bruce Babbitt, 1998

With the invention of electricity in the late 1800s, larger dams were constructed to generate a new means of power for industry. This gave rise to the abandonment of smaller private dams because hydro generated electricity became the cheaper source of power for operating mills. Many of these smaller dams and ponds, that once served a worthy societal function, still exist today with some being more than 150 years old. The linkage between the mill, dam, pond and the growth of the community are the basis of the cultural significance expressed by present day historians, when the long-term management of a concrete monument is questioned.

In 1954, Hurricane Hazel hit southern Ontario hard and eliminated many of the antiquated barriers as the floodwaters swept them away. This flood event caused loss of life, massive property losses and triggered a new way of managing our rivers and floodplains. We became aware that living in the floodplains of rivers was not safe. In response to the flood damage, control structures were built in efforts to solve future threats. Streams were channelized with concrete, new dams were built in headwater areas to store floodwaters, and floodplain protection policies were developed by new regulatory agencies – the Conservation Authorities. By 1973, 72% of the 16,700 kms of streams tributary to Lakes Ontario, Erie and Huron were blocked by dams.

Today we have a variety of man-made barriers that have been constructed for mills, generation of electricity, flood control, shipping vessels, irrigation, livestock watering, sea lamprey control, domestic water supply, and recreation. It is estimated that there are 3,000 dams, weirs and other barriers throughout the province, with some watersheds, like the Humber River in the Toronto area, having over 110 man-made obstructions currently existing. The majority of these barriers are located in the headwaters of our rivers. Some of the structures are beneficial to the public, while others are obsolete. Ownership of these structures may be federal, provincial, municipal or private. In the last decade, many functionally obsolete barriers have come under close public scrutiny due to their outlived intended purpose, risk to public safety and environmental impacts on river ecology. Social values associated with the dams and weirs of our history are slowly changing from the nostalgic to the pragmatic, as the public becomes more informed of the inherent economic and environmental consequences of barriers.

EFFECTS OF BARRIERS ON RIVERS AND STREAMS

The effects of barriers on rivers and streams have been widely studied across North America, Australia and Europe. An extensive volume of science-based information exists. This knowledge has advanced our understanding of rivers and documented the environmental consequences of man-made obstructions in our watersheds.

A series of complex physical, chemical and biological processes occur in flowing rivers that link the watershed ecosystem from its headwaters to downstream limit. Longitudinal changes occur in the characteristics of river form, floodplain, substrate and water chemistry, creating physical gradients through a watershed. The ecology of healthy watersheds has adapted to this gradient over thousands of years. Unnatural barriers tend to exhaust reaches of flowing rivers from the natural processes associated with watershed gradients. From this understanding, dams are considered an extreme cataclysmic episode in the river's cycle of life. Other man-made barriers such as culverts, weirs, and drop structures have similar impacts on a river's health.

The effects of a barrier are directly linked to the physical, chemical and biological processes that occur in a river. It is the combination of process changes induced by an unnatural barrier that cause deleterious consequences. The effects of barriers have been summarized into five categories.

Physical Effects

1. An existing channel form is altered in terms of meander pattern and slope. The flowing river is modified into a still water lake or pond environment.
2. Sediment transport of cobbles, gravel, sand, and finer material can be inhibited, which eliminates replenishing of sediment in downstream reaches. This results in streambed armouring.
3. Sediment builds up behind the barrier over years and gradually fills in the on-line pond or impoundment. Reservoirs become wetlands over decades.
4. Drastic vertical drops in elevation block longitudinal riverine habitat.
5. Barriers block the downstream movement of large woody debris that is important for aquatic habitat.
6. Large impoundments created by barriers decrease light penetration to the river bed
7. Loss of floodplain area occurs as a result of creating an impoundment. This reduces or eliminates the ability of the floodplain to act as a water filtration zone.

Dams, like this 7 metre high structure on the West Credit River, create a drastic vertical drop in elevation that interrupts the natural processes of a river.

Hydrologic Effects

1. Large impoundments can arrest the flow of water.
2. Flow regulation can result in reduced flow during spring freshet and controlled summer discharge. Maintenance of pre-development fish populations has not been achieved in cases where river flows have become regulated.
3. Loss of spring freshets degrades aquatic habitat by inhibiting the annual sediment flush of physical habitats.
4. Reduced flows can strand fish and fry.
5. Culverts and weirs can become velocity barriers, where the current of water moves too quickly for migrating fish.
6. Wide dams and weirs spread water across the top of the spillway; this diffuses the attraction flow, making it difficult for fish to find passage.

Water Quality Effects

1. Impoundments created by barriers cause stratification of temperature through the water column, making surface water warmer. This can lead to the warming of the river downstream of the impoundment.
2. Dams and weirs act as pollution traps. As pollutants move downstream, they become trapped with fine sediment in the impoundments.
3. Impoundments trap nutrient movement and induce over-enrichment (eutrophication).
4. Algae blooms are common in impoundments and indicate too many nutrients in the water.
5. Organic materials trapped in the pond behind a dam use up more oxygen during decomposition than an equivalent area within the river. This results in a reduction of oxygen to downstream reaches.
6. Nitrogen gas supersaturation can occur as water spills over a barrier into turbulent water.
7. Warming of water behind dams leads to increased bacterial concentrations, such as fecal coliforms.

Excessive algae growth in impoundments indicates over-enrichment of nutrients in the water

Natural Heritage Effects

1. Barriers lead to population isolation and fragmentation of habitats.
2. Fragmentation of habitats in a river inhibits gene flow between inhabitants and can reduce the biological fitness of aquatic populations.

3. The flow of leaf litter is a primary food source for the base of a food chain. Interruption of this flow, as a result of a barrier, can impair aquatic insect production.
4. Fish mortality of downstream migrants can occur in turbines and spillways.
5. Upstream migration of fish can be inhibited, or blocked entirely, which can impair natural reproduction. Barriers isolate fish from their traditional spawning areas in a river.

Dams block the downstream movement of sediment and large woody debris starving the downstream habitats of critical substrates.

6. Over time, fragmentation of riverine habitats leads to reduced aquatic productivity.
7. Impoundments can impair migration motivation in adults, due to the reduced flow of water.
8. Impoundments can cause disorientation of smolts, due to the lack of current, and delay their downstream movement.
9. Impoundments can increase predation on migrating juvenile fish.
10. The siltation of gravel and cobble riffles upstream of the barrier impairs aquatic insect populations. Typically, stoneflies, caddiesflies and mayflies populations are significantly less immediately upstream, due to siltation. Likewise, downstream populations of sensitive aquatic insects are diminished, due to the loss of coarse sediment supply.
11. Barriers and their impoundments reduce the food supply, in the form of leaf litter, to downstream aquatic insects.
12. Barriers disrupt the natural movements of wildlife, such as otter, mink, muskrat and beaver, along the stream corridor.

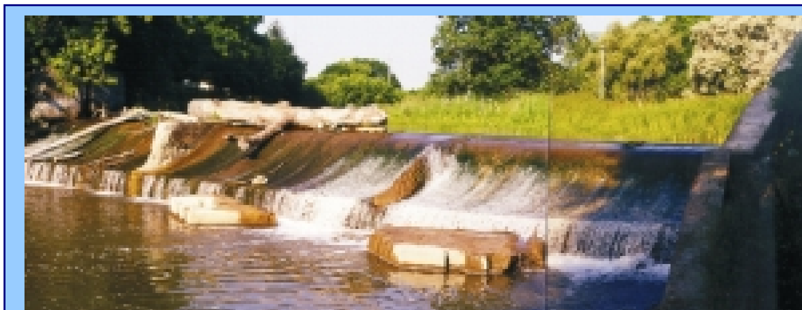
Social Effects

1. Barriers inhibit navigation of people using traditional river watercraft such as rafters kayakers and canoeists.
2. Barriers, such as dams and weirs, can be public safety hazards and a liability to the owner. Risk of failure increases with the age of the barrier.
3. Man-made obstructions in rivers require on-going maintenance and repair.
4. Barriers that inhibit fish reproduction can lead to the loss of fishing revenue when stocks collapse.
5. Impaired water quality in the impoundment leads to impaired visual aesthetics such as algae blooms, odour or loss of clarity.
6. In time, reservoirs fill in with sediment, prompting the need for expensive dredging.

DAMS, WEIRS AND PUBLIC SAFETY

Public safety around our dams and weirs is often taken for granted. We are not informed or sufficiently warned about the potential risks of living or playing near them. Decrepit dams can fail, putting people at risk, property in peril or the river's aquatic health in jeopardy. Children have drowned below them in their turbulent waters and in the depths of their reservoirs. Safety around dams and weirs needs to be better communicated to the public.

Many of our estimated 3,000 dams and weirs across the Province of Ontario need remedial work to ensure public safety. The majority of these barriers were built over 50 years ago, with some structures being over 150 years old. As time passes, the erosive action of water chews away at the concrete, steel and wood within the man-made obstructions. The freezing and thawing of water in concrete in our cold climate, further degenerates the structural integrity of these barriers. The growing roots of trees can also cause deterioration of a dam or weir. Intense storms can produce more water than a dam can handle causing a breach. Water can find routes around and under the structure that leads to foundation defects. As these barriers become structurally unsafe, they become more susceptible to failure and represent a significant liability to the owner.



Dams deteriorate over time from the erosive action of water.

BARRIER MANAGEMENT PROCESS

The road to reaching a management decision for a specific barrier in a river is long and difficult. Competition and conflict exists between private and public interests when the use of freshwater is at stake. At the local level, cultural heritage, economics, public safety and environmental concerns expressed by the community can easily turn a barrier management project into a politically contentious issue. It is often difficult to avoid short-term manipulation and benefit desires when faced with the need to manage for a healthy river on a long-term basis.

Using technologies to mitigate the effects of a barrier may lead to partial gains in river health but, commonly, these engineered techniques do not provide adequate substitutes for natural processes. A balanced, comprehensive approach must be taken that considers assessment of impacts and assessment of alternatives. The simple questions that need to be answered are as follows:

1. Why does the barrier exist today?
2. Do the derived benefits of the barrier outweigh the costs?
3. What measures can be taken to reverse the harm the barrier causes on the river?

To answer these questions and make sound decisions, we need to follow a process that combines the information derived from research, with a thorough cost-benefit analysis of alternative barrier management techniques. It is recommended that experienced professionals be consulted for advice and leadership. Use the planning process described in Chapters 3 and 4 for developing an *adopt-a-stream* project, but center the process on a site level problem. For barrier management projects, it is suggested that you use the following scoped process as a guide:

STEP 1: Focus

Define the barrier problem and identify the study area.

STEP 2: Research and Reconnaissance

Study the physical, chemical, social and biological aspects of the barrier to gain a better understanding of effects and consequences. It is recommended that the *stream team* contact the local conservation authority and OMNR office at this stage in the process, for guidance on developing barrier related studies. They can usually inform you of a barrier's function and ownership, and provide access to background design reports. There are a number of different types of investigations that can be undertaken to assess a barrier.

Physical Studies

- River contours and elevation survey
- Hydrologic models (HEC-2)
- Hydraulic models
- Bathymetric contours and sediment deposition
- River morphology
- Structural analysis
- Sediment transport characterization

Social Studies

- Community opinion surveys
- Stakeholder surveys
- Economic assessment
- Title search
- Cultural heritage appraisal
- Federal, provincial, municipal policy assessment

Biological Studies

- Habitat assessment
- Aquatic insect population
- Bacteria counts
- Fish community inventories
- Fish biomass assessments
- Wildlife surveys
- Plant surveys
- Sediment seed-bank analysis

Chemical Studies

- Oxygen and temperature profiles
- Ammonia, nitrate and nitrites loading
- Phosphorus loading
- Sediment contaminants

STEP 3: Evaluation and Impact Assessment

Good baseline information helps us scope the effects of a barrier and develop river rehabilitation alternatives. Review the information collected in Step 2 and assess the effects of the barrier including costs. Develop a long list of rehabilitation alternatives and evaluate their effectiveness in eliminating or mitigating the effects. Investigate the costs of each of the alternatives. Consult with your community, stakeholders and confirm the effects, alternatives and costs you have identified.

Consider future monitoring requirements.

STEP 4: Goal, Objectives and Targets

Through consultation with the stakeholders and local community, develop your goal statement, objectives and targets for the project.

STEP 5: Plan, Prepare and Consult

Review the alternatives in relation to feasibility, costs and benefits, and your goal, objectives and targets. Determine the preferred alternative and present it to the stakeholders and public for dialogue and design input. Prepare a workplan and detailed designs. Seek regulatory approvals and funding.

STEP 6: Implement

Develop a phasing plan if necessary. Implement the detailed design of the preferred alternative.

STEP 7: Monitor and Report

Monitor the construction progress. Undertake post-construction monitoring plan and report findings to stakeholders and community.

BARRIER MANAGEMENT ALTERNATIVES

There are two categories of barrier management alternatives. Barrier modification includes removal, partial removal, and outlet conversion, as alternatives that help eliminate effects on river processes. Fishways deal with mitigating the obstruction effect of barriers on the migration and dispersal of fish. Descriptions of each of the alternatives have been limited to the purpose, application and information relating to costs and benefits. These techniques should be considered as alternatives when conducting an evaluation and impact assessment on an existing or proposed stream obstruction.

Suggested Reading:

- Palgrave Dam Aquatic Habitat Restoration Project Study Report. (I. B. Buchanan and W. K. Annable, 1997)
- Environmental Considerations for Assessing Dam Removal Alternatives for River Restoration (J. R. Shuman, 1995)
- Dam Removal Success Stories: Restoring Rivers Through Selective Removal of Dams That Don't Make Sense (Friends of the Earth, Trout Unlimited and American Rivers, 1999)
- American Rivers Internet Web Site http://www.amrivers.org