Technical Manual for Watershed Management on Prince Edward Island

Megan Harris, Todd Dupuis, Daryl Guignion, Rosie MacFarlane

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Disclaimer: The guidance provided in this manual is written generally for Island conditions and may not exactly fit the needs of every watershed group or watershed. Much of the information describes technologies that are continually being refined. The authors encourage anyone to seek professional advice wherever there is uncertainty about the applicability of the material in this document. The authors shall not be liable for any loss, actions, claims, proceedings, demand or costs howsoever caused arising directly or indirectly in connection with the use of this material.

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About The Authors

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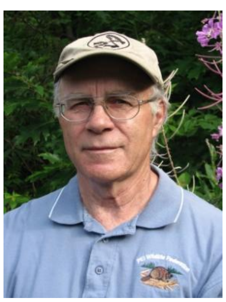

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Rosanne MacFarlane is currently Freshwater Fisheries Biologist with the Department of Agriculture and Forestry's Forests, Fish and Wildlife Division. She is a graduate of the University of Prince Edward Island and Acadia University. Rosanne began her career on the Morell River in 1990 and served as a regional watershed coordinator with the province, working extensively with watershed groups in the central and eastern portions of the Island.

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1. How to Use This Manual

1.1 Target Audience and Objectives

Prince Edward Island has an invaluable human resource, broadly referred to as "the watershed groups." It is for them that this manual is written. Over the past number of years, these community-driven, non-profit, non-government watershed groups used trial-and-error and the talents and skills of the people in their communities to solve the problems they encountered in their watersheds. In some instances, they have worked in isolation, making similar mistakes and finding similar solutions, because the resources were not available for them to collaborate more effectively and efficiently with each other. Despite the challenges, these groups are fostering real change.

This document was commissioned by the PEI Watershed Alliance through funding from Environment Canada. The Alliance is a co-operative of watershed groups and was founded on principles of information / resource-sharing. The manual builds on a previously published document (Dupuis et al. 1994) that was focused on stream improvement at an earlier time in the evolution of watershed management on PEI. This document updates the information presented in the 1994 manual, based on improvements in our understanding of the natural systems present on the Island and how to best manage restoration work in them. It also expands on the material presented in Dupuis et al. (1994), as a reflection of the broader mandate embraced by watershed groups in the interim. Watershed groups today are involved in watershed planning, nature education, improving management practices in upland areas and estuarine monitoring as well as stream restoration. We now better grasp the connectivity of all activities within the natural confines of a watershed.

Watershed groups are typically composed of a volunteer Board of Directors, a paid coordinator and seasonal employees. This technical manual is intended to be useful for the work of all of these individuals. It may also be used by others, such as municipal councils, landowners, classes and students to broaden knowledge and build working relationships with watershed groups.

In keeping with past history, watershed management will likely continue to grow and adapt to the changing pressures and needs presented by our changing world. As such, this is intended to be a living document, subject to revision in the coming years.

Figure 1.1 Recipe for watershed success: knowledge, teamwork, hard work, innovation, caring and a positive attitude!

1.2 Gather Knowledge, Plan, Do, Monitor: Following A Stepwise Process

Watershed groups on the Island and elsewhere are often formed when a number of individuals are united in a common cause: a perceived environmental problem has reached some point of crisis. There is typically a sense of urgency, where time is of the essence and "something" has to be done immediately. Albeit with the best of intentions, these launches into watershed management can be unsuccessful, because there is too little planning at the front end.

While we understand the need for "action," instead of "talking about action," we recommend "doing" something small and manageable while "planning" something greater. That plan should be based on a thorough assessment of the needs of the watershed and of the communities within it. After more than twenty years of watershed management in Ontario (Conservation Ontario 2003), Conservation Authorities and volunteers agree that the most successful strategy is to work through a stepwise process of planning, doing, monitoring and reporting, with periodic review and adaptation (or "tweaking"). Those with the longest history of managing watershed issues in this province also recommend working through these steps.

This manual is structured to follow the same stepwise process. The next three chapters make up a section called "Know Your Watershed," which guides you through the background knowledge you should have to be most effective and strategic about tackling big, complex watershed issues. Following on from there are sections called "Plan Your Strategy," "Carry-out Your Work Plan" and "Monitor Your Results." This is probably the closest we can come to a standardized recipe for success. Each watershed group will face unique challenges and opportunities, and their successes will be determined by the strengths and tenacity of the people in their communities. It will not happen overnight.

Figure 1.2 Know...Plan...Do...Monitor

2. Ecology of a PEI Watershed

2.1 Water, Soil, Terrain: Backbone of an Island Watershed

Islanders LOVE to talk about the weather, and more specifically, about how ours is so erratic. "Don't like the weather? Wait five minutes!" is a standing conversation opener. It also speaks to how strongly the natural elements continue to impact on our daily lives.

The water, or hydrologic, cycle can be described as the continuous movement of water on every earthly scale, from the global right down to the landscape level. Water moves from solid to liquid to gas, as ice or snow, water and vapour, and picks up materials like soil particles, minerals, metals and organic chemicals as it goes. It is the great natural transportation system.

PEI's water cycle is defined by its maritime location and the flow of continental wind and oceanic water currents. With the Atlantic Ocean just around the corner, spring comes late, summer is relatively cool and windy, and winters are long, mild and snowy. The average summer and winter temperatures are 17°C and -6.4°C, respectively, while the average annual precipitation is 1,147 mm. Weather fronts approach us from every direction, setting up the "perfect storm" for unpredictable and rapidly changing conditions.

Our Island has an abundance of small watersheds. "Watershed" is simply defined as the area of land drained by one river, including all of its tributaries. The water that reaches the Island as rain or snow percolates down into the soil to feed groundwater, transpires or evaporates off of the trees and ponds, or runs off the land's surface into streams. Groundwater eventually discharges into streams through springs and seeps, and all waters run the short journey to the ocean.

Within a watershed, water moves from the uplands by groundwater flow or over the land to one river that discharges either directly to the ocean or into an estuary. Everyone living in a watershed is connected to each other through water –

what falls from the sky, runs by their land, or comes from their tap. How that water moves is impacted by our Island terrain and soils.

To fully appreciate the nature of today's Island watersheds, we must look back to how they were formed. Many millions of years ago, a high mountain range loomed to the west. As those mountains eroded, rivers carried the soils and debris away to form the shallow sand-based bottom of the southern Gulf of St. Lawrence. Then several ice ages molded and remolded the shape of the land. At the peak of the last glaciation, there was so much water tied up in ice that ocean levels were perhaps 100 metres lower than today. As these glaciers melted, ocean levels rose. Approximately 5,000 years ago, our "bit of sandstone" lost its land connection with the mainland and our island was born.

With the melting of the glaciers, deep runoff channels were carved into the soft sediment base of the Island. By the time most of the glaciers in eastern Canada had melted, ocean levels were again high, flooding many of those runoff channels. This is why our estuaries are sometimes called "drowned river valleys." The Island's salt water and estuarine coastline now extends some 1,600 kilometres, supporting rich, productive coastal habitat (Figure 2.1).

Figure 2.1 Hillsborough River estuary incises deeply into the heart of the Island, supporting a lengthy expanse of salt marsh

Today, PEI forms part of the Northumberland Plain, a wet, coastal, rolling lowland. The north shore is buffered from the wild Gulf of St. Lawrence by long expanses of sand dune and beaches. The south shore is more placid, facing the quieter, gentler Northumberland Strait. The Island terrain varies from flat lowland areas – such as around Miscouche – to higher plateaus eroded by glaciers – such as at the headwaters of the Morell, Marie and Midgell Rivers. The Bonshaw Hills and Caledonia region are two areas where "rolling" best describes the landscape, but even there the highest peak would barely top 142 metres – a mere bump compared to the mainland. Nonetheless, these small differences in topography shape many of the defining characteristics of each Island watershed.

The sandstone bedrock underlying the Island produces loam to fine sandy loam soils. These are soil types that are high in silt and fine sand and low in clay. Western (Prince County) soils tend to have higher clay content than elsewhere in the province, while those to the east (Kings County) have a higher sand content. This affects how quickly they drain and the nature of the ecosystems they can support. In general, Island soils are shallow, with bedrock sometimes lying within a metre of the surface. They also tend to be acidic and low in organic content. These characteristics of fine texture and low organic material make Island soils highly susceptible to erosion when bare.

Before European settlement, the Island landscape was dominated by a lush Acadian forest ecosystem. Jacques Cartier, sailing along the north shore in 1534, wrote to the king of France of finding trees “wonderfully fair.” Walter Johnstone of Scotland described the Island in 1820 as “one entire forest of wood; all the exceptions to the truth of this...are not much more...than the dark spots upon the moon’s face.” Although that has since changed, these historical journals record that once great capacity of the Island to support dense forests.

Figure 2.2 Morell River and its riparian zone: a glimpse of the lush, dense forest ecosystem of centuries past

The numerous, long estuaries support productive salt marshes, while lowlands to the east and west also support peat wetlands. A scarcity of freshwater marshes has been expanded on by human and beaver impoundment of streams. Natural lakes are few in this undulating Island plain.

What is particularly striking about the Island is the abundance of streams. The rolling topography and long, narrow crescent shape of the province produce many short streams draining towards the coastline. The distance as the crow flies from the height of land to the sea is short. Nonetheless, the total length of all the streams within a single watershed is surprisingly long. Springs and seeps feed these many streams from groundwater discharged to the surface. The abundance of groundwater on the Island ensures that most of our streams remain cool even during the hottest summer months.

2.2 Groundwater, Lifeblood of the Island

Islanders can thank our wet maritime climate and our sandy soils for the abundance of groundwater we currently enjoy. Rainwater and snowmelt percolate down through cracks and pores in the soil and rock to a depth where all the pore spaces are fully saturated with water. The subsurface area in this saturated zone is called an aquifer.

Groundwater, much like surface water, flows from higher elevation to lower elevation areas, but the rate of flow is much slower. The land area where water percolates down to the aquifer is referred to as a recharge area, while that where groundwater resurfaces through springs and seeps into streams, ponds, wetlands or the shore is called a discharge area.

Typically, most of an Island watershed surface area provides groundwater recharge, with discharge areas being limited to relatively narrow bands around streams, wetlands and the coastline. The type of land cover can affect the rate at which groundwater is recharged. Impermeable surfaces such as roofs and pavement divert more of the total precipitation to direct overland run-off instead of allowing it to percolate through the soil and feed groundwater reserves. The discharge of groundwater from springs and seeps is the lifeblood of our Island streams (Figure 2.3). Groundwater provides almost all of the water in streams during dry spells in summer. Over the course of a year, it contributes about two-thirds of the total annual stream flow.

Figure 2.3a Rich, undisturbed spring in woodlands of Priest Pond Creek

Figure 2.3b Groundwater discharge area in woodlands of the Clyde River

The water table is simply the boundary between the upper, un-saturated zone of ground and the lower, saturated zone filled with groundwater. The soil depth of the water table fluctuates over the seasons, according to the relative rates of recharge and discharge. Close to wells, the water table can also be depressed by large groundwater withdrawals.

2.3 Stream Hydrology on PEI

Streams are created when water accumulates on the Earth's surface and begins to run downhill. As the water collects and grows in volume, it begins to cut into the Earth's surface, creating its own channel. With time and differing flows, the stream modifies its channel according to the volume of water it carries versus the amount of sediment it transports.

The extent to which moving water can modify the channel structure depends somewhat on the makeup of its streambed and banks. Loose, unconsolidated substrate can become mobile in high flow, resulting in self-forming channels. This is characteristic of the Island alluvial streams where both the banks and bed are susceptible to erosive forces of water. Most alluvial streams share a similar characteristic of alternating, regularly spaced, deep and shallow areas called pools and riffles. The pools and riffles are associated with the thalweg (deepest channel, fastest flow), which meanders within the stream channel. Pools usually form on the outside bank of bends while riffles usually form between two bends at the point where the thalweg crosses over from one side of the channel to the other (Figure 2.4).

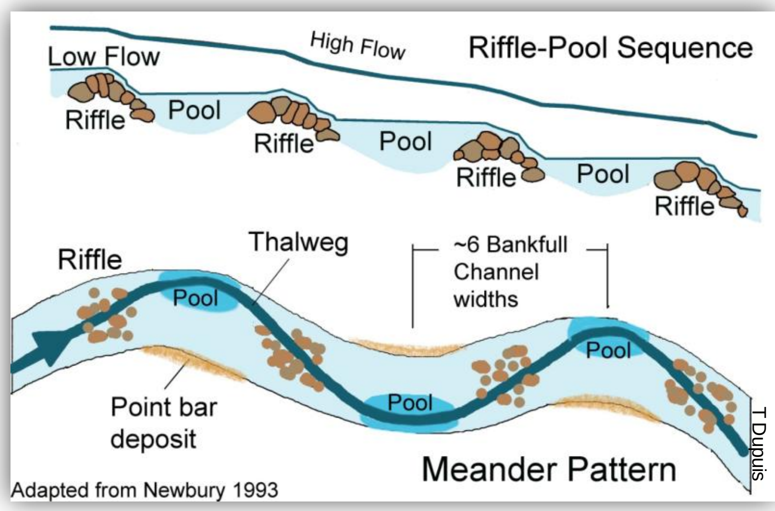
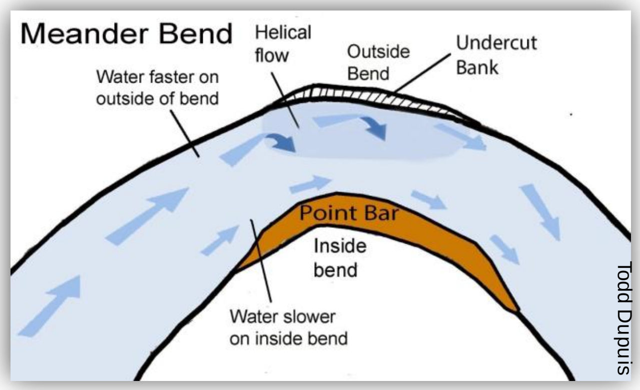


Figure 2.4 General structural characteristics of an alluvial stream

Changes to the stream channel can occur rapidly during high water events. Pools are created as water scours the streambed and undercuts the banks at river bends. Loose rocky substrates like gravel and cobble are mobilized and deposited across the width of the stream channel, forming riffles. Riffles occur where the stream bottom is at a higher elevation relative to the streambed immediately upstream or downstream. Flow velocities increase over riffles due to the increased slope between the riffle crest and the subsequent pool downstream. Healthy alluvial streams have regularly spaced pools and riffles that help maintain channel stability with a pool-to-pool or riffle-to-riffle spacing of approximately 6 times the width of bankfull discharge (Figure 2.4).

2.3.1 River on the move



The differences in flow velocity in meandering streams result in both erosion and deposition at curves in the stream called meander bends (Figure 2.5). As water rushes into the outside bend, it is forced down the face of the bank and across the bottom of the pool toward the inside of the bend. This rotating flow is called helical flow.

Figure 2.5 Helical flow of water through a meander bend, with points of erosion and deposition on the bends

Helical flow moves sediment from the outside to the inside of the stream bend; it is deposited at a point bar where the flow is much slower. As water moves through a meander bend, the bottom water in the pool is rotated to the surface. The water is then rotated in the opposite direction if the next pool is on the opposite side of the channel. This erosion-deposition cycle is ongoing and causes rivers to adjust their course over time.

Stable streams migrate across the landscape over geologic time while maintaining their form and function. Although the stream banks are moving, the channel does not get wider, because the material that is eroded from the outside bend gets deposited on the inside bank. This natural readjustment can be most easily seen with aerial photography, where course changes leave telltale scars on the landscape (Figure 2.6).

Figure 2.6 Remnants of old stream channels shown from the air, Cape Breton, NS

Healthy rivers tend to have healthy forests with riparian zones that resist the erosive forces of water and therefore have very slow moving banks. Well vegetated stream banks bind the soil, slowing down the water's ability to erode. Trees with curved trunks located on the stream banks are good indicators of slow moving rivers. Figure 2.7 is an Island stream with stable banks. As the bank slowly erodes, the trees begin to lean over the water but compensate by changing the direction of their growth upward. These stable banks contain the yearly peak flows, allowing the water to create deeper pools, undercut banks, and provide a greater diversity of stream habitats. These naturally stable stream channels maintain their dimension, pattern and profile such that the stream does not degrade (erode) nor aggrade (rise).

Figure 2.7 An Island stream with stable banks, characterized by trees growing on the bank with curved trunks

2.3.2 Stream flow

Stream flow is often divided into two major categories (Figure 2.8). The first is bankfull flow, when the stream water just begins to leave the channel and spread onto the floodplain. This occurs as a result of very heavy precipitation and/or snowmelt, which are both considered surface water inputs, and that vary greatly with season and weather conditions. The second is baseflow, which is made up mostly of discharge from groundwater springs. It sustains the river flow over extended periods between rainfalls and is most easily observed in the dry weeks of summer on PEI.

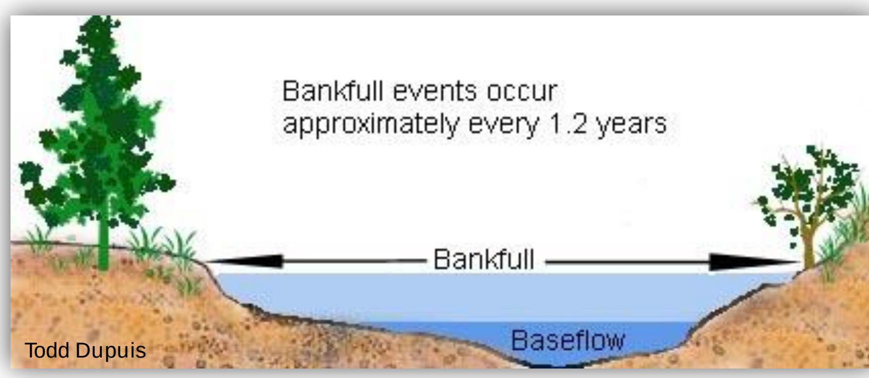


Figure 2.8 Bankfull flow compared to baseflow in cross-section

Bankfull flow occurs approximately every 1.2 years in Atlantic Canada. This is the most important stream process for defining channel form, as most readjustments occur during this high water energy event. Banks are eroded, riffles built and pools deepened during bankfull flow.

Bankfull width is an important measurement used to determine proper pool and riffle spacing and is required before planning any in-stream restoration efforts. When measuring bankfull width, look for clues such as an abrupt change in vegetation, material deposited on the bank or debris stuck in overhanging vegetation. Bankfull width is measured from one side bank mark to the other. To get an accurate estimate of bankfull width, measure at least 10 points along a section of un-degraded stream. Be aware that degraded streams are often over widened, which will not give an accurate measurement. It is important to find a stream reach that is stable and representative of the stream in a natural condition before measuring.

Stream flow at any given time consists of water from groundwater, surface water or a combination of both. If neither source provides water to the channel, the stream goes dry. PEI watersheds are blessed with relatively high volumes of groundwater, which can sustain flow during the driest of summers. However, if the water table is lowered due to large volume groundwater withdrawal, the baseflow will be impacted.

2.3.3 Stream roughness

Stream channel roughness plays an essential role in determining the depth of flow in a stream reach. Substrate (rock), bank irregularities and the amount and distribution of living and dead vegetation all act to increase channel roughness. This roughness disturbs water flow and slows its velocity. As flow velocity slows due to turbulence, the depth of flow has to increase to maintain the volume of flow that entered the upstream end of the reach. Smooth channels have little resistance to flow and are therefore more efficient at moving water.

Figure 2.9 shows two identical river channels in cross section. The left image has a smooth channel, whereas the one on the right has boulders and organic debris that increase the roughness. Both have the same volume of water within. Turbulence forces the water to be deeper in the rough channel to enable it to move the same volume of water. Stream channels that have lost roughness have accelerated water that can produce premature bank erosion and other unnatural channel adjustments. Woody debris in the form of branches, roots and trees can play an important role in increasing stream roughness. A stream with healthy riparian vegetation normally receives a regular input of large woody debris (LWD) from the riparian zone.

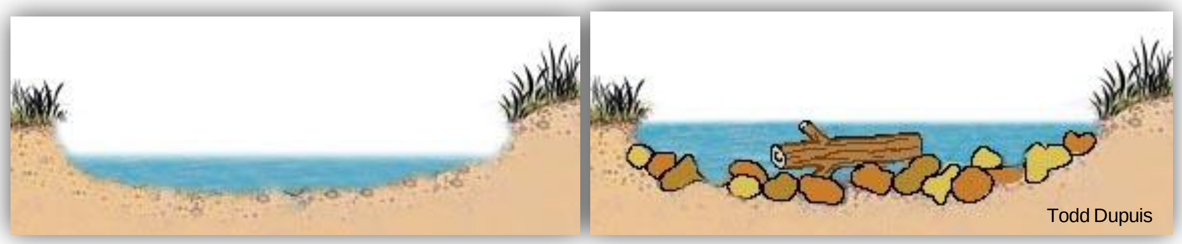


Figure 2.9 Changes in water depth in a stream with two different channel roughness scenarios

2.3.4 Rivers out of balance

When a stream achieves a balance in the erosion and deposition of sediment, and retains its physical characteristics, it is said to be stable. When this balance is upset, the river will respond by trying to re-establish a new equilibrium through a sequence of physical adjustments. This adjustment process is often referred to as channel evolution. Deforestation, sedimentation and urbanization are examples of disturbances that can upset the balance, forcing a river to evolve.

As the amount of sediment entering a watercourse outstrips its capacity to transport it, the stream will often aggrade. Aggradation involves the raising of the streambed elevation, an increase in width/depth ratio, and a corresponding decrease in channel capacity. Because the shallower, sediment-laden stream has a reduced capacity it must adjust by becoming wider to accommodate water volume. Aggraded streams have infilled pools and experience over bank flows more frequently with less than high water events. Shallow, over-widened streams resulting from aggradation are common to Prince Edward Island (Figure 2.10).

Figure 2.10 Over-widened, shallow, sediment-laden reach of the Westmoreland River

Heavy sediment loading can also in-fill interstitial spaces in the stream substrate, having the effect of cementing it in place. Substrates that would normally be mobile in high flow are unable to move. In turn, the natural sorting of bed material and subsequent riffle building process is reduced. Cemented substrate has a paving effect in that the channel becomes less rough and therefore is more efficient at moving water. These smoother channels accelerate the stream flow, the pipe effect, which reduces the stream depth and puts extra pressure on banks.

2.4 Summary of Island Watershed Ecology

The watershed is the land unit that makes the most sense for management from an ecological perspective. The natural environments within a watershed are connected through terrain, soil and water. What occurs in upland landscapes or upstream reaches affects the health and stability of the habitats down-slope and downstream. Not all watershed groups on the Island manage whole watersheds or just one watershed, for a variety of logistic reasons; however, it is much easier to manage the complexity associated with watershed ecology and human interactions, when one complete, connected system is being considered.

2.4.1 Useful resources

Newbury RW and Gaboury MN, 1993. *Stream Analysis and Fish Habitat Design: A Field Manual.* Newbury Hydraulics Ltd. and the Manitoba Habitat Heritage Corporation.

Doll BA, Grabow GL, Hall KR, Halley J, Harman WA, Jennings GD and Wise DE, 2003. *Stream Restoration: A Natural Channel Design Handbook*. NC Stream Restoration Institute, NC State University. 128 pp.

Fisheries and Oceans Canada, 2006. Ecological restoration of degraded aquatic habitats: a watershed approach. DFO, Oceans and Science Branch, Gulf Region, Halifax, NS

Federal Interagency Stream Restoration Working Group (FISRWG), 2001. *Stream Corridor Restoration: Principles, Processes and Practices* (revised edition). Springfield, Va: National Technical Information Service.

Thurston H, 2011. *The Atlantic Coast: A Natural History*. Greystone Books, Vancouver, BC

3. Key Influences on PEI Watersheds

"*If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering*."

Aldo Leopold, A Sand County Almanac, 1949

To manage a watershed, one must know the watershed. It is likely that the more you learn about your watershed, the more questions will arise. Watersheds are functionally complex, influenced by things we can't control – climate, geology, topography – and things we can – land use, habitat diversity, resource use. It may be helpful to keep in mind that most key influences on PEI watersheds relate in some way to how water and soil move within them.

3.1 Land Use and Activities in Upland Areas

Anything that disturbs soils or changes the way water moves in upland areas will impact to some degree on how a watershed functions. Despite endless discussions and commissioned reports over several decades, PEI still does not have a provincial land use plan or consistent regulations or policies for land use in municipal and unincorporated areas. Managing watersheds in that planning void is challenging. Nonetheless, encouraging better land use practices is essential for making lasting improvements to watershed function.

The majority of the Island is broadly influenced by three land uses: agriculture, forestry and residential / urban development. Any given watershed on the Island will likely have all three of these activities occurring somewhere within it. These three forms of land use all commonly impact a watershed in similar ways: through erosion of soils, transport of materials (chemicals and minerals), and degradation of water.

3.1.1 Agriculture

Agriculture on the Island consists mostly of row cropping (especially potatoes), cereal, legume (soybean) and grain cropping, dairy and beef livestock farming. How farming influences any specific watershed depends on many factors, including:

- The properties of the soils under cultivation, such as clay, moisture, organic and silt content
- The proportion of the total watershed under cultivation
- The steepness of the terrain being farmed
- The size and types of farms and the length of fields
- The use of best management practices (BMPs).

All of these elements affect the susceptibility of the land to erosion, the manner in which water moves on or through the watershed, and what the water transports with it as it moves.

Row crops, such as potatoes, are particularly susceptible to soil erosion, because they leave bare soil between plant rows during most of the growing season. Technically, corn is not considered a row crop on the Island, but for all intents and purposes, it is grown in rows and is as susceptible as any other row crop to water erosion during heavy rain events. Best management practices applied by progressive Island farmers can greatly reduce soil erosion on cultivated lands. These practices include 3- or 4-year crop rotations, minimum tillage, winter cover cropping or proper mulching, composting, spring plowing, strip farming, terracing and cross-slope farming.

A high proportion of water falling on pasture or forest land gets retained long enough by the vegetation to allow it to percolate through the soil. Rain falling on bare soil moves differently with no plant material to catch it and hold it or slow it down. A higher proportion of water falling on this type of ground runs off as surface water instead of seeping down and feeding the water table.

Figure 3.1 Bare fields susceptible to water and wind erosion

Land that has been tilled for many years may also have compacted soil; that means that less water can move through the ground, because there are fewer air spaces to fill between soil particles.

Bare soils on PEI are subject to a variety of erosion issues depending on the season and weather. Mid-winter thaws can be particularly bad for soil conservation. Soil frozen at depth but bare, thawed and subject to heavy rains at the surface can lead to sheet erosion of the topsoil. Similarly, bare fields without snow cover are susceptible to wind erosion. Soil blowing off bare fields in eastern PEI has been found in Cape Breton, Nova Scotia.

The nature of the soils and the type of farm also affect what the water transports with it as it moves over and through the land. Clay soils tend to hold phosphorus and water. Nitrogen is highly water soluble, so will be more mobile in soils where water easily percolates through.

Figure 3.2 Agricultural fields sloping towards a river can transport nitrate directly to surface waters

The concentration of nitrate in drinking water from groundwater wells is strongly associated with the percentage of the watershed that is in potato production. Those watersheds with more than 13 % of the land in potatoes in any given year have average nitrate concentrations in well water greater than 5 mg/L (DesRoches 2008). The current maximum recommended concentration for drinking water is 10 mg/L according to the Canadian Water Quality Guidelines.

Soil and water leaving fields may also contain pesticide residues. Pesticides vary in their toxicity to aquatic life and those with the greatest toxicity have been identified by the province and Environment Canada. They are mostly organochlorine and organophosphate insecticides as well as organochlorine and copper-based fungicides. These most toxic compounds are now used sparingly; however, as long as their use continues it is not possible to completely eliminate the risk of runoff and exposure of aquatic life in Island streams. PEI has an unfortunate history of fish kills, most likely associated with pesticide spikes in storm runoff from potato fields or, in very early days, from spills during in-stream filling of sprayers and discarded pesticide containers. Figure 3.3 below indicates that there is no clear downward trend in the frequency of fish kills since they were first recorded in the 1970's.

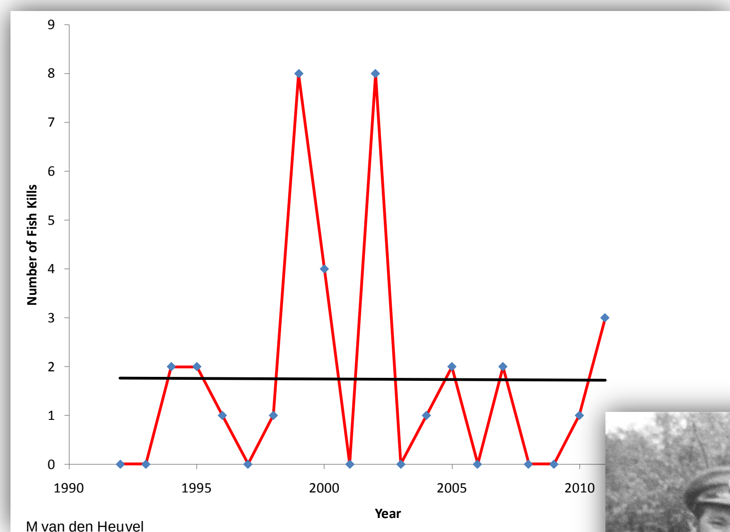


Figure 3.3 Frequency of fish kills in Island rivers (1992 – 2011) showing no downward trend (courtesy of Dr. Mike van den Heuvel, UPEI), and West River fish kill, 1971

3.1.2 Forestry

Island forests contribute greatly to groundwater recharge: forests slow the path of rain and hold snow in place, thereby allowing water to enter the soil and percolate down to the water table. They also can reduce the force of wind and its erosion potential. Hardwoods in particular pull up and absorb nutrients (including nitrate in groundwater) and all trees sequester carbon by pulling carbon dioxide out of the atmosphere and into plant tissues. Their great value to society is often underestimated.

Forestry on the Island is generally undertaken at a relatively small, woodlot scale. Thousands of private landowners own 86 % of the forested land; the remainder is managed by the province.

Figure 3.4 Small clear-cuts with strip retention on provincial forest lands, Brookvale

Similar to agriculture, how forestry impacts on the watershed depends on:

- The steepness of the terrain being logged
- The style of logging (selective or not) and size of clear-cuts
- Best management practices (BMPs) such as replanting, harvesting on dry or frozen ground, good road design and road decommissioning

Most often, the landowners themselves are not involved in commercial logging. Many contractors no longer replant, so the onus is on the landowner to have a forest management plan and undertake the replanting. After extensive public consultation, the province developed a forest policy in 2006 that recognizes the importance of private landowners in Island forest stewardship.

Figure 3.5 Under-planting an old-field white spruce stand with a diversity of native tree seedlings, Brookvale

Forestry roads can be an issue, particularly where they cross streams. Bridges and culverts require maintenance, as do the roads themselves, but these structures can be forgotten between stand harvests and contribute to erosion, stream debris and beaver blockages or fish passage issues. The roads are generally clay and un-ditched, making them susceptible to water erosion. Mechanized logging equipment is heavy and the road infrastructure is not always sufficiently robust.

Logging when the ground is wet can be particularly harmful to soils and understory communities, which are essential to the regeneration capacity of the forest. The original Acadian forest did not undergo large-scale disturbance, such as forest fires or insect outbreaks, very often – only once every 800 years on average (Simpson 2008). Hence large clear-cuts do not mirror the natural forest cycle in this region. The soils are prone to rapid nutrient loss and erosion.

Figure 3.6 Mechanized commercial thinning of a conifer plantation

As with agriculture, the widespread adoption of best management practices tailored to Island conditions of climate and geology are critical for improving overall watershed health.

3.1.3 Urban and suburban development

Despite our perception of PEI as a rural landscape, more than half (54 %) of the people on the Island live in or close to Charlottetown and Summerside (2009 data). In addition, many of those living outside of these areas work in Charlottetown or Summerside and commute to and from the city every weekday.

The influence of residential development is being felt along the coast-lines, in the central portion of the Island between the two main cities and on the perimeter of many smaller communities throughout the Island. Expanded development of year-round residences, summer holiday homes and commercial industries can impact on a watershed in the following ways:

- In septic system and lawn care inputs of nutrients to groundwater
- In loss of wild or pastoral lands and wetlands
- In increased frequency of impermeable surfaces
- In soil erosion during and after construction and from clay roads
- In drawdown of groundwater by drinking water consumption and other commercial uses
- In fuel oil release and other accidental contamination with chemicals

Although there are regulations in place to direct some practices such as septic system installation, the management of residential development as a whole suffers from the lack of a provincial land use plan.

The ongoing popularity of waterfront land for year-round and summer developments puts pressure on coastal regions that are particularly sensitive to climate change (see section 3.5 below) and associated coastal erosion.

Figure 3.7 Coastal towns contribute to near-shore nutrient enrichment and are susceptible to coastal erosion

Trees are removed to provide unimpeded views or access to beaches, but leave the ocean frontage with little protection from winter storms or tidal surges.

Much of the housing in rural landscapes is in ribbon development along rural roads. The excess of rural and urban roads on the Island impacts on watersheds through altered water flow patterns and greater numbers of road crossings of streams. The hydrology of streams changes in areas where land is cleared and a natural landscape is replaced by more impermeable surfaces such as rooftops, roadways, parking lots and sidewalks. One of the consequences of this change is that more of a stream's annual flow is delivered as storm water runoff rather than baseflow. A lower proportion of total precipitation is available for groundwater recharge. Therefore, during extended periods without rainfall, baseflow levels are often reduced in urban streams. More rapid and greater rates of surface runoff also create flashier river conditions (see section 3.2 below) and greater susceptibility to flooding during extreme weather.

As commercial and residential development in the larger centres expands, there are concerns around groundwater recharge and use. All drinking water on the Island is groundwater-sourced. Current extraction rates are usually far below groundwater recharge rates, and well water supplies are not threatened. However, in more intensively developed watersheds, the extraction rate may rise to as much as 40% of available recharge when averaged over the watershed as a whole. When sub-watersheds are considered, the localized rate of withdrawal can exceed the rate of recharge. The most extreme example of this scenario currently exists in the Winter River watershed, which provides the majority of the drinking water to the city of Charlottetown. The volumes required from the aquifer outstrip Mother Nature's ability to recharge it. As a result certain tributaries (sub-watersheds) of the river dry up during the summer months (Figure 3.8). This localized effect has major repercussions for the aquatic life in those stream sections, even though the watershed as a whole may not experience the same level of impact.

Figure 3.8 Tributary of the Winter River with water flowing in the spring, but not during the periods of low baseflow in mid-summer

Water quality is also impacted by nutrient enrichment from septic systems and rural developments that are exempt from cosmetic pesticide and fertilizer restrictions (like golf courses). In some watersheds, the portion of land in agriculture may shrink while that in development expands. If septic systems are poorly maintained or designed, they have the potential to add nitrate to groundwater through the same basic mechanisms as farming – human waste simply replaces that of cattle and inorganic fertilizers. Sewage lagoons also still exist; although they are no longer permitted on private lands, there are still some at public facilities (e.g., Brookvale Ski Park) and schools. These lagoons typically operate under anaerobic conditions (no oxygen) with settlement of solids before release of waters to the stream.

3.2 Alterations in Riparian Margins

As early as the late 1800's the Island was dominated by agriculture – more than 75 % of land was farmed in that era. Since waterways were the main transportation routes in the early stages of land development, the estuarine margins of rivers were often the first areas to be cleared. It was not uncommon for land to be farmed right down to the water's edge, particularly where there was a flood plain with rich soils.

Since that time, the total proportion of land in agriculture has dropped to about 44 % and stream margins have been afforded some level of protection with the enactment of buffer zone legislation. Nonetheless, many riparian margins still do not have a cover that resembles the original Acadian forest.

Figure 3.9 Well forested riparian margin on the Little Trout River

In areas that were previously farmed and recently abandoned, there tends to be old-field white spruce stands, with all of the trees a similar age. White spruce does not live long on the Island, 60 to 80 years at best, and if the stand is even-aged, the trees die and collapse at roughly the same time. When a white spruce stand collapses, it can choke the adjacent stream with excessive woody debris and leave much of the riparian margin bare (see figure 11.4). Softwood species like white spruce tend to make the soils acidic and block so much light that there is little understory beneath them to spring up after they die.

In areas where livestock farming was prevalent, there may have been decades where cattle were able to access streams for water (Figure 3.10). In these cases, even where riparian margins were forested, the understory shrubs and herbaceous plants would have been trampled and depleted, soils eroded and stream banks sloughed. Today, cattle exclusion from streams through fencing is mandatory on the Island. This is not to say that all cattle have been fenced out of waterways, but the extent of access has been restricted substantially and there are funding programs in place to assist farmers in fencing the remainder of cattle pasturelands that front on streams.

Figure 3.10 Riparian margins degraded by livestock access

Watershed deforestation can significantly affect stream stability. Forests act like sponges soaking up rain and snowmelt water and releasing it to streams in a slow, controlled manner. Watersheds with severely reduced forest cover experience flashy rivers where snowmelt and heavy rainfall is not buffered. Flashy streams experience unnatural high peaks of stream flow, which accelerate bank erosion and cause the system to adjust at an accelerated rate. Unhealthy riparian zones only serve to exacerbate this issue (Figure 3.11).

Figure 3.11 Riparian margin severely degraded by soil erosion from an adjacent field, Kingston

There are many instances where riparian margins are not forested, but grassed with native and exotic grass species and occasionally shrubs. While this may be suited to some important functions, such as stream bank stability, it does not reflect the dominant pre-settlement riparian plant community, nor provide important functions like water temperature control and woodland wildlife habitat. This is an area of restoration that can be substantially addressed by watershed groups, through intensive tree and shrub planting programs. Current legislation provides for a riparian buffer of 15 m along waterways. In some instances, this may be sufficient; in others, it will not protect the stream from poor upland land use practices.

3.3 The Legacy of Mills and Other Alterations to Stream Hydrology

The first settlers to Prince Edward Island quickly recognized the resource potential of our numerous, free flowing streams. Dams, often several on one river, were built to provide a source of power for various types of mills – grist, lumber, shingles, wool carding, starch and power to name a few. Mill dams were so plentiful that millers frequently had to operate them in tandem on the same stream, sharing water to power their water wheels or sluices.

Figure 3.12 Old mill dam at Rackham's Pond, Wheatley River

Later, ponds were created as sites for hunting, fishing and other recreation. In the 1970s and 1980s, the provincial government, Ducks Unlimited Canada and private landowners partnered to construct dams (also called impoundments) for freshwater wetlands and waterfowl habitat (Figure 3.13). Dam construction in salt marshes, estuaries, and freshwater, including the headwaters of many systems, increased the amount of freshwater marsh habitat throughout the Island.

Figure 3.13 Pius MacDonald's Dam on the Midgell River, constructed by Ducks Unlimited Canada

Beavers, not present when Europeans first arrived on the Island, were introduced around 1900 when fur farming was booming and pelt prices were high. The first attempt at introduction proved unsuccessful, but beavers did get established after a second introduction about fifty years later, no doubt helped by low pelt prices and protective regulations. The provincial government assisted in expanding their range westward - beyond the Central portion of the Island - by live trapping beavers in Kings County and releasing them in Prince County. There are now thriving populations of beavers throughout the Island.

Figure 3.14 Beaver dam & lodge on St. Peters River

3.3.1 Impact of impoundments on water quality and sedimentation

Some of the rivers we have today with large or multiple impoundments bear little resemblance to the free flowing streams of 1534, the year Jacques Cartier first sailed by the Island. The transformation of flowing river habitat, also referred to as "lotic" habitat, to slow, impounded or "lentic" habitat can have a dramatic impact on the ecology of a river system.

Changing from a flowing, narrow stream to an open water pond system exposes more surface area, which can accelerate warming and water loss through evaporation. Warm water does not hold as much oxygen as cold water, so impoundment water can often be lower in dissolved oxygen than stream water (Figure 3.15). Microbial activity, respiration, and decomposition of organic matter in ponds can further reduce dissolved oxygen concentrations below Canadian water quality guidelines for protection of aquatic life. This is more pronounced in winter, when ice and snow block the light needed to sustain photosynthesis for oxygen-producing freshwater plants. In an anaerobic (no oxygen) environment, there is potential for the release of hydrogen sulfide, a substance toxic to fishes at extremely low concentrations. Hydrogen sulfide has been detected at some impoundments on the Island (Figure 3.16).

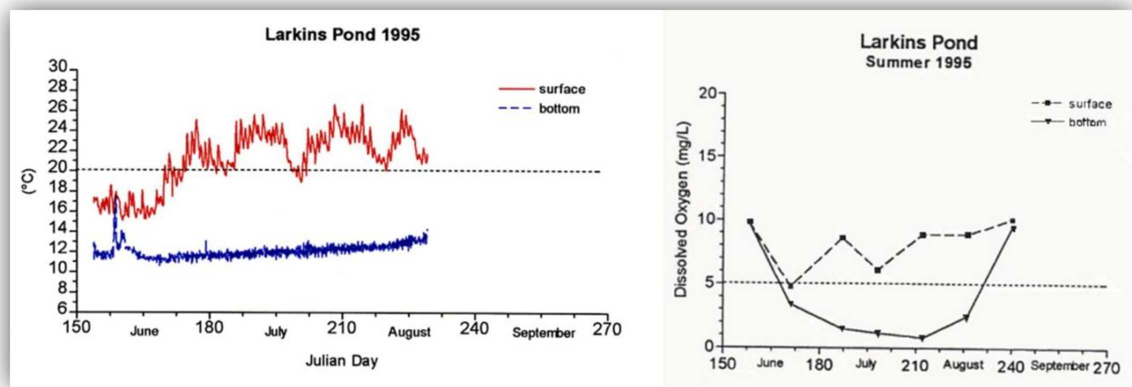


Figure 3.15 Larkin's Pond water temperature (left) and dissolved oxygen concentrations, summer 1995 (courtesy of R. MacFarlane)

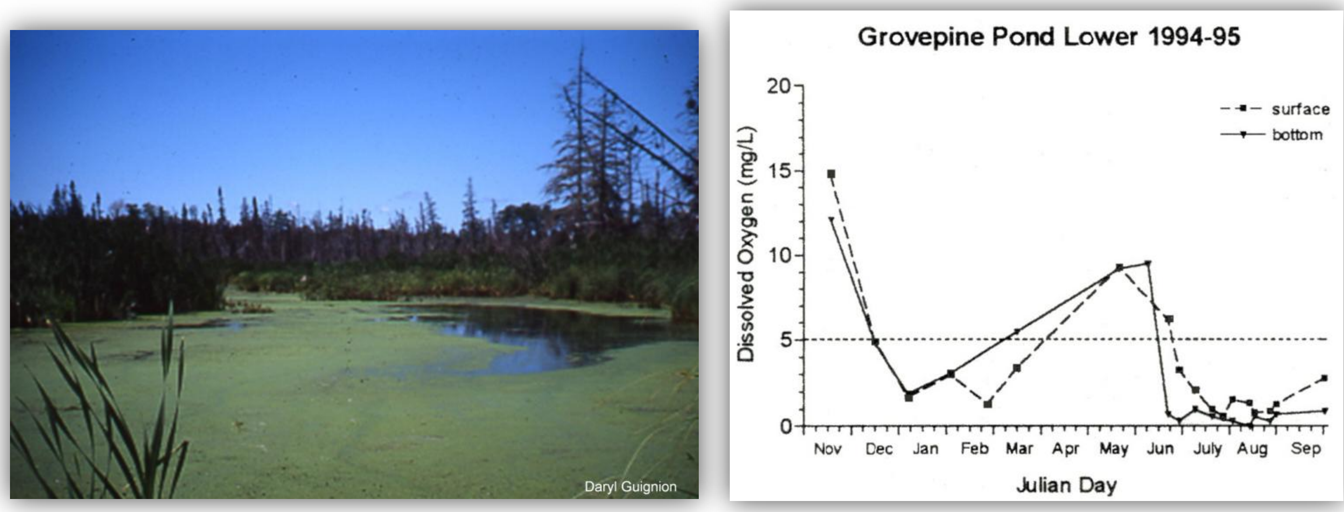


Figure 3.16 Grovepine Pond (Fortune River) in 1995, with dissolved oxygen concentrations (courtesy of R. MacFarlane)

The length of time that water remains in an impoundment is called “water residence” time and can strongly influence the effect of the pond environment on water quality. The longer the residence time, the greater the impacts on water quality caused by increased water temperatures and reduced dissolved oxygen concentrations in the impoundment. Water residence time in the Maritime Electric Pond on Valleyfield River can be 0.4 days at low flow, whereas at Pius MacDonald’s Pond on the Midgell River, residence time is 17 days. The outflow of Wisener’s Pond, a massive, shallow pond in the headwaters of Clark’s Creek, is reduced to a trickle in mid-summer, due to a residence time of ~400 days. When this occurs, stream habitat for cold water fish downstream of the pond can be compromised by low flow and poor water quality.

Where multiple impoundments, both artificial and beaver dams, are present on one system, warm water with low oxygen concentrations can be common. In extreme situations, many kilometers of stream can be impacted. It is not the number of dams that creates the problem but rather the surface area affected. A river with many small impoundments can have a low surface area ratio of impounded water (lentic) to running water (lotic). However, a couple of extremely large impoundments can reach 3:1 or higher, a lentic-lotic ratio that has been shown to be indicative of water quality problems within Island watersheds.

All impoundments function as sediment traps, which, in some of P.E.I.’s more deforested watersheds, can be of benefit to downstream waters. However, when long reaches of stream are impounded, the accumulation of sediment and organic material, the absence of riffle-pool sequences, and the removal (through flooding) of riparian vegetation can have a long term impact on the suitability of the stream for coldwater organisms (Figure 3.17 top). Changes to geomorphology are also evident within former mill pond basins (Figure 3.17 bottom). Unstable stream banks prone to slumping, and the inability of the stream to restore a natural and stable meander pattern because of unnatural sediment loading can be long-term problems.

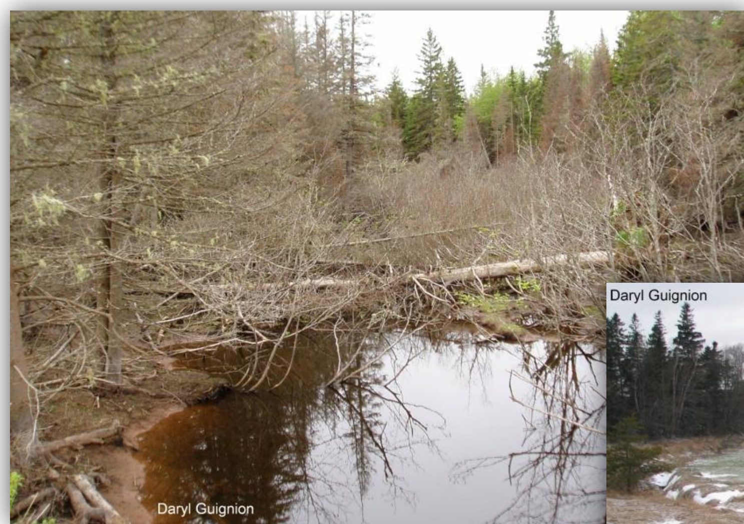


Figure 3.17 (top) Sediment and debris downstream of a beaver dam on the South Branch, Morell River (bottom) Stream through former Ives Pond, Tryon River

Across the range of the Canadian beaver, it is normal that beavers colonize a site, stay for 3-4 years (usually until food resources become scarce) and then move on. In high gradient streams, abandoned beaver dams typically wash out with high water. Where abandoned beaver dams occur in the low to moderate gradient streams typical of the Island, they may not be washed away for many years. Sediment builds up behind beaver dams, both from the natural movement of sediment in-stream and because of beavers digging channels and plastering dams with mud for “waterproofing.” Upstream from inactive beaver dams, the stream becomes wide, often shallow, and poorly shaded because of loss of overhead riparian zone tree canopy (Figure 3.18).

Figure 3.18 Flooded area (right) of the Little Trout River above a beaver dam (top)

Those beaver dams located in relatively flat topography often have water spilling over and through them in different locations. Thus, the stream below the beaver dam site can become braided into several channels all of which contribute sediment downstream. With a series of beaver dams in relatively flat topography an almost impenetrable brush marsh can develop. As they age, these may eventually turn into wet meadows where trees have trouble colonizing because of changes in the soil chemistry and moisture regime. Like artificial impoundments, a series of beaver dams can dramatically influence the lentic:lotic ratio for the stream, sediment deposition, and water quality in a watercourse.

3.3.2 Impacts of impoundments on fishes

Impoundments have multiple effects on fishes, by impacting on water quality and by blocking upstream passage.

Some impoundments were built with fish ladders that pass some but not all Island species of fish. Other impoundments were built with no provision for upstream fish passage, through the installation of drop inlet culverts (Figure 3.19). Beaver dams also will block young and some adult fishes.

Figure 3.19 Drop inlet culvert with beaver exclosure cage, catching debris and blocking fish passage

Inadequate or non-existent fish passage facilities can affect populations of resident and anadramous fishes, in particular brook trout, Atlantic salmon, gaspereau or alewife, blueback herring and rainbow smelt. Populations of some migratory fish species in particular have suffered because of resulting habitat fragmentation and a reduction in available habitat. Sherren's Pond in Crapaud is a good example (Figure 3.20); this former mill pond at the head of tide on the east branch of Westmoreland River once had a fish ladder, but for many decades it was out of commission. All anadromous fishes were denied access to the entire east branch of this river.

Figure 3.20 Sherren's Pond, Westmoreland River in Crapaud

Water temperature is one of the most critical factors in determining habitat suitability for coldwater fishes like brook trout and Atlantic salmon. We generally assume that the abundance of groundwater on the Island translates into optimal temperature conditions for salmonids. Our primary fresh water sport fish, brook trout, prefers summer water temperatures from 13-18°C. Shallow, standing water in impoundments can often exceed this optimal temperature range (Figure 3.21). When pond temperatures exceed this range, salmonids can be seen concentrating in springs and coldwater refugia at the headwaters of the pond. Since most Island impoundments discharge from the surface, the warm water exiting an impoundment can render downstream habitat unsuitable for salmonids for many kilometers before cooler tributaries and springs, as well as overhead cover, combine to lower temperatures.

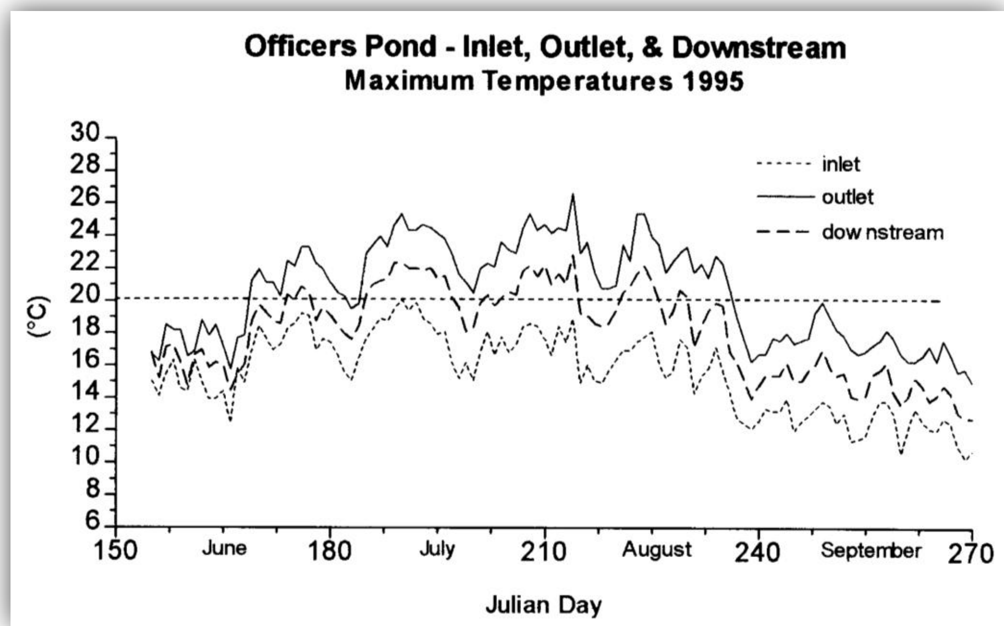


Figure 3.21 Water temperatures in summer 1995 at Officers Pond, Winter River (courtesy of R. MacFarlane)

Islanders have become so accustomed to the impounded conditions created by a dam that we struggle to imagine the river habitat that originally existed. Scales Pond on the Dunk River, for example, was a landmark in the Freetown area for over 150 years. It provided economic values, as well as wildlife, aesthetic, and recreational benefits to the area. After the dam failed in 2009, the river reclaimed the pond basin revealing excellent upstream holding habitat for trout and Atlantic salmon (Figure 3.22). When Leard's Pond in Coleman was drawn down in the 1990s because of water quality concerns, salmon immediately began spawning in the channel within the pond basin. Salmon and trout are routinely observed spawning immediately downstream from many dams and they would most certainly utilize all available and suitable lotic habitat.

Figure 3.22 Scales Pond basin after dam failure

3.4 Estuaries

Estuaries dot the coast of the Island, tucked in behind sand dunes on the north shore and opening to the gentler Northumberland Strait on the south shore. Estuaries are where river meets ocean and fresh and salt waters mix. On PEI, they are highly productive shellfish-growing areas and present vistas increasingly popular with residential developers. And they are influenced by everything that happens to soil and water upstream. On the Island, that translates to the same two key issues of sediment and nutrient loading of waterways. The estuaries are at the end of the line, and the buck stops there.

Figure 3.23 Oyster fishermen in the Grand River estuary

Sediment is gradually filling in estuaries around the Island, posing hazards to fishing boats in navigable harbours and smothering shellfish beds. The problem of infilling is particularly prevalent on the north shore, where estuaries are not as well flushed, being protected behind dune formations from the full force of wild Gulf waters, and having only half the tidal amplitude as south shore estuaries. Where commercial harbours exist, dredging is sometimes done to clear navigable waters, but just one winter storm can reverse the dredging efforts.

Nutrient enrichment from upland activities, mostly agriculture and housing developments, has also long reached the point where it cannot be ignored. Island estuaries were once dominated by extensive eelgrass beds, which provided habitat for a diverse community of marine near-shore invertebrates and fish. Eelgrass loves light and brackish water and so it thrives in shallow, estuarine conditions. However, as the waters of Island estuaries have become enriched with excess nitrogen and phosphorus, conditions have shifted to favour growth of the annual sea lettuce instead. Because it floats, it can shade out the eelgrass.

Figure 3.24 Eelgrass (left) vs. sea lettuce (right)

In a process called eutrophication, the surplus of nutrient inputs creates an overabundance of sea lettuce that can die en masse, decompose, and in so doing, can use up virtually all of the oxygen in the water (as microbial decomposers consume it all). This leads to anoxic events: with no oxygen, most living things in the estuary die or move away if they can, severely altering the community makeup in the estuary and producing a rotten egg smell that permeates the air for weeks.

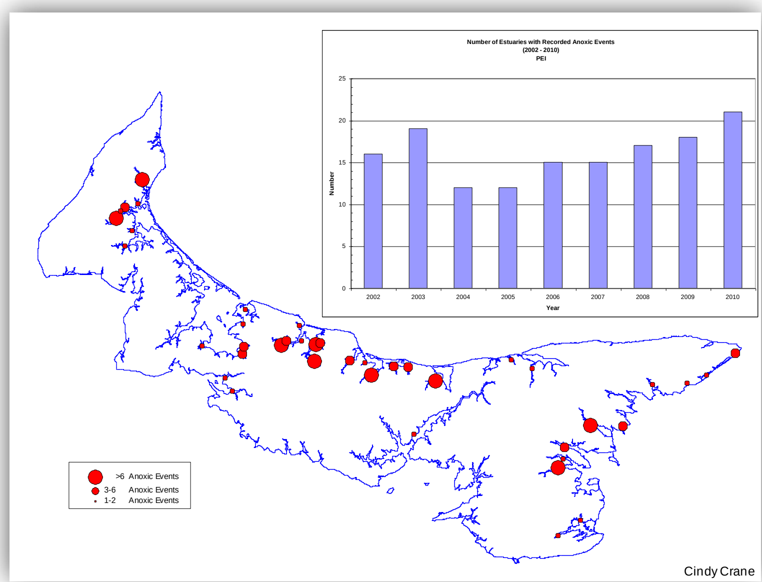


Figure 3.25 Island estuaries showing anoxic conditions during summer

Estuaries are often the part of the watershed that people most identify with and care for. Unfortunately, it is almost impossible to fix problems that occur in them without first addressing the upstream issues. The Community Aquatic Monitoring Program (CAMP) is established in some estuaries around the Island and contributes to a better understanding of their state of biological health. In addition, a second monitoring process for physical condition of waters and sediments is in the early stages of development at the University of PEI. However, this Technical Manual will not delve into restoration strategies for Island estuaries. These systems are extremely complex, and we do not yet know enough to make defensible recommendations on restoration techniques. At this time, the best strategy for improving the health of estuaries is to find ways to curtail inputs of sediment and nutrients and continue to monitor conditions within them.

3.5 Fragmentation of Natural Habitats

Over the past century, natural habitats on the Island became isolated from each other, through human activities of various kinds. On land, forest patches persist in a discontinuous pattern with agricultural lands and towns or villages in between. Some bog and fen wetlands that were once continuous now have drained areas or pockets of commercial peat harvesting. Streams that once flowed with no artificial obstructions now contain impoundments left from old mills, beavers or wetland creation projects, and culverts at public and private road crossings. All of these serve to fragment natural habitats and impact on the resilience of the environment as a whole.

Connectivity of natural areas is critical for some species and provides a healthier population structure for others. For instance, some species of birds (ovenbird, black-and-white warbler) require large blocks of forest, with no "edge" species competitors or predators, in order to breed successfully. Some forest tree species (sugar maple, red oak) can manage a limited amount of fragmentation, but must have legacy individual trees left in place to act as seed sources for re-establishment of another generation of trees after cutting. Riparian margins can provide intact corridors for many forest-dwellers to move between habitat patches or for dispersal of native seeds. In upland habitats, hedgerows can provide some of the same functions if diversely planted.

In rivers and streams, many of our cold-water native fishes are anadromous – that is, they spend part of their life in freshwater and part in saltwater. Impassable culverts or impoundments can prevent these species, including rainbow smelt and brook trout, from moving between habitats used for spawning, juvenile rearing and adult maturation. Culverts may also prevent some invertebrates from migrating between different stream reaches as well.

In addition to creating barriers for movement of native species, habitat fragmentation can make the environment less resilient or able to withstand additional stresses, like those expected with climate change (see section 3.6 below). Forest patches with a high proportion of edge (adjoining fields or residential areas) are more susceptible to tree losses from blow-downs in wind storms, for instance. Edge habitats also experience greater fluctuations in air temperature and other micro-climate conditions. Peatlands that have experienced some degree of drainage or harvesting may undergo unforeseen changes in their capacity to store groundwater and carbon. In rivers and estuaries, reaches with elevated temperatures or reduced oxygen may deter movements of fishes through affected zones, thereby acting as a non-physical barrier.

Identifying how fragmentation impacts on any given watershed requires consideration of a 'landscape perspective'. Small improvements to connectivity may produce large improvements to resilience of natural environments, and produce positive effects in other environments like increased pollination of crops and reduced flashiness of streams.

3.6 A Future Influenced by Climate Change

"*We have options, but the past is not one of them*."

excerpt, From Impacts to Adaptation: Canada in a Changing Climate, 2007

Climate change is not coming – it has already arrived. Whether or not we can agree on the root causes does not alter the unequivocal evidence that our world is in a warming trend, for which we are largely unprepared and the consequences of which we have not fully grasped.

On PEI, average temperatures in the last ten years have been the warmest on record. From 1948 to 2003, records indicate that Island spring and summer seasons have grown warmer, while winters have grown colder. Precipitation has increased on average by 10 % over a similar time period. Model projections predict an increase in summer temperatures of 2 to 4 °C by 2050. Precipitation is also projected to increase, on the same gradual upwards trend as we've experienced since 1948. Seasonal shifts will likely result in milder winters with less snow cover, more and extended thaws, late springs, drought-prone summers and early frosts.

Averages tell only part of the story; they can't adequately describe the increased frequency of extreme storm and tidal surge events that have such a disproportionate impact on lives and ecosystems. Extreme weather events are expected to increase in frequency. The incidence of intense 24-hour rain events will increase 5% by 2020 and 16% by 2080 (Richards and Daigle 2011). A storm surge of 3.6 m in the southern Gulf of St. Lawrence has traditionally occurred every 40 years, but by 2100 will be an annual occurrence. Sea level has risen by 30 cm since 1911 and will continue to rise by as much or more every century. Models suggest that there will be little to no sea ice in the Gulf of St. Lawrence south of the Îles de la Madeleine, making the north shore of PEI more vulnerable to erosion and damage from winter storms. All of these changes will influence both the natural ecosystems of the Island and the human infrastructure we have built over the past 200 years.

3.6.1 Natural ecosystems and climate change

Effects on the water cycle as a whole and on groundwater recharge rates more specifically are still uncertain and potentially complex. They depend on the balance of a number of factors, including the total amount of annual precipitation, its distribution and form (as rain or snow) throughout the year and the rates of evaporation and transpiration during warmer months. More intense rain events could result in a higher proportion of water running off directly into streams rather than soaking in and down to the water table. At the same time, warmer winters could result in more rain recharging the water table as it will not be stored in snowpack and then released quickly as spring runoff. However, if there is a deep freeze in the fall with little snowpack, mid-winter rains could cause severe sheet erosion and runoff to streams. These factors could all result in seasonal changes to recharge and water table elevations.

Stream water temperatures may rise, particularly where there is insufficient shading from the riparian margin. Higher water temperatures will have consequences for frequency of algal blooms and dissolved oxygen levels as well. These elements all combine to produce more stressful living conditions for some invertebrates and most fishes. The biological community in Island streams today are typical of coldwater systems. Rivers with high inputs of spring water may fare better, as the water temperature from springs is not expected to change considerably.

The species makeup of forests on the Island is expected to change in response to warmer temperatures, water stress from reduced groundwater levels, increased risk of spring forest fires, increased frequency of winter freeze-thaw stress, and range expansions of insects and diseases from the south.

The provincial government commissioned a modeling exercise by foresters at the University of New Brunswick, to evaluate how individual tree species will cope with climate change. The findings indicate a potential for large range shifts for many of the most common species (Bourque and Hassan 2009). Interestingly, many of the boreal forest species that became dominant on the Island after the original Acadian forest cover was cut will not be favoured by predicted climate shifts. Boreal species such as white birch, black spruce and balsam fir, along with many other conifers are predicted to find less favourable growing conditions on the Island in the next one hundred years. Several Acadian hardwood species are expected to fare better and in some instances, even flourish with a different climate pattern.

Table 3.1 Changes to distributions of native trees on PEI, based on modelled changes in climate over the next one hundred years

Predicted Scenario for PEI	Associated Species
Modelled potential distribution is severely reduced	White spruce, black spruce, balsam fir, red pine, eastern white cedar, eastern larch, white birch
Modelled potential distribution is somewhat reduced but species may still grow well in pocket micro-climates	Red spruce, white pine, eastern hemlock, yellow birch, sugar maple, trembling aspen
Modelled potential distribution is increased	White ash, red maple, red oak, beech

Increasing populations of insects and fungal diseases are also predicted, along with increased competition from invasive plant species that are native to warmer climates. It will be important to foster the growth of robust forests, exhibiting high species diversity or disease tolerance. This should lower the risk of wide expanses of diseased and/or stressed forest ecosystems.

Figure 3.26 Pure American beech stand in Strathgartney Provincial Park, showing natural resistance to the beech bark disease

Coastal ecosystems are particularly vulnerable to climate change and it will be more difficult to help these systems adapt. Saltwater will intrude further inland, both in surface and ground waters. Salt water marshes and sand dunes may see plant species shifts and encroachment of invasive non-native species.

Populations of land animals may also shift as the climate changes. Breeding success of forest and water birds could be impacted, but it is difficult to predict how since each species is affected so much by the others in each community. They, too, may be more susceptible to northern range extensions of southern diseases. Bats over-wintering in New Brunswick are already being devastated by the white-nose fungus that has gradually crept up from more southern climes. Monitoring programs will be critical in identifying species at risk.

3.6.2 Human infrastructure and climate change

The provincial government has developed a climate change strategy, which has as one of four main goals the improved capacity to adapt to change. Coastal communities are particularly vulnerable to the consequences of climate change, because they will be affected by:

- saltwater intrusion of groundwater, potentially impacting drinking wells
- coastal erosion reducing land frontage on properties along the coast and in estuaries
- extreme storm events damaging roads, bridges, power distribution systems and municipal infrastructure
- increased elevation of storm and tidal surges flooding homes and businesses

Inland communities may also be affected by storm events damaging roads, culverts and power transmission (Figure 3.27). Larger centres like Charlottetown and Summerside will experience greater pressure on storm-water and sewer systems in extreme rain storms.

Figure 3.27 Culvert collapse on Brackley Point Rd (top) and flooding of Lower Malpeque Rd (bottom) during an extreme rain event, September 2008

Although longer growing seasons may have a positive impact on the agriculture sector, crop farming will likely be contending with negative impacts from extreme rain events in the summer, loss of protective snow cover in the winter, increased populations of pests and frequency of fungal diseases as well as drought conditions some years. There may need to be a shift in the types of crops grown and how the growing season is managed.

Fisheries and aquaculture industries may be contending with shifts in native and introduced marine species that are well beyond our capacity to control. Impacts of invasive species such as the green crab could become more severe, as conditions favour warmer water plants and animals.

Planning for climate change may be a bit easier, with the release of a document detailing scenarios and guidance for adaptation at a regional level for P.E.I. (Richards and Daigle 2011). Watershed groups can find information on specific sea level rise and other indicators for their area in this document.

3.7 Summary of Key Influences on PEI Watersheds

"The environmental problems we experience on PEI and in our watersheds and the task before us [are] clear, and have been for some time. We are all "upstream" and we are all "downstream." We need to become aware of our ecological footprint with every step we take, and take active responsibility for reducing our impact on our watersheds and on the environment. We are all part of the problem and part of the solution."

Environmental Advisory Council, Report on the Public Consultations on Managing Land and Water on a Watershed Basis, 2007

At its core, watershed management on the Island is about protecting our key natural assets – our water and our soil. In turn, these two basic elements affect natural ecosystems and biodiversity, on the land and in fresh and coastal waters. This chapter has described the main influences on these assets, but it is by no means an exhaustive list. By getting to know a watershed, each group can begin to map the interconnections between all activities on the land and water.

Issue	Contributing Factors	Impact	Mitigation
Soil erosion	Row and other tilled crops, clay roads, housing and commercial construction, current & historical in-stream structures (dams, culverts, beavers), large-scale clear-cutting	Loss of valuable topsoil, destabilization and/or loss of land, changes in stream hydrology, smothering of stream beds, loss of fish spawning beds, loss of navigable depths in estuaries	Adoption of best management practices (BMPs), improved land use planning
Nitrate enrichment of groundwater	Manure and inorganic fertilizer use on agricultural fields, municipal sewage, septic systems, cosmetic fertilizer applications	Contamination of drinking water, eventual enrichment of surface waters in rivers and estuaries	Adoption of BMPs, interim use of water purification technologies in the short term
Nutrient enrichment of surface waters	As above	Loss of biodiversity in rivers and estuaries, community shifts to tolerant / invasive species	Adoption of BMPs, restoration of a healthy riparian margin
Pesticide contamination of surface waters	Crop spraying	Acute toxicity / fish kills, chronic toxicity / potential effects on survival and reproduction of aquatic biota	Adoption of BMPs, reduced reliance on pesticides for crop protection, restoration of wider riparian margins
Drawdown of groundwater	Deep commercial wells, urban drinking water use	Dry wells, low to no baseflow in streams	Reduced uptake by heavy users
Loss of riparian and coastal forest cover	Residential development, historical agricultural practices, beavers	Increased susceptibility to stream and coastal erosion, loss of land, sedimentation of waterways	Widespread adoption of tree and shrub replanting programs, cattle exclusion
In-filling and eutrophication of estuaries	Upland land use practices, beavers, impoundments	Loss of navigable waters, loss of habitat, extended impact of tidal surges, anoxic events	Curtailment of upstream inputs of nutrients and sediment
Habitat fragmentation	Upland land use, stream crossings, beavers, impoundments	Gradual loss of species, impacts on reproductive success	Increase connectivity of natural habitats through planting, correction of culverts & dams
Climate change	Anthropogenic acceleration of natural climate trends	Increased temperatures, precipitation, tidal surges, extreme storm events	Adoption of adaptive management of failing infrastructure, forest planting, coastal losses

3.7.1 Useful resources

ASE Consultants Inc and Department of Biology UPEI, 1997. Impact of impoundments and their suitability for resident and anadromous fish species on Prince Edward Island. Final Report, Volume I. Prepared for the Department of Fisheries and Oceans, Habitat Management Division, Moncton, NB.

Bourque CP and Hassan QK, 2009. Modelled potential tree species distribution for current and projected future climates for Prince Edward Island, Canada. Available online

DesRoches A, 2008. The report of the commission on nitrates in groundwater. Charlottetown, PE. Available online

Dunn AM, 2004. A relative risk ranking of pesticides used in Prince Edward Island. Environment Canada Environmental Protection Branch, Atlantic Region, Dartmouth, NS. Report No. EPS-5-AR-04-03

Environmental Advisory Council, 2007. We are all downstream, we are all upstream, we are all part of a watershed. A report on the public consultations on managing land and water on a watershed basis. Prepared for the Minister of Environment, Energy and Forestry, Charlottetown, PE. Available online

Lemmen DS, Warren FJ, Lacroix J and Bush E (editors), 2008. From impacts to adaptation: Canada in a changing climate, 2007. Government of Canada, Ottawa, ON, 448 p. Available online

Mutch J, 1999. Relative ranking of acute pesticide risks to fish. PEI Department of Technology and Environment, Charlottetown, PE. Available online

PEI Department of Environment, Energy and Forestry, 2006. Moving to restore a balance in Island forests: Prince Edward Island forest policy. Available online

PEI Department of Environment, Energy and Forestry, 2008. Prince Edward Island and climate change. A strategy for reducing the impacts of global warming. Available online

PEI Department of Fisheries and Environment, and Environment Canada, 2005. Water on Prince Edward Island: understanding the resource, knowing the issues.

Richards W and Daigle R, 2011. Scenarios and guidance for adaptation to climate change and sea level rise – NS and PEI municipalities. Atlantic climate Adaptation Solutions Association, Halifax, NS. Available online

Simpson, J, 2008. *Restoring the Acadian Forest. A Guide to Forest Stewardship for Woodlot Owners in the Maritimes*. Four East Publications, Tantallon, NS. Available online

Thompson R, 2009. New foundations: Report of the commission on land and local governance. Prepared for the Government of Prince Edward Island, Charlottetown, PE. Available online

Links to all online resources are provided on the Watershed Alliance website www.peiwatershedalliance.org

4. Assessing Priority Needs

4.1 Assessment of Land Use

It is essential that watershed groups and community residents understand their watershed's overall land use patterns before drafting management plans and undertaking restoration work. Land use has the greatest influence on watershed health and getting access to recent information is important. Land use data for the Island is collected by the PEI provincial government and that, from 2000 onwards, has been stored on a geographical information system (GIS). This can be an invaluable tool for assessing land use patterns. A group can determine how much of their watershed is in agricultural production, forested or developed for urban centres. As an example, Figure 4.1 is a GIS map of the Bayview River sub-watershed with the various types of land use colour-coded.

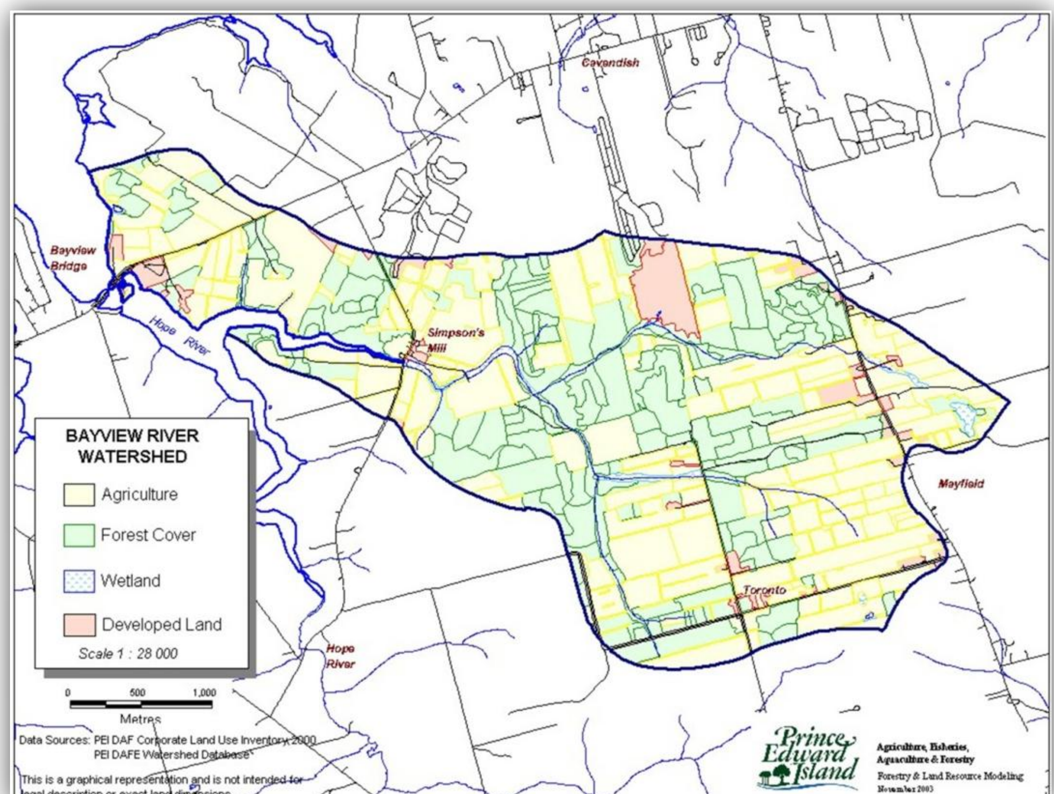


Figure 4.1 Bayview River sub-watershed with land use

GIS land use data are limited to the years when an aerial census was conducted. The land use designations are based on digitization of photographs from an aerial census. Presently the Province has information for the years 2000 and 2010 (available in autumn 2012) and some inferences can be made by comparing the changes seen over the course of the decade. Is the amount of land in agricultural use increasing or decreasing? Is the forest cover in the watershed changing? How has the prevalence of wetlands changed? Groups interested in using these census data can ask for assistance from the provincial Department of Agriculture and Forestry to ensure that they are accessing all of the available information.

Although GIS can provide a snapshot of land use it is limited in its spatial detail. The location of direct access of livestock to streams, the storage of manure, the type and efficiency of urban sewage systems and other important site-specific information may not be provided. However, it is a great starting baseline from which to expand your knowledge-gathering.

4.1.1 Historical land use

An understanding of past land use can often be useful in explaining the underlying problems found in a watershed. For instance, a notable transformation occurred with the gradual disappearance of small mixed family farms and replacement with more industrial agriculture. That shift has had a major impact on watershed functioning.

Major trends and other historical influences on watersheds can be observed by comparing an aerial photography time series. A series of Island aerial photos for the years 1935, 1958, 1974, 1990, 2000 and 2010 are available in digital format on PEI Land Online. Figure 4.2 compares a 1935 image of farmland north of Kensington (left) with a 2000 image for the same area (right); note the larger fields in 2000, indicative of industrialized farming.

Figure 4.2 Historical comparison of a rural area in north Kensington; (left) in 1935 and (right) in 2000

It is not uncommon to see less forest cover in certain watersheds in 1935 as compared to 2000. Figure 4.3 compares 1935 and 2000 aerial photographs of Black Brook on the West River. Over the course of 65 years, some of the agricultural land has been replaced with managed and unmanaged woodlots. The river has been colour enhanced here, to provide a common reference point.

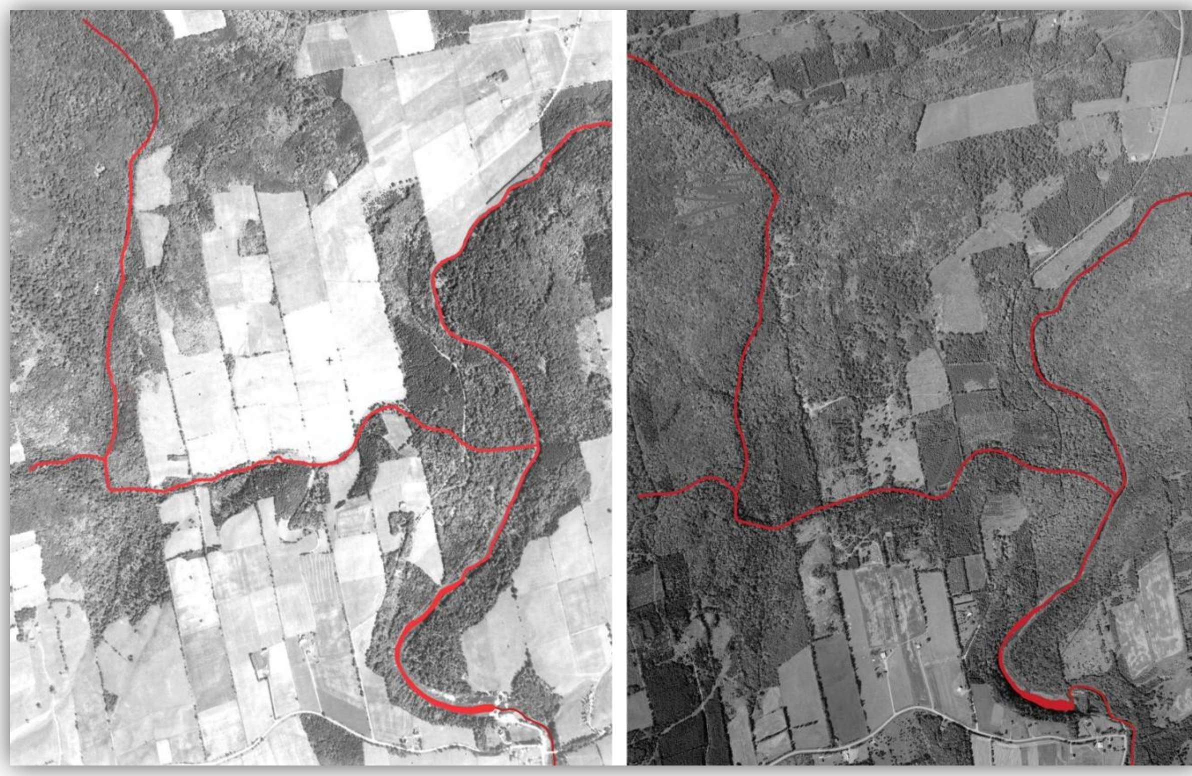


Figure 4.3 Historical comparison of land use on Black Brook, West River; (left) in 1935 and (right) in 2000

Patterns of clear-cutting and road construction will be evident in historical aerial photography. This information may provide insight into the current patterns of forest age and community composition. Old forestry roads may be affecting fish passage at stream crossings on abandoned or overgrown roads.

The height of the mill dam era had passed by 1935, but many of the impoundments still existed and are clearly visible on the 1935 aerial photographs. Many of these impoundments have since disappeared, yet could still influence riparian and stream characteristics such as riparian plant community composition and stream hydrology in the reaches where they once were. Figure 4.4 (left) is a 1935 photo of the Clyde River showing two ponds. Figure 4.4 (right) is the matching 2000 photo showing the section of stream without the ponds. Both images have been coloured to better illustrate the surface water. A group can use this information to anticipate issues that might arise in those reaches (sedimentation, severe bank erosion, buried logs, etc.) and better plan a restoration strategy.

Figure 4.4 Clyde River in 1935 (left) and in 2000 (right) showing the disappearance of two mill ponds

Any past industrial activity in the watershed may have had long-lasting, deleterious impacts. Some mill types may have used chemicals during the milling process that could still be present in the pond and stream sediments. Industrial dump sites can also contain virtually hundreds of chemicals and old sites should be noted and mapped for further investigation.

4.2 Assessment of Streams

A stream assessment is an important tool for a watershed group in their development of stream restoration plans. Issues such as point and nonpoint source pollution, stream bank erosion, riparian zone composition, obstructions to fish passage and location of spawning sites can be identified by conducting an on-the-ground field assessment. The health of the stream is a good indicator of the health of the whole watershed and thus stream assessments will also be invaluable in the development of overall watershed management plans.

There are numerous approaches to gathering background data on streams. Some watershed groups have created or modified their own assessment protocols while others have adopted ones developed elsewhere in North America. Stream assessments can be comprehensive, quantitative exercises based on rigorous sampling methods and completed by trained specialists. Although comprehensive assessments provide extensive information, they tend to be time-consuming, labour-intensive and are currently well beyond the resource capacity of most groups. In contrast, a visual-based stream assessment can be relatively easy to complete and may provide sufficient information to move forward with restoration planning. Although the information is not as quantitative, much of value can still be learned by simply walking the stream (Figure 4.5).

Figure 4.5 Walk the stream to identify new or persisting issues that need to be addressed in work plans

4.2.1 Whole stream assessment

Walking the stream and recording disturbances and other notable items with a camera and global positioning system (GPS) can be useful in identifying the opportunities for stream corridor restoration. The locations of stream bank instability, road crossing issues, beaver dams, old mill pond basins, and riparian zone disturbances are just some of the items a whole stream assessment (also called a rapid visual assessment or RVA) can document. GPS coordinates allow for easy relocation if further investigation and actions are needed (Figure 4.6). Digital still and video photography are also useful tools, particularly when seeking the advice of a professional and deciding if further assessments or work are required. Walking the stream in different seasons provides additional insight. A spring survey, before the emergence of leaves and grasses, allows for a clear view of erosion sources. A summer survey can reveal rare plants and wildlife uses and a fall survey the location of preferred fish spawning locations.

Figure 4.6 Digital records of stream assessments may be made in-stream with a higher-end GPS unit, such as a Trimble

Little measuring is done in this type of assessment as the process is focused on what can be recorded quickly. The objective is to get a general overview of the state of the stream corridor to help make informed management and restoration decisions. The following are some issues/items that should be recorded.

Bank stability Record whether the stream banks are eroded or unstable. Steep banks are more susceptible to erosion than gently sloping banks. Signs of erosion include crumbling, un-vegetated banks, exposed tree roots, and exposed soil. Bank erosion contributes sediment to the stream. It can indicate that the watercourse is unstable and attempting to realign because of rapid changes in flow volumes or other disturbances.

Sediment deposition Deep sediment deposits in a stream bottom are a symptom of an unstable and continually changing hydraulic environment that is unsuitable for many aquatic organisms (Figure 4.7). Sediment deposition may cause the formation of islands by channel braiding and result in the infilling of pools. Usually deposition is evident in areas that are obstructed by natural or manmade debris and areas where the stream flow decreases.

Figure 4.7 Sediment deposit on the stream bottom before restoration, Little Trout River

Substrate embeddedness refers to the extent to which rocks (gravel, cobble, and boulders) are covered by or sunken into silt, sand, or mud on the stream bottom. Generally, as rocks become embedded, the surface area available to macroinvertebrates and fish (shelter, spawning and egg incubation) is decreased.

Riparian vegetation Take note of the width of natural vegetation from the edge of the stream bank outwards. Narrow riparian zones can occur adjacent to roads, parking lots, fields, lawns or buildings. Residential developments, urban centers, golf courses and agriculture are common causes of riparian degradation and their presence should be noted. Also take note if the riparian zone is dominated by any one species or a handful of species (e.g., alders or white spruce).

Old growth forest is becoming increasingly rare on the Island, comprising roughly 1% of land cover. Stands of old growth should be noted for consideration of protection strategies. The dominant species composition is useful information.

Road crossings Culverts and bridges can cause fish passage issues. Record the location and photograph the entrance and exit of the stream as it passes under the road. If the culvert is perched, measure the distance from the bottom of the culvert to the stream surface (Figure 4.8). Take note of the condition of the floor of the culvert and any blockages.

Figure 4.8 Perched culvert, Clyde River

Beaver activity Record any signs of beaver presence in or near the stream, which would include chewed sticks, trees, dams and lodges (Figure 4.9).

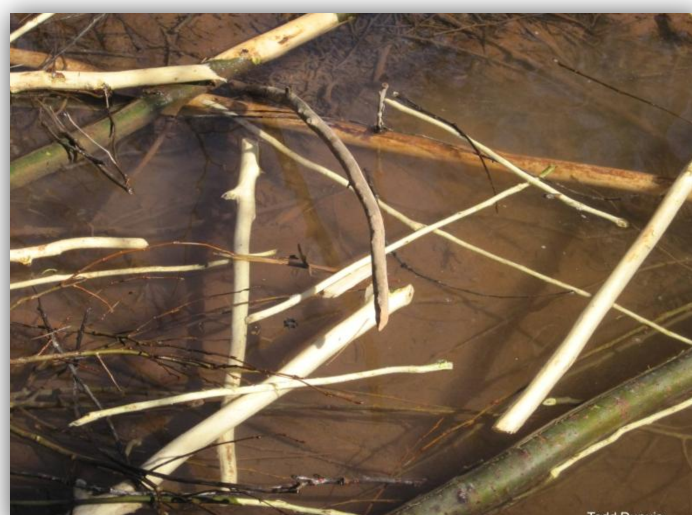


Figure 4.9 Chewed sticks – a sign of beaver activity in the stream reach

Point source pollution The term "point source" means any discernible, distinct input, including a pipe, ditch, channel, conduit, container and/or concentrated animal feeding operation, from which pollutants are being or may be discharged.

Non-point source (NPS) pollution is delivered to the stream in a diffuse fashion. It reaches the stream when rainfall or snowmelt moves over and through the ground. As surface runoff moves, it picks up and carries away natural and synthetic pollutants, ultimately depositing them into rivers, wetlands, coastal waters and ground waters. Examples of such pollutants include nutrients, pesticides, oil, grease, heavy metals, and bacteria. Look for gullies leading to developed lands and signs of chemical films or intense algal growth indicative of high nutrient loading (Figure 4.10).

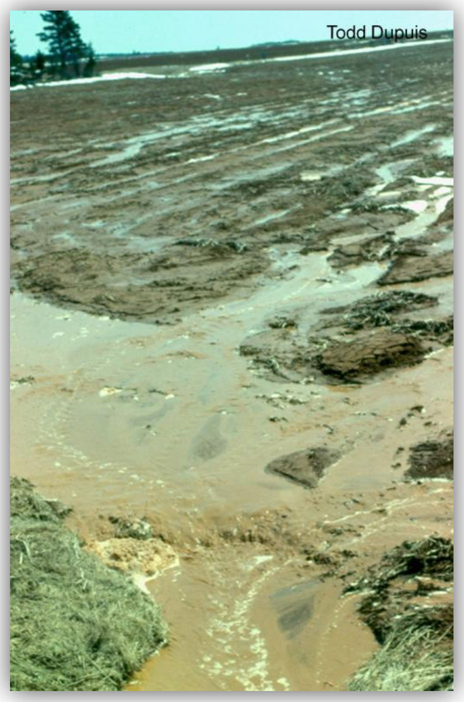


Figure 4.10 Gully and surface runoff from agricultural fields

Invasive plants In some regions, the introduction of non-native plant species can result in the elimination and replacement of native vegetation with mono-species stands having little wildlife or other functional values. The location of invasive plants should be recorded and photographs taken for verification purposes (Figure 4.11).

Figure 4.11 Japanese knotweed growing at the outlet of Lewis' Pond, Schooner Creek

Rare or unusual plants Take note of any rare or unusual plants. If you see something that looks interesting, take a photograph and send to a botanist for identification (Figure 4.12).

Figure 4.12 Prince's pine (*Chimaphila umbellata*) with an S4 designation (widespread but long-term concern) found in the Bristol Creek watershed

Wildlife use Keep an eye out for bald eagle or osprey nests. Eagles prefer to nest in large white pine, although they have been known to nest in other types of trees such as red maple. Osprey nests are typically on the top of a broken conifer tree. It is also worthwhile to note animal dens, for example fox and coyote. Take note of unusual birds, such as the pileated woodpecker. Note suitable crossing logs for mammals.

Springs This is the time to map out your springs. They are best located in winter because they remain open. A qualitative description of the size, flow, length of lead (distance of source to the river), substrate, vegetation, fish use (e.g., young brook trout) and surrounding land use is valuable.

Recreational use Note trails, camping, and angling areas.

4.2.2 Site-specific assessments

In some instances, watershed groups may wish to collect more detailed information about particular sites that are of concern or of special interest. Site-specific assessments tend to be more labour-intensive and require more experience in specialized areas such as stream hydrology, geographic information systems and digital mapping. These may be beyond the capacity of many watershed groups, unless individuals with these areas of expertise exist within your community.

Long-term water quality assessments may help watershed groups to identify existing or emerging water quality problems and design a targeted work and/or monitoring plan. Long-term water quality data can also be used to measure the effectiveness of past or present mitigation measures where the problem has already been partially addressed. The Province provides online public access to surface water and groundwater monitoring data. Historical and current surface water results include parameters measured in streams, ponds and estuaries located at specific monitoring stations across PEI. Drinking water quality and groundwater levels are also available by community or watershed.

Some watershed groups use GIS mapping programs to document the results of whole stream, riparian habitat or intensive stream reach assessments in a visual format. Two programs currently in use are MapInfoPro and ArcView. Both require training and are reasonably expensive to purchase. One big advantage of these graphic presentations of results is that they allow a group to convey their data to the community-at-large and other stakeholders (e.g., funding agencies) in an easy-to-understand visual format.

Site-specific, intensive stream assessment protocols also exist for a more in-depth evaluation of reaches that your group has identified as having issues. These all require a good understanding of stream hydrology and the ability to accurately measure or estimate variables such as bankfull width and substrate embeddedness. The Department of Fisheries and Oceans' *Ecological Restoration of Degraded Aquatic Habitats* provides more detail on these methods.

4.3 Useful Resources

Fisheries and Oceans Canada, 2006. Ecological restoration of degraded aquatic habitats: A watershed approach. DFO, Gulf Region.

PEI Land Online is a digital resource that provides information on land use and aerial surveys. Available online

Prince Edward Island Department of Environment, Labour and Justice holds data on surface water and groundwater quality that is available from long-term monitoring stations across the Island. Available online

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

5. Developing a Management Structure

Most watershed groups on the Island have a similar management structure in place: they have a volunteer management board and a paid watershed coordinator and/or executive director. Other employees are often hired seasonally, but do not participate as much or at all in planning and/or decision-making. Since many Island watershed groups are already in place, the intent of this chapter is chiefly to provide guidance on organizational strategies that allow everyone involved in watershed management to work together effectively and efficiently, without having talented individuals burn out.

5.1 Board of Directors

Watershed groups are not-for-profit organizations that depend on dedicated individuals who are passionate about the Island and their watershed in particular. Most watershed groups on the Island began as small groups of like-minded individuals looking to make a difference in the state of their local environment. Getting organized into a formal group might have been the first struggle and seen as a distraction from the goals. Nonetheless, having a solid, effective board with clear rules safeguards the group from being sidelined by individual agendas or by indecision.

The principal goal of a Board of Directors is to govern the work of the group. Boards set policy, they develop a work strategy and they create a watershed management plan. They can be set up as either a policy governing board or an administrative governing board. A policy governing board sets policy and then hires an executive director to implement the policy. Watershed groups who hire an executive director or a watershed coordinator adhere to this structure. An administrative governing board sets policy and then appoints a committee to implement the policy. Watershed groups whose board directs the on-the-ground work through a volunteer committee adhere to this structure. Both governing structures can work for watershed groups, and the right choice will depend on the time commitment and expertise available on any given board.

A board participates in establishing the purpose of the watershed group: what are the vision and goals for the group? It also provides continuity: how does the work of the group proceed from year-to-year? It sets an expected timeline for progress and it establishes a presence for the group within watershed communities. These are weighty, "big picture" functions whose performance requires a strong team of individuals (Figure 5.1).

Figure 5.1 Regular board meetings keep members engaged and involved

In recruiting good people to form a board, founding members should consider the geography of the watershed, the size and type of land-holdings and the expertise of the people within it. Consider their perspective on the group's vision and the time they might be able to commit to a board. Does the watershed have one or more community councils within its bounds? Perhaps a council member would consider sitting on the watershed group board as a liaison with municipal government. Is the watershed land area dominated by one or a few main land-holders? If they will buy in to the idea of managing on a watershed basis, their participation could prove invaluable in achieving the goals of the group. Are there landowners who feel strongly about making a contribution to community and have a good understanding of the needs of their community? Are there individuals with a long history of working outdoors in the watershed? Is there a First Nations community within your watershed? Are there biologists, accountants, managers, computer gurus, trades-people in your watershed who have talents they are willing to contribute to the work of the board? Sometimes, any or all of these individuals are present in your area, but for one reason or another they don't make it to an annual general meeting. It is the job of the founding members to actively recruit these members to a board, and to have a structure in place that allows them to participate equally in meetings and planning.

The chair of the board can often play a pivotal role in the turnover rate of board members, because the chair is responsible for managing communication at meetings and in workshops.

Signs that a chair is not being effective at a meeting are: there is no agenda or it is not followed or given out ahead of the meeting date; more than one person talks at once; one person dominates the conversations while others don't talk at all; little real progress is made; the meetings run longer than scheduled. When chairs don't manage the work of the board effectively, good people get frustrated and leave. Choose the chair carefully for his or her abilities to facilitate positive discussion, draw in reluctant participants, mediate during controversial topics, and unite members behind the common threads of the group's vision and goals. Most chairs do not get a vote unless it is to break a tie.

Other members of the executive include a vice-chair, secretary, treasurer and sometimes a past-chair. Watershed groups will also have founding members who might wish to continue to sit as a member-at-large without carrying an executive position. Board members at large may be asked to sit on special committees tasked with fund-raising, community consultation for a management plan or collaborative research projects, to name a few.

A common issue for many non-profit boards is succession planning. Tied to this is the propensity for burn-out by over-worked board members. Boards can prepare for these issues by planning for set terms of board members, by allowing members to step away for a year or more before coming back, by trying to plan in 5- or even 10-year intervals, by ensuring that there are sufficient board members willing to share the work load, and by rotating the more demanding executive roles among board members. Recognize the work of board members in writing or at meetings and keep the over-riding goals to the fore-front to dissuade personal agendas from compromising good work. Above all, achieving results is the most valuable reward to retain members, on the board or otherwise. Celebrate the positive gains!

5.2 Executive Directors and Watershed Coordinators

Executive directors or watershed coordinators are paid to manage the on-the-ground work of watershed management groups. Unfortunately, most groups on the Island still don't have the fiscal luxury of hiring someone full-time year-round. This is a huge challenge for groups who need to retain quality, trained staff. It affects the continuity of the work immensely when groups cannot offer a full-time position to a coordinator.

The scope of duties for a coordinator or director is largely defined by the Board of Directors. However, an executive director tends to have a greater understanding of and longevity with a project, and may have a significant influence on the work plan adopted each year. Having the benefit of experience in the field, identifying what works and what doesn't, what are the most pressing issues and their sources allows continuing directors and coordinators to engage in an advisory role when they are present over a series of work seasons.

Figure 5.2 Richmond Bay Watershed Association benefits from having the experience and continuity of a long-serving Executive Director and returning seasonal employees

These paid staff may be asked to wear many hats, including landowner liaison, payroll manager, human resource officer, trouble-shooter, paperwork filer and chainsaw operator to name a few. Individuals filling these roles must be well-rounded, personable, team-oriented personalities with considerable diplomacy skills, while still being able to dig into the hard labour on a daily or at least weekly basis. Having a solid background in biology or a good understanding of the natural history of their watershed is critical. It is also crucial that an executive director or coordinator know the people in their watershed communities and preferably live somewhere within the bounds of the watershed.

Boards need to expect that a new coordinator will require considerable training to understand and implement strategies for watershed management. This technical manual will help, but groups may want to consider mechanisms to allow transitioning from a former experienced coordinator to someone new or mentoring with a neighbouring group.

5.3 Advisory Bodies and Information-sharing Opportunities

There is a common misconception among the general public that watershed groups are engaged in stream clearing and tidying – low skill work that can be done by anyone with a reasonable level of fitness. In reality, nothing could be further from the truth. If watershed groups are indeed engaged only in a bit of simple stream clearing, they are missing an opportunity to create something far more lasting and of greater impact to society.

Watershed management is about developing strategies to conserve water and soil in a landscape prone to the degradation of one and the loss of the other. The issues that every watershed on the Island faces are complex, interwoven puzzles requiring the advice of professionals of many stripes. Seeking advice at every opportunity will help a group develop a robust plan to manage the issues they have identified. Ideally, groups would have easy access to hydrologists, geologists, conservation biologists, ecologists, planners, educators, agronomists and foresters. The reality is that many of these professionals are not available on the Island. Nonetheless, there may be opportunities to connect with these individuals when they are visiting other government, academic or special-interest groups. Having good relations with other Island agencies can lead to such learning opportunities. In some instances, experienced individuals may be present in other watershed groups.

Figure 5.3 Stream restoration workshop held for Island watershed groups

The opportunities to train staff or attend workshops can vary from year to year. On the Island, the PEI Watershed Alliance facilitates first aid and chainsaw training opportunities each year. The University of PEI provides a watershed management course in May of some years that watershed groups can have coordinators attend. UPEI also holds a watershed ecology course in the fall with student projects completed collaboratively with watershed groups that apply for help with specific research-oriented projects. Holland College offers diplomas in wildlife conservation and environmental applied science technology that require students to spend a number of hours in practicum settings, well suited to watershed collaboration. There are also courses offered by the Canadian Rivers Institute (Fredericton, NB) in electro-fishing and stream hydrology on occasion.

Boards and coordinators/directors must identify their needs as a group: what skill sets or specialities are you missing? Seek out individuals who can meet those needs. Talk to your neighbouring watershed groups. If it means bringing a professional in to provide advice, consider sharing the potential cost with them to ease the financial burden. It is important to move ahead with bridging knowledge gaps in this highly interdisciplinary field of work.

5.4 To Incorporate or Not?

One weighty decision to make when building a watershed group is whether or not to incorporate and thereby have legal status as a non-profit society. Although there are real advantages to incorporation, it is not yet necessary by law for watershed groups and there are paperwork requirements to incorporation that can take time.

The Dalhousie University Non-Profit Sector Leadership Program offers the following checklist to help you make the right decision about incorporation. If you answer “yes” to all of the following five questions, then incorporation would benefit the group.

1. We are very clear about our mission and the kinds of things we want to do (clear vision / goals)
2. The work we do is of ongoing value to the community (long-term commitment)
3. We will likely be managing funds, possibly hiring staff and renting office space (financial responsibilities)
4. We may actively fund-raise by soliciting donations, asking for membership fees or organizing special events (financial accountability)
5. We want to be recognized by others as “legitimate”, which will mean adopting a formal structure (credibility for funders, government partners) (Dalhousie University 2001)

If your group would answer “yes” to some but not all of these questions, it might be more appropriate to obtain legal status by partnering with another organization such as a community council or larger, established non-profit. A watershed group just starting out often wants to organize their strategy and membership before considering incorporation. There is much value in a group “finding its feet” before committing to incorporation.

Incorporation will need the services of a lawyer (a requirement of the Prince Edward Island Companies Act); it takes time and it requires that the group develop and abide by bylaws. The bylaws relate to membership, governance structure (board of directors, executive), officer duties, board tenure, voting procedures, financial record-keeping, audit processes and other rules to provide clear guidance in organizational matters. Although a bylaws document may be tedious to draw up, it can be invaluable in solving problems that arise unexpectedly at inopportune times (like in the middle of a summer work season, for instance). The Muttart

Foundation in association with Alberta Culture and Community Spirit (2008) provide an excellent set of guidance workbooks on drafting bylaws and developing non-profit organizational structures. In addition, the PEI Watershed Alliance and other established watershed groups on the Island can help you decide whether incorporation or an alternative is better for your group. There are currently examples of incorporated and partnered watershed groups on the Island.

5.5 Useful Resources

The Land Stewardship Centre of Canada provides organizational resources for watershed groups. Available online

Muttart Foundation and Alberta Culture and Community Spirit, 2009. Board development. Drafting and revising bylaws for not-for-profit organizations in Alberta. Edmonton, AB. Available online

Muttart Foundation and Alberta Culture and Community Spirit, 2008. Board development. Board building – recruiting and developing effective board members for not-for-profit organizations. Edmonton, AB. Available online

Dalhousie University, 2001. Should we incorporate? Non-Profit Sector Leadership Program, Dalhousie University, Halifax, NS. Available online

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

6. Creating a Watershed Management Plan

A watershed management plan provides focus and continuity in a watershed group. It describes a widely-held set of values about the watershed, identifies primary issues of concern and outlines a strategy to address those concerns through a series of goals and actions. It allows a group to persist through losses and additions of individuals from the board and staff by providing a collective context for year-to-year work plans. Make the management plan engaging and dynamic so that it will be read and applied widely!

6.1 Steps, Timelines and Community Consultation

Most founding members of a watershed group might consider they have a good grasp of the main issues of concern and just want to move quickly to problem-solving. It is important to allow the community at-large enough time to arrive at common ground together, to set a strong foundation for long-term management. Watershed groups must find a happy medium between rushing the planning process and letting it get bogged down by fractious issues or stalled by loss of momentum within the group. Figure 6.1 provides a possible stepwise process for creating a watershed management plan.

Some groups will have a Board of Directors in place before beginning the process of creating a management plan, while others may not. Although that management structure should be developed early on, it is not essential to have it established before beginning community consultation and knowledge-gathering.

The planning process begins by scoping – identify the issues of concern for people in the watershed and establish how much is really known about these issues and their impact in the region. It is quite likely the scoping exercise will come up with more questions than answers. That leads to a period of knowledge-gathering, through assessments in the field and digging into historical and recent written records that might exist in government or academic archives. Other tools like aerial photography and soil mapping will help groups visualize the complexities within their watershed. This researching step may take more time than any other single step on the path to a management plan, but it is critical for creating a balanced and comprehensive plan. Some assessments may require walking streams or identifying land use issues (see Chapters 3 & 4) that are more visible during the spring and summer months. Community engagement and crafting of written elements of a plan may be best left to the fall and winter, after farmers and fishers are through with their busy months.

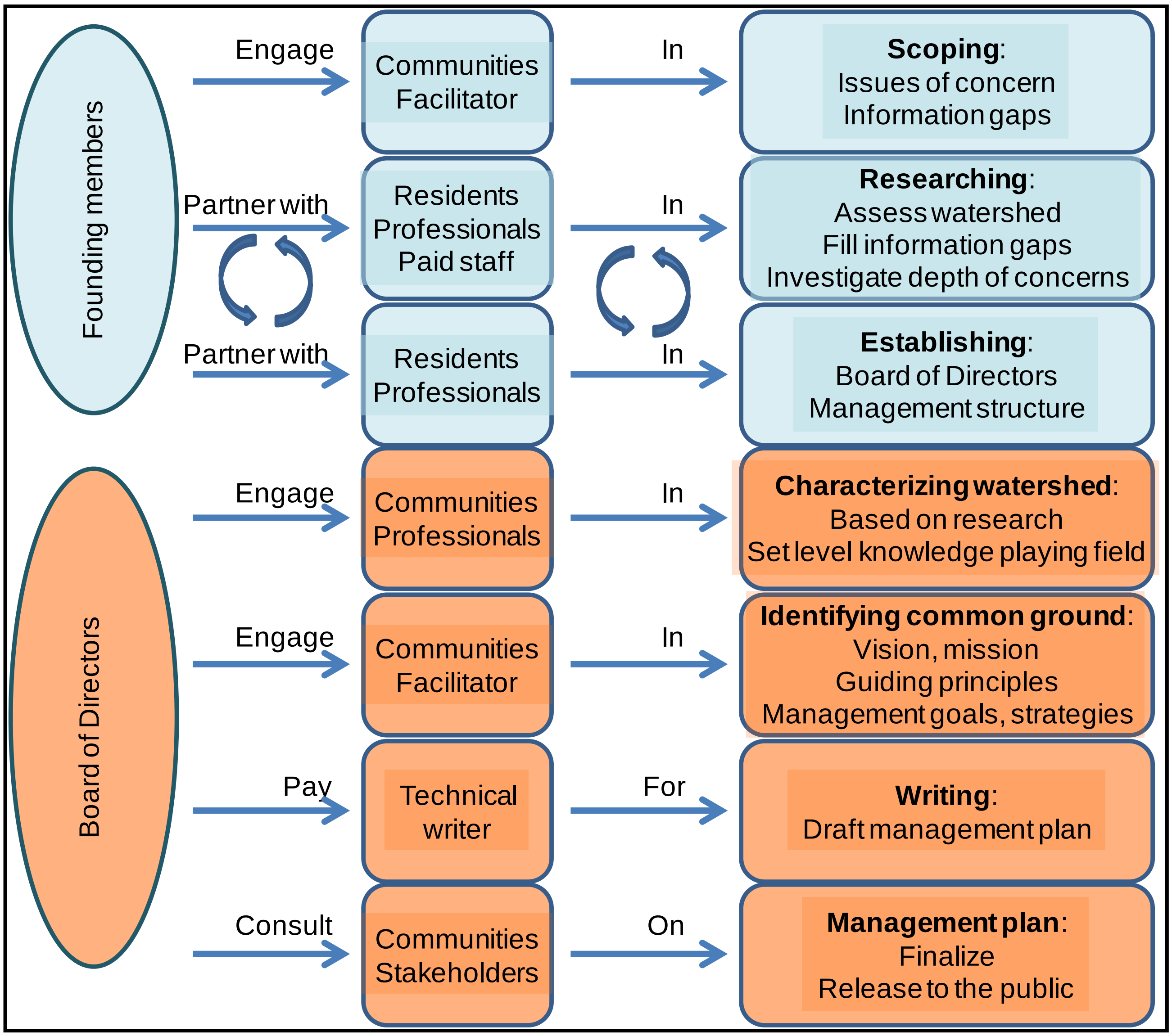


Figure 6.1 Possible stepwise process for creation of a watershed management plan

Once a reasonable level of background information has been collected, it is important to present as much as possible of what is known to the wider community. In order to arrive at common ground, everyone needs to have access to all of the same information. It is helpful at this point to recruit experts to present at a series of community talks to describe what is known about such technical issues as groundwater hydrology, climate change, eutrophication of estuaries and soil conservation technologies.

Figure 6.2 Taking the Board of Directors to the field to discuss the issues of importance to the watershed

When the time has come to move from discussing the collected information to finding common ground and establishing goals, it can be invaluable to enlist the services of an objective facilitator. If your group does not have access to a volunteer with these skills, it may be worth paying someone to guide the Board and community through the hurdles. Choosing the right words to describe a common vision and mission can be a struggle. It requires a special skill set to keep the “big picture” at the forefront and not drift into contentious single issues. The larger the group, the more likely it is to find disagreements. Nonetheless, the plan should ultimately represent the views of as many people in the watershed as possible.

6.2 Writing a Plan

6.2.1 Developing framework statements

The first writing to be done for a management plan should be the drafting of the framework statements. These are the overarching context statements on which the community can agree. They usually include a vision, a mission and sometimes a belief statement. They need to be sufficiently broad to be inclusive, while still reflecting the key path forward for the watershed group.

The vision statement describes how the community wants the watershed and the settlements it supports to be, today and in the future. Many existing watershed groups have visions that talk about sustainability of rural economies, clean water, clean air and healthy ecosystems. For example, the Wheatley River Stewardship Plan vision is “...of a watershed in which the soil, forests and water are healthy and supportive of a rich diversity of aquatic and terrestrial plants and animals...and...in which farmers and fishers are able to make a living, for generations to come, and where all residents have access to clean, healthy water." In developing a vision statement with watershed residents, you could use the following two questions to identify the common threads in people's views: what is it about the watershed that you love the most and want to retain; and what do you foresee could impact on those things you want to retain?

The mission and belief statements address the work of the watershed group more specifically. The belief statement describes the group's beliefs and principles, for instance "we believe that soil and water conservation in the Great River watershed is essential for the long-term health of people and wildlife living within its bounds and we will work with the residents of the watershed to improve and retain soil and water quality and quantity."

Some groups choose to develop a set of guiding principles in lieu of or in addition to the belief statement. This is useful for guiding the collective "group ethic" for management; for instance, that the work of the group be guided by mutual respect and shared responsibility, how the group communicates with stakeholders, engages communities and recognizes the rights of landowners.

The mission statement is more of a call to action, describing how the group intends to work toward achieving the vision for the watershed. It must reflect the intentions of the group that "owns" the management plan. In most cases, that will be a watershed group, but depending on the management structure, could be a broader-based organization such as a consortium of community groups from the area. An example of a mission statement is "the Great River Watershed Association is a non-profit, community-driven organization that works to conserve and protect the natural capital of the Great River watershed, by restoring degraded habitats, reconnecting people with the land and facilitating positive resource use."

6.2.2 Developing goals, objectives and strategies

Once you have agreement on your framework statements, write them out and display them throughout the rest of the community consultation process, as a reminder of what has already been achieved and agreed upon. It might be useful to do the same for the issues of concern that were identified during the initial scoping process.

The goals, objectives and strategies should work to resolve the issues of concern using the background research for guidance, while honouring the vision and mission statements. The goals should reflect the issues for the watershed and what the group wants to achieve in that regard. For instance, if a community is concerned about the potential for excessive extraction of groundwater from deep-water wells, a goal might be “to protect groundwater quantity sufficient for ecological needs and the needs of residents.” Other goals may relate to water quality, wildlife, erosion of coastlines, natural landscape features, recreation or rural living to name a few.

Goals must be realistic, founded on sound reasoning, clear, achievable and have the endorsement of the watershed communities. They should also be focused on the result rather than on the problem. Goals are used to frame the actions identified by objectives and strategies.

Objectives and strategies describe how the watershed group intends to achieve their goals. Depending on the complexity of the goal, it may not be necessary to define both objectives and strategies. Some would consider them to be one and the same. If a group is getting bogged down by the details, it is better to keep it simple and choose one or the other. Objectives and strategies identify the same targets, but at different scales. For example, if a goal is to “protect water quality in headwater streams,” one objective under that goal might be to “reduce further inputs of sediment from uplands in the communities of Great Bear and Little Bear,” whereas two strategies under that objective might be to “monitor suspended sediment in the Great River headwaters and identify the main sources for sediment inputs” and to “facilitate changes to landowner practices for soil containment at identified locations.” You can see that in both instances, the focus of the wording is on the action instead of the goal.

It is important that this record of intent reflects only what the watershed group has the power to achieve. If objectives stray into the realm of governance or land use, the wording needs to reflect the capacity of the group to attain the goal by using terms like “facilitate” or “encourage” or “advocate.” In some instances, watershed groups will need to rely on building relationships with other stakeholders such as landowners and local government, and these realities should be reflected in the wording of these directives.

Also when drafting the strategies, consider what the life of this version of the management plan will be. Most management plans are intended to be living documents, subject to review and revision in the future. A period of ten or fifteen years might best reflect the changing ecological and demographic dynamics we currently face on the Island, as a realistic timeframe to revisit objectives and strategies. Given the time commitment required to develop and implement a management plan, any less would likely be insufficient to evaluate the plan’s successes and obstacles. The group may then want to frame objectives and strategies as being short-term (less than 5 year) or long-term (more than 5 years). Where many strategies will be used to achieve a particular goal, this can help the watershed group to focus and prioritize their work.

6.2.3 Structuring and writing a management plan

Once the watershed communities have achieved some consensus on all of the above framework and planning structure, the hard part is done! Community dialogue can be set aside to focus on the writing of the plan. A watershed group with a dedicated and active Board could potentially work together on drafting this document, but most groups will likely choose to pay an executive director, watershed coordinator or contracted technical writer to complete this stage.

A watershed management plan should be readable, engaging and informative. The plan – namely the framework statements, goals and objectives – should form the bulk of the document. The remainder of the document should provide the basic context in which the plan was formed. That context does not need to be exhaustive and lengthy, but it should relay the issues identified during the scoping process as well as the background research that was conducted to learn more about the significance of those issues in the watershed. Natural histories and community histories for the watershed also help to provide context and may already form part of the background research. However, keep in mind that the context should not dominate the management plan. The plan should dominate the management plan. No matter how interesting and valuable they may be, extra details diminish the message and call for action. They can find a home in another exciting watershed group document that is not a plan!

The structure as well as the content of the management plan should reflect its primary purpose. A table of contents might flow as follows:

- purpose and ownership of the plan;
- framework statements;
- context for plan, including watershed background research and identified issues;
- goals, objectives and strategies;
- plan for implementation;
- plan for periodic review and revision.

Additional context such as Board policies and extra natural and community histories could potentially be placed in appendices.

Once a management plan is drafted, it should be distributed for comment to the original community members who participated in the consultation process, to ensure that it is an accurate reflection of that process and the consensus derived. Following this process of review, revisions can be made and a final document produced.

6.3 Setting Additional Policies and Targeted Plans

A management plan is the first step toward developing a strategy for improving the health of a watershed, but it may not be the only guidance document a watershed group will need. Some key issues may require more specific policies or plans to guide the work of field staff and volunteers (Figure 6.3). Some permitting bodies may also require these written statements to be in place. Common issues that frequently require a policy or more targeted plan on the Island are fish habitat management, beaver management and impoundment management.

A policy is an expression of the will of the Board of Directors. It may be drafted after the completion of a management plan and without the same level of public consultation, but it should honour the spirit of the vision and mission statements. The examples for policy given above would be considered operational policies, because they outline the board's direction for a work program.

An operational policy should include the background context, a statement of intent, and the actions recommended. The context should outline the issue – what is the problem and how does it impact on the health of the watershed? The statement of intent explains the policy of the board in one sentence. The recommended actions outline how the policy will guide work in the field. Recommended actions may also include educational or research components.

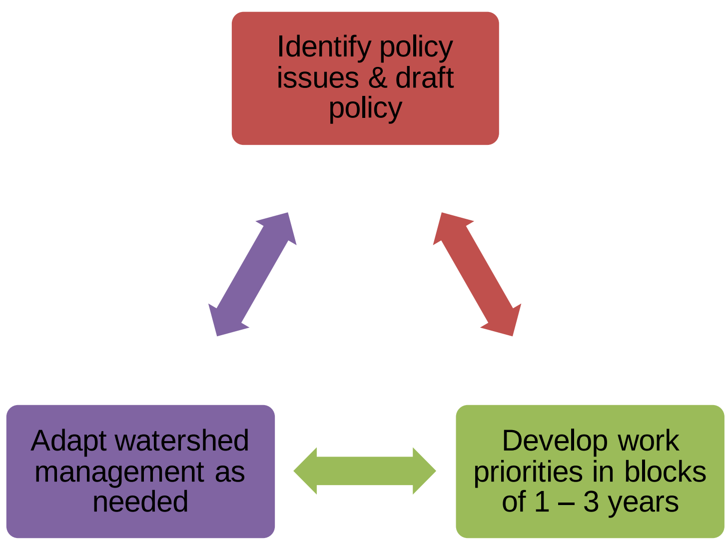


Figure 6.3 Adaptive management of work plans based on Board policy and the monitoring of results

A policy should be sound and defensible. The context might include references to published studies that support the seriousness of the issue or describe the science behind it. Ensure that the board has a good understanding of the issue and can put it in the context of the watershed. In some instances, the policy may be questioned or subject to regulatory review. Be very precise and accurate with your wording so that you can defend it in good conscience if necessary.

Policies and targeted management plans do not need to be lengthy – two or three pages will often suffice. Their purpose is to focus the work of the group and to communicate a collective approach to that work. The work of a watershed group should be open and transparent for residents and other stakeholders.

6.4 Following a Plan

A watershed management plan and associated policies can benefit the work of a watershed group immensely in two key ways. First, these written statements of intent help the group to set priorities for field and other work each year. Second, they are an invaluable tool for the group in communicating their plan to other stakeholders, particularly funding agencies and regulatory bodies.

The Board of Directors should consult the management plan at least annually, to refresh themselves with the main goals and incorporate them into work plans. If strong personal agendas are taking root within the board that do not reflect the spirit of the plan, it is an objective means of getting the work priorities back on track. This manual clearly indicates a breadth of possible activities that watershed groups can undertake – too many for the time and fiscal resources of most, if not all, groups. It is essential that the board have a clear understanding of what issues are most pressing and what work of the group takes precedence each year.

Reference back to the plan can also be valuable in evaluating the work accomplished. Can you measure your success? If not, perhaps the group needs to allocate more resources to monitoring. Chapter 18 describes monitoring tools in detail. Are there goals that have not been addressed because the focus is elsewhere? Perhaps the group can develop a strategy to fill those work gaps, at least in a small way.

When a management plan is complete, do not let it collect dust on a shelf. Use every means to ensure that people can access it. Residents can take pride in their participation in its production and often learn more about their environment through reading it. Funding agencies see a plan as a commitment to work and a strategy to achieve results. They are more likely to fund a watershed group that can show in this way that it is organized and has a well-developed direction. Create an electronic version of the management plan and make it available on the watershed group website or through other digital means. Production of hard copies may be expensive, but some in your communities may not be able to access the plan in any other form. Ensure that there is sufficient money allocated to printing for these interested individuals. If necessary, spread the cost over a number of years.

6.5 Useful Resources

Alberta Culture and Community Spirit, 2009. Developing policy. Board Development Program, Voluntary Sector Services Branch, Edmonton, AB. Available online

Conservation Authorities of Ontario, 2003. Watershed management in Ontario: lessons learned and best practices. Toronto, ON.

MacFarlane R, 1999. Developing a watershed management plan: a guide for community organizations. Unpublished report prepared for PEI Department of Technology and Environment, Fish and Wildlife Division, Charlottetown, PE.

Ontario Ministry of Environment and Energy and Ministry of Natural Resources. 1993. Water management on a watershed basis: implementing an ecosystem approach. Toronto, ON. Available online

PEI Environment, Energy and Forestry [publication date unknown]. A guide to watershed planning on Prince Edward Island. Available online

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

7. Sustainability Strategies

Prince Edward Island has lost much of its 'wildness' over the course of the last century, because of its small size and density of habitation. The majority of land in any given watershed is privately owned. In essence what this means is that watershed groups must work very closely and communicate often with landowners and communities. Management in this instance is not just about working with nature, but also with people, and fostering stronger connections between the two.

The objectives at the heart of the work of watershed groups are conservation and sustainable use of resources – the soil, the water, the forests and wildlife. To be successful in achieving sustainability requires the efforts of all stakeholders; it doesn't matter how passionate the board of your group is – if you don't enjoy the support and engagement of residents and local governments, there will be slow progress toward sustainability goals. This chapter tries to address some of the strategies watershed groups can use to "lighten and enlighten" the lifestyles of people. Many of these out-of-stream strategies could be spearheaded by willing volunteer members of the Board of Directors, as they may progress slowly over the course of several years.

7.1 Sustainable Land Use and Reducing the Human Footprint

Watershed groups are faced with the unenviable task of trying to foster better land use practices in their region without having any real regulatory power to effect change. In the absence of province-wide land use policies, there is also no clear directive for municipalities and landowners in many instances. With the recent announcement that the Province is moving to develop land use policies in 2012, this section will not delve into specifics that could quickly become out-dated.

It is quite likely that several of the goals and objectives developed by your watershed group during the drafting of a watershed management plan related to land use and issues with soil erosion, water quality and possibly water quantity. The same issues tend to surface whenever a provincial state of the environment report is produced or a land use report commissioned. For instance, among the key findings of the Commission on Land and Local Governance reported in 2009 were the following:

- "Contemporary land use debates center on the plight of the farming community, the high profit motive of land speculators, the need to protect our most valuable resource for future generations, and the benefit [that] the Province derives from development-driven tax revenue;
- Subdivision development remains a contentious land use issue on P.E.I., with the interests of property owners and developers often appearing to prevail over the public interest where development outside municipalities with official plans is involved;
- It is in the public interest to compensate farmers financially for measures they take to protect the environment, whether these are mandatory or voluntary;
- Recreational and retirement subdivisions will have a significant impact on property values and coastal viewscapes and, if the present trend toward year-round occupation continues, on the very makeup of rural communities;
- Successful protection of sensitive land following decisions by landowners to donate land or to protect it against development has been amply demonstrated;
- This Commission cannot hope to improve upon the excellent work of the Commission on Nitrates in Groundwater"

These findings speak to the breadth of the land use issues and the need for a long-term plan for watersheds.

The board of a watershed group should identify the land use issues that place the most pressure on the watershed. These could be high nitrate loading to groundwater, coastal rates of erosion, high rates of soil disturbance on steep uplands or some other issue with chronic and widespread impact. In the beginning, it is not necessary to have identified the source of the problem. Sometimes it is better to diagnose the cause – effect relationship through dialogue with the wider community and through targeted, funded research (Figure 7.1).

With information on the identified priority issues in hand, groups can start a dialogue with the agency responsible for local governance – a community council in some instances or currently the Province in unincorporated areas. Prepare a brief on the issue and possible contributing factors, communicate the importance of its timely resolution for sustainability in the watershed and work with governance bodies to develop a path forward.

Figure 7.1 Souris and Area Branch of the PEI Wildlife Federation work with UPEI and government researchers to study the impact of fall versus spring plowing on nitrate concentrations in groundwater

That path may involve conducting more research, with an associated financial commitment from the watershed group. Ensure that you are prepared for that eventuality by setting aside funds or by developing a plan to seek funds. Where the source of the issue is quite clear, seek the commitment of the governing group to create bylaws that address the problem. Again, be prepared to be specific in your recommendations and back them up with defensible data. It may be helpful to designate a board member as liaison with community councils, to maintain an active line of communication with councils.

Where there is uncertainty about the sources or solutions for a land use issue, watershed groups can facilitate the targeted discussion of the issue within the wider community. Solutions will not be found if no one will talk about the problem. Community councils may need to be coaxed into tackling a complicated and controversial issue. Where watershed groups do not have the skills on their board to facilitate such town hall–style meetings, they can find an individual who does. Be patient but persistent. It is quite likely that the issue under discussion did not develop overnight and will not be solved overnight. Nonetheless, the process of resolution must begin somewhere.

Where an issue is clearly associated with a commercial land use, such as row cropping and potato production, then watershed groups can work with industry organizations to promote the adoption of best management practices (BMPs, Figure 7.1). Watershed groups are already involved in providing labour for some BMPs such as hedge-row planting. These activities should continue and possibly be expanded upon to include things like fencing maintenance, wetland restoration, logging road maintenance and irrigation strategies. Weigh the capacity of the individual landowner to carry-out the needed work against the value of the work for the public interest in deciding what tasks should have priority for watershed group financial resources.

Figure 7.2 Best management practices on sloped agricultural land in Gowan Brae (Rollo Bay Holdings), with terracing and grassed headlands

7.2 Public Engagement

"I like to play indoors better 'cause that's where all the electrical outlets are"
Fourth-grader in San Diego, from Last Child in the Woods by Richard Louv

Whereas development of bylaws takes the "stick" approach to attaining sustainability targets, public engagement may be more akin to the "carrot." Provide opportunities for residents to get off the information technology highway and reconnect with the natural environment in their backyard. Reward landowners who practice sustainable living. Enlighten people who may not see the positive and negative impacts they have on their watershed. This section describes some strategies that haven proven successful in engaging the Island public.

First, be clear about what you want to achieve with your public activity. Are you trying to educate a particular sector of society, for instance youth? Are you interested in promoting outdoor recreation? Do you want to foster a closer link between residents and the food they eat by supporting local fishers and farmers? Do you want to unite them behind a particular cause, such as protection of an ecologically sensitive site?

Second, consider the best type of activity and its timing to reach your target audience. Engagement of school groups must occur during the school year and there are logistic considerations if you want to travel with them to field sites. Volunteer days must be held during the permitted activity period if in-stream or riparian work is planned. If you want to engage farmers, don't bother them during their busy planting and harvesting seasons. If you want to promote all-season use of natural areas, plan activities during all four seasons.

Figure 7.3 Family fishing day in Tyne Valley, hosted by the Richmond Bay Watershed Association

Third, decide whether quantity or quality of engagement is your primary objective. Sometimes a watershed group may wish to reach as many people as possible, to pique their interest and nurture a communal understanding and desire to participate in watershed activities. In other instances, a group may be more interested in developing key relationships with a specific sector, such as birding enthusiasts, anglers or the farming community. You may want to reward individuals by nominating them for environmental awards available in some sectors (such as farming). If public engagement is a high priority for your group, it might be helpful to develop an annual public engagement plan and target specific audiences with planned activities.

Field activities can be high-impact. Some examples of field activities that have proven successful for watershed groups in the past include youth fishing days or weekend camps, volunteer spring tree planting half-days, participation in community parades, and guided walks through stream restoration areas or local parks. The Hunter-Clyde Watershed Group and Wheatley River Improvement Group have held a winter woodlot tour in the past that drew several hundred visitors.

Figure 7.4 Maple syrup tapping table at the Winter Woodlot Tour 2012

Hands-on activities often work well

with school groups. Young children learn by doing more so than by being "talked at" even if the location is outside rather than in a conventional classroom. Most schools on the Island have a natural area within walking distance and it may be logistically easier to develop learning opportunities based on this natural material that is close at hand. Also, there are existing education event days and programs that a watershed group could lend support to without the need to develop a curriculum from scratch. For instance, some groups host activities that celebrate Biodiversity Day, World Wetland Day, World Environment Day or Earth Day. The Atlantic Chapter of the Sierra Club administers a program to schools called Water Wizards, which might be expanded upon with the assistance of watershed groups. Older school age groups may even be able to assist with tree-planting events or monitoring programs such as the Community Aquatics Monitoring (CAMP) and Adopt-a-River Programs (Figure 7.5).

Figure 7.5 Outdoor classrooms: students help the Bedeque Bay Environmental Management Association and learn about estuaries and aquatic life during a Community Aquatics Monitoring Program (CAMP) beach seine (top) and an Adopt-a-River macroinvertebrate survey (bottom)

Indoor activities may appeal more to another segment of your community who do not or cannot be physically active in nature. Evening talks on nature-related or community history topics can be both entertaining and informative. Weekend half-day workshops on fish, native plant, amphibian or bird identification or invasive species identification will appeal to a certain interest group within and beyond your watershed. The Souris Area Branch of the PEI Wildlife Federation hosts an annual wildlife dinner that always proves popular. Several groups also hold photo contests that appeal to the competitive personalities in the community.

For all planned activities, advertise, advertise, advertise! With so many activities competing for the interest of Islanders, ensure that people know about and have sufficient time to plan for your events. Community newsletters, newspapers, public service announcements on radio and television, and websites are good media for getting out your message. Allow at least two weeks for people to plan and then remind them a day or two prior to the event.

Websites are another technique for communicating with and engaging the public. However, their maintenance is a substantial and ongoing commitment, so ensure that you have the resources to dedicate to a website before deciding to construct one. It is a good idea to use a framework that allows collaboration, such as offered by WordPress, so that more than one person can take on the responsibility of maintaining the site. Once you have a website constructed, try to update it regularly every two weeks to a month, to maintain interest. A Facebook page can also help in this regard. You may find these electronic tools are a good way to make contact with youth and people who spend large blocks of time away from the watershed, either for work, school or because they are summer residents. Be clear about what you want your website to convey... who is your audience and what level of background do they have on your activities? Will they know what a brushmat is and how it functions? If not, here is an opportunity to explain it to them. Will they know the boundaries of the watershed? If not, provide them with a map. Engage them by asking for their input or materials for the site – photos and stories, vetted for content by the webmaster, can commit people to a vision for the watershed where they could not previously see their role.

However, always keep in mind that a website cannot convey your message to everyone in the watershed. Older individuals and those without internet access at home will not be reached through this venue. Mail-outs, personal visits and phone calls cannot be rivalled for breadth and quality of contact. Quarterly or bi-yearly newsletters can reach everyone with a mailbox in your watershed. Newsletters may only be one or two pages, but provide a priceless opportunity to inform, educate and engage your communities. Although it will cost more, the use of colour photographs in these mail-outs greatly increases the impact value. Try to make these communications positive, with the emphasis on achievements, celebrating local stewards and looking forward to special events or volunteer days. The tougher messages can be given as well, but a lot of finger-pointing or ranting is likely to be counter-productive here.

Figure 7.6 Engage the community by being visible and accessible on parade day

7.3 Protection Mechanisms for At-Risk or High Priority Areas

Watershed groups may find that there are particularly sensitive ecological areas in their watershed that remain unprotected from development. There may also be areas that are currently in development, which produce such an extreme and chronic impact on the health of the watershed that the group would like to work to get the land use changed. With less than 10% of the land mass on the Island in public ownership, it is probable that changing the protection status of these lands will involve negotiating with private landowners.

Island Nature Trust has worked hard to protect sensitive lands in the province (Figure 7.7) and has considerable expertise in the mechanisms available for protection. Their booklet “Private Stewardship: The Landowner’s Options. A Guide to Voluntary Land Protection” is a great resource for watershed groups who are initiating the dialogue on protection. Before your group gets too far into this investigation, determine whether the Island Nature Trust or the Nature Conservancy of Canada have already identified the area as of interest. The latter national organization has a strategy that targets coastal representative old forest or unique ecosystems on the Island.

The PEI Natural Areas Protection Act (1988) allows a restrictive covenant to be placed on land that specifies what uses are or are not permissible. A restrictive covenant can be tailored to the landowners needs to a certain degree, while protecting the desirable features of the land. Landowners who do not wish to give up title to their land may show interest in a covenant or in entering a management agreement with the Province or a conservation organization. The MacPhail Woods Ecological Forestry Project will manage a property for a fee, either working with the existing woodland or replanting cleared land and working directly with the landowner to develop a plan. Landowners can also lease, sell or donate the land to the Province or to a conservation organization.

Figure 7.7 Island Nature Trust owns or has a long-term lease on over 350 acres of pond, forest, wetland and back dune habitats in the Deroche Pond area

If a watershed group is incorporated, it may be possible for the group to buy land. However, this is a long-term commitment and could require considerable financial and human resources. The option selected should be the right one for the landowner and, in some instances, the watershed group. The following table summarizes the current possibilities for protection. If a watershed group embarks on a serious negotiation for protection, it is advisable to consult a lawyer for the most up-to-date information on the financial, land tax, income tax and legal implications.

Table 7.1 Protection mechanisms for private land that is identified as sensitive or ecologically special

Protection Mechanism	Description of Protection	Requirements	Role of Watershed Group
Restrictive covenant	• Landowner retains ownership • Voluntary placement of limitations on future use • May or may not be designated as Natural Areas • Protection is not impacted by future transfers of land ownership	• Provincial government or Island Nature Trust holds the restrictive covenant • Management plan for property is mandatory • Can include all or part of the land parcel	• May facilitate paperwork requirements • May help owner to develop management plan
Management agreement	• Landowner retains ownership • Voluntary placement of limitations on future use • Protection is not permanent, but set for a specific length of time or until the property is sold	• Provincial government or a conservation organization holds the agreement with the landowner • Formal written agreement with a management plan component • Can include all or part of the land parcel	• May facilitate paperwork requirements • May help owner to develop management plan • May enter into agreement and manage land
Lease & management	• Land is leased from owner and managed over the period of the lease • Set time period for lease, negotiated with landowner • Management does not transfer with change in ownership	• Lease agreement, with or without specific terms and conditions • Typically covers the full land parcel but may include only the area of interest • May require a land survey • May involve a registered lease	• May become tenant and manage land
Sale to a land trust	• Landowner sells land to Province or a land trust	• Simple sale or reserved life estate sale or sale with leaseback or installment sale • Restrictive covenant may or may not be included	• May facilitate early in sale process • May purchase depending on structure & capacity of group
Donation to a land trust	• Landowner donates land to Province or a charitable land trust • May take effect while landowner is living or after death • Property may be subdivided and only one parcel donated	• Donation agreement or will deeding (bequest) • Restrictive covenant may or may not be included • May be conditions attached to donation	• May facilitate donation • May receive donation depending on structure & capacity of group

7.3.1 Alternative Land Use Services (ALUS) program

In many instances, landowners and particularly farmers want to do the right thing, but are unwilling or unable to take a personal financial loss in doing so. The Alternative Land Use Services (ALUS) program addresses this issue by providing financial compensation to retire sensitive land or take it out of production.

There are three broad categories of land eligible for compensation through sensitive land retirement:

- Expansions of buffer zones beyond 15 m
- Establishment of grassed headlands where they are not required by legislation (more than 200 m from waterways or wetlands)
- Retirement of high sloped land (9% slope or greater) from cultivation

These areas cannot be tilled, sprayed with pesticide or used for annual crops, although they can be maintained in grasses rather than trees or shrubs. The high-slope land is inventoried for every watershed on the Island and is marked in red on the PEILandOnline land maps. If your watershed group has identified areas where soil erosion is a severe problem, the landowner may be willing to work with the group and the Province to protect that area through this mechanism.

The ALUS program will also pay farmers to take land out of production for the installation of soil conservation structures, including diversion terraces, berms and grassed waterways. These structures must meet minimum design standards and be approved by a soil conservation specialist. Watershed groups may encourage farmers to apply for this compensation for sloped fields or long fields that suffer from chronic erosion problems.

Farmers may work through the ALUS program to conduct tree-planting within the 15 m buffer zone. Many watershed groups already do this work through the Greening Spaces Program, but where resources for the group are limited it provides another means of reforesting the riparian margin. ALUS will also pay livestock farmers to maintain existing fencing adjacent to waterways and wetlands.

Often landowners are unaware of the compensation programs they may be eligible for or do not have the skills or motivation to work through the tedious paperwork process. Watershed groups may nudge such individuals in the right direction, by offering assistance with the application or other paperwork hurdles. Ultimately, these changes to land use may produce the greatest long-term positive impact on the health of the watershed as a whole.

7.4 Useful Resources

DesRoches A, 2008. The report of the commission on nitrates in groundwater. Charlottetown, PE. Available online

Garrison N and Hobbs K, 2011. Rooftops to rivers II: Green strategies for controlling stormwater and combined sewer overflows. Natural Resources Defence Council, New York, NY. Available online

Island Nature Trust, 2000. Private stewardship, the landowner's options. A guide to voluntary land protection. Charlottetown, PE. Booklet available at the INT Charlottetown office.

Louv R, 2008. *Last Child in the Woods. Saving Our Children from Nature-deficit Disorder*. Algonquin Books of Chapel Hill, Chapel Hill, NC.

PEI Department of Agriculture and Forestry [publication date unknown]. Soil conservation for potato production. Charlottetown, PE.

PEI Department of Agriculture and Forestry, PEI Department of Fisheries, Aquaculture and Environment, and Environment Canada, [publication date unknown] Best management practices: Agricultural waste management. Charlottetown, PE. Available online

Thompson R, 2009. New foundations: Report of the commission on land and local governance. Prepared for the Government of Prince Edward Island, Charlottetown, PE. Available online

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

8. Sediment Controls

Soil erosion on land and sediment deposition in waterways is the main obstacle to a healthy natural environment in most Island watersheds. Sediment is usually considered to be a mixture of clay, silt and sand but various other elements such as gravel, cobble and organic matter may be present (see section 12.3 for a comparison of rock particle sizes). Fine clay and silt particles may stay suspended in the water column for long periods of time but eventually they drop out as the current slows, especially in ponds or estuaries.

Sediment movement within watercourses is natural and desirable. However, some Island stream reaches become overwhelmed with sediment: pools fill in, streams aggrade, open spaces in gravel and around cobble disappear, and habitat for fishes and invertebrates degrades. The logical management sequence in these instances would be to:

1. Focus on prevention of soil erosion,
2. Intercept sediment that has not been contained on-site, and
3. Remediate habitat that has already been affected by sedimentation.

Prevention of soil erosion is largely a private land use or public infrastructure issue. Nonetheless, group members can help to identify problems and encourage the adoption of solutions (see Chapter 7 for further guidance).

Figure 8.1 Rill erosion of Cape Breton Road (Clark's Creek watershed)

Soil conservation techniques to address points 1 and 2 above are described in section 8.1. The remainder of the chapter describes strategies used to repair or restore stream habitat that has already been affected by sedimentation.

8.1 Strategy for Upland Soil Conservation and Sediment Control

There are many upland practices that disturb soil and leave it susceptible to erosion. The main erosion sources on the Island include cropping, urban and rural development, road construction and clay (unpaved) roads (Figure 8.1). The following section describes the key sources of soil erosion and what capacity watershed groups might have to help control them.

Identifying the numerous sources for soil erosion in a watershed and fixing them may take decades. From an ecological perspective, it is advisable to focus on eliminating the sources entering the headwaters first. If you start low in the watershed and work up, you may find that the hard work completed downstream is undone by upstream inputs of sediment from sources that have not been addressed through changes in upland land use practices.

8.1.1 Agricultural croplands

The booklet "Soil Conservation for Potato Production" describes the problems and outlines techniques to greatly reduce agricultural soil loss from erosion on the Island. It suggests that acceptable soil loss rates are in the range of 3 tonnes per acre per year; this rate of loss is believed to be roughly equal to the annual rate of soil created by Mother Nature, thus achieving a 'zero balance' of loss to gain. However, the soil loss rates on steep Island terrain or more gently sloping but long (½ km or more) fields may be several times that amount, with loss rates recorded as high as 40 tonnes per acre per year (Figure 8.2).

Figure 8.2 Gully erosion on a field in Bellevue

The Provincial Department of Agriculture and Forestry as well as non-government farming organizations (Federation of Agriculture, National Farmers Union) can offer advice on environmental sustainability and assistance to producers. Nevertheless, the trend towards short rotations, intensive cultivation of late-season crops like potatoes and soybean, more intense rainfall events and more frequent winter thaws increase the challenge of keeping soil on the fields and out of the watercourses.

The greatest soil losses from croplands occur in winter and spring if fields are left bare and at risk from water and wind erosion (Figure 8.3). Our changing climate promises to amplify the soil loss risks associated with fall tillage and inadequate winter protection strategies. Best management practices recommend a fall cover crop or at least winter mulching.

Figure 8.3 Bare fields in winter and spring are susceptible to wind and water erosion

Watershed groups can identify areas in the watershed where agricultural best practices are routinely absent. The ideal would be to see high gradient land taken out of tillage-style farming and into forestry, livestock production or perennial crop production. Watershed groups may be able to facilitate this with involvement of other stakeholders, such as the farming organizations noted above, in instances where a severe and chronic soil erosion problem is occurring. These are issues requiring good, open working relationships with farmers and should not be approached in an adversarial manner. Forms of compensation for income losses could be explored. The ALUS program described in section 7.3.1 could prove useful in these instances.

Ultimately, soil health and long-term sustainable use of agricultural land is the responsibility of producers, their organizations and regulatory government departments. If given high enough priority and support, negative impacts of agricultural land use on watercourses could be greatly reduced.

8.1.2 Highways, private roads, and maintenance of unpaved roads

Roads and highways can contribute to erosion through ditch and shoulder erosion, rill erosion of unpaved (also called clay) roads, and through flow capacity problems with culverts at road crossings.

Unpaved roads can be a major source of sediment for many Island streams; watersheds with steep terrain and many clay roads experience the greatest problems. Especially challenging are clay roads that have had decades of surface erosion and corrective grading, where the roadway surface has been lowered to well below the surrounding elevation. The roadways below elevation are unable to shed water during heavy rain events, resulting in even more erosion. Figure 8.4 is a clay road in North Granville. Note that the road is below the surrounding land elevation, which does not allow the water to be shed. The bottom scene shows where the road spills sediment laden water into the stream at the bottom of the hill.

Figure 8.4 Clay road in North Granville, Trout River (Granville) watershed

The increased frequency of extreme rain events that we are witnessing may have consequences for roadway management and culvert maintenance in particular. Flashy stream conditions can overwhelm under-sized culverts, of which there are many across the Island, resulting in more wash outs. Culvert wash-outs result in large quantities of sediment entering watercourses. Culverts designed for the 1:100 year rain event should be sufficient to accommodate most heavy rains.

In recent years, there has been considerable improvement in stabilization of sediment during construction and maintenance of roads. The environmental management section of the

Department of Transportation and Infrastructure Renewal often help watershed groups by providing advice, materials, and improvements in sensitive areas such as stream crossings.

Considerable strides have been made in roadway ditch design and sediment containment on clay (unpaved) roads. The traditional V-shaped ditches may still be used where space is a problem, but elsewhere road-works crews who have access to the right equipment have moved towards creating flat-bottom (trapezoidal) ditches (Figure 8.5). The flat design slows the velocity of storm-waters, allows normal meander flow patterns while minimizing side-slope erosion and allows for greater infiltration of water into the ground. In all ditches, the installation of rock check dams at regular intervals has helped to stop soil erosion within the ditch itself.

Figure 8.5 Traditional V-shaped ditch showing signs of water erosion (top) compared to flat-bottom ditch (bottom). Note check dams in V-shaped ditch are spaced too far apart to provide adequate erosion protection

Check dams do require routine cleaning and removal of built-up sediment. Watershed groups can assist the Department of Transportation and Infrastructure Renewal by monitoring the status of check dams in their area and notifying staff when maintenance is required. A full check dam may go un-noticed for several months and be ineffective in sediment control during that time.

Sediment traps have been installed in the ditches of many unpaved roads at points where stream crossings occur. These are essentially rock-lined depressions at the down-slope end of a ditch that prevent soil eroded from the road-bed from entering the stream (Figure 8.6). Again, these structures require regular maintenance and emptying, for which a watershed group can monitor and report. Stream crossings with culverts can also benefit from the addition of gravel or crushed asphalt bumps, to direct water into ditches or vegetation many metres before reaching the stream.

Figure 8.6 Trap on Ross Road (Brookvale) intercepts sediment running down the road before it can reach the river (background)

Private roads are subject to all of the same erosion issues outlined above, with none of the public financial resources available for routine maintenance. Watershed groups can prioritize the issues identified on private roads and work with landowners to resolve chronic problems. Culverts at stream crossings will likely be the greatest challenge, and some further advice is provided on culverts in Chapter 13.

The Island has more roads per capita than any other province in the country and many of our rural and coastal roads are susceptible to increased erosion pressure from a changing climate. Watershed groups can open a dialogue with communities to consider the possibilities for road decommissioning. As difficult as it may be for Islanders to give up roads, the financial costs of maintaining problem roads may become prohibitive in the near future.

8.1.3 Urban and rural development

Whether it is private home construction or "box store" development, the prevention of soil erosion and containment of sediment are inadequately addressed in Prince Edward Island (Figure 8.7).

Figure 8.7 Traditional storm water infrastructure was inadequate when an intense rain event coincided with the construction of a new mall in Charlottetown, summer 2011

“Green” storm water management is also in its infancy on the Island. Green infrastructure is a growing trend in North America and often alleviates multiple issues with storm-water, including flooding of basements, sedimentation of waterways, poor recharge to groundwater and pollution control. Toronto instituted a green infrastructure plan in the late 1990’s and have realized double benefits of a healthier Lake Ontario environment and cost savings to the city. They instituted a voluntary, then mandatory, downspout disconnect program, and have a well-recognized, winning strategy to encourage green roofs within the city. Other initiatives include rain barrels, rain gardens, infiltration trenches, pervious pavement in alleys and laneways, vegetated swales, urban tree-planting and rainwater plumbed inside buildings for non-consumptive uses.

Sedimentation of waterways can also be controlled through greater use of constructed wetlands. The technology for treatment wetlands is well-established, but has not been widely applied on the Island. Constructed wetlands slow down water and allow the suspended solids to settle out. They can also trap nutrients and contaminants travelling with the water. Wetlands may be particularly useful in nitrate removal from water (see Chapter 15).

Subdivision and city planning need more strategies to reduce the proportion of impervious cover in the landscape of Island watersheds (Figure 8.8). Pervious paving alternatives are available and appropriate for use in locations such as low-traffic-volume roads, driveways, sidewalks, parking lots, golf courses and laneways. Pervious concrete has withstood freeze-thaw cycles for many years in other jurisdictions. Cluster development rather than ribbon development also reduces the amount of roadway needed in a subdivision, while freeing up more area for communal green space to assist infiltration of rain and snow to groundwater aquifers.

Figure 8.8 Impervious surfaces and exposed piles of soil combine to create serious soil erosion issues during rain events in Charlottetown

8.2 In-stream Structures for Sediment Containment and Removal

When excess sediment builds up in watercourses, its removal is essential for proper functioning of the stream ecosystem. Removal of obstructions such as impoundments, “jackpots” of woody debris or dense live vegetation (e.g., alders) can release trapped sediment. Any in-stream work that releases sediment into the water column is likely to create further problems downstream if there are no structures in place to capture the material. Clay, one of the main soil types in sediment, has a high ion-exchange capacity, which means that it will hold onto compounds that do not dissolve easily (Waters 1995). Some pesticides fall into that category, and clay sediment has the potential to transport and hold these contaminants where it settles. Preliminary data from UPEI researchers indicate that sediments in some Island estuaries contain elevated concentrations of azinphos-methyl, the active ingredient in an insecticide that was routinely applied to potatoes in the recent past (Dr. M van den Heuvel, personal communication). The full extent of this contamination issue remains unknown, because extensive sediment testing has not been done. For this and other reasons, wisdom dictates that before obstruction removal begins, sediment management structures (and a sediment management plan) should be in place.

Pumps or bottom disturbance technologies have been used in other regions to rid streams of excess sediment. However, stream reaches with deep deposits of sediment – typical of Island conditions - would require massive amounts of slurry to be pumped onto land and contained. This is problematic from an engineering perspective and unlikely to be any less intrusive than the techniques in standard practice on the Island today. We have included the three methods of sediment removal that are used extensively on P.E.I. and that work well if properly applied. These are brushmats, in-stream sediment traps and bypass sediment ponds.

8.2.1 Brush mats

Brush mats are one of the most widely used stream restoration techniques on the Island. Any group removing in-stream obstructions, including alders, where there is a heavy sediment bed-load should consider brush mat construction in their work plan (Figure 8.9). Construction of brush mats is described separately in Chapter 10, since they serve an important role in habitat restoration as well as sediment containment.

Figure 8.9 Brush mat construction around a point bar in the Little Trout River

8.2.2 In-stream sediment traps

Purpose In-stream sediment traps focus the deposition of suspended sediment in one, accessible location. The natural stream bed is deepened to create a pool in which water velocity slows, resulting in the settling of sediment particles. From this location, accumulated sediment can be periodically and permanently removed from the stream ecosystem.

Where applicable In-stream sediment traps are suitable for low gradient, straight sections of streams (Figure 8.10). The technique requires a location with access for heavy machinery and space in or near the stream buffer for deposition of excavated material. These traps can be used in reaches where there is insufficient room for a bypass pond (see 8.2.3 below). In some sections of stream, two or three such in-stream sediment traps located close together (rock stabilization required at the end of each hole) might be more practical than one, but as of yet, this strategy has not been tried nor approved in P.E.I. The advantages would be more space for sediment to drop out of the water column and perhaps less movement of sediment if they are emptied before the one farthest downstream was full.

Figure 8.10 In-stream sediment trap in the Trout River (Tyne Valley), with riparian cover retained on one side

Precautions Make sure that the landowner is agreeable and knows what to expect, particularly the need to periodically empty the sediment trap. The stream bed has to be disturbed and even with sediment curtains in place, some material will be transported downstream during construction or when they are emptied. The sides of the trap must be tapered and the length is limited, so relatively small amounts of sediment can be contained. Where there is an old mill pond upstream, ensure that there is no sediment contaminant issue by getting a sediment screen test done (see Chapter 14).

The protocol for sediment trap construction was developed jointly by the Province and the federal Department of Fisheries and Oceans, based on the principle that traps would be used as a band-aid solution while the watershed group addressed the sources of sediment inputs to the river. They were not intended to be used indefinitely.

Construction Test the depth of substrate by driving a piece of rebar into the bottom. This is important, as, occasionally, the stream bottom can be too hard for a normal long-reach excavator bucket to penetrate. If the rebar easily enters the substrate, the excavator will be able to remove the material. The chosen storage area should be relatively flat and not be a wetland or have unusual or rare vegetation.

A permit from government is required and a site visit with regulatory authorities will outline requirements such as: length, depth and slope of sides in the sediment trap; stabilization of spoils and streambed upstream and downstream; use of in-stream sediment curtains to catch sediment moving downstream when digging; and use of a sediment fence between spoils and stream. If the watershed group does not yet have a watershed management plan, a fish habitat management plan will be required by DFO as part of the permit application process.

Contact the excavator operator well in advance to discuss plans, costs and terms of the permit. An operator experienced in sediment trap construction is invaluable! If your group has not constructed a trap before, ask other watershed groups for a referral. Make sure that the permit is in hand prior to proceeding. A fish rescue, involving seining or electro-fishing, may be required to remove fish from the area before work is started. A 180 spill response kit should be on site and, for very wet areas, swamp pads, which are logs used to keep the machine from sinking in the mud.

Figure 8.11 Hymac excavator removing sediment from the in-stream trap shown in previous figure (Tyne Valley)

Mulch the spoils with straw and seed them out with oats or a highways mix (oats, grains, grasses) as soon as possible once the excavation is completed. For safety reasons, erect a sign advising the public of deep water. Ideally, the side not accessible by excavator (or people) should be left vegetated to provide some overhead cover for fishes using the deep water. Some form of sunken cover would also help protect young fish from diving predators such as cormorants and mergansers. The cover must be easily moved when the trap requires clean-out and placed so that it is not immediately buried by sediment. We suggest trying movable pallets with cinder block weights, located within 3 – 4 m of the sediment deposition area in the trap (Figure 8.12). Always ensure that any cover does not pose a hazard for people walking around the edges of the basin.

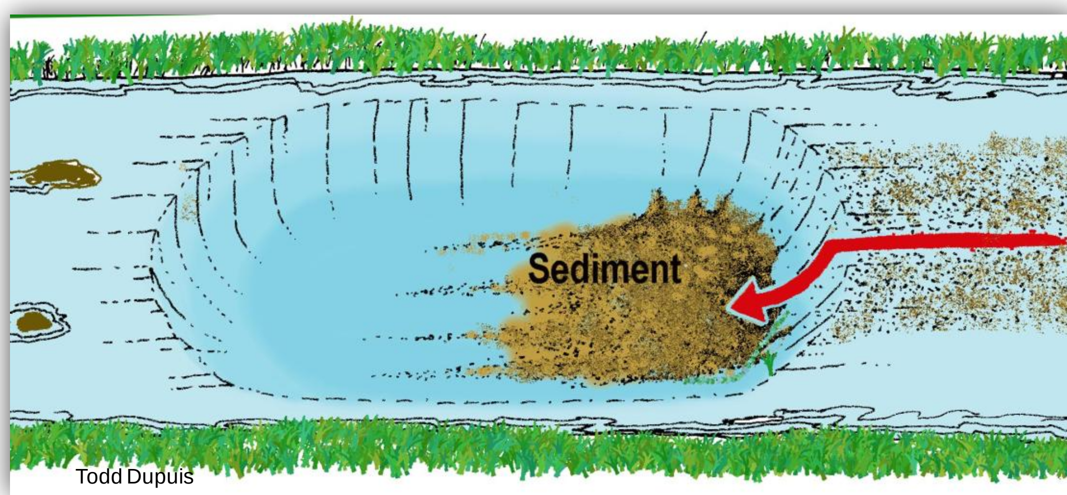


Figure 8.12 Depth profile and pattern of sediment deposition for an in-stream sediment trap

8.2.3 Sediment by-pass ponds

Purpose Bypass ponds serve the same function as sediment traps by permanently removing sediment from the stream ecosystem, but differ in being constructed beside the stream instead of in-stream (Figure 8.13). Stream water is diverted into the excavated basin after construction.

Where applicable Bypass ponds can be located beside low gradient stream sections. This type of sediment trap is excavated "in the dry" (e.g., when it is not yet connected to the stream), which limits the input of sediment into the watercourse during construction. The residence time of the water is much longer in this type of sediment trap, due to its size, allowing silt as well as larger material to settle out. They can also hold more sediment before clean-out is necessary.

Figure 8.13 Two examples of bypass sediment ponds: the original stream channel is visible at the point of granite armouring (top right, Trout River) and behind the partially completed sandbag barrier (bottom left, West River)

Precautions Bypass ponds are expensive and labour intensive to dig and maintain. The stream diversion structure can be time consuming to build if sand bags are used. "Blow-outs" of the diversion structure can occur if they are not constructed properly. The same permitting requirements apply as for sediment traps.

Construction Test the hardness of the stream bed with rebar to ensure the excavator can dig into the material. If it cannot, find another location. The site of the entrance channel from stream to bypass pond must be carefully chosen (Figure 8.14). The stream thalweg should be swinging in the same direction as the entrance channel. The exit channel from the proposed bypass pond back to the stream should also be on a similar angle as the stream thalweg in that location. In other words, the natural meander pattern should not be disrupted when water is diverted into the bypass pond.

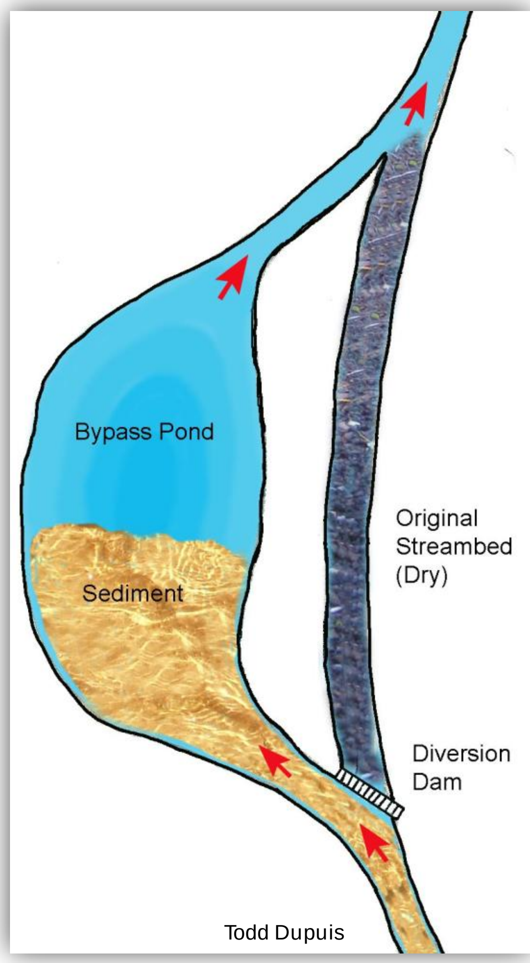


Figure 8.14 Entrance to a bypass pond is in line with the natural meander pattern of the stream

Clearly mark the boundaries of the proposed bypass pond and spoils deposition area. A site visit will be required by government authorities before permission to use the site is granted. The bypass pond should normally be as large and as deep as regulations permit. We recommend a sloped shoreline on all sides as a safety feature. Expect that bypass ponds will be accessed by anglers and others who could potentially fall in. Be sure to consider the size of the spoils deposition area, since the bypass pond will likely require periodic cleaning.

An angled sand bag barrier may be required to close off the original stream channel (Figure 8.15). A filter fabric blanket should completely cover the sandbags to protect them from break down upon exposure to UV sunlight. Larger stones should then be placed against both sides of the filter fabric, to further stabilize the structure. Be sure that the exit channel from the sediment trap and the opposite bank where it enters the stream are lined with stone to prevent erosion.

Figure 8.15 Construction of a sandbag barrier to close off the original stream channel and divert stream flow into the bypass pond (shown here on West River)

Because trout are often abundant in bypass ponds, both mammalian (mink) and avian (especially double-crested cormorant and common merganser) predators may concentrate their foraging efforts at these sites. Try to retain cover as recommended for in-stream traps on the bank that is not accessed by the Hymac and at depth using sunken pallets or other strategies (see section 8.2.2).

8.3 Clearing In-stream Obstructions

Some obstructions, such as household appliances, vehicle tires, and even car bodies should always be removed from streams (Figure 8.16). They impede sediment flushing, alter stream hydrology and do not belong in a natural system. However, watershed groups should notify and consult with authorities before attempting to remove unusual objects such as motor blocks that may still contain contaminants.

Figure 8.16 Garbage in the North River

Natural obstructions to watercourses may include live growth such as speckled alder or large woody debris such as whole trees. The altering or removal of obstructions may be essential, if the stream sediment load is considered excessive (Figure 8.17). In the past, stream restoration projects have sometimes removed too much live and woody debris. The composition of the stream substrate should be used as a guide when determining how much debris to remove. Stream reaches with rocky substrates should be left virtually untouched, whereas sediment-laden sections should have selective debris removed to speed water flow. Large woody debris is addressed in more detail in Chapter 11.

Figure 8.17 A woody debris "jackpot" that could force water into stream banks, Midgell River

8.3.1 A precautionary approach to alders

Island riparian zones have been altered by centuries of forestry and agricultural practices, such that they rarely resemble the mature Acadian forest of the past. Trees have either been cut or collapsed (e.g., old-field white spruce), leaving ideal habitat for alders to colonize. Alders thrive in areas with lots of sunlight and exposed sediment deposited by floods, where their roots are moist but not submerged for extended periods. They grow very rapidly in this environment, often growing in excess of one metre each year. Alders usually out-compete other tree and shrub species as long as soil moisture and light are prevalent; some other deciduous species, such as choke cherry and pin cherry may intermingle with them. Alders are early successional, nitrogen-fixing plants that may have to be pruned back, removed, left alone or encouraged to grow, depending upon the stream reach.

As alder clumps grow and expand, they provide good summer shade for the stream, but as they mature, they can collapse into the water. The collapsed branches may die, but the alder compensates by sending out multiple shoots. Within a few short years, particularly in narrow reaches of low gradient streams, a virtually impenetrable mass of alders can grow up and significantly impede stream flow (Figure 8.18). As the water slows, sediment drops out and the stream becomes wider and shallower, overflowing its banks with each high water event. This is common in watersheds with high sediment loading. Normal riffle-pool sequences disappear within the entrapped sediment. In these instances, alders will need to be intensively managed to restore the natural hydrology of the stream.

Figure 8.18 Excessive alder growth in-stream causes major flow obstructions. Here the West River is barely visible and laden with sediment

In some stream reaches, especially in old pond basins and sections of inactive beaver dams where banks are unstable, clumps of alders may become frozen in winter ice. During spring thaw, these clumps may dislodge and move, thus widening the stream, destabilizing banks and adding additional sediment to the system (Figure 8.19). Then, intensive alder management is recommended.

Figure 8.19 Alder clumps dislodged and moved downstream in a spring thaw

In wider reaches of stream, the alders may not reach all the way across the channel and therefore, even if collapsed in winter, do not usually retain sediment in large quantities. Often they provide important shade and cover for salmonids, and likely only need periodic trimming (Figure 8.20). Higher gradient channels can be composed primarily of hardpan (bedrock) with short areas of gravel and cobble. Removal of alders in these zones could encourage exposure of more hardpan and result in diminished salmonid habitat. Reaches of larger rivers such as the Morell, Dunk and West, and also lower portions of many smaller streams, may have alders as the principal type of cover available in some pool sections. In these instances, alders should not be removed.

Figure 8.20 Alder growth adjacent to wider reach of stream, providing cover without obstructing flow, Morell River

8.3.2 Intensive alder management

Where applicable Manage alders in low gradient streams where they collapse under the weight of winter snow and ice, collect debris and sediment, widen the stream channel and where fine sediment is the predominant substrate. In these conditions, the resulting (seasonally) flooded riparian zone is not conducive to the growth of a diverse riparian tree community.

Precautions Due to the amount of fine sediment tied up in this type of habitat, a sediment containment plan must be in place prior to the removal of in-stream vegetation or debris. When alders are removed, the site will become barren, mucky, and offer little cover for fish (Figure 8.21). However, after several high water events, there will be dramatic improvement and within a few years, normal riffle-pool habitat should be present. This is an excellent example of short term pain for long term ecological gain.

Figure 8.21 Sediment-laden section of stream revealed after removal of a dense cluster of alders

Procedure Remove all the alder cover within the channel width, including the dead limbs buried deep into the substrate. Large woody debris may be waterlogged and difficult to move but if swung parallel to the current and anchored, this may be added as cover at a later time (Figure 8.22).

Figure 8.22 Woody debris swung parallel to the water flow and anchored for habitat cover

Much of the alder removal will require chainsaws. Ensure that you have certified chainsaw operators on staff and that there are sufficient funds set aside for chainsaw maintenance. Stream work, particularly where there is a heavy sediment load, is very hard on chainsaws and they will require daily or at least weekly maintenance. In-stream chainsaw work should use vegetable-based bar oil, to limit the entry of petroleum products to the watercourse. Other field workers could carry folding pruning saws to tackle smaller alder growth.

Woody material taken from the stream and overhanging can be piled along the stream bank. Ensure that the piles are far enough back in the riparian margin that the top branches will not re-enter the stream during high water events. Alder and other deciduous woody material will break down quickly, usually within a few years. Coniferous woody debris will take longer to decay. Brush piles will have value for wildlife as they decay.

Cut alder patches (size and frequency determined by regulations) and plant riparian zone trees and shrubs in openings so that the riparian zone will develop with more trees and shade, thereby moving towards greater biodiversity. If you are planting new trees in the adjacent riparian margin, ensure that they are protected from rodents and snowshoe hares. The types of plantings and their protection are outlined in Chapter 9. Restructuring the riparian zone in this fashion will ensure that the in-stream restoration work undertaken will have long-term impacts, because the open, wet habitat ideal for alders will be replaced by drier, shaded, diverse riparian forest.

8.4 Sediment Control Summary

The unintended movement of soil resulting from human disturbance is one of the main challenges for watershed management on the Island. Watershed groups can identify and prioritize the problem sites for soil erosion and sedimentation in their watershed by walking their streams and/or assessing aerial land use maps. Best management practices in the agriculture, forestry, transportation, development and construction sectors can significantly reduce these losses of our precious Island topsoil. Watershed groups can encourage the use of BMPs, although the bulk of the responsibility lies with these sector groups and their respective organizations.

Waterways impacted by sediment can be restored using two main strategies, as outlined in this chapter. In order of application, the first is to develop a sediment containment plan and structures, while the second is to remove in-stream obstructions thereby freeing the material from the stream bed. The following table summarizes the restoration structures commonly applied to this problem.

8.4.1 Useful resources

Brown HJ, 2008. Pervious concrete research compilation: past, present and future. RMC Research and Education Foundation. Available online

Center for Watershed Protection, 1995. The economics of watershed protection. Watershed Protection Techniques volume 2 issue 4, pages 469-481.

Garrison N, and Hobbs K, 2011. Rooftops to rivers II: Green strategies for controlling stormwater and combined sewer overflows. Natural Resources Defense Council, NY. Available online

Imhof JG, 2011. Phased approach to the restoration of lower gradient, sediment-choked streams. Unpublished draft. Trout Unlimited Canada

P Jacobs and Associates Ltd. Best management practices. Soil conservation for potato production. Prepared for Environment Canada, PEI Fisheries and Environment, PEI Agriculture and Forestry, Charlottetown, PE.

US Environmental Protection Agency, 2004. Constructed treatment wetlands. USEPA, Office of Water. EPA-843-F-03-013. Available online

US Environmental Protection Agency, 2000. Guiding principles for constructed treatment wetlands: providing for water quality and wildlife habitat. USEPA, Office of Wetlands, Oceans and Watersheds. EPA-843-B-00-003. Available online

Waters TF, 1995. Sediment in Streams. Sources, Biological Effects and Controls. American Fisheries Society Monograph 7. AFS, Bethesda, MD.

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

Restoration Structure	Purpose	Where to Use	Where Not to Use	Additional Comments
Brush mats	Containment of suspended sediment, consolidation on stream bank; habitat creation	Where there is a heavy sediment bed-load; on point bars	On outside bend and other areas where natural sediment deposition does not occur	Brush mats serve many functions and their construction is covered in chapter 12
In-stream sediment trap	Collection of in-stream sediment for permanent removal	Low-gradient, straight sections of stream, downstream from heavy bed-load of sediment; space is insufficient for bypass pond	High-gradient reaches; where the riparian margin is ecologically sensitive; where sediment is contaminated	
Bypass sediment pond	Collection of in-stream sediment for permanent removal	Low-gradient reaches where there is sufficient space beside stream & the diversion of water does not disrupt the natural meander pattern	High-gradient reaches; where the riparian margin is ecologically sensitive; where sediment is contaminated	Bypass ponds are expensive to build and maintain (clean out)
Garbage debris removal	Removal of unnatural elements from waterway	Wherever dumping of materials is present	Assistance may be required where water contamination is a risk	Garbage should be completely removed and not piled in the riparian margin
Alder removal	Removal of excess flow obstructions	In narrow stream reaches where alder density is sufficient to impede sediment flushing & channelization of stream	In wider stream reaches where mid-channel remains open	

9. Riparian Zones

"*Riparian ecosystems are the most diverse, dynamic and complex biophysical habitats on land.*"

Steven Pelletier, quoted in Biodiversity in the Forests of Maine (1999)

A riparian zone is the land area adjacent to and influenced by a waterway (stream, river, lake or wetland). It is an ecological unit – not the same as the buffer zone, which is the stream margin protected by environmental legislation. Although they will overlap, the true riparian zone may be much wider than the legislated buffer zone. The width of a riparian zone will vary with the steepness of surrounding terrain.

Many Island watershed groups undertake reforestation of riparian zones to diversify plant communities in the long term. This chapter suggests some planting strategies, based on watershed group experiences and the recommendations of forestry professionals, for forest, grassland and coastal riparian habitats.

9.1 Forest Habitats

At the time of European settlement, the Island was almost completely covered in an Acadian forest. The Acadian forest community is composed of a mix of trees and shrubs similar to other forests transitioning between the Northern (Appalachian) Hardwood Forest to the south and the Boreal Forest to the north. Forested riparian zones are used by ~90 % of forest wildlife in this region (Simpson, 2010). Their ecological value to Island environments is great: they can provide overhead cover to the stream for fishes, cool water temperatures, minimize surface erosion and flood water damage, filter nutrients from runoff, and provide food and habitat for a variety of organisms. This section describes planting strategies that could eventually return the riparian zone of Island streams to an Acadian forest community structure.

9.1.1 Tree and shrub selection by habitat zone

With the exception of present and former impoundments, the riparian zone along most watercourses can be divided into three zones with variable widths (Figure 9.1).

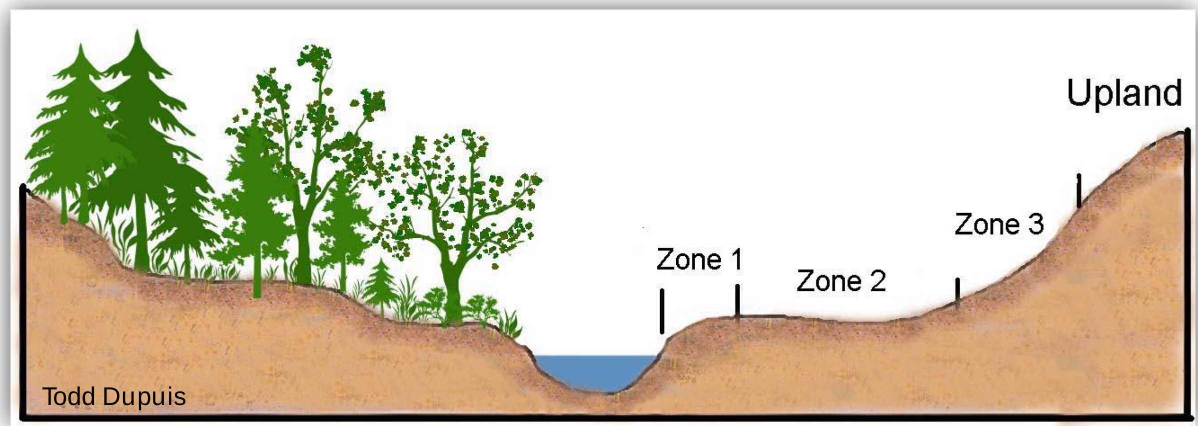


Figure 9.1 Zones in natural vegetation communities of a forested riparian margin

Zone I is the inner riparian (stream) bank, which extends from bankfull height inward for 5 metres (Figure 9.2). Trees, shrubs and grasses selected for this zone should be species that do well in full sunlight. Vegetation in this zone should also have extensive root systems that can tolerate wet conditions and stabilize stream banks. Plants close to the watercourse should shade the stream, produce food (berries) for wildlife, create edge cover for fish and large woody debris for aquatic organisms. Avoid using many species that are short-lived and densely branched. These lead to the tangled log jams commonly encountered with old-field white spruce stands today. Plant yellow birch on the long side of stream bends for bank stability and shrubs like red-osier dogwood and sweet gale on point bars and adjacent to brush mats.

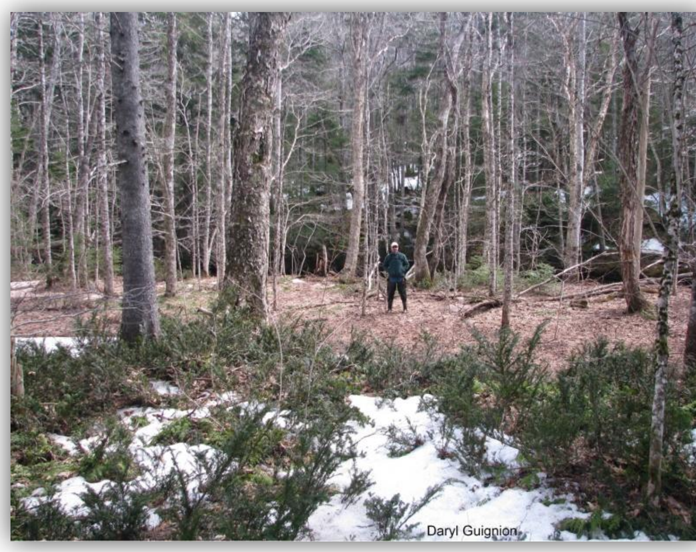


Figure 9.2 Zones of natural vegetation in a remnant Acadian forest along the West River; zones I (with person) and II (river in background)

Zone II is the riparian flats, which can have variable width. Select mainly deciduous trees for this zone, well spaced to allow good light penetration, especially in spring. This vegetation community should include large trees for cavity nesters, shrubs that fare well in muted light, and clumps of conifer trees for winter shelter. Depressions that function as riparian wetlands, often fed by spring seeps, should not be planted or modified (Figure 9.3).

Figure 9.3 Marsh marigold and native sedges in a riparian wetland

Zone III is the outer riparian bank, which blends into the uplands and will have variable width and slope (Figure 9.4). This vegetation community should include trees, shrubs and understory herbs suited to drier slopes. Remnant old growth forest fragments found on these bank locations have mainly conifer on the slopes and hardwoods where the bank levels off at the uplands.

Figure 9.4 Zones of natural vegetation in a remnant Acadian forest along the West River; zone III (left), moving into the uplands (right)

Within each zone, there may be many native trees and shrubs that are already flourishing and thus planting will involve adding a complement of missing or uncommon species. Some tree species are more prevalent at eastern or western ends of the Island (e.g., hemlock, cedar) and their historic distributions can be a good indicator of their suitability for your region (see Bourque and Hassan 2009). However, keep in mind that climate change is predicted to impact on species distributions over the next 100 years. Modelled predictions for tree distributions are discussed in Table 3.1.

If dense alders are present and your group wishes to diversify the canopy, it can be useful to create patch cuts in the alders and plant a variety of long-lived trees and shrubs suited to the riparian zone. The concept of patch-cutting was championed by Gary Schneider of Macphail Woods Ecological Forestry Project and is profiled for upland sites in the Acadian forest stewardship book of Jamie Simpson (2008). In the current, legislated 15 m buffer zone, watershed blanket permits restrict patch cuts in alders to being less than 30 m^2 in area and no closer than 5 m from each other. A watershed group may wish to plant a riparian reach in patches over the course of several years, to accommodate these permit restrictions and to promote an uneven age structure in the stand as a whole. Further background on alders in the riparian zone is provided in section 8.3.1 (clearing in-stream obstructions).

There will be some locations where single species dense stands, for example of white spruce, will occur. In these areas and with landowner permission, strip cuts and replacement with species more typical of the zone might be considered. A successive 25-year sequence of strip cutting and replanting of old-field white spruce stands is described by Gary Schneider in Simpson (2008). Tree species with tap roots may be advisable for planting in instances where a hard compaction zone is present from decades of repeated tillage; shallow-rooted species will be limited by this zone and susceptible to blow-down. Within the 15 metre buffer zone, removal of live trees or shrubs other than alders requires a special permit, which may be granted where there are issues of safety or where the group wishes to restore the margin to an Acadian forest structure. Canopy openings can be planted with shade-tolerant trees that have evolved to begin their life under an aging canopy structure. Diversifying the riparian forest community provides habitat for a wider variety of wildlife and also provides greater forest resilience against disease and insect infestation than is provided by monoculture stands (Figure 9.5).

Figure 9.5 Acadian forest trees planted in the Trout River watershed; the red oak was planted 7 years ago, the eastern white cedar 5 years ago, and the white pine 6 years ago

We would also recommend planting occasional patches of relatively short-lived trees such as balsam fir and trembling aspen, for canopy age diversification and for inherent wildlife values. Clumps of balsam fir planted about 2 m apart will provide shelter for birds from cold winter winds and predators. When trees die, they are referred to as snags, and holes made in softwoods of fir and aspen are used for nesting by birds (e.g., chickadees, nuthatches). These softwood snags are complemented by other hardwood snags used by birds with more robust bills for cavity-nesting and secondarily by other animals seeking shelter (squirrels, raccoons).

Some people would suggest that planting trembling aspen, a favourite food for beaver, in the riparian zone is only asking for problems with flooding. However, research elsewhere has clearly shown that the presence of male catkins of aspen is the single most important factor in the abundance of ruffed grouse. In winter, the snow under these trees tends to be deeper, softer and thus good habitat for ruffed grouse and other species that burrow in snow for shelter. Planting trembling aspen as one small component of zone III can therefore hold great value for enhancing the woodland bird community. Further wildlife enhancement strategies are described in section 16.2.

Where a watershed group wants to add uncommon species, these may not always be available at the provincial government nursery. If this is the case, the group may wish to try propagating some species themselves. The Macphail Woods Ecological Forestry Project has experience in propagation of many of the more uncommon native tree and shrub species and they are a great resource for watershed groups.

Before choosing shrubs and trees to plant, we recommend that watershed groups ask someone with forestry experience to visit and assess the sites to be planted. The Department of Agriculture and Forestry have a website (see 9.4.1 below) that groups can use to get specific recommendations. Be aware, however, that this site describes both native and introduced species. The following two tables offer suggestions on where various species of trees and shrubs could be planted in a hypothetical Island riparian zone (Figure 9.1). The locations and types of species represent what actually occurs in the few small, remnant old riparian zones that occur in the central part of the province.

Table 9.1 Native tree species recommended for planting in riparian zones

Trees	Comments	Inner Riparian Zone I (~5 m wide)	Riparian Flats Zone II (excluding wetlands)		Outer Riparian Zone III	
			Moist	Drier	Steeper gradient	Low gradient near top
Balsam fir (*Abies balsamea*)	Away from the stream edge, makes good large woody debris, clumps provide shelter from wind, sun to shade, soft snags for cavity nesters	Y	Y	Y	Y	-
Striped maple (*Acer pensylvanicum*)	Browse species (moose maple), shade to part shade	-	Y	Y	Y	-
Red maple *(Acer rubrum)*	Can grow in many sites, flowers very early, sun to part shade	Y	Y	Y	Y	Y
Sugar maple (*Acer saccharum*)	Found in drier areas back 4-5 metres, shade to part shade	-	-	Y	Y	Y
Mountain maple (*Acer spicatum*)	Needs shade but grows profusely in the right location, shade to part shade	Y	Y	Y	-	-
Yellow birch (*Betula alleghaniensis*)	Long lived, superb root system for stabilizing soil, sun to part shade	Y	-	Y	Y	Y
White birch (*Betula papyrifera*)	Birch bark canoes, sun to part shade, avoid sites with dry conditions	-	Y	Y	-	Y
American beech (*Fagus grandifolia*)	Nuts provide food for wildlife, sun to part shade, do well in woodlot openings	-	-	Y	Y	Y
White ash (*Fraxinus americana*)	Wood used for axe handles, lobster traps, hockey sticks, sun to part shade	-	Y	Y	-	-
Black ash (*Fraxinus nigra*)	Used in basket weaving, sun to shade	Y	Y	Y	-	-
Eastern larch (*Larix laricina*)	4-5 m away from stream edge, can live in damp locations, sun to part shade, makes strong rot-resistant lumber if the tree is healthy when cut	Y	Y	Y	Y	Y
Apple (*Malus spp.*)	Requires good sunlight from all directions, great food tree for many wildlife species	Y	-	-	-	Y
Ironwood (*Ostrya virginiana*)	Incredibly strong wood, slow growing, shade to full sun	-	Y	Y	Y	Y
Black spruce (*Picea mariana*)	Well spaced but may grow very large, sun to part shade, susceptible to saw fly in dry conditions, 4-5 m from stream	Y	Y	Y	-	-
Red spruce (*Picea rubens*)	Tall, straight, timbers used to rebuild Fortress of Louisburg, sun to part shade, not tolerant of windy conditions	-	-	Y	Y	Y

Trees	Comments	Inner Riparian Zone I (~5 m wide)	Riparian Flats Zone II (excluding wetlands)		Outer Riparian Zone III	
			Moist	Drier	Steeper gradient	Low gradient near top
White pine (*Pinus strobus*)	Outstanding trees, sported the "Kings broad arrow" for navy masts, sun to part shade	-	-	Y	Y	Y
Trembling aspen (*Populus tremuloides*)	Great beaver attractant, sun to part shade, soft snags for cavity nesters	-	-	-	Y	Y
Balsam poplar (*Populus balsamifera*)	Well back from the bank, large cavity nesting tree, sun to part shade	-	Y	Y	Y	Y
Red oak (*Quercus rubra*)	Our provincial tree, can have extensive acorn production, sun to part shade	-	-	Y	Y	Y
Eastern white cedar (*Thuja occidentalis*)	Scattered, 4-5 m away from stream edge, long lived, great cover, full sun to part shade, rot-resistant lumber	Y	Y	Y	Y	-
Eastern hemlock (*Tsuga canadensis*)	Shade tolerant, dry soils, sun to full shade, protect from winds	-	-	Y	Y	Y
American elm (*Ulmus americana*)	A beautiful tree that should survive several decades with Dutch elm disease-resistant stock, tolerates flooding	-	Y	Y	Y	Y

Table 9.2 Native shrub species recommended for planting in riparian zones

Shrubs	Comments	Inner Riparian Zone I (~5 m wide)	Riparian Flats Zone II (excluding wetlands) Moist	Drier	Outer Riparian Zone III Steeper gradient	Low gradient near top
Speckled alder (*Alnus rugosa*)	Provides cover over pools in wider sections of stream, full to part sun	Y	Y	Y	-	-
Shadbush / Serviceberry (*Amelanchier spp.*)	Prefers good sunlight, 2-3 m from stream edge, flowers early in spring	Y	Y	Y	Y	Y
Black chokeberry (*Aronia melanocarpa*)	Good food source for wildlife, full sun to part shade	Y	Y	Y	Y	Y
Alternate-leaf dogwood (*Cornus alternifolia*)	Great wildlife food, part shade to shade	Y	Y	Y	Y	Y
Red-osier dogwood (*Cornus stolonifera*)	Prefers full sunlight, tolerates shade, edge of stream bank, food for wildlife	Y	Y	-	-	-
Beaked hazelnut (*Corylus cornuta*)	Good food source for wildlife, full sun to part shade	Y	Y	Y	Y	Y
Hawthorn (*Crataegus sp.*)	Good sunlight	-	-	-	Y	Y
Winter berry (*Ilex verticillata*)	Prefers good sunlight, tolerates part shade, fruit holds into winter	Y	Y	-	-	-
Sweet gale (*Myrica gale*)	Good sunlight, edge of stream bank	Y	Y	-	-	-
Mountain holly (*Nemopanthus mucronatus*)	Found in damp woods and bogs, full sun to part shade	Y	Y	-	-	-
Choke cherry (*Prunus virginiana*)	Great source of fruit for birds and small mammals, black knot is a serious problem, full sun to part shade	Y	-	-	Y	Y
Wild rose (*Rosa virginiana*)	Good shelter and food for wildlife, full sun to part shade	-	-	-	Y	Y
Common elderberry (*Sambucus canadensis*)	Moist soil, can withstand flooding, full sun to part shade	Y	Y	-	-	-
Mountain ash **(***Sorbus americana*)	Two species will grow in partial shade, good sunlight, high on stream bank where flooding is rare	-	Y	Y	Y	Y
Meadow sweet *(Spiraea latifolia)*	Provides food for birds, full sun	Y	Y	-	-	-
Ground hemlock *(Taxus canadensis)*	Evergreen shrub, harvested for cancer drugs, seeds and wilted twigs are poisonous, shade to part shade	-	Y	Y	Y	Y

Shrubs	Comments	Inner Riparian Zone I (~5 m wide)	Riparian Flats Zone II (excluding wetlands)		Outer Riparian Zone III	
			Moist	Drier	Steeper gradient	Low gradient near top
Hobble bush (*Viburnum alnifolium*)	Good berry producer, full sun to part shade	-	Y	Y	-	-
Wild raisin (*Viburnum cassinoides*)	Mixed woods, clearings, full sun to part shade, susceptible to Viburnum beetle	Y	Y	Y	Y	-
Highbush cranberry (*Viburnum trilobum*)	Holds fruit all winter, full sun to part shade, susceptible to Viburnum beetle	Y	Y	Y	-	-

9.1.2 Planting methods and tips

Planting location, species composition and densities should reflect the needs of the site and the wishes of the landowner. Where possible, it is preferable to create a planting plan in the fall for spring planting. A person with good plant identification skills can advise on which species may already be present or within the seed dispersal distance from a planting site. To help volunteers or summer students who may be less familiar with native trees and shrubs, particularly early in the year before or just after leaf-out, it can be helpful to colour-code species using flagging tape. In the proposed planting sites, existing shrubs and trees may be flag-coded, and colour-coded stakes driven into spots where nursery stock is to be planted.

Appropriate spacing for trees and shrubs will enhance the development of different canopy levels. A standard planting spacing is 3 – 4 m (10 – 13 ft). Tighter 3 m spacing is often recommended for upland forestry plantations, because it encourages the trees to grow up rather than out, creating a high canopy with straight, less-branched trees. Much wider spacing, as much as 12 m (40 ft), has been applied to ecological restoration in uplands by groups such as Macphail Woods Ecological Forestry Project where the objectives are less strictly mechanized commercial forest harvesting. Be aware, however, that wider spacing may create a shorter canopy of broader trees with fewer sub-canopy vegetation layers. A happy medium may be to use a wider spacing between trees, but inter-plant with shrubs and small trees that will compete for lateral space and force the canopy trees to grow up instead of out.

Once species are chosen and plants are on-site, the planting process itself is fairly straight-forward. Nonetheless, survival rates can be affected by improper planting. Trees and shrubs typically come in 1-gallon pots and sometimes can be slightly root-bound. It is important to loosen roots either by hand or by a few lateral cuts to ensure that they don't grow in a circular fashion. This provides more stability from high winds (Figure 9.6).

Figure 9.6 Loosening pot-bound roots before planting

Good root growth can also be encouraged by digging large holes, at least two to three times the size of the nursery pot (Figure 9.7). Scratch the sides of the hole to roughen the surface and encourage better outward root growth. The surface of the soil should be even with that of the surrounding soil, not above or below. Also, once the plant is in the ground, the surrounding soil must be tamped down firmly to eliminate excess air pockets around the roots.

Figure 9.7 Dig a good-size hole to help roots grow outward

Very dry ground should have water added to the bottom of the hole before planting and a mulch of bark or straw added around the planted tree to encourage the surface retention of moisture during the summer. Compost additions to each hole are advisable for soils low in organic matter (e.g., many agricultural soils), but not essential if a good source is not readily available. In grassy locations, the use of a hawk attachment on a brush saw may be useful to clear spots prior to planting (Figure 9.8). A little extra time spent during the planting process can result in marked improvements in seedling survival over the long term.

Figure 9.8 Hawk attachment on a brush saw for planting site preparation in grass

9.1.3 Maintenance of plantings

One of the greatest disappointments that some watershed groups have experienced is to return to sites planted so carefully the previous year and find the trees and shrubs browsed. The provincial government Frank Gaudet Nursery has provided high quality plants to watershed groups over the past number of years. It is the responsibility of the watershed groups to put the plants in proper environments and do whatever possible to protect them from damage by voles, rodents, or snowshoe hare.

The principal culprit that will browse most trees and shrubs during winter is the meadow vole (*Microtus pennsylvanicus*). In winter, they are active under the snow in what is referred to as the subnivian environment (above the frozen ground but under the snow). Hence, they are relatively protected and may even produce young in nests there. If a crust freezes on the top layer of snow and more snow falls, the meadow vole then has a three dimensional habitat. It forages over the layer of crust, feeding on bark and twigs of various plants that were formerly out of reach. Therefore, if they did not girdle the plant at the ground level, they have another opportunity to kill it in their elevated habitat.

Meadow voles are usually only a serious problem in open habitat such as old fields where they thrive on green, living grasses. In woodland areas, they are replaced by red-backed voles (*Clethrionomys gapperi*), which may reach high numbers but do far less browsing on trees. The answer to meadow vole problems is to refrain from planting in areas of dense grasses or to add a protective barrier to the plant in late summer. In areas where soil organic matter is high (~5%), the soil does not freeze as thoroughly so voles often burrow under the surface and cut off roots. In such sites, the protective device should penetrate the soil 5 – 6 cm.

In woodland areas and along field edges, snowshoe hare will be the most likely to sample your new plantings. Snowshoe hare, like many other herbivores, switch between a herbaceous (green, leafy) dominated diet in the summer and a woody (twig) dominated diet in the winter. Most of the browse damage to trees will occur over the months when green growth has slowed or stopped. However, white pine may have terminal buds clipped as early as mid-summer so waiting for autumn to protect the preferred woody species from snowshoe hare may be too late. Other preferred woody browse includes red oak and sugar maple.

It is essential to monitor survival of shrubs and trees planted, at least for the first couple of years, and adjust protective strategies if the survival rate is less than 75%. Some protection strategies that have proven successful in watershed plantings are shown in Figure 9.9. The least costly method is likely the use of three or four wooden stakes and cut lumber wraps (used to protect lumber during transportation to retail stores). Often, all materials except staples and staple gun can be collected from building supply or wood manufacturing stores for free. If using lumber wraps, ensure that the black side faces inward, so as not to over-heat the tree or shrub inside. These should be lowered during the summer to allow unhindered photosynthesis. This method is particularly successful in stopping hare browse and limb breakage from heavy snow loads. Meadow vole browse or bark ringing (a lethal browse) may be best prevented using plastic ring guards or a wider ring of hardware cloth. Hardware cloth may be the most effective, particularly when placed into the ground; however, it is also the most expensive option and the cloth itself is not particularly easy to work with so the wrapping will be more labour intensive. Groups can try a variety of methods at one location to test effectiveness. Voles and hares will show preferences in the species they browse, so the more expensive options should be reserved for their preferred browse species.

Figure 9.9 Strategies to protect woody plants from browse damage by meadow voles and snowshoe hares; left to right – hardware cloth, plastic ring guard, lumber wrap & stakes

In the early spring when plantings are monitored for survival and, depending on the protection strategy, unwrapped, it is a good idea to carry secateurs for pruning of broken branches. Pruning helps prevent fungal disease and in some cases will reduce insect damage. Insect grazers are attracted by chemicals produced by stressed plants. There will always be some limb breakage from winter snow loads.

Many plantings in previously agricultural settings will experience heavy competition from grasses. These areas will require routine weeding, grass trimming or the application of a heavy mulch to suppress grasses at the time of planting. A mulch of wood chips is likely to last the longest, if a source (e.g., lumber or saw mill) is readily available. Brush saws can be useful to control regrowth of alders and grasses in open plantations with young trees and shrubs.

Additional site-specific maintenance may be necessary in high-traffic areas. Agricultural machinery, 4x4 bikes and snowmobiles can damage plantings. In these areas, it is advisable to cordon off the planting sites with stakes, flagging tape and/or lumber wrap fencing.

9.2 Grassland Habitats

Natural grassland habitats on the Island are mainly associated with sand dune ecosystems. Marram grass (*Ammophila breviligulata*) is especially predominant on the extensive coastal sand dunes of the north shore. These ecosystems appear to be rather simple but the zonation from front to back dunes, slacks and adjacent coastal woodlands can be very complex with many micro-climates. Their position at the harsh edge of land and sea makes them vulnerable to change by humans and nature.

With the introduction of beavers to the Island, conversion of wooded riparian zones to grassy meadow and grass/alder swales began in low gradient stream reaches (see Chapter 14). Over the past couple of decades, these extensive fresh meadows have been expanding rapidly. The width of the riparian zone that is converted to grasses varies from a few meters to about 100 metres, depending upon the terrain; the length may include the whole stream reach. The impact of this conversion on wildlife has not been studied on the Island and it is not yet known whether the loss of so much riparian woodland and its inhabitants is counter balanced by an increase in different wildlife populations in the wet meadows. Water quality, in particular temperature and dissolved oxygen, should be the deciding factor as to whether the grassy meadow should be left as is or an attempt made to replant trees and thus provide shade to the stream. If water quality is good, and the stream has appropriate riffle-pool sequences and is not excessively wide, it might be best to forego tree planting. Grasses can do an excellent job of binding the soil and stabilizing the banks.

In Island streams, sediment is regularly deposited on point bars and behind partial obstructions, providing sites for grasses to colonize (Figure 9.10). When water slows behind partial stream barriers, as found at some road culverts, regular riparian flooding will kill conifers and provide suitable habitat for grasses and shrubs that better tolerate extended wet periods.

Management of grasses along streams is primarily accomplished by adjusting the amount of shade. Overhead canopy limits grasses, while full sunlight encourages them. Be aware that these open sites, often initially having exposed soils, are favoured by a number of invasive plant species for colonization. Be vigilant in preventing the establishment of species such as purple loosestrife, Japanese knotweed and Himalayan balsam (see Chapter 16 for more details). Native grass species should also be encouraged over exotics, such as switch-grass.

Figure 9.10 Grasses in the riparian margin (left) and on islands in-stream near the head-of-tide

9.3 Coastal Habitats

The coastal environment can be a harsh one for plants, with salt spray and high winds as ever-present stresses on vegetation. Most coastal vegetation communities are composed of a less diverse assemblage of species that are tolerant of these more extreme growing conditions. On the Island, many watershed groups will encounter dune systems, steep sandstone cliffs or sloped bay shorelines in these locations. On dunes, the community is dominated by marram grass with shrubs behind. On cliffs and more sheltered bays, there may be a smattering of white spruce, sometimes toppling over the edges, along with a variety of low-growing shrubs.

A common concern in coastal habitats is erosion from waves and winter storm action; watershed groups may be seeking strategies to stabilize slopes adjacent to residential developments or roads. Although some stabilization can occur, it is not possible to prevent this natural erosion process. The issue is not the erosion per se, but the placement of infrastructure and homes too close to the water.

There is, however, some room to strengthen the resilience of the natural ecosystem in these locations, where human activities have exacerbated the rate of erosion. The following table recommends some hardy tree and shrub species that could be planted in estuaries and coastal margins, to potentially slow the erosion to a level at which the vegetation community can accommodate and adapt. Keep in mind, if a slope in a bay region is being planted, the full expanse should be planted. Stabilizing the slope in only one or two locations will simply divert the force of wave action to the adjoining bare slopes, where the rate of erosion will then be accelerated. This has been seen in some locations where one landowner has paid to armour the shoreline with stone and produced greater erosion of neighbouring properties as the wave force diverts to those locations. Similarly, planting full-canopy trees such as white spruce and jack pine within 5 – 10 m from the edge of the bank will ultimately serve to de-stabilize the soils. White spruce in particular, with its shallow root system, is susceptible to blow-down and will take a good portion of the sandy soil bank with it when it falls. Elsewhere on rocky shores, white spruce are prominent and longer-lived on the coastline (e.g., Newfoundland). Shrubs and deep-rooted, shorter trees are far better suited to these Island coastal riparian margins.

Table 9.3 Native tree and shrub species suitable for planting in coastal riparian zones

Species	Drought tolerant	Wind tolerant	Salt tolerant
Trees			
Grey birch *(Betula populifolia)*	-	Y	Y
White birch *(Betula papyrifera)*	-	Low - moderate	Low - moderate
Apple *(Malus spp.)*	-	-	Y
Jack pine *(Pinus banksiana)*	Y	Y	Y
Red oak *(Quercus rubra)*	-	Y	Y
Showy mountain ash *(Sorbus decora)*	Y	Low - moderate	Low - moderate
Shrubs			
Downy alder *(Alnus crispa)*	Y	Y	Y
Serviceberry *(Amelanchier spp.)*	Y	Y	Y
Purple-fruit chokeberry *(Aronia prunifolia)*	-	Y	Low - moderate
Sweetfern *(Comptonia peregrina)*	Y	Y	Y
Red-osier dogwood *(Cornus stolonifera)*	-	Y	Low - moderate
Hawthorn *spp.*	-	Y	Low - moderate
Common juniper *(Juniperus communis)*	Y	Y	Y
Shore juniper *(Juniperus horizontalis)*	Y	Y	Y
Sweet gale *(Myrica gale)*	-	Y	Y
Northern bayberry *(Myrica pensylvanica)*	Y	Y	Y
Staghorn sumac *(Rhus typhina)*	Y	-	Low - moderate
Wild rose *(Rosa carolinia)*	-	Y	Y
Spiraea *(S. tomentosa)*	Y	Y	Y
Domestic blueberry *(Vaccinium angustifolium)*	Y	Y	Y
Groundcovers			
Silverweed *(Potentilla anserina)*	Y	-	-

Some restoration of dune systems has been attempted by Island Nature Trust and watershed groups, through marram grass planting programs. These appear to have been successful in establishing a grass cover again. However, it is still unclear how these restoration projects will fare under increasing pressure from extreme winter storm events, predicted to come with climate change. At this point in time, there are no government-sponsored planting programs that provide free grasses or perennials for coastal and grassland riparian locations.

9.4 Riparian Zone Summary

Restoration of riparian zones is gradually occurring through the work and long-term vision of watershed groups and the assistance of the provincially-run forest nursery. A changing climate adds an element of uncertainty that may best be addressed by diversifying plantings. Section 3.6.1 describes what trees are predicted to fare the best and worst with climate change. This chapter describes the trees, shrubs and grasses that are suited to specific micro-climates (zones) in the riparian margin. If a plant is positioned in an optimal setting, it may be able to overcome any additional stresses created by warmer, wetter, more extreme weather patterns. Plants must also be given a good start, by thorough maintenance and browse protection for the first few years after planting. The following table summarizes the settings watershed groups might be expected to plant and what diversity of vegetation would best suit those environments.

Environment	Vegetation Components	Comments
Riparian margin, upstream from the head-of-tide, zone I	Light-loving trees, shrubs and grasses, tolerant of periodic flooding	These species should have well-developed root systems to hold the bank
Riparian margin, upstream from the head-of-tide, zone II	Deciduous trees, shade tolerant shrubs, herbaceous under-story plants	Riparian wetlands should be retained as is, or enhanced with wetland plants
Riparian margin, upstream from the head-of-tide, zone III	Mixed wood forest with shrub and herbaceous under-stories	Soil moisture conditions will change along the slope and must be considered
Riparian margin, beaver meadow	Light-loving native grasses and shrubs	Where stream water quality is reduced, a tree canopy may be gradually established
Estuaries and coastal shorelines	Salt- and wind-tolerant shrubs near bank, trees well back from bank	Shorelines cannot be patch planted, white spruce is not recommended by cliffs
Dunes	Marram grass on dune, shrubs behind	These are naturally highly dynamic systems

9.4.1 Useful resources

The MacPhail Woods Ecological Forestry Project and the provincial Frank Gaudet Forest Nursery have online guides to native trees and shrubs (note the nursery site also lists non-native hardy species).

Bourque CP and Hassan QK, 2009. Modelled potential tree species distribution for current and projected future climates for Prince Edward Island, Canada. Available online

Simpson J, 2010. *Restoring the Acadian Forest. A Guide to Forest Stewardship for Woodlot Owners in the Maritimes*. Four East Publications, Tantallon, NS. Available online

Tallamy DW, 2007. *Bringing Nature Home. How You Can Sustain Wildlife with Native Plants*. Timber Press, Portland, OR.

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

10. In-Stream Habitat Restoration – Brushmats

Natural in-stream habitats are complex, with a diversity of micro-niche environments available for aquatic macroinvertebrates and freshwater fishes. Where a stream bed does not naturally contain much complexity (for instance, where rocky substrate is not naturally present) or where the stream environment has been degraded, introduction of natural structural components can diversify the habitat. This chapter describes brushmats and some natural cover elements that can be encouraged in-stream. Large woody debris and structures that alter flow patterns are described in the following two chapters.

10.1 Brushmats

Brushmats are one of the most widely used stream restoration techniques on the Island. They are most often installed to capture in-stream sediment, particularly where in-stream work flushes a heavy bed-load. However, they ultimately become permanent and natural structures in the stream that perform many more habitat functions. They can provide cover for juvenile fishes after hatching and a substrate for macroinvertebrates. In some instances, they may also be used to narrow over-widened stream reaches.

10.1.1 Installation of brushmats

Purpose Brushmats consolidate sediment by accelerating the deposition process on the inside of stream bends. They also concentrate stream flow toward the outside bend, deepening the stream channel, and encouraging undercut banks. Finally, they provide in-stream cover for young-of-the-year brook trout and attachment sites for insects.

Where applicable Brushmats should only be employed where high sediment loading is a problem. These structures are most commonly placed overtop of point bars on the inside edges of stream bends where deposition of fine sediment naturally occurs (refer to section 2.3.1). The woody material that comprises the brushmat provides a sediment trapping matrix that accelerates the encroachment of the inside bank (Figure 10.1). The resulting narrowing of the channel increases water flow, flushing fine sediments from the stream bed. Most of the sediment trapping will occur during high flow events and it may take a few years before the brush mat is completely covered, forming a new inner bank perimeter. The new bank will re-seed itself, hiding evidence of the restoration work.

Figure 10.1 Completed brushmat on the Little Trout River

Precautions It is important not to extend the brushmat beyond the borders of the existing point bar as doing so may put too much pressure on the opposite bank. Periodic inspections are required to ensure the brushmat remains intact, functional and the opposite bank is not eroding prematurely. Providing protection to the opposite bank may be required. Where there is a high density of in-stream obstructions that are slated for removal, it may not be possible to install brush mats immediately. In these instances, the regular riffle-pool sequence and stream width may not be evident until after a spring flood event. Installation of brushmats should be delayed until the location of point bars is obvious.

Installation Constructing a brushmat consists first of pounding 1 – 1 ½ m long wooden stakes about 1 m apart into the substrate along the outside perimeter of the existing point bar at low flow. Be sure not to infringe further into the channel than the existing point bar (Figure 10.2). Also, place a series of stakes along the existing inside stream bank. Cover the point bar with the conifer branches working up from the downstream end making sure that the stump ends are facing upstream and the branches are wedged against stakes at about a 45° angle to the flow. Overlap the branches like shingles.

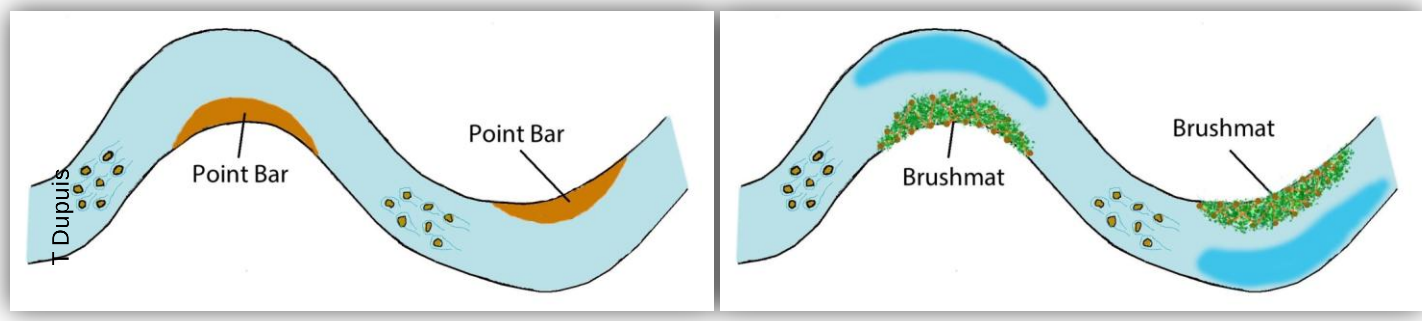


Figure 10.2 Location of brushmats on point bars

Where conifers are not readily available, Christmas trees may be stock-piled or alders used in bundles. Fasten plastic twine (jute degrades too quickly) across the brush from one stake to the other to help compress and secure the brushmat. Extra stakes can be added to the middle of the brushmat for additional stability. Brushmats should slope down toward the water and not be higher than the existing bank (Figure 10.3). Tapered brushmats provide important protection for juvenile trout during high flows. Brushmats can be topped up in subsequent years, as sediment accumulates in layers, as long as they retain a natural slope and do not extend higher than the natural bank.

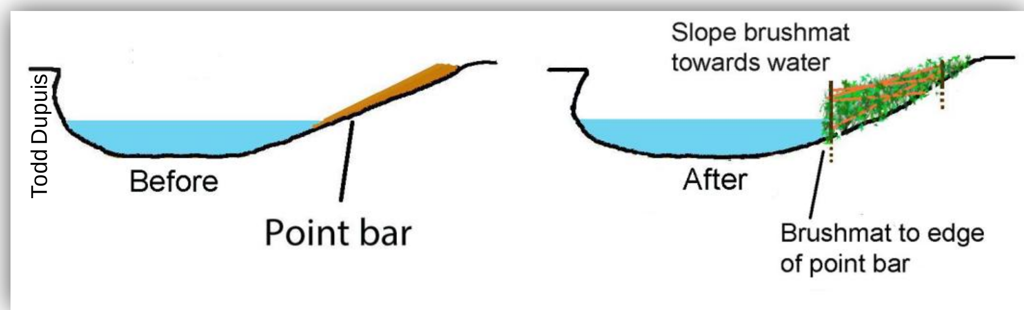


Figure 10.3 Cross-sectional view of a brushmat with a taper up the bank

The following time-series of photos show a brushmat project on the Little Trout River (Figure 10.4). The point bar (upper left) was the location chosen for a brushmat, which was completed in 2007 (upper right). After four years, there are no signs of the brushmat in 2011. The new inner bank has seeded itself, blending with the surroundings. Note that the substrate in the channel has had most of the fine sediments flushed out.

Figure 10.4 Time sequence of brushmat installation on the Little Trout River, from 2007 (top) to 2011 (bottom)

10.2 Other Natural Cover Habitats

There are other habitat elements that can be achieved by indirect means, through the work of watershed groups. A stream that is functioning well will achieve these elements on its own, given the right local conditions.

Aquatic plants provide a home for any number of invertebrates, including terrestrial species with an aquatic larval stage, such as dragonflies, midges and caddisflies. They also provide cover for small fishes, protecting them from larger fishes and wading birds. Overhanging bank vegetation and aquatic vegetation both increase the formation of ice in winter, which helps to moderate the extreme changes in water temperature that can occur otherwise. The presence of aquatic plants is largely determined by the amount of sunlight reaching the stream surface. Where the stream widens and the water slows enough to drop some sediment, aquatic plants will establish in the absence of competition from fast-growing alders and willows. The larger rock sizes also encourage growth of periphyton (plants and animals that attach to underwater surfaces and may cause rocks to be slippery) in more open stream habitats.

Undercut banks are another important source of cover for fish and other aquatic animals and may serve as protected den sites for mink or muskrat in slower-flowing reaches (Figure 10.5). The establishment of undercut banks can be encouraged by riparian planting of grasses (see Chapter 9) and by careful planning of a natural pool – riffle pattern and stream meander.

Figure 10.5 Natural undercut bank with the addition of a split log for extra cover, upper West River

10.3 Brushmats and Cover Restoration Summary

Diversification of habitat cover structures in streams benefits the aquatic ecosystem as a whole. Brushmats, boulders, cobble, gravel and woody debris all add complexity to our coldwater Island waterways. However, it is critical that the stream reaches under consideration are well understood, in terms of how they currently function, before restoration activities are attempted. For instance, in areas that are critical spawning habitat for brook trout, the site should be left, or cover and gravel added with professional advice. Stream edges downstream from such an area would need special attention to support large populations of juvenile trout.

Brushmats are principally constructed for sediment containment in streams with a heavy sediment bed-load. However, they also contribute to in-stream habitat by providing cover for juvenile fish and attachment sites for aquatic invertebrates. They should be constructed on point bars, the natural location for sediment deposition in a meandering stream. Where the natural meandering pattern is not well understood, brushmat construction should be delayed until more background data is available on the stream hydrology.

10.3.1 Useful resources

Dupuis T, Guignion D, MacFarlane R, and Redmond R, 1994. A technical manual for stream improvement on Prince Edward Island. Morell River Management Co-op Inc., Morell, PE

Heaton MG, Grillmayer R, Imhof JG, 2002. Ontario's stream rehabilitation manual. Ontario Streams, Belfountain, ON Available online

Hunt RL, 1993. *Trout Stream Therapy*. University of Wisconsin Press, Madison, WI

Waters TF, 1995. Sediment in Streams: Sources, Biological Effects and Control. American Fisheries Society Monograph 7, Bethesda, MD

Links to all online resources are provided on the Watershed Alliance website; www.peiwatershedalliance.org

11. In-Stream Habitat Restoration – Large Woody Debris

In-stream restoration works to re-establish natural structures that would have been present before habitat degradation took place. In PEI, as elsewhere, the structures that have traditionally been re-introduced target specific habitat needs for fishes; however, in reality, they have also served to diversify habitats for macro-invertebrates and plants.

A recent review of the effectiveness of in-stream rehabilitation techniques used in 345 studies across the world (Roni et al. 2008) makes clear recommendations about the timing of these efforts in the larger context of watershed management. Frequently, in-stream structures fail if they are installed before normal watershed processes have been restored. In other words, the techniques described in chapters 11 and 12 should be implemented in the final stages of restoration. On the Island, that means stream reaches should be cleared of blockages or in-stream obstructions such as dense alder growth, to allow the bed-load of sediment to flush and a natural meander pattern to partially re-establish before in-stream habitat restoration starts. If not, history shows that the introduced structures will often not function as they are intended, will likely not last more than a few years and, what's worse, can cause unintended problems downstream.

11.1 Importance and Functions of Large Woody Debris

In a natural setting, trees hang over or fall into a river and contribute a critical habitat component called Large Woody Debris (LWD). LWD is a general term referring to all wood in streams greater than 10 cm in diameter and 2 m in length, naturally occurring or artificially placed and including whole trees, branches, root wads, logs and log-jams (Figure 11.1). Almost all LWD in streams is derived from trees located in the riparian zone. Streams affected by urbanization, agriculture, development, or clear cuts often lack the quantity of LWD necessary to maintain an ecologically healthy and stable ecosystem. Streams with adequate LWD tend to have greater habitat diversity, a natural meandering pattern and greater resistance against high water events. In recent years, biologists have come to recognize the importance of LWD in stream channels and the contribution it makes to channel function, fish habitat and aquatic biological diversity.

Figure 11.1 Natural large woody debris on Bristol Creek

Large woody debris that falls across the entire stream channel can jam and anchor itself, forming a plunge pool downstream as water flows over the wood. These natural digger logs (see section 11.2 below) provide localized scour pools and excellent cover for fish. The natural digging effect of water being forced through or under LWD provides gravel that can improve downstream habitat. The accumulation of LWD debris also provides water velocity shelters for fish. Brook trout often seek out woody debris to hide from predators and avoid swift current.

LWD can also serve a critical function in controlling the grade of the stream channel by holding back or stabilizing the movement of gravel and other substrates. Atlantic salmon have been known to spawn in close proximity to LWD where it creates favourable changes to the stream substrate (Figure 11.2). It can also advance the transport of fine sediments where the accumulated wood has narrowed the channel thereby increasing the water velocity. LWD that has accumulated along the stream banks can often protect banks from erosion during high flow.

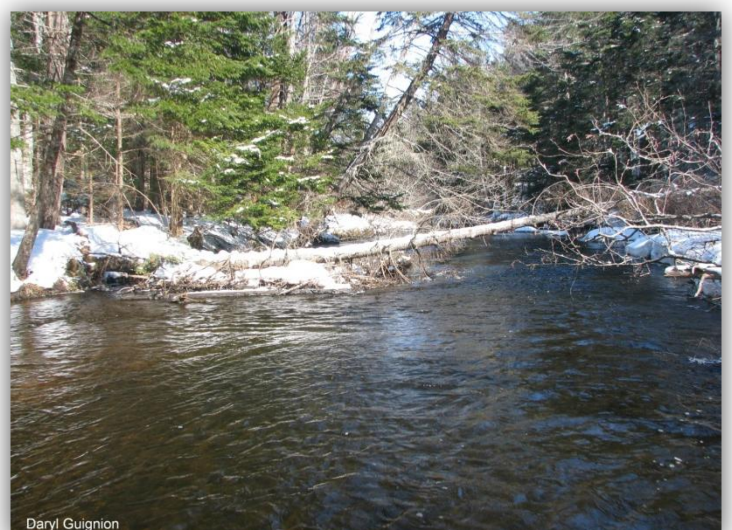


Figure 11.2 Fallen tree downstream from Leards Pond, Morell River retains gravel and encourages the spawning of numerous Atlantic salmon

Large woody debris creates micro-niches that contribute greatly to a stream's overall biological diversity and health. It provides attachment sites for microscopic algae and for the insects that feed on them. Leaves and other small organic debris often become trapped in LWD, where they are consumed by insects. These are the same insects that make up a major component of fish diets.

11.2 LWD in Island Streams

On the Island, the natural influx of large woody debris to rivers and streams has been altered due to changes in upland land use by agriculture, residential development and logging. The size and type of woody debris falling into Island streams has changed, usually resulting in too little woody debris. A riparian margin depleted of a diverse and dense tree canopy can take 100 – 200 years to recover a healthy influx of woody debris into the adjacent stream.

Very few reaches of stream on the Island have riparian zones with original vegetation. In those streams flowing through old growth forests (less than 1 % of today's Island forests) or in some that have been selectively cut, LWD occurs at a volume natural to the stream system. Although this debris catches some sediment, it also creates riffles, pools and back eddies and retains gravel (Figure 11.3). Salmonids thrive in this diverse habitat.

Figure 11.3 LWD from a mature riparian forest, Howell's Brook (West River)

Counter to the common scenario of too little LWD, some Island streams today are choked with too much woody debris. At one time, watering and grazing of livestock in and beside streams was the norm. As these areas were taken out of pasture, the natural regeneration of forests was dominated by growth of white spruce. Dense white spruce stands of a single age, growing in unstable soils with shallow roots and broad limbs are highly susceptible to collapse. Because these stands are even-aged, originating with the abandonment of the pasture, the trees can collapse en masse at around 50 – 70 years of age (Figure 11.4). This results in an unnatural input of LWD, often resulting in a tangled mass of windfalls across and in streams. The riparian margin is left open, severely depleted and the stream flow is hindered. Old beaver meadows often have dead tree stands, drowned by years of flooding, which can also collapse en masse. Figure 11.5 is a stream restored to natural flow after the removal of a beaver dam. Note the stand of dead trees on the right bank that will eventually fall into the stream.

Figure 11.4 Excess woody debris caused by stand collapse, Bear River

Figure 11.5 Dead, previously flooded stand of trees on the right bank of a stream restored after a beaver dam removal

Numerous Island streams historically supported sawmills, and there may be logs and other woody debris buried in the sediment of the old pond basins. Once exposed through dam removal, this LWD may interfere with the re-establishment of a natural stream hydrology by altering the flow patterns. The following section discusses in more detail how a watershed group may find the right balance for LWD in their stream systems.

11.3 When and When Not to Remove LWD

Studies have demonstrated that the complete removal of LWD can result in major erosion of the stream banks and subsequent degradation of in-stream habitats. Bearing in mind the many benefits provided by LWD, a cautious approach must be taken to its removal.

There is no easy formula for management of LWD, as every natural setting will be different. Often the health of the riparian zone will provide some insight. For P.E.I., a mature Acadian forest riparian zone will provide the optimum amount and combination of LWD to the stream channel. If the stream reach in question has a healthy mature mixed forest riparian zone, then removing LWD should only be considered if there is convincing evidence that it is causing significant stream bank erosion. If that is not the case, the rule is leave it be. If the decision is to cut out some LWD, the wood can be repositioned so the ecological benefits are not lost. Figure 11.6 shows LWD laying both parallel and perpendicular to stream flow; there is nothing to suggest that it should be removed from this reach.

Figure 11.6 LWD in varying alignments with stream flow but not impacting negatively on the banks, Howell's Brook (West River)

Degraded riparian zones often do not provide an adequate volume of LWD to the stream channel, but there are times on PEI, as described above, that too much is present. A white spruce stand collapse is not an uncommon event on the Island and often contributes an unnatural volume and type of LWD to the stream. Similarly, where large beaver dams are removed or impoundments decommissioned, an unnatural volume of LWD may be mobilized. In these cases, efforts should be made to remove much of the debris (Figure 11.7) and restore the riparian zone to a more natural state (see chapter 9 for planting suggestions).

Figure 11.7 Removal of white spruce deadfall after a stand collapse on Bear River

Log-jams in healthy forested reaches are natural accumulations of LWD that may span the entire width of the stream channel but rarely will obstruct fish passage. Again, unless there is evidence of stream erosion or the log-jam is impounding water they should be left to their own devices. Often these log-jams are temporary, breaking apart during high flow events. Log-jams that collect at culverts or bridge crossings should be removed because they may cause roadway washouts.

Log-jams caused by changes in adjacent land use practices can have negative impacts on channel stability. If the log-jam is mostly composed of thickly branched conifers from a single stand collapse, consideration should be given to its removal. Because of the density of branches, these jams tend to catch too much drifting material, impounding the water and putting excessive pressure on stream banks at high flow. Figure 11.8 is a log-jam comprised mostly of conifers; it should be investigated to ensure that it does not pose an erosion risk to the adjacent stream bank. A partial removal by trimming lower branches of the downed trees will often be enough to allow sufficient flow through the jam, taking pressure off the stream banks.

Figure 11.8 Log-jam of conifers on the Midgell River

Streams with high sediment loading may need to have some LWD removed to enable flushing of the sediment, but be cautious as it is easy to take a little more out in following years where need be.

Recreationists sometimes want woody debris removed because it blocks a canoe route or it catches fishing lines. Accommodating resource users by removing woody debris may require a compromise between ecological and community values. Sometimes educating people about the ecological value of this seemingly “untidy” natural material is sufficient to appease their desire to remove it. It is illegal to remove such material without a permit.

Where watershed groups need to remove natural woody debris temporarily, to allow excessive sediment to flush, they can reinstate LWD in following years after the natural stream bottom has reappeared. Other watershed groups managing streams in areas with a high proportion of cleared land may need to add considerable amounts of LWD to compensate for a deteriorated riparian zone. The most common forms of artificial woody debris that may be added to streams are digger logs, split or half logs and whole downed logs with limbs removed. Their specific uses and installation are described below.

11.4 Restoring Large Woody Debris to Streams

Restoring woody debris to Island streams should only be considered once a stream reach has been relieved of most of its sediment burden (see Chapter 8). If substantial sediment remains in the stream bed, woody debris will simply catch and deposit more, thereby increasing the potential for bank blow-outs or exacerbating stream widening. Where appropriate, woody debris can be introduced in the form of digger logs, split or half logs, or as whole logs with limbs pruned.

11.4.1 Digger logs

Purpose. Trees that fall into streams can get wedged between the banks, concentrating high water flows down into the stream bed, which scours out pools. These logs create pools, oxygenate the water, can provide quality habitat for aquatic insects and gravel beds for fish spawning. The pool and white water below the log provides excellent cover for fish (Figure 11.9). This is the natural formation that constructed digger logs are trying to recreate.

Figure 11.9 Natural digger log in eastern PEI

Where applicable. Since digger logs work best in smaller streams, usually those less than 7 metres wide, their installation is a suitable restoration technique for many Island watercourses. Figure 11.10 shows the expected size and location of the pool in relation to a digger log. The pools created in this way are generally not large, but sufficient, given the size of the stream, to provide the habitat functions described above.

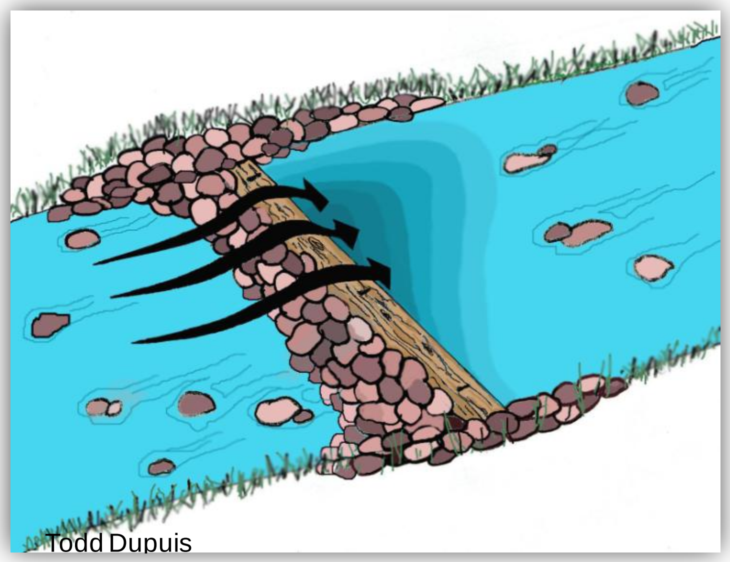


Figure 11.10 Location of the pool below a digger log

Before the addition of digger logs, consider whether the stream reach is lacking pool habitat. Most healthy streams, regardless of size, have a natural spacing of one pool every 6 bankfull widths. In addition, the substrate of the stream needs to be gravel or cobble so the water can excavate a pool in the bottom. A stream substrate composed of hard bedrock or large boulders will limit the effectiveness of these structures. Substrates that are heavily silted are similarly unsuitable, as it is difficult to secure the log to the bottom of the stream without water eventually eroding underneath.

Precautions Currently, permits require that professional assistance be obtained when considering the placement of digger logs, as proper spacing and installation is critical to their success. The permit will list specific individuals who must be contacted for advice.

Construction It is important that digger logs are securely fastened to the substrate in the proper location. Improper placement can result in bank erosion and hydraulic changes that will produce more negative impacts on stream habitat than positive enhancements. Digger logs should be spaced every 6 bankfull widths of the natural stream with the pools on alternating sides (Figure 11.11). They work best when they are positioned at the head of a natural pool. Once the bankfull width is determined, subsequent digger logs can be positioned 6 widths apart starting from the last one that was positioned correctly. Be advised that 6 bankfull widths is a general measurement and there is some flexibility in moving slightly up- or downstream if the measured positions seem unsuitable. There is also no need to place one where there is already a sufficient pool or natural digger log in place. Skipping one and moving on to the next 6 widths is acceptable.

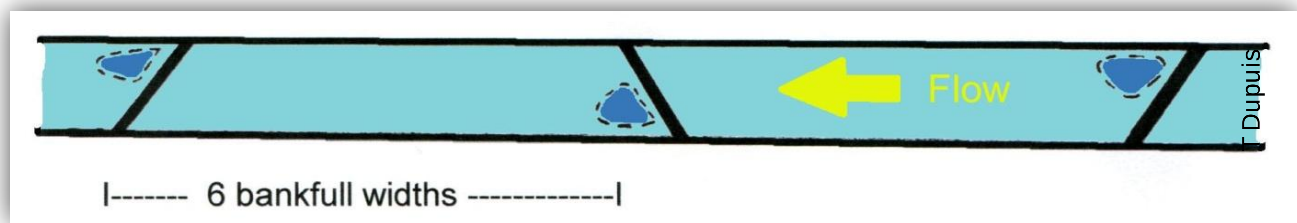


Figure 11.11 Digger logs should be spaced every 6 bankfull widths

The logs should be angled 30 degrees with the upstream end on the side of the stream where the pool is proposed. They should extend bank to bank and be not more than 15 cm in diameter to ensure fish passage. The upstream end of the log must be at a lower elevation to concentrate some of the stream flow (see figure 11.12). This will ensure that the pool develops where it is intended and provide sufficient water volume for fish passage in low flow. The log must be pinned to the stream bottom with steel rebar, which is driven through pre-drilled holes and into the substrate. Rebar should be driven a metre into the substrate to ensure the structure does not move in high flow. About 15 cm of the rebar should be bent downstream and over top of the log so the structure does not lift or catch debris.

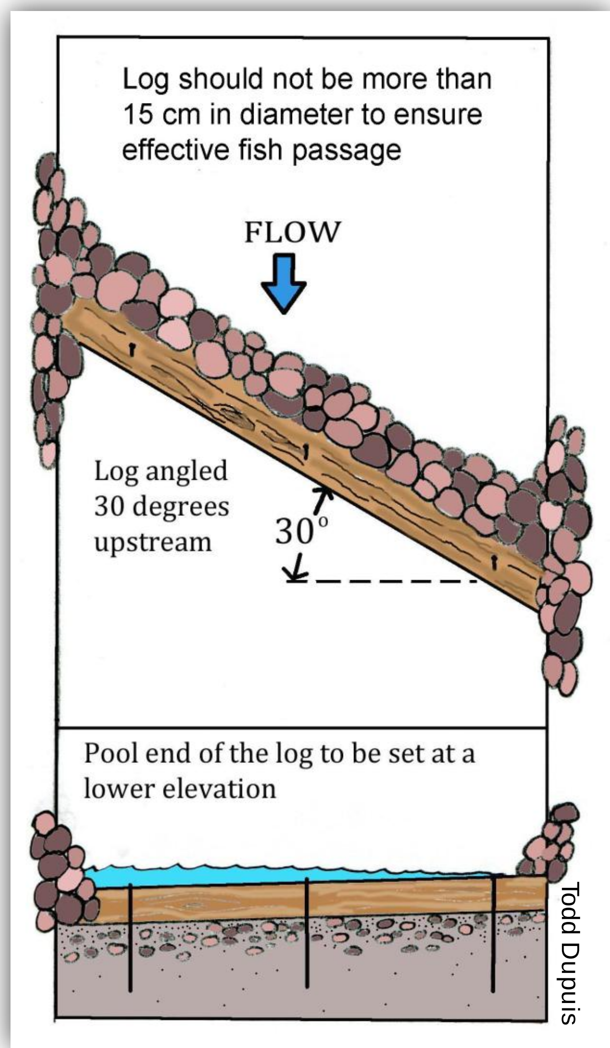


Figure 11.12 Position of a digger log in stream, overhead and cross-section

Placing rocks on the upstream side of the log and on the banks to guard against water undermining and bank erosion is critical. Ensure the rocks are of sufficient size so they are not washed under the log, even during high velocity flow events. Removing cobble and boulders from the anticipated pool area will speed the scouring process. These rocks can be used to armour the structure. Larger rocks can be added to the pool for cover after it has formed. Most of the digging will occur during high water events and it may be a couple of years before results are apparent. A pool 30-45 cm deep is sufficient for many of the Island’s smaller streams.

In the past, it was suggested that digger logs be notched to allow fish passage at low flow. However, if properly installed with one end lower, a notch should not be necessary. Digger logs should be checked annually, as some maintenance may be required.

This photo shows a digger log on the Souris River. Note that the log is angled cross-wise with most of the water tumbling over at the intended pool area. If properly installed, constructed digger logs look and function much like natural downed logs.

Figure 11.13 Digger log installed in the Souris River

11.4.2 Split or half logs

Purpose A spit log is simply a log cut lengthwise and secured to the stream substrate using wood spacers and steel reinforcement bar (Figure 11.14). Spit logs, also termed half logs or cover logs, are devices that mimic large organic debris by providing resting and hiding areas for juvenile and adult fish where in-stream cover is limited.

Where applicable Stream reaches that have stable substrates but are lacking in large organic debris are good candidates for the addition of split logs.

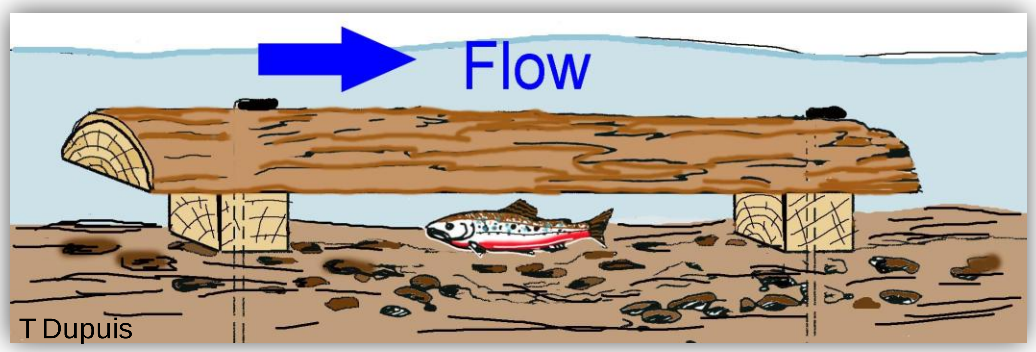


Figure 11.14 Split log submerged in the stream

If large organic debris has been recently cleared to facilitate stream flushing it is advisable to wait a year to determine where the stable substrate and thalweg will be before determining suitable locations. Split logs are best placed along the edge of a stream's thalweg where they do not take the full force of the current, but where there is enough flow to keep the structure clean. They are always placed such that they are entirely submerged in all flows as exposure to air will shorten their lifespan. Their orientation should be slightly out of line with the direction of flow to facilitate flushing under the structure. Split logs can be installed individually or in a series. Outside of river bends near the edge of the stream bank, in pools or in runs are suitable locations for split logs (Figure 11.15). Structures placed adjacent to spawning habitats are often used by adult fish during the spawning season. In stable channels, the expected life of the structure is a decade or more provided the location is not subject to too much sediment deposition or ice scour.

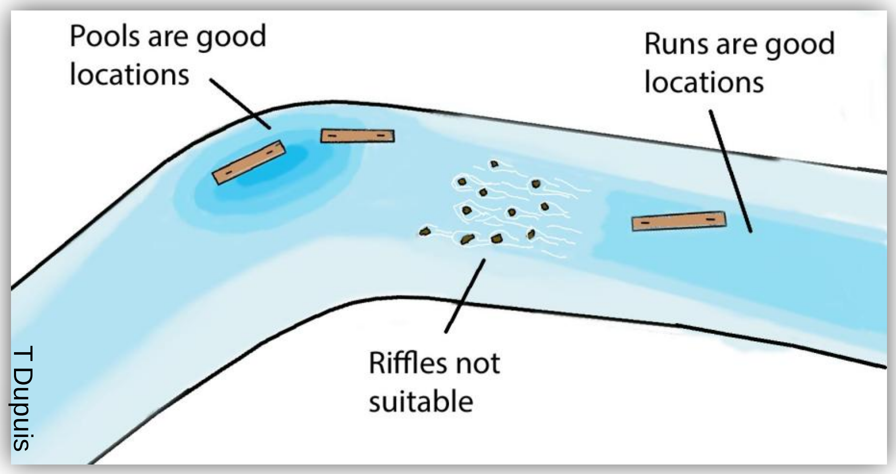
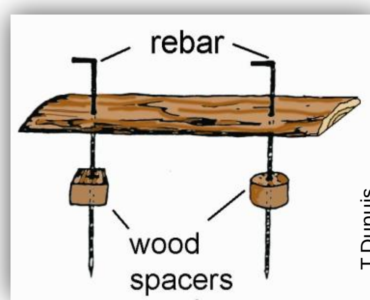


Figure 11.15 Positioning of split logs in relation to the stream thalweg

Precautions The split log design does not lend itself well to use in streams with very hard bedrock, because the steel rebar cannot be driven far enough into the substrate to hold the structure during high water flow events. A high concentration of suspended sediment coming from upstream reaches will diminish the effectiveness of split logs as cover. Frequent monitoring is required for the first year to ensure proper installation and function. Annual maintenance is recommended after the first successful year.

Construction Split logs generally have a 20-30 cm width and a length of up to 2.5 metres, but these dimensions can vary depending on material availability and the size of the structure desired. Local lumber mills are often the best place to have the logs cut lengthwise or to acquire waste slabs. Wood spacers (blocks) of approximately 15-20 cm square will keep the spit log off the stream bottom providing a hiding space preferred by trout. Steel reinforcement bars, 1- 1.5 meters long and 1.5 cm in diameter, are driven through predrilled holes in



both the log and spacer and into the stream substrate using a sledgehammer. A short section of the rebar (15 cm) should be left protruding above the structure, then bent over in a downstream direction, pinning the log to the stream substrate. To make certain that the structure will remain totally submerged in all seasons, they should be positioned during low flow conditions.

Figure 11.16 A split log with spacer blocks and rebar ready to be positioned in the West River

The split log in figure 11.16 has a tapered end, which will face the current in an effort to reduce pressure at high flow and minimize debris collection. Figure 11.17 shows a spit log being installed in the Little Trout River. Two individuals stand on the spit log while a third drives the rebar through the structure and into the stream substrate. Note the cobble substrate, which will prove a stable platform for the structure.

Figure 11.17 Installing a split log in Little Trout River

Figure 11.18 shows an installed structure. Note the close proximity to the stream bank and rocky substrate.

Figure 11.18 Installed split log, Little Trout River

11.4.3 Whole logs

Purpose Pinning whole logs to the substrate is also an effective technique for providing in-stream cover (Figure 11.19).

Where applicable Suitable locations for whole logs are identical to those for half logs.

Precautions As with split logs, frequent monitoring is required for the first year to ensure proper installation. Annual observation is recommended after the first successful year.

Figure 11.19 Whole log positioned in stream

Construction The log should have its branches trimmed to 15-20 cm of the trunk. The resulting branch stubs will prop the log off the stream substrate so no spacer blocks are required. The log can be placed so some of the branch stubs protrude out of the water resulting in broken surface flow, which will provide additional fish cover (Figure 11.19). The log should be positioned so the largest trunk diameter is facing the current. This will ensure the branch stubs are facing downstream, reducing the chance of snagging debris. The whole log is pinned to the substrate with re-bar in the same manner as for split logs.

Helpful hints The handle near the head of the sledge hammer can be damaged by a missed swing if it is not first wrapped with heavy wire and taped. For safety reasons some watershed groups have had metal holders fabricated to grasp the rebar while it is being pounded into the substrate.

Alternative technique In some instances, it may be beneficial to secure downed trees to the stream bank, as partially submerged LWD. This technique is suitable for wide sections of large rivers where there is hardpan, little other cover available and where the reach is prone to flooding. In these settings, downed trees could be cabled to the river bank where they would not move during high water events. Deciduous species may be easier to work with than densely limbed conifers. Cabling must be strongly secured to prevent movement of the tree.

11.5 In-Stream LWD Habitat Restoration Summary

Large woody debris is one of the most important habitat components in any coldwater stream. Island watershed groups may choose to leave, remove or add LWD, depending on the stream reach. Where groups are tasked with adding LWD, the following table summarizes the most common techniques for LWD installation.

Artificial Structure	Purpose	Where to Use	Where Not to Use	Additional Comments
Digger Logs	Large woody debris habitat; pool creation; fish cover; water aeration	Where natural pools are lacking in streams < 7 m wide, with gravel / cobble	Where the stream bottom is hardpan or where there is excessive silt / sediment	Professional assistance with construction is recommended
Split / Half or Whole Logs	Large woody debris habitat; fish cover; aquatic insect attachment	Where large woody debris is lacking and substrates are stable, on outside of bends near stream bank, in pools or runs	Where the stream bedrock is very hard (except cabled trees) or where there is excessive silt / sediment; in riffles	Placement relative to current is important in limiting fouling with debris

11.5.1 Useful resources

Dupuis T, Guignion D, MacFarlane R, and Redmond R, 1994. A technical manual for stream improvement on Prince Edward Island. Morell River Management Co-op Inc., Morell, PE.

Fisheries and Oceans Canada, 2006. Ecological restoration of degraded aquatic habitats: A watershed approach. DFO, Gulf Region.

Heaton MG, Grillmayer R, Imhof JG, 2002. Ontario's stream rehabilitation manual. Ontario Streams, Belfountain, ON Available online

MacInnis C, Floyd TA, Taylor BR, 2008. Large woody debris structures and their influence on Atlantic salmon spawning in a stream In Nova Scotia, Canada. North American Journal of Fisheries Management volume 28, pages 781-791.

Roni P, Hanson K, Beechie T, 2008. Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. North American Journal of Fisheries Management, volume 28, pages 856-890.

U.S. Geological Survey and Missouri Department of Conservation, 1998. Riparian-Vegetation Controls on the Spatial Pattern of Stream-Channel Instability, Little Piney Creek, Missouriunities with their natural environment.

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

12. In-Stream Restoration: Flow Deflectors

In their natural state, most streams have a meandering course and an alternating pattern of riffles and pools (see section 2.3). Plants and animals inhabiting streams have evolved to live and thrive in that environment. Retaining that natural hydrology in the long-term is dependent on upland land use and a healthy riparian margin (Figure 12.1).

Figure 12.1 Meander pattern in the lower reaches of the West River

Where natural habitats have been severely degraded, it may be necessary to help the stream recover a natural meander and pool-riffle pattern. For instance, in old pond basins or where widespread removal of upland forest cover has created very flashy stream flow conditions, the stream may have difficulty re-establishing a normal flow pattern. High sediment loading from watersheds in intense agricultural production also creates conditions where normal flow patterns are disrupted. Where that is the case, artificial structures can be constructed to jump-start the recovery process.

What follows is a general description of the main flow deflector structures used in Island streams. Deflectors are used to redirect stream flow. They serve many purposes, including deepening channels, developing pools and assisting in the restoration of meander patterns. Some designs deflect flow away from eroding stream banks, concentrating it in the center of the channel. Deflectors can be constructed of natural material such as boulders and logs, and are adaptable to a variety of conditions and stream sizes. There are many types of deflectors and selecting an appropriate design requires careful analysis of the site and consideration of the restoration goal.

12.1 Wing Deflectors

Purpose Wing deflectors are structures that extend out from the stream bank into the stream channel (Figure 12.2). Their intended function is to focus the water flow towards the centre channel and thereby narrow, deepen and/or create sinuosity in the channel. They also diversify the stream reach by concentrating the flow and scouring pools. The scouring action maintains clean substrates, which can attract aquatic insects and spawning fish. The resulting pools provide cover and resting areas for fish.

Figure 12.2 Wing deflector construction, Little Trout River

Where applicable Straight, sluggish and silted sections of stream at or near the head of tide are locations frequently chosen for construction of wing deflectors on PEI. Wing deflectors can be placed in any shallow, widened reach of stream that lacks a well-defined, meandering thalweg (deeper mid-channel), where you want to speed water velocity and reduce the deposition of sediment on the stream-bed. The solid triangular or rectangular structure reduces the width of the stream channel, thereby increasing the stream velocity.

Wing deflectors can be placed as singles, in an opposing (pinching) configuration or in an alternating series. Common construction materials include stone, logs or a combination of the two. The construction of wing deflectors can be relatively low cost depending on the availability of materials and site access. As channel width increases, so does the amount of materials and labour required to construct them. These structures have varying degrees of durability depending upon the materials used. Some log-rock wing deflectors on PEI have survived two decades before any repair was necessary.

Precautions A good understanding of the stream reach is compulsory before the installation of wing deflectors is considered. Determining the intended location of the channel in relation to the natural pools, bankfull height and bankfull width will be essential for determining suitability, size and positioning of these structures. If improperly designed, they can cause bank erosion and other issues, and it is advisable to seek professional assistance before they are constructed.

Construction Shape and size of these structures are site-specific and must consider how the stream will be guided at both low and high water flows. Wing deflectors direct the water current toward the opposite bank at low flow; during high flow, submerged deflectors will direct the current perpendicular from the downstream edge of the structure. Downstream edges of deflectors that face the near stream bank will force the current into the bank, causing erosion. To avoid this, downstream edges of deflectors must always face away from the near bank. This can be achieved with either a triangle shape or an upstream angled deflector (Figure 12.3).

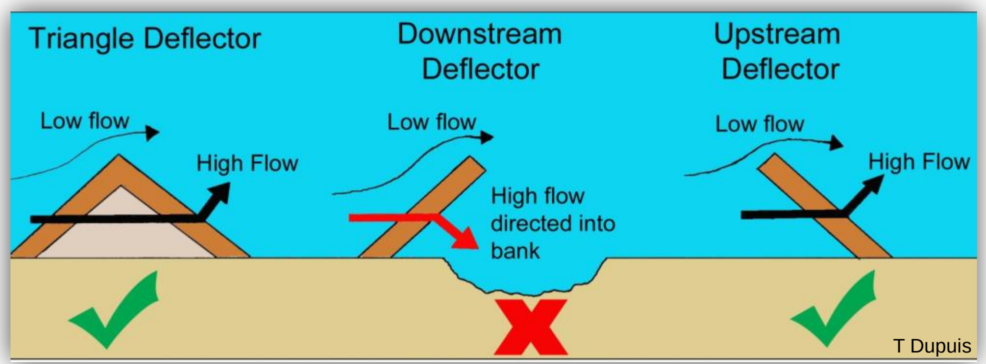


Figure 12.3 Deflectors should be triangular or facing upstream to avoid bank erosion

Triangle shaped wing deflectors should have an inside angle of 30 degrees on the upstream corner; the edge facing downstream should be at an angle of 90 degrees or more to the edge facing upstream. Single linear wing deflectors should be angled 30 degrees upstream from the stream bank. Deflectors should not extend more than one-third of the bankfull width of the stream; longer ones may result in erosion of the opposite bank.

The end of the deflector closest to mid-channel should be allowed to project above the water surface during low flows and be submerged during high flows. This will take the pressure off the opposite bank and allow easy passage of ice and debris during high flow events. The end of the structure that meets the stream bank should be at or above bankfull height.

Wing deflectors placed in an alternating series can create a deep, meandering thalweg in a previously shallow and over-widened channel (Figure 12.4). Alternating deflectors are placed on opposite banks a distance of 6 bankfull widths apart or based on meander spacing of a similar undisturbed reach of the same stream.

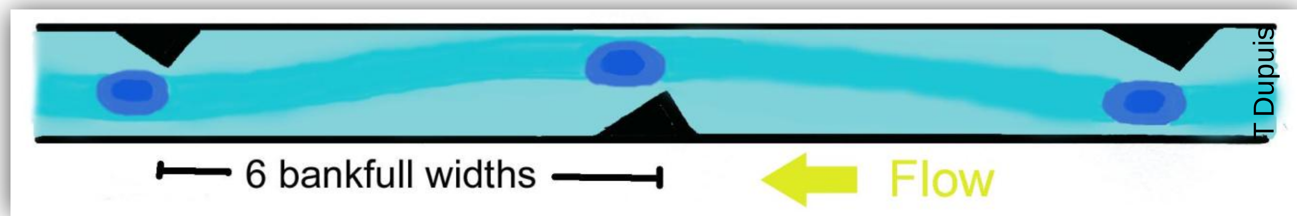
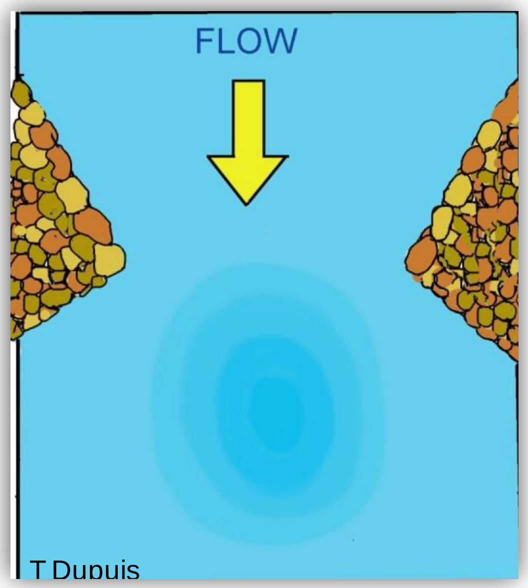


Figure 12.4 Positioning of alternating deflectors in a stream



In opposing pairs (pinching), wing deflectors increase mid-channel velocity causing the formation of a scour pool in the center of the channel (Figure 12.5). It is important not to over-pinch the stream when constructing opposing deflectors. The summed width of both deflectors should not impede more than 1/3 the bankfull width. Over-pinching will create unnatural hydraulic conditions that may not be suitable for fish passage and may also reduce the life expectancy of the structures.

Figure 12.5 Deflectors positioned to pinch the stream

12.1.1 Rock wing deflectors

Wing deflectors built solely of rock are natural in appearance and require large stone for long-term stability (Figure 12.6). They should be constructed of boulders or rocks twice the diameter of the largest ones in the stream you're working in. This may require trucking in rock of a suitable size to the site. Arrange the largest rocks on the upstream side of the deflector. The subsequent layers of rocks should be overlapping (staggered) so as not to allow excessive water to flow through the structure. Slope the deflector up the stream bank to bankfull height or above. Deflectors constructed of appropriate size stone generally have a long life span. The most common long-term issue is the undermining of the point of the deflector. Frequent inspection of the structure is necessary to assess any maintenance needs.

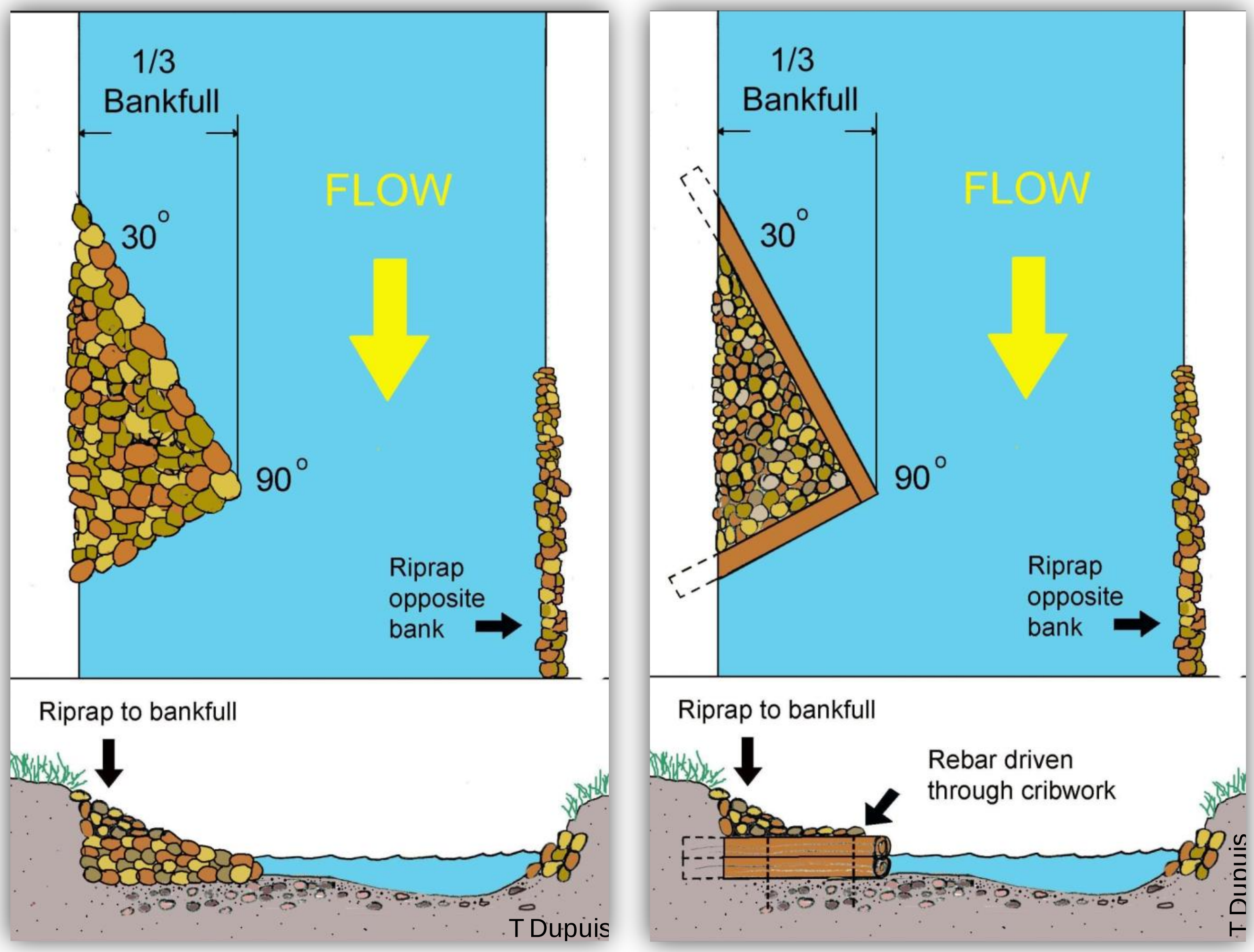


Figure 12.6 Wing deflector construction from (left) rocks alone, or (right) a log crib and rocks

12.1.2 Log crib wing deflectors

Log cribwork filled with rocks is a common structural combination for deflectors on PEI (Figure 12.6). Steel reinforcing rods are driven through pre-drilled holes in the log cribwork to secure it to the stream bottom. If multiple layers of logs are needed, spike them together with overlapping seams. Cross bracing within the structure can be added for increased strength. The finished cribwork is back-filled with rocks to provide the mass required to withstand high water events. The cribwork is typically embedded into the bank but that may not be necessary if the structure is well rip-rapped. These structures, if constructed correctly, have a 20 year lifespan. Because the logs are not continually submerged, they will eventually decay. Cedar or hardwoods will last longer than spruce timbers.

12.1.3 Gabion wing deflectors

Using gabion wire baskets filled with stone was once a popular technique for constructing deflectors (Figure 12.7). Deflectors made with gabion baskets, along with being unnatural in appearance, are susceptible to damage and may require frequent repair. This method is rarely employed today in favor of using more natural materials.

Figure 12.7 Older style gabion basket deflector just below the head-of-tide, West River

12.2 Vane Deflectors

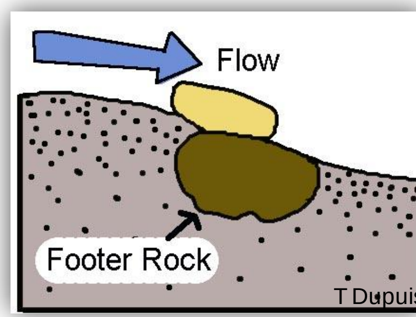
As river restoration efforts evolve there is an increasing demand for a “softer” approach to engineered solutions. The departure from traditional “hard” procedures, like rip-rapped stream banks, has been slow but steady, as the use of natural materials and methods has grown in popularity. Working with the natural hydrology of a watershed, instead of armouring against it, is the ultimate long-term solution. Continued monitoring of these structures will provide the information necessary for further design improvements, to meet the ever-increasing demand for environmentally "softer" approaches.

Purpose Vane deflectors are essentially stone walls that produce adjustments in the streambed by redirecting the flow away from the stream bank and into the center of the channel. They are most often constructed to reduce excessive bank erosion. They also improve in-stream habitat by creating plunge pools, which provide cover for fish and help to oxygenate the water.

Where applicable Vane deflectors can be positioned on an outside bend or on a straight section of stream where bank erosion is occurring. Most are linear and extend out from the stream bank in an upstream direction. These will also act to create deep pools as habitat.

Precautions Although these structures appear simple they need to be engineered correctly to ensure preferred results. Failure to stick to construction guidelines may cause premature failure of the structure and/or habitat damage.

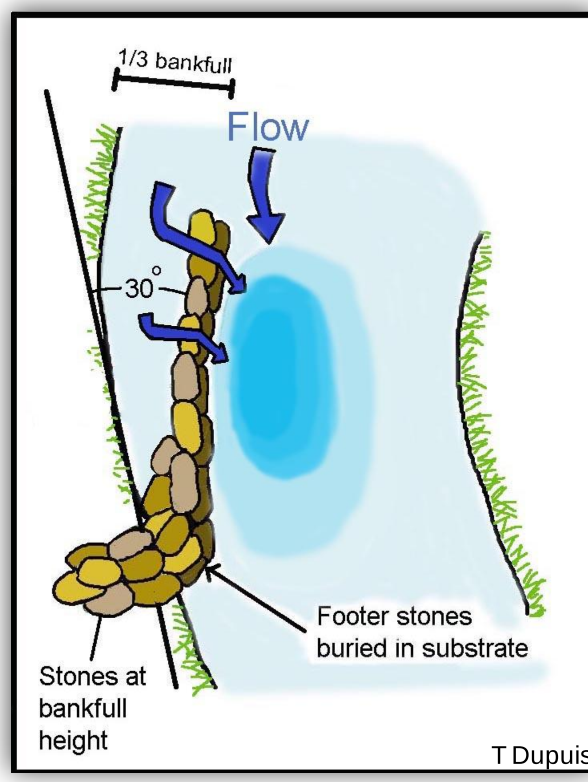
Construction Vanes require footer rocks as a foundation. The footer rocks are buried in the streambed as a support to the boulders above. Generally, one to two rocks underneath and downstream of every top boulder will suffice. This is very important as without footer rocks the structure will sag and rocks will sink into the scour holes they create. The minimum footer depth for cobble and gravel bed streams is 3 times the protrusion height of the rock it supports. For sand-silt laden streams, the minimum depth for footer rocks is doubled due to the deeper scour depths that may occur.



12.2.1 Single vane deflector

Single vane deflectors are located just downstream of the point where the stream flow encounters the stream bank at acute angles (Figure 12.8). They should be oriented upstream at about a 30 degree angle and not extend more than 1/3 bankfull width into the channel. They should be at bankfull elevation at the stream bank and slope down as they extend into the channel. Rock size depends on the stream, but it is recommended that the largest size possible be used to prevent movement during high flows. Heavy machinery may be required if the river is large. A single vane structure should be not protrude beyond 1/3 bankfull width into the channel. The slope of the structure can range from 2 to10 percent; longer, flatter structures are preferred for maximum stream bank protection. There should be no gaps between the rocks. Voids between the header and footer rocks can be filled with hand-placed stone.

Figure 12.8 Single vane deflector design



12.2.2 J-Hook vane deflector

The J – Hook vane deflector is basically the same as a single rock vane deflector with the exception that it curls around at the end in the shape of a “J” (Figure 12.9). While the J-hook is more complicated to construct than the single vane, it allows the builder to direct the placement of the pool scour more precisely. The rocks should touch each other with the exception of the rocks of the hook portion of the structure. Space these rocks apart about one-half the diameter of the rock. The spaces between the rocks will serve to concentrate flow and scour out a pool, while the length closer to the shore deflects flow away from the bank. The vane portion of the structure occupies 1/3 of the bankfull width of the channel, while the “hook” occupies the center third.

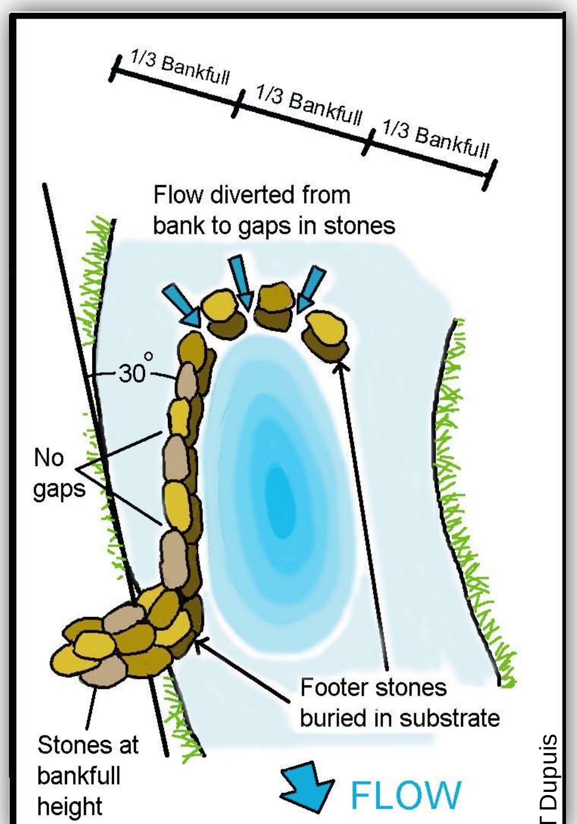


Figure 12.9 J-hook vane deflector design

12.2.3 Cross vane deflector

Cross vane deflectors are used on straight sections. They concentrate the water flow into the middle of the channel protecting the banks. The water flowing over the structure digs a hole downstream, creating a pool where fish can congregate with some protection from overhead predators. These structures consist of a single vane extending upstream from either bank joined by a centerpiece perpendicular to the flow (Figure 12.10). Like the single and J-hook vanes, the slope of the structure can range from 2 to10 percent. The centerpiece is the lowest point, and, as water levels rise seasonally, the vane directs the greater stream flow to the center, scouring a pool and relieving stress on the banks. These structures are sometimes used to focus flow through bridge openings, thereby reducing the scouring around bridge abutments.

Back-filling on the upstream side of the structure with cobble and gravel will reduce the chance of washout between the boulders. A geotextile such as filter fabric can be used on the upstream side of the boulders to reduce the chance of undermining in sand and silt laden streams. Alternatively, spacing between rocks in the middle third, as for the J-hook vane, could be used to allow sediment to flush through.

These vane structures have not been attempted in Island streams to date, although these designs have proven effective in other regions.

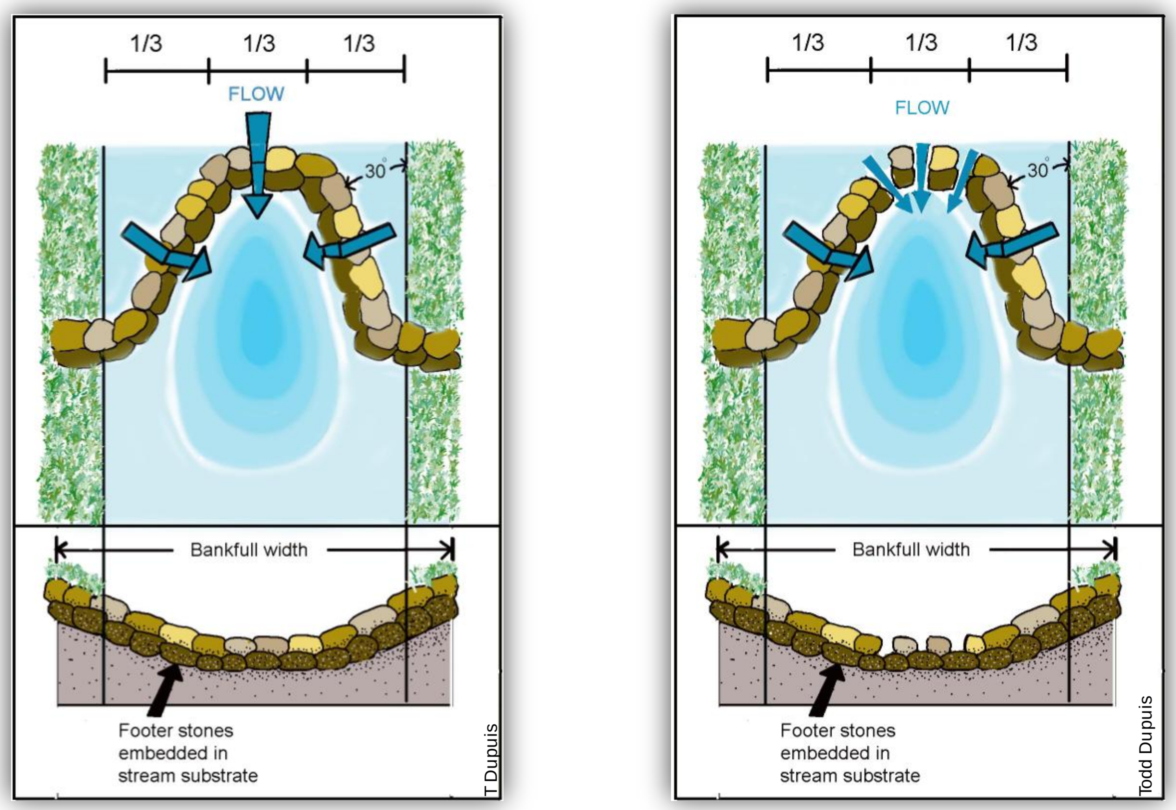


Figure 12.10 Cross vane deflector design, without spacing (left) and with spacing (right) for sediment passage

12.3 Boulders, Cobble and Gravel

Rock plays an important role in maintaining the pool – riffle pattern of natural streams. It is also habitat for plants, invertebrates and fish, and where habitat is concerned, rock size does matter! The following table defines the various sizes of rock and their habitat functions in Island streams (from Waters 1995):

Table 12.1 Rock types based on particle size

Rock Size Category	Diameter	Biological Functions
Boulder	>25 cm	Creates turbulence, cover and resting spots for large fish, attachment sites for aquatic plants, smelt eggs & invertebrates
Cobble	6.4 – 25 cm	Creates turbulence, cover and resting spots for small fish, attachment sites for aquatic plants, smelt eggs & invertebrates, cover for developing fish eggs
Pebble	16 – 64 mm	Creates interstitial spaces suitable for burrowing invertebrates, attachment sites for smelt eggs
Gravel	2 – 16 mm	Cover for small fish that may burrow over winter, cover for developing fish eggs, aerated spaces for invertebrates
Sand	0.0625 – 2 mm	When mixed with clays provides rooting medium for aquatic plants, when adjacent to springs and mixed with gravel provides spawning habitat for brook trout
Silt	4 – 62 µm	When mixed with clays provides rooting medium for aquatic plants
Clay	< 4 µm	Can carry nutrients suitable for plant growth

Island streams have an over-abundance of fine sediment, which has often buried important rock forms on the natural bottom. Although sediment (sand, silt and clay) has its own function in a healthy stream system, it is out of proportion in streams that have bore the brunt from decades of excessive erosion in Island landscapes. Gravel, cobble, pebbles and boulders are particularly important for fish spawning and invertebrate production. Three major groups of aquatic insects, namely the mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) depend on these rock classes as attachment sites from which to grow and feed.

Chapter 8 describes how to uncover the natural rock formations in a stream by sediment removal, while this section describes how to manipulate or enhance aggregations at select locations. Adding rock to Island streams should only be considered once a stream reach has been relieved of most of its sediment burden (see Chapter 8). If substantial sediment remains in the stream bed, rock will quickly become buried, negating any habitat benefits. Where appropriate, rock can be introduced in the form of boulders, cobble or gravel. This is an area of restoration that is relatively new to Island streams and adaptive management techniques may be especially important when monitoring the success of these measures.

12.3.1 Introduction of boulder clusters

Purpose Boulders generate vortices in their wake, which create overhead cover for fish and scour small pockets of deeper water, which adds diversity to the stream. The scour holes are areas of reduced water velocity that provide holding and feeding areas for fish, and substrate for benthic invertebrates. Boulders can also assist fish passage through swift water by creating slower velocity back eddies. Figure 12.11 shows a typical flow pattern around a boulder and the scour area utilized by fish.

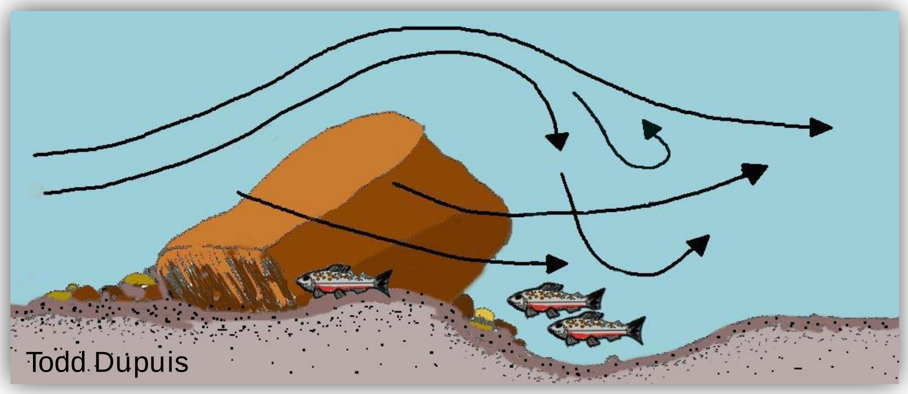


Figure 12.11 Pattern of water flow around a boulder

Where applicable Boulders can be added to areas where cover and/or habitat diversity is limited and they are usually placed in cluster patterns that mimic natural stream conditions. Boulders placed in riffles are great habitat for juvenile fishes. In runs and pools they are useful for all fish size classes and invertebrates. Figure 12.12 shows boulder clusters added to the Pisquid River to assist upstream migration of rainbow smelt in a high gradient stream reach and provide attachment sites for smelt eggs.

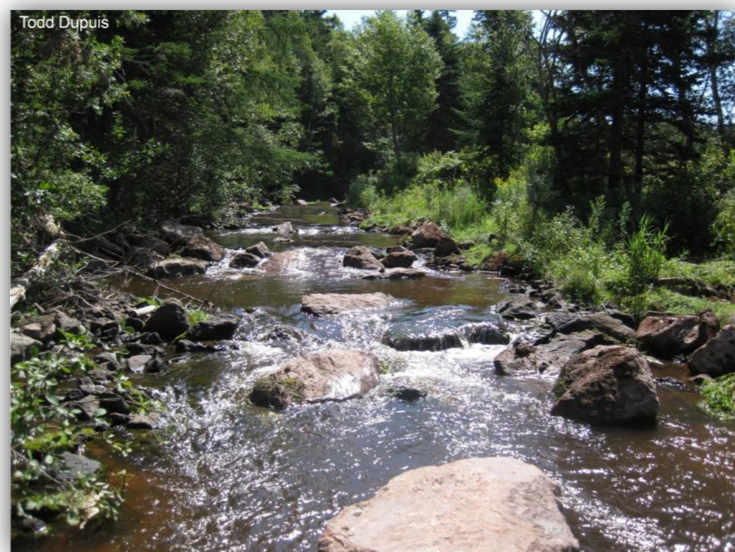


Figure 12.12 Boulders added to the Pisquid River in a random cluster formation

Figure 12.13 is a riffle-run sequence on the main stem of the Clyde River. This section of stream lacks in-stream cover and is a good candidate site for the addition of boulders. Boulder clusters added to the riffle and run sections here would diversify the habitat, benefiting both Atlantic salmon and brook trout.

Figure 12.13 Three riffles on the Clyde River, lacking in large boulders

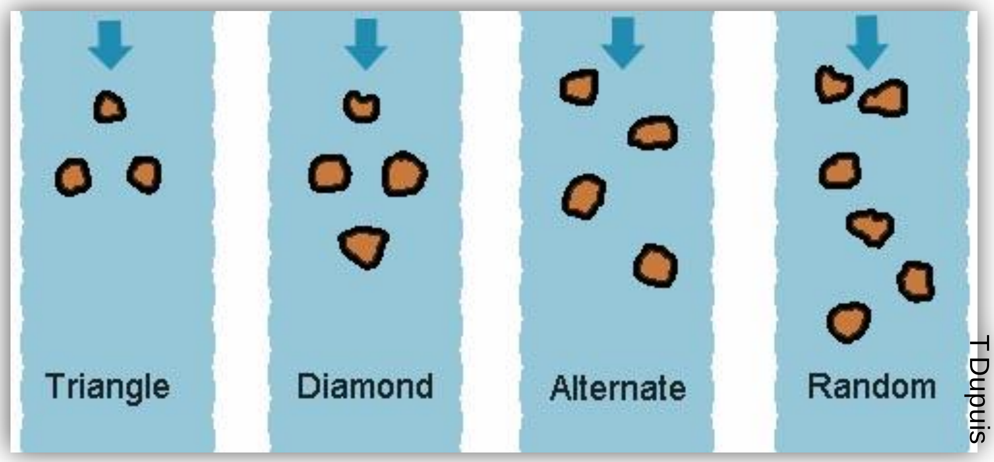
Precautions The addition of boulders can reduce stream channel capacity, putting increased pressure on stream banks, and they should not be considered when stream banks are susceptible to erosion. They are not recommended in stream reaches with unstable substrates (sand/silt) because they can fall into the scour holes they create and become buried. Sometimes, the addition of footer stones can reduce the chance of boulder movement or burial in these conditions.

Construction The size of boulders that are typically used range from 30 to 90 cm in diameter. They may be Island-sourced sandstone or granite from off-Island. Although granite will wear more slowly, there will be an associated higher cost for getting it to the site. It is important that any boulder added is sized for stability at bankfull flow. Placement of boulders can be labour intensive and large boulders will likely require heavy machinery.

Generally, boulders should be placed in the deepest third of the stream reach and not obstruct more than 20% of the stream's cross sectional area. Avoid placing them within a metre of the stream bank as the vortices around the boulder may result in erosion at high flow.

Boulders are often positioned in cluster formations containing 3-5 stones. Figure 12.14 illustrates boulder configurations common to salmonid habitat restoration projects. A boulder that is placed in the wake of another upstream has minimal benefits, so successive downstream boulders should be placed at the periphery of the wake of upstream boulders.

Figure 12.14 Cluster patterns for boulder placement



Boulder placement techniques vary depending on the type of stream habitat – riffle, run or pool. Riffles on P.E.I. generally lack boulders and are therefore suitable areas for this restoration technique. Boulders placed in riffles should be 25 to 35 cm in diameter or sized to be stable at bankfull water flows. Boulder clusters placed at or near the riffle crest (upstream limit of the riffle) should be avoided as they may cause stream aggradation. Boulders are best positioned in the bottom half of the riffle as shown in figure 12.15. To maximize turbulence and scour, boulders should be spaced about 1 rock diameter apart.

Boulders can be installed at the upper, middle, or lower sections of runs. In a deep run, they are sized so that the top of the boulder is at the surface of the water in low flow. In pools, the best positioning of boulders is at the head and tail of the pool and not within the deepest water (Figure 12.15).

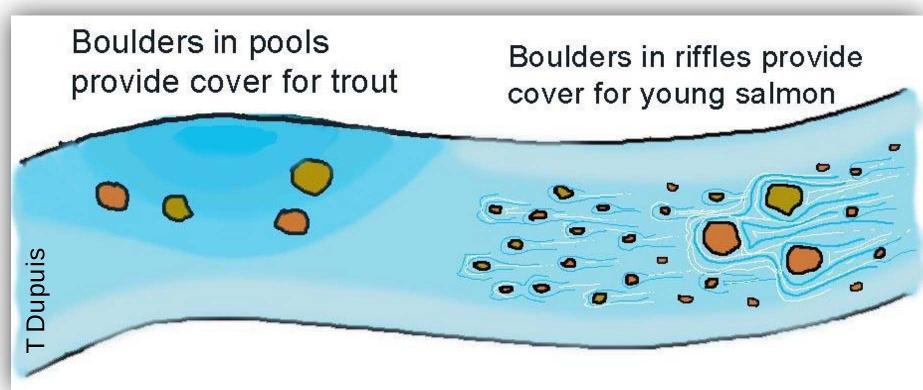


Figure 12.15 Positioning of boulders in pools and riffles

12.4 In-Stream Hydrology Restoration Summary

Making modifications to how water in a stream moves has an associated risk. It is critical that the stream reaches under consideration are well understood, in terms of how they currently function, before these restoration activities are attempted. Professional assistance will be required with all flow deflector structures. The following table summarizes the various techniques that could be used to alter flow in Island streams.

12.4.1 Useful resources

Dupuis T, Guignion D, MacFarlane R, and Redmond R, 1994. A technical manual for stream improvement on Prince Edward Island. Morell River Management Co-op Inc., Morell, PE.

Fischenich C, and Seal R, 1999. Boulder clusters. U.S. Army Engineer Research and Development Center, Vicksburg, MS; EMRRP Technical Notes Collection, ERDC TN-EMRRP-SR-11.

Fisheries and Oceans Canada, 2006. Ecological restoration of degraded aquatic habitats: A watershed approach. DFO, Gulf Region Available online

Rosgen DL, 2001. The cross-vane, w-weir and J-hook vane structures…their description, design and application for stream stabilization and river restoration. Proceedings of the 2001 Wetlands Engineering & River Restoration Conference held in Reno, Nevada, August 27-31.

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

Artificial Structure	Purpose	Where to Use	Where Not to Use	Additional Comments
Log Crib or Rock Wing Deflectors	Stream channel deepening; flow diversion to mid-stream; increased flow velocity; often salmon spawning sites improved	Where stream is sluggish, silted, shallow and/or widened and lacking a well-defined deep mid-channel	Where initial stream parameters (bankfull height, etc.) are unknown	Professional assistance with construction is recommended; care is required not to over-pinch the stream
Gabion Wing Deflectors	Flow diversion to mid-channel; increased flow velocity	Where stream is sluggish, silted, shallow and/or widened and lacking a well-defined deep mid-channel	Where initial stream parameters (bankfull height, etc.) are unknown	Gabions do not look natural and their use is discouraged
Single or J-Hook Vane Deflectors	Stream bank protection; pool creation; fish cover	Where bank erosion is occurring on an outside bend of stream; where a pool is desired	Where meander pattern of stream has not stabilized	Professional assistance with construction is highly recommended
Cross Vane Deflectors	Stream bank protection; pool creation; fish cover	Where bank erosion is occurring on straight sections of stream; by bridges	Where stream is very wide	Professional assistance with construction is highly recommended
Boulders	Flow diversification; fish resting holes / cover; fish passage	Where cover or substrate diversity is limited, in riffles, runs or pools Where fish passage through swift water is needed	Where stream banks are susceptible to erosion or where stream substrate has a lot of sediment	Best placed in clusters of 3 to 5 stones

13. Fish Passage

13.1 Road Crossings

13.1.1 Culverts and fish passage

Culverts are an economical way to construct road crossings over small- to medium-sized streams. They can be made from various materials (concrete, steel, plastic or wood) and come in a variety of configurations (pipe, box and arch). Poorly designed, installed or maintained culverts can pose serious obstacles to fish, preventing them from reaching important rearing and spawning habitat. The connectivity of diverse habitats is vital to supporting an abundance of fish species and their life stages in fresh water.

Many older road culverts on PEI are undersized and not well placed to provide effective fish passage. They were designed only to resist roadway washouts with little consideration given to the needs of fishes. Undersized culverts “pinch” the stream and increase the water velocity, which then often exceeds the swimming capabilities of fish. In addition, uniform conditions of slope and depth within the culvert can lead to an absence of the low-velocity zones that fish use to rest and recover. Conditions within smooth culverts are very different from what fish experience in natural streams, where rocks and woody debris always provide a variety of water depths and speeds.

A survey of 16 culverts in the West River watershed in 2009 revealed that only three were providing effective passage for all native fishes of all ages. Eight of the culverts provided passage for only the biggest fish while five were complete blockages. Some culverts can be modified to allow fish passage while others would need to be replaced. PEI has thousands of older culverts, and the replacement of the ones with fish passage issues will take many decades. Present day culvert replacement procedures have fish passage needs incorporated into the planning process.

Resolving any fish passage issues associated with road crossings starts with an inventory of the culverts in the watershed and subsequent development of a plan to mitigate any issues. Priority should be given to culverts low in the watershed (closest to the estuary) as culverts nearest salt water may impact anadromous fishes like sea run brook trout, Atlantic salmon, rainbow smelt and gaspereau. A poorly functioning culvert at or near the head-of-tide can impact fish distributions in the entire watershed by blocking access of native sea run fishes to spawning habitat or causing them to spawn in less suitable habitat.

Culverts situated low in the watershed can often be evaluated for fish passage during the spring rainbow smelt run. Rainbow smelt are the weakest swimmers of the anadromous fishes found on PEI. They begin entering freshwater on their spawning run in early April, with many streams continuing to have them well into May. A drive around the watershed during the spring migration can provide valuable information on roadway culverts. Finding smelts or smelt eggs upstream of roadway culverts is a good indication of fish passage (see Appendix II for supporting natural history information). If smelts are able to move upstream through a culvert then it should not be an issue for other species. Culverts located further upstream from saltwater (10 km or more) are likely beyond the preferred spawning habitat for smelts. These culverts will require closer inspection to determine if there are fish passage issues.

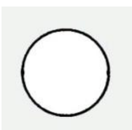
Where problem culverts are identified and given a high priority, the process of repair or replacement will involve partnering with others outside of the watershed group. Public road crossings fall under the jurisdiction of the Department of Transportation and Infrastructure Renewal. Their repair or replacement must be done by public works staff or contractors; however, watershed groups can assist by documenting the problems, bringing them to the attention of the province and lobbying for their priority status. Work on private road crossings can be undertaken by watershed groups, with landowner approval and with the advice of experienced, qualified contractors. Some mitigation of public culverts can also be done by watershed groups, provided it doesn't directly involve structural changes to the culvert itself.

This section will discuss some of the most common culvert types found on PEI and the most frequently associated fish passage issues. When in doubt, take pictures and forward them to an experienced person who can decide whether the culvert needs a site visit. The goal of the watershed group should be to have effective year round upstream and downstream migration of all native fish species in all life history stages. The *Prince Edward Island Watercourse and*

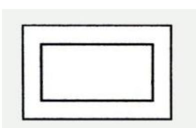
Wetland Alteration Guidelines provides a good framework for the installation of safe, sturdy, low maintenance and environmentally sound culverts that allow for peak flow, provide fish passage and prevent debris jams. Guidelines for culvert removal are also included.

13.1.2 Culvert designs

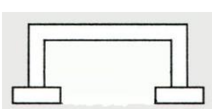
Five different designs cover most of the culvert types found on PEI. Some designs are better at providing fish passage than others. Some lend themselves to retrofitting while others do not.



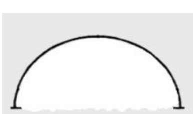
Round is the most common small culvert type on PEI. These are low-cost to install, but provide poor passage in many conditions. They are difficult to retrofit and are often installed undersized and perched at the lower (downstream) end. High water velocities and other hydraulic properties greatly discourage fish passage. These designs should be avoided where fish passage is important.



Closed Bottom Box is often constructed of treated wood and sometimes multiple boxes are used side by side. They may restrict fish passage during low flows due to decreased water depth, and during high flows due to increased flow speeds. Box culverts tend to be better than round culverts, as hydraulic conditions can be modified by the addition of baffles. Creosote-treated timbers will release contaminants, even when weathered, that may produce toxicity in fish or other aquatic life.



Open Bottom Box, if properly installed and sized does not limit fish passage, as it retains the natural stream bottom. They can maintain a normal width of the stream channel and are preferable over round and other false-bottom culverts. Little maintenance is required if they are designed and installed properly.



Open Bottom Arch, if properly installed and sized, also does not limit fish passage, as it retains the natural stream bottom. The statements made above for open bottom box culverts apply equally to open bottom arches.

Closed Bottom Arch tends to restrict fish passage during low flows and high flows as for the closed bottom box style. The culvert floor is often constructed of untreated wood planking. Hydraulic conditions can be improved for fish with baffles.

13.1.3 Culvert problems

Perched culverts are positioned above the level of the stream bottom at the downstream end, creating a waterfall (Figure 13.1). These culverts often get worse over time as the streambed erodes away, making the waterfall higher. The pool below the culvert can get overcrowded with fish, where they are vulnerable to predation and fishing. Undersized and perched round culverts are challenging for even the strongest swimmers and highest leapers; they often mark the end of the road for fish trying to get further upstream. Those perched more than 15 cm pose a significant challenge to many Island fishes. Often the only solution is to replace the culvert.

Figure 13.1 Perched culvert with no access for fish from downstream

Historically, culverts were commonly sized with a diameter about one-third the natural width of the stream that passed through them. Culverts are so efficient at passing water that they do not need to be as wide as the stream in order to pass the same volume of water. They are smooth, with little turbulence to slow water velocity. Unfortunately, a secondary consequence of that efficiency is that the water is so fast, it blocks fish passage by creating a velocity barrier. Some fish may be able to swim faster than the velocity of water in culverts, but only over short distances (Figure 13.2).

Figure 13.2 Plastic culvert on the West River that is too long and smooth to allow effective fish passage (velocity barrier)

Shallow water can also be a problem for migrating fish. Closed bottom arch and box culverts are susceptible to shallow water events during the dry summer months. This culvert on the Hunter River has a dry spot in the middle with fast flowing shallow water on either side (Figure 13.3). Baffling is often the only solution to slow down and backup water, allowing for better fish passage.

Figure 13.3 Shallow water barrier to fish passage in a Hunter River culvert

The wood planking in false-bottom culverts has a limited lifespan and the floor will usually need replacing or repair after a few decades. Culverts with rotted planking allow water to drop below the floor, reducing the depth of water in the culvert and restricting fish passage. In this image most of the water is running underneath the planking and rainbow smelt are seen below, blocked from further passage upstream (Figure 13.4). Replacement of the rotted floor with new planking is required if effective fish passage is to be realized. Sometimes sections of the floor will be rotten, but not be visible until a walk-through of the culvert is done. The whole floor should be sound to ensure the best fish passage.

Figure 13.4 Rotten flooring in culvert on Joey's Road, blocking passage of rainbow smelt

Many private road crossings have undersized culverts where fish passage is an issue. Undersized culverts cannot accommodate the volume of water flowing during intense storm events or in the high flow spring and fall seasons. Water frequently erodes around the culverts during high flows, creating a chronic problem of road wash outs followed by re-stabilizing earthworks (Figure 13.5). Fish passage issues with private crossings may have an additional complication as some landowners will not have the financial means to resolve them. Watershed groups need to be innovative when undertaking such projects. Second-hand culverts of higher water capacity and some ingenuity can go a long way in resolving many of these problems. Working with the landowner and discussing all options often leads to a solution that all parties can agree on.

Figure 13.5 Private farm road crossing with three undersized culverts perched at various heights and subject to a chronic washout problem

13.1.4 Fixing perched culverts

Some perched culvert issues can be resolved by adding downstream rock riffles. Rock riffles, sometimes called low-head dams, back-flood the waterfall at the culvert, and provide a natural-looking access for fish. The culvert waterfall is replaced with a series of rock dams, each with a water drop of not more than 15 cm. Most fish on PEI can negotiate a 15 cm water drop, especially if it is over a rock riffle, which closely mimics how natural river water moves.

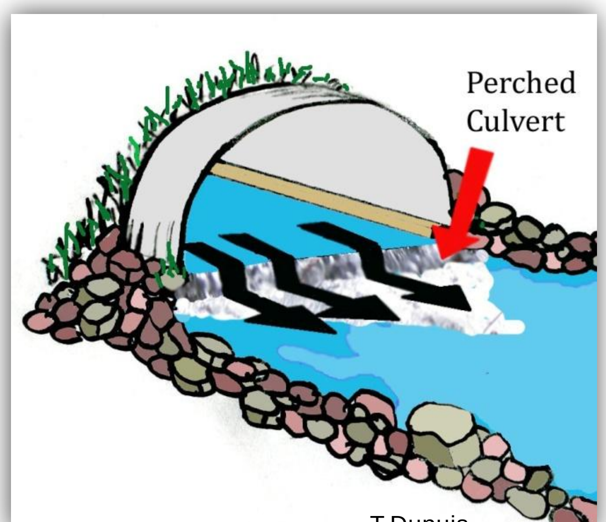


Figure 13.6 Perched culvert with the drop and associated white water

Before such a project is undertaken, any confounding issues with the culvert, such as velocity barriers, must be addressed. It is one thing to get the fish to the end of the culvert, but quite another to get them through it. Not all perched culverts lend themselves to a rock riffle project. Rock riffles require careful design and consideration. A provincial permit for rock riffle construction must be obtained and it requires that there be assistance from a professional.

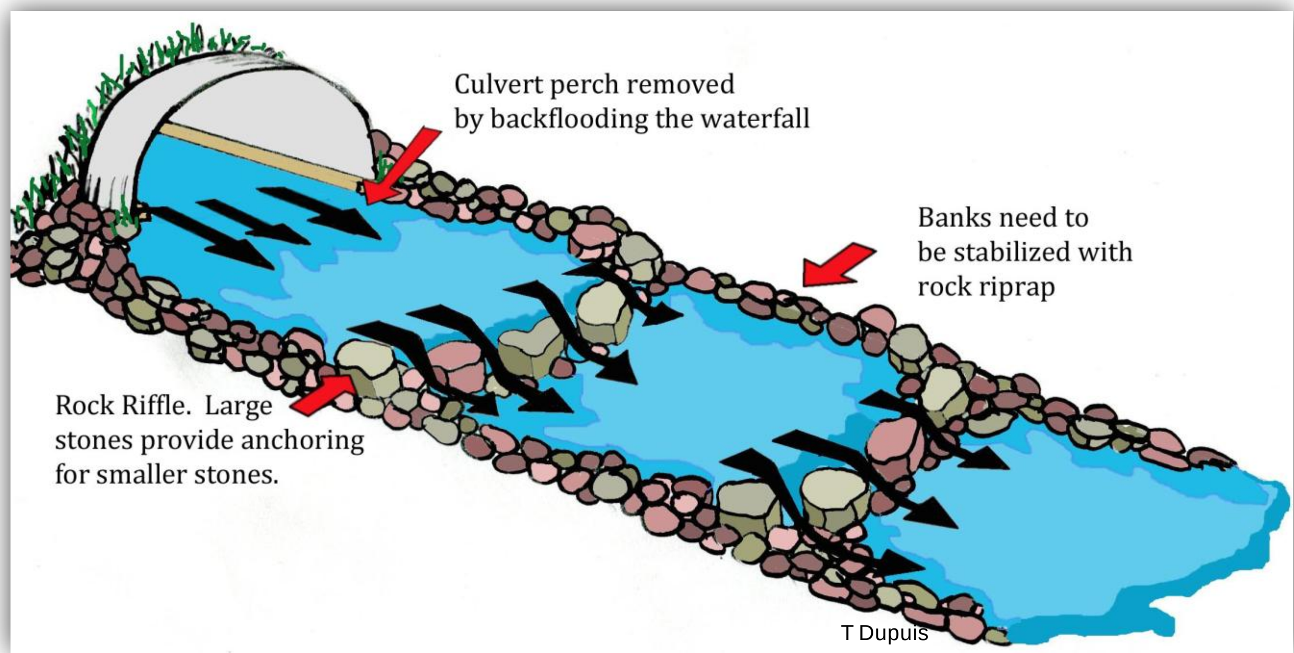


Figure 13.7 Two rock riffles constructed below a previously perched culvert to back-flood the waterfall

Figure 13.7 shows two rock riffles constructed to resolve a perched culvert issue. Large anchor stone is first placed with heavy machinery. A layer of filter fabric is added to the upstream side of the large anchor stone and then covered with smaller stones. The filter fabric and smaller stones help with the back-flooding of the stream and forcing the water to tumble over the riffle structure rather than through it. This mimics natural stream riffles, which fish can negotiate without difficulty. It is important that the banks of the stream be rip-rapped to guard against water eroding around the ends of the structures during high flow events.

This photo series shows the Clarkin Road culvert (West River) in Emyvale (Figure 13.8). Adult fish can ascend the culvert but many younger and smaller fish cannot. A drop of more than 15 cm followed by a section of shallow fast flowing water is enough to stop juvenile fish from moving upstream. Since this culvert is many kilometres from salt water, smelt passage is not an issue. The goal here is to provide effective passage for young trout and salmon. A crew positions large anchor stone at the first of two riffle sites below the culvert. Smaller stone are placed in front of the anchor stone forcing the water to go over the structure and back flooding the waterfall of the perched culvert. In its finished form, there is a low spot in the centre, which focuses water during low flow conditions. Also notice that the banks are rip-rapped with stone to reduce the chance of washout around the riffle during high flow events.

After project completion, the perched culvert issue has been resolved and it is a short run to the first baffle within the culvert structure.

Figure 13.8 Construction sequence for a rock riffle, West River

13.1.5 Fixing low water and high velocity barriers in culverts

Some culverts with fast flowing water and/or low water issues can be partially resolved by the addition of baffles. Baffles can be effective at providing fish resting areas during high flows and maintaining adequate water depth during low flows. Culverts with wooden flooring provide the best opportunity for the installation of baffles. Baffles are often fastened to the floor with metal spikes. Be sure that fish are able to get to the exit end of the culvert as baffling will not give access to a culvert that is severely perched. Baffle spacing and sizing is important, so technical assistance is required before installation. Refer to the *Prince Edward Island Watercourse and Wetland Alteration Guidelines* for specifics on baffle design. Baffling provides suitable passage for adult fish. If effective juvenile fish passage is desired, it is recommended that a natural bottom culvert be installed. The complexity and diversity of a natural channel is better suited to providing fish passage opportunities for small fish.

Figure 13.9 Baffles set on the diagonal (left) or perpendicular (right) to the culvert wall

Figure 13.9 above illustrates two different culvert baffling configurations. Culverts with baffling should be inspected periodically to ensure they are functioning as designed. Baffles sometimes trap woody debris. Remove only the debris that is necessary to re-establish fish passage and to ensure the integrity of the culvert and roadway. Any remaining debris will provide numerous habitat attributes ranging from refuge for fish to insect production. Be aware that culverts are favourite places for the construction of beaver dams. Beavers at public culverts have a real potential for roadway blow-outs and the Department of Transportation and Infrastructure Renewal should be immediately made aware of the situation. Periodic culvert inspections are always advisable to ensure woody debris is not accumulating from upstream work, blow-downs or beaver dam construction.

13.1.6 Replacement of culverts

In some instances, there will be no fix for a poorly installed or maintained culvert, and complete replacement is then the only option. Culverts may be replaced with better culverts or in some cases by a bridge. These options are all expensive and will inevitably not be undertaken by watershed groups except in special circumstances. However, watershed groups can assess the needs of the site and make recommendations on the best form of replacement, either to the province or to the private landowner. Small culverts or bridges may be suitable watershed group projects, with input from professional engineers. Be aware that there may be liability issues to consider.

Natural bottom culverts are being recognized in more jurisdictions in North America as the best solution for fish passage. Figure 13.10 shows a prefabricated culvert, which is wider than the stream. The stream remains relatively natural, thus functions best for fish passage. Culvert washouts are rare with these designs.

Figure 13.10 Prefabricated, natural bottom culvert installation on Lennox Island

Prefabricated, open bottom concrete culverts can also be placed over a smaller stream with little disturbance to river banks or water flow (Figure 13.11). Some structures contain prefabricated baffles to create better fish passage.

Figure 13.11 Concrete, natural bottom culvert on Clark's Creek

13.1.7 Bridges

When designed and constructed with abutments that do not constrict the stream channel, bridges have the least impact on fish passage and fish habitat. They range from log stringer bridges with timber decks, to steel girder bridges with timber or pre-cast concrete decks (Figure 13.12). Bridges can be supported by various means, including log cribs, cast-in-place concrete, timber and piers. Wherever possible, in-stream piers should be avoided, because they can collect debris during flood events and result in scouring of bridge foundations. In-stream piers can also result in hydrologic changes such as substrate scour or deposition, which may negatively affect fish habitat. Most natural bottom bridge designs do not hinder fish migration. If a watershed group decides to assist a landowner with construction of a private, trafficable bridge crossing, it would be advisable to consult a lawyer to identify any potential issues of liability in the case of injury to public users of the bridge.

Figure 13.12 Two renovated bridge structures on the Trout River, Tyne Valley (top) and West River (bottom), showing concrete or rock bank reinforcements and no in-stream piers

13.2 Fish Ladders and Run-around Bypass Channels

A fish ladder, also known as a fishway, is a structure designed to assist fish migration over barriers such as dams. Most fish ladders consist of a series of relatively low steps up which a fish can swim and leap, hence the term ladder (Figure 13.13). There is no single fish ladder design that will accommodate all species of fish at every location. The ability of fish ladders to provide passage is dependent on a number of factors including water flows, the drop between individual pools (cells), attraction water, the area of cells and the swimming abilities of the fish. Adult trout and salmon have excellent swimming abilities and can negotiate short sections of fast water. Other Island fish species do not have the same athletic ability; they require slower water to negotiate barriers.

Figure 13.13 Newly constructed fish ladder at Parsons Pond on Granville Creek

Because fish ladders never provide passage for all fish species and age classes, they can have an impact on the aquatic ecology of the watershed. Their location within the watershed is a major determinant of their impact on fishes. Fish ladders positioned at or near the head-of-tide have the greatest potential to impact negatively, as they often block movements of weaker swimming, non-salmonid, anadromous fishes. Rainbow smelts, alewives and blueback herring are species common to PEI that often struggle to ascend fish ladders. Smelts and blueback herring rarely migrate more than 7 – 8 km into freshwater on PEI before spawning, but it is critical they have access to this lower region of the watershed to complete their life cycle. Alewives migrate much further upstream than rainbow smelt and blueback herring so consideration must be given to them if they are present in the watershed. Otherwise, salmonid passage should be the focus where fish ladders are located many kilometres above saltwater. Be advised that fish ladders, although designed mainly to provide passage for trout and salmon, are not efficient at passing young (one and two year old) salmonids.

13.2.1 A case for non-salmonids

Rainbow smelt, blueback herring and alewives often enter freshwater on their spawning migration in large numbers. In doing so, they transport important marine-derived nutrients into the freshwater portion of the watershed. Nutrients, in the form of eggs and fish, feed many species of animals including insects, trout and birds and have value for the overall health of the watershed.

Many fish predators are opportunistic feeders and large runs of non-salmonids can provide prey cover for salmon and trout as they migrate to and from saltwater. The timing of the spring Atlantic salmon downstream migration of smolts often coincides with the upstream spawning migration of rainbow smelts. Tens of thousands of smelts provide prey cover for the relatively small number of salmon making their first foray into saltwater. Sea run brook trout returning to the West River enter freshwater with many thousands of blueblack herring that are on their spawning run in mid-June. The herring outnumber the brook trout many times over, thus providing cover in the form of a prey buffer from fish predators.

Whether the main interest is salmonids or not it is important to grant access to all fish species that would normally migrate into the watershed as they all play an essential role in its health.

13.2.2 Pool-Weir fish ladders

Pool and weir fish ladders are the oldest of the fish ladder designs and the most common on PEI. Pool and weir fishways all have a series of cells (pools) with a hole in each baffle, which creates a pathway for fish to move upstream (Figure 13.14). Pool and weir designs work well for jumping species like trout and salmon and are not as effective for species that do not jump. The efficiency of this design to pass fish changes with water flow changes.

Figure 13.14 Pool and weir fish ladder on the Vernon River

13.2.3 Vertical-slot fish ladder

A vertical-slot fish ladder is similar to a pool and weir system, except that each cell has a narrow slot (Figure 13.15). This allows fish to swim upstream without leaping over an obstacle. Vertical slot fishways are more complex than pool and weir ladders, but they have a constant flow pattern at all operating depths and are not as sensitive to water flow changes. This design allows fish to pass at any depth and is effective for a wider range of species as long as the current speed in the baffle is not too fast.

Figure 13.15 Vertical slot fishway on the Valleyfield River

13.2.4 Run-around bypass channels

A bypass channel, also called a 'nature like' fishway is a type of fish ladder you may not even realize is there. In this instance, only natural materials are used to build a channel that runs around the dam. Fish simply swim up the bypass channel and around the barrier. Bypass channels hold promise because they emulate natural hydraulic conditions for which fish have evolved; therefore they provide passage for more native species and life stages. Natural bypass channels are being constructed worldwide and their design is still under development. The design and construction of bypass channels is no small matter and technical advice is compulsory before community groups should consider them.

Some ponds on PEI have functioning bypass channels, which remain from the mill dam era. They were built mostly in the 1960s under the guise of forest fire protection. Water could be routed around the mill dam by using the bypass channel. As mills were abandoned some dams and bypass channels remained. The outflow from Crosby's Pond (Figure 13.16) on the West River is an example of a bypass channel. The channel is near the head-of-tide and provides passage for rainbow smelts and all other anadromous fish species native to the watershed.

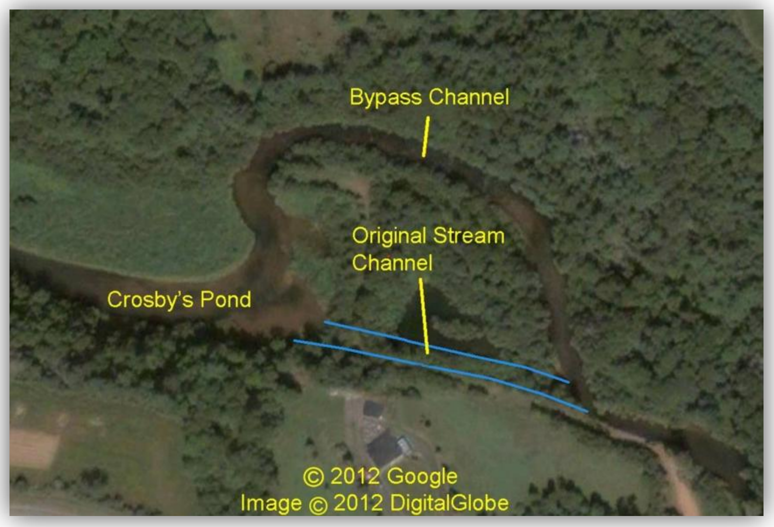


Figure 13.16 Aerial image of bypass channel remaining from Crosby's Mill, West River

It is important to note that not all bypass channels left over from the mill era are effective at passing fish of all species. Figure 13.17 shows a bypass channel through which adult Atlantic salmon and trout can ascend, but not rainbow smelt, due to the rock ledges.

Figure 13.17 Bypass channel on the Vernon River, accessible to some but not all fish species

13.2.5 Common fish ladder issues

High flow High water flow through some fish ladder designs poses a problem for fish passage. Both alewives and rainbow smelt enter fresh water during the spring when water flow is often high. Fish passage efficiency of pool and weir fish ladders are diminished in high flow, making passage for non-salmonids and younger salmonids difficult. Figure 13.18 is a pool and weir fish ladder at high flow. Note the white water, which is an indication that passage is poor.

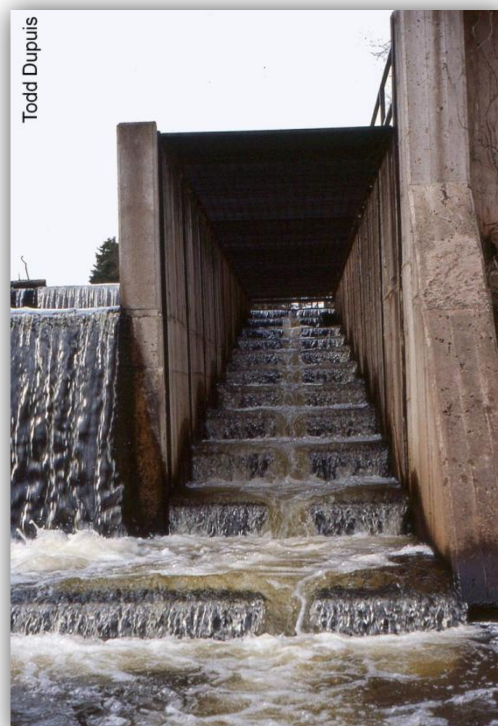


Figure 13.18 Pool and weir fish ladder at Officer’s Pond, Winter River

Attraction water Fish are attracted to flow when making migrations. For a fishway to work effectively, flow rates at the entrance of a fishway need to be sufficient to attract migrating fish. This can be especially difficult during times of medium to high flow, where large amounts of flow may be coming over the dam.

Blockages Blockages can occur when wood and other debris become lodged in vital areas of the fish ladder. Physical blockages can change the hydraulics of a fish ladder, making it impassable to fish (Figure 13.19). Periodic inspection of fish ladders is needed to ensure that debris has not accumulated.

Figure 13.19 Island fish ladder blocked with trash

If it is deemed that a fish ladder is adversely impacting the watershed by not providing effective passage for the native fish species that would normally migrate to that location, there are three options.

1) Retrofitting the fishway to increase its capacity for fish passage is possible in some cases. A few fish ladders on PEI have had their cell positions and numbers adjusted to modify the hydrology in an effort to make it easier for fish to ascend (Figure 13.20).

Figure 13.20 Fish ladder at Warren's Dam, head of Hillsborough River (Cherry Hill), retrofitted by adding more cells and metal chutes to provide better fish passage

2) Replacing the fish ladder with a more modern design is also an option to be considered. Our better understanding of fish passage needs and fish ladder engineering has resulted in more efficient designs compared to those of decades past.

3) Removal of the fish ladder with removal of the impoundment is also an alternative. Many artificial ponds have in-filled and do not provide the same quality of habitat they once did. Returning the area to river habitat would certainly alleviate any fish passage issues.

13.3 Fish Passage Summary

The once free-running rivers and streams of the Island were fragmented by roads and mill impoundments after Europeans settled. Roadway culverts and dams can present barriers to fish migration. Barriers present in the lower watershed have the potential to impact on a greater number of species, since there are several non-salmonid fishes (smelts, blueback herring) that spawn in streams close to the freshwater – brackish water boundary. Barriers present higher in the watershed will likely impact on alewifes, brook trout and Atlantic salmon (in rivers where they are still present).

Watershed groups can inventory the culverts and impoundments present in their watershed and evaluate their capacity to pass fishes. Starting that process low in the watershed during the rainbow smelt spawning season is advisable, since smelts blocked and congregating below a barrier are highly visible. Groups can use inventories to prioritize the fish passage issues present in their watershed.

Correction of fish passage problems posed by culverts and dams are described in this chapter. The solutions to these issues are typically very expensive and may ultimately be the responsibility of provincial government departments. Nonetheless, some solutions may be supported by watershed groups with human resources and landowner engagement. All of the strategies described in this chapter require provincial and sometimes federal permits before being spear-headed by a watershed group. Fisheries and Oceans Canada must approve all fishway designs before a permit would be given. The following table summarizes the most common issues and their potential solutions.

Fish Passage Issue	Potential Solution	Solution Conditions	Watershed Group Role
Perched culvert	Construction of rock riffle	Fish must be able to ascend through culvert once rock riffles are constructed downstream	May construct riffles with professional assistance and appropriate permits
Culvert with water velocity or shallow water barrier	Add baffles to the culvert	Culvert must have a flat-bottom, wooden floor that is in good condition (otherwise may need to replace floor first)	Can prioritize for watershed (as above) or install in private culverts with professional assistance
Culverts with multiple or unsolvable issues	Replacement of culvert	Where a perched culvert cannot be adequately back-flooded with a rock riffle sequence; Where the culvert is a round type or where flow cannot be sufficiently slowed with baffles	Can prioritize for watershed and communicate priorities to Dept Transportation; may replace on private land with professional assistance and permit
Fish ladder with debris barrier	Remove the debris		Maintain with permission of owner
High flows or waterfalls in runaround bypass channel	Add boulder / cobble to stream or build riffles	Gradient must be less than 5 % and stream bed free of excess sediment load	Follow guidance provided in chapters 13 and 14
Fish ladder with multiple or unsolvable issues	Replacement of ladder	Site must have room for a better design	May raise funds required and facilitate replacement with permission of owner
Fish ladder with multiple or unsolvable issues	Remove ladder and impoundment	Must have the support of stakeholders	May raise funds required and facilitate removals

13.3.1 Useful resources

ASE Consultants Inc and Department of Biology UPEI, 1997. Impact of impoundments and their suitability for resident and anadromous fish species on Prince Edward Island. Final Report, Volume I. Prepared for the Department of Fisheries and Oceans, Habitat Management Division, Moncton, NB.

Heaton MG, Grillmayer R and Imhof JG, 2002. Ontario's stream rehabilitation manual. Chapter 6 – fishways. Ontario Streams, Belfountain, ON. Available online

Watercourse Alteration Advisory Committee, [publication date unknown] Prince Edward Island watercourse and wetland alteration guidelines. Prepared for PEI Department of the Environment and Fisheries and Oceans Canada. Available online

Zwirn M, 2002. Forest road construction and culvert installations in salmon streams: Best management practices and lessons for the Samarga Watershed. Draft, The Wild Salmon Center. Available online

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

14. Management of Constructed Dams and Beaver Dams

14.1 Constructed Dams or Impoundments

Most watershed groups will have one or more impoundments in their watershed. The dams that produce impoundments are owned, usually by individuals, the provincial government or Ducks Unlimited. Sometimes the latter two institutions will also lease or co-manage dams and impoundments. The form of ownership will often determine the type of management activities that have taken place or that can occur. For example, Ducks Unlimited prefers to maintain shallow water impoundments with a mix of vegetation and open water conditions that are optimal for waterfowl. A private landowner interested in fishing may want to maintain deeper water with a minimum of emergent vegetation along the edge. Competing uses are not mutually exclusive; some ponds have been known for excellent fishing early in the season while also providing wetland habitat for other wildlife species.

In some instances, owners may wish to share the management of an impoundment with a watershed group. If that is the case, it is important to collect as much information as possible about the pond and to create policies and/or specific management plans for it. Understanding the impoundment's morphological, physical and chemical characteristics (e.g., depth, water temperature and dissolved oxygen profiles), as well as structural design elements of the dam (e.g., fish passage, draw down capabilities) are essential in developing such plans (Figure 14.1). The benefits of the impoundment to wildlife and the environment, as well as the recreational and social values must be considered. The provincial Forests, Fish and Wildlife Division keep information on some impoundments, such as fish trap and water temperature data, and sometimes previous management plans or records of management activities. An excellent resource is the *Prince Edward Island Impoundment Study* (1997), which identifies a classification model for Island impoundments. There is also the more recent *Guidelines Respecting the Management of Impoundments on Prince Edward Island* (2009), which discusses specific issues such as dewatering and decommissioning in greater detail.

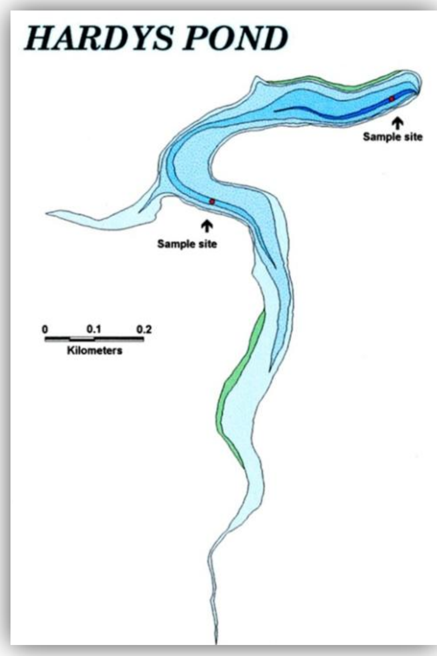


Figure 14.1 Bathymetric map of Hardy's Pond, showing the morphology of the pond basin (courtesy of ASE Consultants and UPEI 1997). The darker blue indicates deeper water

It is important to look at an impoundment in the context of the entire watershed. The ratio of lentic (impounded) to lotic (flowing, riverine) habitat for each impoundment's sub-watershed may impact water quality. Impoundments near the head of tide can limit fish passage from estuaries to upstream areas. Dams on headwater tributaries may profoundly alter water quality and cold water fish populations. Watershed groups should also look at threats to the impoundment. Is the pond infilling quickly because of upstream land use practices? Is there a danger that the dam may blow out if remedial steps are not taken (Figure 14.2)? Each impoundment is unique and has its own characteristics and issues. A management regime that might work for one may not necessarily work for another, even within the same watershed. Dams are expensive to build and maintain and can profoundly alter the river environment. While it is rare to have new impoundments constructed on PEI, the existing dam structures continue to need maintenance and financial resources as they age. Owners and watershed groups need to make tough decisions about whether to maintain, upgrade or decommission the artificial, "hard" engineered structures associated with some impoundments.

Figure 14.2 Scale's Pond in spring 2009, after an acute dam failure

14.1.1 Maintenance and monitoring of impoundment structures

Island impoundments were originally constructed from a variety of materials. Some, such as Hunter's Pond, were created behind a simple earthen berm (Figure 14.3). Trees were sometimes cut in the pond area before flooding, but little earthworks were required other than the berm construction, which held back enough water to produce ponding. This type of impoundment may remain in place with very little maintenance for a hundred years. Water level will drop because of infilling and erosion of the bypass channel. Other impoundments, such as Livingstons Pond (Big Pierre Jacques River), were hard-engineered with concrete and/or wooden dam structures. These latter structures have a finite lifetime, no matter how well they are maintained, and will eventually need to be either replaced or removed. While there is still structural integrity and management options, watershed groups should begin the community dialogue: is the long-term maintenance of an impoundment in your watershed realistic and affordable?

Figure 14.3 Hunter's Pond in Baltic (top) is contained behind an earthen berm with a run-around bypass channel that does not block fish passage, whereas Livingstons Pond on Big Pierre Jacques River (bottom) has a concrete dam structure with a finite lifetime

Impoundment infrastructure requires maintenance to protect against dam failure, to maintain effective fish passage, and to optimize the wildlife, aesthetic, and recreational benefits the pond may provide. For instance, there may be a need to replace stop logs in the dam structure. Regular monitoring of a fish ladder to ensure that all cells of the ladder are operational and free from debris is also important. It is essential to keep debris, including beaver dams, from blocking drop inlet culverts, fish ladders or run-around bypass channels, as these blockages can increase the risk of a dam failure in high flow conditions. If you have concerns about fish passage or deterioration of a dam's infrastructure, check with appropriate authorities. Fish ladders and culverts can be dangerous places and maintenance activities should not be attempted without professional help.

Watershed groups may be involved in the routine monitoring of impoundments for early detection of maintenance issues. A monitoring checklist and other invaluable management guidance are provided in the provincial document *Guidelines Respecting the Management of Impoundments on Prince Edward Island* (2009).

14.1.2 Upgrades and pond restoration

There are situations where major renovations may be needed to improve water quality or fish passage at an impoundment. A pond that is discharging warm water from the surface and having a detrimental impact on water quality downstream may be retrofitted to allow the outlet of water from lower depths where the water may be cooler. Because deeper ponds often have stratified water temperatures, drawing only bottom water, which is cooler, can alleviate downstream impacts on cold water fishes. The provision of "bottom draw" can sometimes be accomplished by adding an extra row of stop logs at the front of the dam, leaving a gap at the bottom for water to discharge (Figure 14.4). Water then discharges from the bottom and may provide temperature relief downstream during warm summer months. Mooneys Pond (Morell River), Larkins Pond (Naufrage River) and Parsons Pond (Granville Creek) are examples of structures with the capacity for bottom draw.

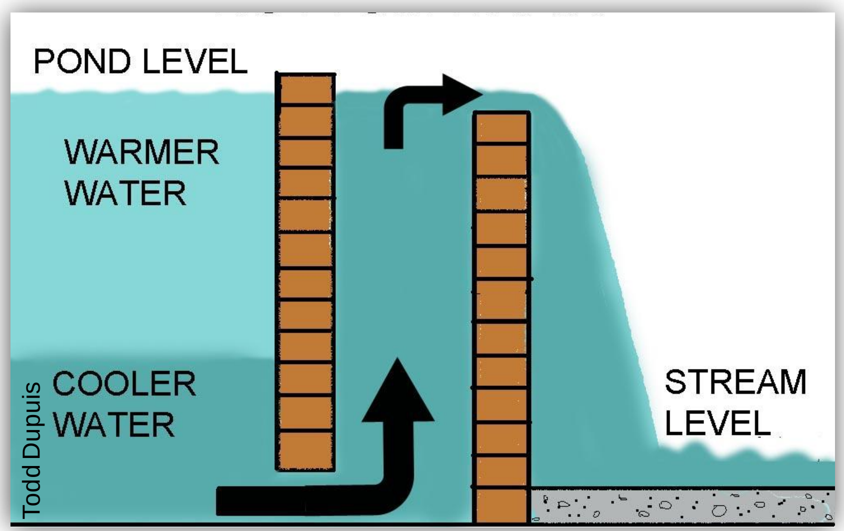


Figure 14.4 Bottom draw allows cool water from pond bottom to exit downstream and moderate in-stream temperature

A complete dewatering of a pond, a drawdown, can be an effective technique for improving conditions within an impoundment. On the Island, streams are already productive so the impact of drawdown on productivity may be minimal. There are, however, benefits to water quality (temperature and dissolved oxygen). Drawdowns have been used to flush or clean out the original stream channel, provide opportunity to remove sediment from the pond basin, and to control excessive submergent vegetation. In order to effectively move sediment within the pond basin, the drawdown must be long enough to include a freshet. To reduce disruption and harm to wildlife using the pond, timing of drawdown is critical (Figure 14.5). The months with the least impact are generally March – April or September (Fisheries and Oceans Canada and PEI Environment, Energy and Forestry 2009). In some instances a complete winter drawdown might be desirable, especially to control weedy vegetation.

Figure 14.5 Livingston's Pond in Glenwood, Big Pierre Jacques River has had periodic winter drawdowns in an attempt to control pond vegetation. The local community has been satisfied with the results of this management program

Controlling sediment movement downstream during drawdown may be achieved with strategic use of temporary sediment traps. Each pond is different and may require a different approach. Because of structural design, some ponds can be completely dewatered while others cannot. Those that do, move the most sediment downstream. In some instances, a bypass sediment pond or in-stream sediment trap can be constructed downstream in anticipation of this movement. In other situations, particularly in high gradient sections of stream, it will be impractical and inadvisable to dig a downstream sediment trap. Another option would be to attempt removal of sediment within the impoundment (near the dam) as the pond is slowly being dewatered. Because of the expense and difficulty in removing sediment within pond basins, efforts must be focused on preventing sediment from reaching the watercourse and failing this, removing sediment before it reaches the impoundment. Also, excavation outside of the usual time window of June – September would require a special permit and may have more restrictions.

Many Island ponds are becoming in-filled with sediment. This is particularly visible at the upper ends of the impoundments as the stream entering drops its sediment load into the slower waters. Some groups have undertaken pond restoration projects, in which a portion of the sediment is removed. This is possible where the pond can be drawn down and water diverted prior to excavation. Excavators are used to side cast the spoils, which are then stabilized on site. It is important to consider the potential for sediment contamination in old mill ponds. Depending on the nature of the original mill, there could be heavy metals bound to the sediment in the pond bottom. Also, pesticides such as azinphos-methyl may be present at high concentrations. Sediment samples should be collected and analyzed prior to excavation. The standard test for petroleum-based contaminants will not detect metals and pesticides, so ensure that you are testing for the materials most likely to be present, based on watershed history. The end result of pond excavation is a narrower, deeper pond. Figure 14.6 shows two good examples of this type of pond restoration on the Island.

Figure 14.6 Rackham's Pond on Wheatley River (top) and Carragher's Pond on West River (bottom)

Pond restoration, when properly planned and executed, can produce wonderful results and may serve as a flagship project for a watershed group. A word of caution: pond restoration requires extensive planning, permits are required and such projects are costly. These are complicated projects involving landowners, both levels of government, and the watershed group. Since every impoundment is different, it would be impractical to offer step by step procedures here.

14.1.3 Impoundment decommissioning

When the benefits of an impoundment are outweighed by its negative impacts and cost of upkeep, an option may be to proceed with decommissioning. Where it is known that there is a high risk of the dam failing, there may also be an element of liability for the downstream damage incurred after a blow-out. Do not make the mistake of assuming that this is the cheapest option, as proper decommissioning can be costly. Impoundments contain a massive amount of sediment and organic material, some of which will be liberated and move downstream when the dam is removed. Thus, considerable planning is needed before removing a dam to ensure that downstream habitat is protected during the decommissioning process.

Such a project should involve a slow drawdown and a subsequent capture and removal of material, either downstream from the dam or immediately in front of the dam (Figure 14.7). As for a pond restoration, sediment sampling for the presence of contaminants is advised.

Figure 14.7 Decommissioning of Breadalbane Pond on the Dunk River. Sediment was removed from the stream bed upstream from the dam during the decommissioning process

Dromore #1 Ducks Unlimited impoundment on the Pisquid River is a good example of a controlled decommissioning. The concrete in the dam structure had deteriorated since its construction in 1973 and the projected cost of repairing the fishway prompted Ducks Unlimited to decommission the dam in 1996. A slow, careful draining of the pond over nine weeks from July to September minimized the movement of inorganic material downstream.

Occasionally, decommissioning of an impoundment has simply involved the removal of stop logs from the dam structure and fish ladder. This can have mixed results, as the stream may not return to its natural elevation depending on the nature of the dam infrastructure, and beavers may plug the outlet thus re-flooding the pond. As a result, the stream remains in a state of flux, neither fully lentic or lotic habitat and the benefits of the dam's removal may not be fully realized.

14.2 Beaver Dams

14.2.1 Beaver management plans

Wherever beavers are present, a watershed group should develop a beaver management plan. These plans require approval from the Forests, Fish and Wildlife Division. Watershed groups should be aware that, if beaver populations are not adequately controlled in low gradient reaches of streams, the complete reach will eventually lose riparian tree cover and transition to grassy meadows. Some groups have partitioned the watershed, allowing beavers and their dams to remain undisturbed in headwater reaches of streams and identifying lower portions as "beaver free"- areas where beavers and their dams can be removed. In some cases, the upper stream reaches will contribute many beavers to the "beaver free" zone unless appropriate habitat management occurs, e.g. removal of inactive beaver dams so new trees can grow and populations of beavers are trapped so food does not become limiting. Other groups may wish to designate entire streams as beaver free. The first step is for the group to be familiar with all reaches of the stream in question and have identified valuable wetlands and critical habitat for salmonids. Fish dependent upon cold water for survival and relying on springs and upwelling areas for spawning must have access to critical habitat areas during different times of the year. Identify these areas and ensure that they remain open and accessible for salmonids. When planning, it is useful to consider the lentic to lotic ratio. If there is a large artificial impoundment on one tributary, for example, it might be prudent to maintain as much remaining stream as possible in lotic habitat, thereby reducing the potential for the warming of water.

Landowners should be consulted, as they may have certain objectives for their properties and have the final say in their management. Most importantly, ensure that you have trappers available within your area to assist in any beaver management activities. Finally, the watershed group must remain vigilant and commit to monitoring an area in various seasons. This may involve walking or canoeing the stream to ensure that those areas designated as "beaver free" are maintained as such. Currently, a group that regularly monitors a beaver free section of river will be given permission to remove beavers throughout the year. If monitoring does not occur, then the group must wait for the trapping season to remove the beavers and the dams remain in place until the following year. The size of management areas for many watershed groups is so large, it is virtually impossible for them to live up to their obligations for monitoring and control of beavers.

14.2.2 Beaver dam removal

Landowner permission and a permit to remove the dam will be necessary. The primary objectives of removing beaver dams are to:

- restore normal stream flow while limiting the movement and impact of sediment stored within beaver impoundments,
- prevent streams from becoming abnormally wide and choked with organic material,
- restore native trees and shrubs in the former riparian zone,
- provide fish passage,
- minimize impacts on water temperature and dissolved oxygen.

It should be confirmed that all beavers have been removed or that the colony is inactive before the dam is removed. An active dam that is breached will be repaired quickly by the beavers.

Figure 14.8 Inactive beaver dam and lodge on St. Peters River, evidenced by lack of food cache at the lodge and no green sticks on the dam (left) versus active dam on the Morell River (bottom)

If there is a series of dams it can be difficult to determine the location of the original stream channel and some investigation may be required. Some beaver dams are wide and efforts should be made to breach at the original channel to allow for a more natural reestablishment of the stream. For multiple dams, removing the upper dams first while leaving the lower dams to capture sediment liberated during dam removal is an option. However, it may be necessary to work from downstream dams to upstream if the original channel is not evident or flooded. Removing the dam slowly will reduce the volume of sediment and organic matter that moves downstream (Figure 14.9). This may require a couple of days to do properly. When the water level is sufficiently reduced, brushmats should be added to capture sediment and narrow the stream channel. If the dam is large or there are many dams in succession, consideration should be given to establishing a sediment trap (in-stream or bypass) downstream from the affected reach prior to removing the dams.

Figure 14.9 Breaching a beaver dam on the Fortune River

Restoring the stream channel may take a number of years and involve removal of woody material from the channel and brush mat construction. The restructuring and restoration of the riparian zone following beaver dam removal, especially after many years of impoundment, will take much longer. Hunt (1993) suggests, "…the soil chemistry changes, depressing the encroachment of natural woody vegetation for decades after the meadows are drained. Without deliberate remedial efforts, the stream channel will remain excessively wide, shallow, and choked with organic sediment."

14.2.3 Re-vegetating flooded land

On low gradient Island streams, beavers are capable of changing forested riparian buffer zones to brush marshes and/or grassy meadows. Initially a newly created beaver impoundment appears to be good habitat for nesting waterfowl, such as black ducks and green-winged teal. When the beaver food supply diminishes after a few years, they abandon the area leaving dead standing conifers and shrubs. The dam will not blow out with flood waters on low gradient streams. This may prevent both upstream and downstream movement of fish that do not jump (e.g., rainbow smelt and gaspereau).

Without regular maintenance by the beaver, the water in the beaver impoundment gradually drops and some regeneration of shrubs and trees starts along the perimeter of the former water edge. Within a decade or so, beavers return to the area, but this time the impoundment they build is both higher and wider to provide access to new lateral food supplies. This sequence of new dams, abandonment and reestablishment continues until the flooded zone reaches an embankment (zone III in Figure 9.1).

In low gradient areas with long term expansion of beaver colonies and accumulation of inactive dams, vast acreages of land have been flooded (Figure 14.10). Former treed riparian zones, which supported a diversity of wildlife species (the greatest for Acadian forests in general) have been transformed into grassy meadows. The extent of this conversion and the dramatic environmental changes should be documented by watershed groups and incorporated into watershed planning. The impact of beavers on low gradient streams on the Island in combination with the construction of numerous artificial impoundments during the 1970s and 1980s will make lotic restoration of sections of many rivers extremely difficult.

Figure 14.10 Aerial photographs from the Midgell River, spring 2012, showing the loss of forested riparian margin and replacement with long, wide expanses of grassy meadow caused by multiple beaver dams on all tributaries

Many tree species that are normally expected to thrive in flood plains have not done well in former beaver impoundments (Figure 14.11). Groups should wait until the area is well drained before attempting to plant trees and shrubs. This may take longer in the west, where the soils naturally have higher clay content, than in the east of the province. It is advisable to wait at least a year before planting. More information is needed about the best approach to planting these areas on the Island. Sweet gale (*Myrica gale*), native holly (*Ilex verticillata*), tamarack (*Larix laricina*), black spruce (*Picea mariana*) and red maple (*Acer rubra*) may be the best plants to try to establish after a beaver dam is removed.

Figure 14.11 Bank Brook Tyne Valley (upper left) and Morell River (all others), showing progression of vegetation community change in riparian zone with beaver dam construction

14.3 Dam Management Summary

Impounded waters in Island streams can have both positive and negative ramifications. Islanders love their ponds and the slower lentic waters also suit some kinds of wildlife. However, there is no doubt that the pre-European nature of these rivers was more free-flowing and suitable for aquatic species adapted to cold, well-oxygenated waters. In this regard, today's Island streams are fragmented, with loss of habitat connectivity. In addition, the hard-engineered impoundment structures scattered throughout the Island have a finite lifetime. Difficult decisions will need to be made, about which to maintain or replace and which to decommission. With well over 800 impoundments across the province, the cost of retaining all of them would be prohibitive.

Watershed groups have the task of evaluating the extent of stream impoundment within their watershed, assessing the impacts and attributes in the context of their community-based vision and goals, and developing a plan that is best for their area. Groups will need to work closely with impoundment owners and the community in developing such a plan. In almost every instance, impoundment management will be costly.

Similarly, the impoundment of rivers by beavers is a natural activity that can both create and destroy habitat. Decisions on management must consider the watershed as a whole and the vision the community has for its rivers. Where the decision is made to return the river to a free-flowing state, the restoration process is likely to be a gradual one. Flooded riparian soils will need decades to recover before they will again support a diversity of Acadian forest trees and shrubs.

14.3.1 Useful resources

ASE Consultants and University of Prince Edward Island (Department of Biology), 1997. Impact of impoundments and their suitability for resident and anadromous fish species on Prince Edward Island, Volume I. Prepared for Department of Fisheries and Oceans, Moncton, NB.

Fisheries and Oceans Canada & Prince Edward Island Environment, Energy and Forestry, 2009. Guidelines respecting the management of impoundments on Prince Edward Island. Charlottetown, PE.

Hunt RL, 1993. *Trout Stream Therapy*. University of Wisconsin Press, Madison, WI

15. Special Habitats: Springs and Wetlands

There are a number of special aquatic ecosystems around the Island that serve important functions in watersheds, but whose characteristics and value are often overlooked or poorly understood. In most instances, we do not know enough about these places to recommend restoration strategies. This chapter describes what we know about their ecological values and how to protect them from degradation.

15.1 Springs

Because of the nature of our fractured shale bedrock, substantial quantities of groundwater are stored beneath the Island. As groundwater moves, cracks in the rock allow it to rejoin the land surface at springs and seeps.

Springs are prevalent in steeper terrain, where they may exit the ground into a riparian margin or directly into the bottom of a stream. Some springs that originate near the height of land may run dry during extended warm periods because the water table has dropped too low. Sometimes, digging out the spring may restore a bit of flow but only temporarily as the water table continues to drop. High volume wells can lower the water table causing nearby springs or shallow wells to run dry.

Springs come in all shapes and sizes on the Island. They can cascade down a hill over mossy stones, as in the Naufrage River (Figure 15.1). Others gently spill out of a depression and have bottoms of pure sand, with bubbling cauldrons seen in many locations (Figure 15.1). There are springs that bubble up through moss-coated woody debris and others are green with aquatic vegetation. Where a groundwater discharge area occurs along a seam of fractured rock on a stream bank, the dispersed pattern of the groundwater entry to the stream is distinguished by calling it a seep rather than simply a spring.

Figure 15.1 Hughie Joseph spring on the Naufrage River (top) and a bubbling spring in North Lake Creek (bottom)

Springs have traditionally been seen as special areas. For early settlers, they offered a source of drinking water and refrigeration. Farmers relied on springs to water livestock. Islanders also discovered the value of springs in the production of "spirits." A colourful history has produced colourful names like the "Roaring Springs" in Naufrage, Fountainhead in North Lake Creek, the Healing Springs at the head of Hillsborough near Cherry Hill, and Spirit Springs in Dromore (Figure 15.2).

Figure 15.2 Spirit Springs in Dromore is a popular resting area for residents and visitors

15.1.1 Importance of springs for watercourses and wildlife populations

In summer months when there is less rainfall, springs provide almost all of the water in our Island streams. Although some upland springs may dry up in summer, most flow all year introducing water to the stream at a temperature of about 7 – 8°C. These inputs moderate the stream temperature and maintain a basewater flow, thereby forming the very foundation of our coldwater streams.

During winter in free flowing streams, springs maintain the water temperature at a level that may be well above air temperature, restricting the formation of ice on smaller streams. If considerable spring water enters the stream at the head-of-tide, the upper estuary may also frequently be free of ice. These open water sites can be important winter feeding areas for various waterfowl species, like mallards, black ducks, golden-eye and common mergansers.

On the Island, most brook trout seek out groundwater seeps and springs in which to spawn. Cover nearby for protection of adults and good quality gravel for better development of the eggs are also preferred, but the groundwater itself appears to be the primary attractant (Figure 15.3). Considering the amount of sediment deposition in most of our streams, this behaviour enhances egg survival and emergence because of the well-oxygenated upwelling spring water. A study on the Morell River revealed that eggs from brook trout placed in incubation baskets with washed stream gravel had good hatching success in both springs and spring leads. Poor hatching success was recorded for eggs incubated in stream locations with frequent turbid water.

Figure 15.3 Trout redd (indicated by disturbed gravel) next to overhanging bank cover in Bristol Creek

Springs in estuaries were once all “mapped” in the minds of locals who had to use the ice surface on rivers as winter roads (springs equated to open water), but that knowledge has largely been lost and the ecological importance of these springs is not well understood. They may provide refuge for resident and migrating fishes when estuaries’ summer and winter temperatures approach the extremes for species’ survival. It is well known that some species, such as rainbow smelt, move into estuaries from colder salt water in winter and that American eels bury into the mud in estuarine springs during winter. In the Morell, Pisquid, and Midgell Rivers we have observed groups of brook trout spawning downstream from the head of tide. Anecdotal information from local residents in other areas (e.g., Head of Hillsborough) would indicate that upper estuarine spawning is not unusual (Figure 15.4).

Figure 15.4 High volume spring entering Hay River in mature forest about ½ km from the coast

Spring-fed water discharging down-river into estuaries also may moderate the high summer temperatures in bays that have become shallower and warmer as upstream sediment loads increased during the past century. Higher water temperatures exacerbate the nutrient issue in estuaries prone to anoxic events, by allowing sea lettuce to grow more rapidly.

Springs with long (50 m or more) vegetated leads (channels) to the river are especially important habitat for young-of-the-year brook trout. The water and vegetation do not freeze in winter because of the influence of the moderating groundwater temperature. Therefore, trout hatched in these locations should have no trouble finding and metabolizing food. Even when brook trout do not spawn in these spring leads, the juvenile fish can frequently be found there (Figure 15.5) so they must try to seek out the warmer water after hatching.

Figure 15.5 Electrofishing the lead from Fountainhead Spring

Springs can have unique plant and animal communities that are adapted to the microclimate offered by relatively stable 7°C water temperatures. Some wildlife (for instance, beaver and muskrat) seek out springs in winter as “spas,” much appreciated when outside temperatures fall well below freezing.

15.1.2 Spring restoration, a precautionary tale

Springs are important in maintaining cool water temperatures in small streams and, in turn cooler rivers and moderated water temperatures in estuaries. We should therefore consider them to be critical aquatic habitat for coldwater systems on the Island. It would be prudent, then, to provide protection for all springs and spring leads within a riparian zone of diverse vegetation, preferably much wider than 15 metres.

Figure 15.6 Brook trout congregate to spawn in a spring, Cross River

It is important to identify locations in each watershed where brook trout spawning groups concentrate before and during spawning. To be successful, these fish may require some intervention and management by watershed groups: maintenance of appropriate cover, prevention of beavers setting up dams in such locations, and controlling angler exploitation. On the Morell River, a 500 m length of stream was designated a sanctuary to help protect brook trout from anglers and poachers in an area known to have concentrations of trout. Souris Wildlife Federation has partially excavated Harmony Spring, added cover and also sought regulation changes to prevent angling in the area (Figure 15.7).

Figure 15.7 Harmony Spring (Souris River watershed), open habitat in winter

Where a spring meets the stream, differences in water density produce a lateral flow of spring water along the bank edge. Brook trout will often use these areas to spawn and they may be enhanced by adding adjacent cover (e.g. split logs) and gravel. If the entry location from the stream to a spring lead is blocked, the debris should be removed to allow access for various sizes of trout.

Numerous Island springs were used as watering sites for livestock for decades. Even though this practice has largely been discontinued, vegetation and soil in the spring lead often remain severely degraded and may still have sediment input from adjacent agricultural fields. To provide stop-gap protection in these degraded systems, it may be possible to build a metre-high berm around a portion of the spring and thus deflect run-off water. Over the longer term, try to establish a wide, diversified buffer zone around these springs and spring leads.

Digging out a spring will appear to increase the volume of cool water entering the stream, but in most cases, it simply concentrates the groundwater flow by diverting it from nearby seeps. Make sure that you get professional advice before you contemplate digging out a spring, particularly if your objective is simply to enhance brook trout habitat. Juvenile brook trout populations may already be robust in the watercourse. Contributing to the congregation of mature trout can contribute to increased predation pressure on trout. When in doubt, leave the spring alone!

Several watershed groups have dug out springs that exist close to streams, expanding their size and adding gravel and cover (Figure 15.8). The response to these modifications may vary, but there can be a substantial increase in use by spawning brook trout. These additional trout are drawn from other spawning sites, perhaps from areas with less spring water. More trout hatching sooner, in early spring, may not be beneficial if the water in the adjacent stream is still too cold for them to forage or if adequate juvenile habitat is not present immediately downstream. If the spring is already being used by spawning trout, it may be best to leave it as is. There is insufficient monitoring data available to determine whether spring expansions like this will increase or decrease overall brook trout populations. However, what is very clear is that populations of brook trout in Trout River (Coleman) are extraordinarily high, probably because of quality habitat and wise management strategies.

Figure 15.8 Dave Biggar's Trout River Spring, excavated with gravel and cover added

15.2 Wetlands

Wetlands are lands that are saturated with water for extended periods; they are characterized by poorly drained soils, water-loving (hydric) vegetation and other organisms specialized to live in that wet environment. The 2000 wetland inventory, a provincial GIS database, identified 5.6% of the Island's land base as wetland, including classes such as open water, deep marsh, shallow marsh, seasonally flooded flat, meadow, shrub swamp, wooded swamp and bog. These provincial classifications do not align exactly with the national Canadian Wetlands Classification System, but there is some overlap.

Once maligned by the general public, there is now greater recognition of the values of wetland ecosystems. A Wetland Compensation Policy for Prince Edward Island was developed in 2003 to help protect wetlands from development. Under this policy of no net loss, the first priority is to avoid damage from development; where that is not possible, mitigation and compensation strategies are applied. In the latter case, the developer must pay compensation to account for losses of wetland area and/or wetland function. Watershed groups may be asked to restore or alter wetlands for resource use, in which case they would be subject to the same restrictions as developers under this provincial policy. We recommend protection and enhancement of these special areas, with preservation of ecological function taking precedence over resource use.

15.2.1 Barrier beach ponds

The few natural inland freshwater ponds that occur on the Island are all less than 50 ha in size. Near the coast there are many more ponds of varying sizes, some freshwater but primarily brackish and usually associated with sand dune ecosystems. Some of these, the barrier beach ponds, are established at the mouth of watercourses as they reach the sea (Figure 15.9).

Figure 15.9 St. Peters Lake, one of the larger barrier beach ponds

Occasionally, the outlet to the sea may be temporarily closed by storm events but will reopen as water pressure builds from stream input. In some regions, such as Greenwich, many barrier beach ponds occur with varying wind exposure, depth, size, salinity and access to the sea (Figure 15.10).

Figure 15.10 Greenwich Sand Hills, with barrier beach ponds scattered along the outer coastal edge

Coastal ponds and associated vegetation offer a unique diversity of habitats, which attract innumerable species of wildlife. Permanent residents and migrant bird species utilize these coastal zone ecosystems. Humans are also very attracted to the coast areas, at least on a seasonal basis and their interests often conflict with those of wildlife. Cottage construction, golf course development, and blueberry field expansion have been encroaching on these sensitive areas (Figure 15.11).

Figure 15.11 The Links at Crowbush Cove infringing on barrier beach ponds

In the past, dams have been built near the shore to convert barrier beach ponds to strictly freshwater ponds (Figure 15.12). Such dams would not receive permission to be constructed today. Outlets are prone to debris blockages from storms and wave action at high tide may affect the dam infrastructure.

Figure 15.12 Former dam site in St. Margarets reclaimed by the dunes

In other areas, people have received permission to excavate the outlet channel to improve flow. This would require regular maintenance as the sand will naturally continue to infill the area (Figure 15.13).

Figure 15.13 Buried outlet for Clearsprings Pond

The best management for coastal ponds is for humans to leave them to change as nature dictates and enjoy the biodiversity and opportunities created. Watershed groups should consider these as special areas, deserving of protection. Because of the value of these areas to wildlife, and the aesthetic and recreational benefits they provide, they are truly natural gems. They are often particularly sensitive to infringements, because of the sandy, coastal environment in which they are situated.

15.2.2 Peatlands

Peatlands are organic wetlands – these are the bogs, fens and some swamps. Peatlands are wetlands where peat (dead – mostly plant – material) has accumulated on organic soils for thousands of years. Over time, swamps transition to bogs or fens and fens transition to bogs as the peat accumulates and the water table changes. The Island has expanses of bog and swamp in the lowlands to the west of Summerside and to the east of the Hillsborough River, often where the elevation is less than 10 m above sea level (Figure 15.14).

Figure 15.14 Peat bog at Lake Verde

Peatlands were once considered wastelands, because they could not be farmed without draining and few trees grew in the harsh, wet and usually acidic environment, other than black spruce and a few hardy willows, birches and larch. Today, we better understand the irreplaceable value of these ecosystems for globally significant functions like carbon sequestration and water storage.

Globally, peatlands store 500 billion metric tons of carbon, roughly 1,450 metric tons per hectare. As such, they have a significant capacity to keep carbon dioxide out of the atmosphere, thereby moderating human-induced climate change. Conversely, where peatlands are mined with modern vacuum technologies, they have a significant capacity to release tons of carbon dioxide into the atmosphere. It is the deforestation and draining of peatlands in Indonesia that makes this tiny island country the third largest emitter of greenhouse gases in the world.

Peatlands also have an unrivalled capacity to store water. These wetland soils are 95 % water – they are “wetter than milk, but you can walk over (them)” (Hans Joosten, University of Greifswald, Germany). The water in fens connects to and exchanges water with surrounding soils, whereas the high water table in bogs means that water can only move in one direction – that is out to the surrounding soils. In a province that is completely reliant on groundwater for drinking and other resource uses, the water stored in peatlands has tremendous value to all residents. In addition to these human-centric values, peatlands are unique ecosystems with highly specialized plant communities that occur nowhere else.

Maritime peatlands have long been mined by the peat moss industry. There are two commercial peat mines on the Island at Black Banks and East Bideford. Modern peat mining involves draining the bog or fen, allowing the peat moss to dry out and then vacuuming up the dried material. Because this process destroys the living surface component of the wetland, there is little to no natural regeneration of these mined sites. Where re-vegetation does occur, it is a very different community from what existed prior to mining and has none of the original carbon and water storing functions.

Restoration of abandoned peat mines has been attempted in North America and Europe with mixed success. Most often, a mineral wetland may be created where an organic wetland once stood. One of the leading research facilities for this restoration work is housed at the Université Laval in Quebec – the Peatland Ecology Research Group. Their collective decades of research suggest that the greatest chances for restoration success lie with the prompt rewetting of mined surfaces. It is the lack of water and changes in the water table that destroy the capacity of the ecosystem to recover from mining.

Watershed groups that have peatlands in their region can work to inform their communities of the values to humans and wildlife of these unique ecosystems. Where mining already occurs, there is merit in working with industry and the provincial government to ensure that restoration strategies are considered. Where bogs and fens remain untouched, groups can work to protect them from future development. The Island Nature Trust has had some success in protecting a few Island peatlands. The Province also has a vested interest in their protection as they work to meet carbon emission reduction and carbon sink targets in the PEI Climate Change Strategy.

15.2.3 Freshwater marshes and open water wetlands

Natural freshwater mineral wetlands – the marshes and ponds – are not common on the Island. Four of the largest of these freshwater ecosystems are Pisquid Pond (Morell River, Figure 15.15), Afton Lake, Glenfinnan Lake (Hillsborough River watershed) and O'Keefe's Lake. Although the latter three are colloquially termed lakes, much of their habitat would be considered open water wetland, being less than 3 m in depth during the summer months. These larger wetlands exhibit a tremendous variety of habitats with specialized plant communities, including open water submerged rooted species and emergent species inhabiting micro-niches of varying water depths. This great diversity of plant life supports an equally great diversity of invertebrates, resident and migrant birds, amphibians and small mammals. The high biodiversity in freshwater wetlands is recognized by many nature enthusiasts, and these areas in turn are important for bird watching, canoeing, angling, hunting and trapping.

Figure 15.15 Pisquid Pond on the Morell River, showing both open water, marsh and wet meadow wetland habitats blending into wet forest

In many cases, marsh and open water wetland habitat occur together as one functional wetland unit. Marshes are dominated by reeds, rushes and sedges, while open water wetlands have at least 75 % of their surface area in open water. They may be associated with a shoreline (littogenous, Pisquid Pond) or be separate and distinct from any other water-body (terrigenous, O'Keefe's Lake). Wildlife value for breeding waterfowl is optimal where there is a 50 % ratio of open water to vegetation, whereas optimal muskrat habitat contains closer to 75 % cover of emergent and submergent vegetation. Waterfowl habitat may benefit from seasonally fluctuating water levels and periodic drawdowns, whereas muskrat and beaver prefer stable water levels. Amphibians and many invertebrates will use the marsh habitats dominated by emergent vegetation, while fish will congregate in deeper water areas.

In addition to the wildlife values that wetlands hold, they can also benefit surrounding watersheds by acting as natural water filtration systems. Wetland vegetation, such as cattails, takes up nutrients like nitrate from water, thereby reducing the nutrient load of surface water (Figure 15.16). These wetlands also allow sediment to settle out of runoff water before it reaches freshwater streams. The filtration values of wetlands have long been recognized by those involved in urban and agricultural water treatment, and an incentive program of wetland construction is currently available to Island farmers (Canada Prince Edward Island Agriculture Stewardship Program, sponsored jointly by Ducks Unlimited and provincial and federal agriculture departments).

Figure 15.16 Cattails are a native wetland plant with the capacity to absorb nutrients like nitrate

Although few natural freshwater marshes and ponds occur on the Island, there are many more such wetlands that were created by early mill-works and later by Ducks Unlimited to increase waterfowl habitat in our region of the Atlantic flyway (Figure 15.17). In addition, beavers – nature's engineer – have created hundreds of acres of wet meadow in low gradient reaches of streams in the east and west of the Island. While the natural values of wetlands are immense, it is questionable whether their value outweighs the ecological value of the natural ecosystems – salt marsh and forested riparian margin – that they replace in some instances. We would always recommend retaining ecosystems as close to their natural state as possible, in an attempt to recover a small fraction of what has been lost of the original, dominant Acadian forest, coldwater stream and Atlantic coastal ecosystems.

Figure 15.17 Sherren Marsh in Augustine Cove, created as part of the Ducks Unlimited Small Marsh Program

15.2.4 Salt marshes

Early Acadian settlers were drawn to the extensive salt marshes of Atlantic Canada, especially those of the upper Bay of Fundy region where high tides regularly deposited silt carrying nutrients. The Acadians created dykes, drained the wetlands and used “aboiteau” structures built in the dyke with flap gates, which allowed fresh water out as the tide receded but kept salt water at bay as the tide rose again. Allowing occasional flooding from the famous Bay of Fundy tides brought fresh silt to increase fertility, providing ideal areas for settlement without having to clear the dense forests.

On the Island, early settlers found far less acreage of salt marshes. Some dyking of salt marshes did occur on the Island and occasionally property deeds included a section of salt marsh. The marsh grass was used for forage and livestock grazed in these exposed coastal zones.

On the Island, salt marshes are most prominent on the lee side of protective sand dunes, especially on the north shore and along the many estuaries, such as Bedeque Bay and the Hillsborough River (Figure 15.18). Exposed headlands continue to erode at an ever-increasing rate on the Island but where salt marshes occur, they act as a buffer to dissipate the energy of storm tides and afford some protection to the coastline.

Figure 15.18 Salt marshes along an Island estuary

Salt marshes are dominated by cord grasses (*Spartina spp*.), which are perennials usually spread by rhizomes. In deeper water and along tidal channels, there is cord grass (*S. alterniflora*) in dense stands, usually covered with each tide. Higher in the marsh is salt meadow cord grass (*S. patens*) dominating in regions flooded occasionally by high tides and intermingled with salt marsh potholes. The potholes are typically created when ice freezes to the marsh in winter and lifts with the tide, taking with it some marsh mud. Water in these potholes is replenished during high tides and it may change dramatically in both temperature and oxygen levels throughout the day. It is hard to imagine fish hardy enough to survive the rapid environmental changes but here is where birds like great blue herons feed on the abundant sticklebacks (e.g. four-spine – *Apeltes quadracus*) and mummichogs (*Fundulus heteroclites*). Still higher in the marsh and extending into ditches and fresh meadows is freshwater cord grass (*S. pectinata*), which grows 1-2 metres high in dense stands (Figure 15.19).

Figure 15.19 Salt marsh vegetation along the margins of the Ellis River

Extending into deeper water than the cord grass is the only vascular plant, eel grass (*Zostera marina*), which flowers and completes its life cycle submerged in salt water. In autumn, eelgrass often piles up on shorelines in windrows and some rural families still bank their houses with this plant for insulation through the winter months. Many estuaries and bays on the Island have huge swaths of eelgrass and the diversity of animal life from invertebrates to pipefish to trout found using this habitat is truly incredible.

Frequently, streams flow into the upper reaches of salt marshes. Sometimes these streams are large and come from far inland but most are from springs originating along the edges of the marsh. The warmer water in winter prevents the channel from freezing and eventually a deep trench with meanders connects the spring through the marsh to salt water. These salt marsh channels are home to ribbed mussels and many small fish species. Both muskrat and mink are commonly trapped in the upper marsh tidal creeks and runs. Raccoons forage there at low tide and foxes find abundant small mammals along the upland edge. Usually, fresh-water marshes are prime areas for waterfowl nesting. However, ducks will often raise broods in the upper reaches of salt marshes and in autumn, various waterfowl species both from the Island and further north, concentrate in coastal salt marsh areas for feeding and roosting. Here they find open water, both in autumn and spring when fresh water areas are frozen.

Salt marshes are incredibly productive ecosystems with *Spartina* supposedly one of the most efficient plants in our part of the world at converting energy from the sun to organic matter and thus feeding food chains. Our estuaries and their salt marsh perimeters are extremely diverse, rich habitats home to innumerable species of organisms. They are also often the ecosystems most at risk, at the interface of land and sea.

15.3 Springs and Wetlands Summary

The diversity of natural spring and wetland habitats on the Island is great and these environments are critical to the overall healthy functioning of our natural places. As those most aware of such natural value, watershed groups can try to afford protection to these habitats, can help nature restore those that have become degraded, can encourage people to touch nature more gently, can help our youth be more aware through example and they may even be able to convince politicians that sustainable use of land and sea is essential for continuing the quality of life that Islanders cherish.

15.3.1 Useful resources

Biello D, 2009. Peat and repeat: can major carbon sinks be restored by rewetting the world's drained bogs? Scientific American Tuesday, December 8 issue.

Gorham E and Rochefort L, 2003. Peatland restoration: A brief assessment with special reference to Sphagnum bogs. Wetlands Ecology and Management volume 11, pages 109-119.

Poulin M, Rochefort L, Quinty F and Lavoie C, 2005. Spontaneous revegetation of mined peatlands in eastern Canada. Canadian Journal of Botany volume 83, pages 539-557.

Price JS, Rochefort L and Campeau S, 2002. Use of shallow basins to restore cutover peatlands: hydrology. Restoration Ecology volume 10, issue 2, pages 259-266.

Prince Edward Island Department of Fisheries, Aquaculture and Environment, 2007. A wetland conservation policy for Prince Edward Island. Charlottetown, PE. Available online

Warner BG and Rubec CDA (eds.), 1997. The Canadian Wetland Classification System, Second Edition. National Wetlands Working Group, Wetlands Research Centre, University of Waterloo, Waterloo, ON. Available online

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

16. Enhancement of Upland and Riparian Habitats for Wildlife

16.1 Connectivity of Wild Areas

From the air, Prince Edward Island has been called a “patchwork quilt,” a term that aptly described the traditional small fields separated by hedgerows. While the larger fields common today have altered this appearance somewhat, the Island is still an agricultural landscape. There are few continuous expanses of forest, resulting in highly fragmented habitat. Housing construction in rural areas and urban sprawl has added to this fragmentation. Our freshwater environment is also fragmented, with dams and culverts altering flow and affecting the passage of fish in most rivers.

Proximity and access to different habitat types is essential for many animals to complete their life cycles and is crucial for strong populations. Home range varies in size for different species but if any necessary element is missing – food, cover, water, breeding sites – population levels will decline. A brood of ruffed grouse chicks, for example, will disperse in autumn to find suitable winter habitat. Their variable diet changes with season. In autumn they often feed on the edge of farmer’s fields at dusk, eating primarily waste grain, apple and clover but during the day, they forage in adjacent woodlands. In winter, they turn to browsing on terminal twigs of deciduous trees, especially aspen and birch (Figure 16.1). When the temperature plummets, they must have deep soft snow to burrow into for the night. This snow type is usually available in open hardwoods, but not in other habitat types such as spruce plantations. In spring, male ruffed grouse choose logs on which to drum and attract a mate. These logs should have proper overhead cover to protect them from avian predators and good lateral visibility so they are able to see ground predators. Without such cover, the birds will be short lived. Female ruffed grouse choose early successional mixed forest to raise their brood where low-hanging cover and food are readily available for the young. This annual cycle of the ruffed grouse demonstrates the need for specific habitats at each life stage.

Figure 16.1 Ruffed grouse foraging on frozen high-bush cranberries

Anadromous fish on the Island spend various parts of their life in salt water but return to fresh water to spawn. In many Island streams, Atlantic salmon and alewives are no longer present. In some rivers, they could not navigate obstacles such as dams near the head of tide and populations eventually disappeared. Others such as blue-backed herring and rainbow smelt did survive but with reduced populations because they are able to utilize spawning areas near the head of tide. Even within streams, connectivity is important. Brook trout spend the first two years of their life mostly in shallow water away from pools, which they will use later as larger, carnivorous fish. In summer, as water temperature rises, trout may have to move to cooler tributaries to survive. Most large brook trout in open systems descend to estuaries for a few weeks where they grow rapidly but must return to streams to spawn.

Corridors to connect habitat types are essential to maintain thriving populations. These corridors may be water-courses, woodland strips, or grasslands. Without them, animal populations are often cut off from essential or additional habitat. Riparian buffer zones are especially important corridors. There is currently a 15 metre protected zone on each side of a watercourse. In many instances, this habitat can be enhanced by increasing the biodiversity of plants within this zone, which in turn may lead to improved habitat for other wildlife species or increased wildlife populations. Some landowners have volunteered to add additional acreage to the 15 m buffer zone. In some areas, for example the Morell River conservation zone, property owned by the provincial government has been added to the protected area (Figure 16.2). Organizations like the Island Nature Trust and the Nature Conservancy of Canada have also helped by purchasing key properties to expand corridors or protect critical habitat.

Figure 16.2 Aerial view of Morell River Conservation Zone

Watershed groups can help in many ways: planting diversified hedgerows, encouraging landowners to reforest marginal land or clear-cuts with a diversified mixture of trees and shrubs, helping establish habitat corridors through urban areas, persuading planners to leave additional green space in commercial or residential development projects. Currently, many watershed groups are doing their part to improve connectivity in the river environment by working with landowners and government agencies to improve fish passage.

16.2 Wildlife Enhancement Strategies

There are a variety of ways for watershed groups to work with wildlife rather than (unintentionally) against it. As a general rule, if an area looks neat and tidy and aesthetically pleasing, it probably has limited value for wildlife. Think messy, think complex! There are no manicured expanses of lawn in nature.

There are two basic approaches to wildlife enhancement: one uses the natural structures and materials already present in the environment and one adds artificial structures that suit specific life cycle needs for species of interest. Both approaches work best in tandem and are not mutually exclusive.

16.2.1 Working with natural materials

In short – resist the urge to tidy everything. Wildlife uses all that messy stuff. That includes brush piles, rotting woody debris on the forest floor, standing and snagged deadwood, vernal (temporary) pools in wooded lands, unkempt long grassy margins around wetlands, short-lived trees that are rotting from the inside out, rock piles and old falling-down stone walls, dense thickets of spindly balsam fir and abandoned borrow pits. Nature should not be sterilized.

Woody debris in the riparian zone and woodlots makes an invaluable contribution to wildlife. Amphibians such as red-backed salamanders, mammals such as raccoons, and birds such as ruffed grouse depend on the downed debris on the forest floor for foraging and/or reproduction (Figure 16.3). Standing deadwood is critical for cavity-nesters such as owls, woodpeckers and chickadees. Dead or dying trees at the edges of forests or in hedge-rows provide perches for avian predators such as kestrels and hawks, to survey fields for mice and other prey. Brush piles are used by different species as they rot down, including snowshoe hares, shrub-nesting birds and snakes. Hare also use dense thickets of conifers as a safe refuge from larger mammalian predators and hawks. Even short-lived trees like trembling aspen are worth the time to plant, simply because they add so much habitat value for woodpeckers and other cavity-nesters when they soon rot. Tree species with shredding bark like paper birch provide nursery and roosting habitat for bats.

Figure 16.3 Rotting woody debris on the forest floor is valuable wildlife habitat

Rock piles and old stone walls are favourite sites for snakes, small mammals like shrews or chipmunks, toads and salamanders. Vernal pools and abandoned, water-filled borrow pits are also invaluable as breeding habitat for amphibians, because these water-bodies are free of fish predators. Even larger ponds with extensive grassy margins and emergent vegetation around the edges will be used by frogs and toads for breeding.

Before you remove anything from the sites you work in, unless it clearly does not belong (old tires, invasive species), consider what function it might have. In most cases, unless the landowner is clearly not in favour, the best option will be to leave it for wildlife. Some minimum targets for deadwood in Acadian forest woodlots have been suggested as 15 live cavity trees per 2 hectares and 15 dead snags per 2 hectares, all having a diameter greater than 30 cm (Simpson, 2010). You may want to try strategic placement of drumming logs for ruffed grouse in upland areas, but male grouse can be fickle about the logs they choose. A better strategy may be to ensure that there are many downed logs in protected locations. Crossing logs can also be left over streams at regular intervals to help the larger mammals like foxes to travel their territories.

Planting food species in riparian margins is also an important way to improve wildlife habitat (Figure 16.4). There are a number of berry-producing native trees and shrubs identified in Chapter 9 that can be planted. There are also many areas of the Island where old apple trees remain and mark where a homestead once stood. Often, these old trees can produce an abundance of fruit again, once pruned, fertilized and exposed to more direct sunlight. Slow-release tree and shrub fertilizer spikes may be most appropriate for these old trees and are available at most gardening stores. Pruning should involve removing any deadwood (it can be used for a brush pile) and branches that cross other branches or meet the main trunk at a small angle (30-45°). The latter branches are weaker at their attachment point and susceptible to winter or wind breakage.

Figure 16.4 Bohemian waxwings forage on high-bush cranberry in winter

16.2.2 Artificial structures for wildlife

In some instances, you may want to enhance specific habitat for key species of interest, possibly because they have been identified as important for the community or because they serve an important function and natural habitat is limited. For instance, open grassland adjacent to a stream or wetland where people congregate for angling, canoeing or picnicking might benefit from the installation of tree swallow boxes, to keep the population of mosquitoes in check. Similarly, if organic farmers are looking for natural ways to control crop pests, kestrel boxes in hedge-rows and forest margins might be worthwhile. Keep in mind that these artificial structures will need to be cleaned annually and otherwise maintained, either by the group or by landowners, and they have a limited lifespan of 10 to 15 years. The following table lists some size specifications for breeding bird boxes.

Table 16.1 Nesting box size guidelines for native, breeding birds on the Island

Species	Floor size (inches)	Box height (inches)	Diameter of entrance hole (inches)	Height of box above ground (feet)	Habitat placement
American kestrel	9 x 9	15 - 18	3	10 - 30	Hedgerows, forest edges, hydro poles
Barred owl	14 x 14	28	7 – 8 (arched top)	>15	Forest interiors, isolated
Chickadees	4 x 4	9 - 12	1 1/8 – 1 ½	4 ½ - 15	Forest edges, open woodlands
Downy woodpecker	4 x 4	8 - 12	1 ½	5 - 20	Woodland clearing, forest edge
Hairy woodpecker	6 x 6	12 – 15	1 ½	12 - 20	Open woodland, forests
Northern flicker	7 x 7	16 - 24	2 ½	10 - 20	Hedgerows, open fields
Northern saw-whet owl	7 x 7	10 - 12	2 ½	8 - 20	Near dense forest, wooded swamp, bogs
Nuthatches	4 x 4	8 – 12	1 ½	5 – 12	Forest edge, mature woodland clearing
Tree swallow	5 x 5	10 - 12	1 ½	5 - 10	Open land near water
Wood duck	12 x 12	24	3 x 4 Horizontal oval	5 - 20	Wetland with flooded trees, open water

Note: Data source = Bradley (2004)

The hole size is particularly important, especially for smaller birds where you want to keep out starlings and other pest species. A metal plate surrounding the entrance hole or a thick block of wood is recommended to prevent squirrels from widening the hole. If a metal plate cannot be attached, sometimes small mammals can be deterred by placing a ring of metal thumb-tacks around the outside of the hole. Do not use perches outside the hole, as these aid predators more than they benefit the breeding pair. The inside of the box below the entrance hole must be roughened wood or have a piece of hardware cloth attached, to allow young birds to climb up when they are ready to fledge. Some birds prefer to gather all of their own nesting materials, while others prefer to have wood chips added to the bottom of the box. The latter include owls, woodpeckers, flickers, chickadees and ducks. There should always be a way of opening the box to clean it out at the end of the season. Otherwise, the interior of the box can become a breeding ground for fungal spores that produce fatal respiratory infections in birds, such as *Aspergillosis*. Add a piece of wood to the back of the box to attach it to a support (pole, fence post, tree, barn).

Bird boxes should be put up in the fall, to allow some weathering to occur before occupation in the spring (Figure 16.5).

Figure 16.5 Bird boxes constructed for tree swallows

In forested riparian margins or where houses adjoin onto forests, bat boxes may serve to keep flying insect populations under control. Bats can eat half their own weight in insects during one night of foraging. Basic construction details are available for roosting houses and nurseries (larger breeding boxes). Choosing the right location may determine whether or not bat houses will be occupied. The wooden structure should receive at least 6 hours of sun each day, to provide enough heat to keep these small mammals from falling into torpor. Sometimes it helps in our northern climate to paint the exterior of the box a dark colour as well (Figure 16.6). Mounting them on a house or a pole rather than a tree helps to control predation. Bats also need daily access to water and prefer houses that are within a half kilometre of water.

Figure 16.6 Roosting bat box in protected location on side of house

Construction instructions for bird and bat boxes are available online. Long-lasting woods or exterior paints can be used to prolong the life of these structures; however, the interior of boxes should never be painted or varnished. A watershed group may be able to convince a high-school shop class to make some boxes; Bluefield High School has made tree swallow boxes as a first project in shop for a number of years.

Occasionally, a watershed group may find that owl and raptor populations are suffering from a lack of perches where the foraging area is open grassland or where deadwood has not been left standing. In these cases, artificial snags can be erected as perches (Figure 16.7). The key to longevity for these structures is ensuring that the base is well secured. It may be necessary to concrete them into the ground to withstand winds and freeze-thaw cycles in the soils.

Figure 16.7 Artificial snag for bald eagles

The larger raptors such as bald eagles and ospreys will also use artificial platforms for nest-building. These are often erected with the assistance of Maritime Electric, because they help to prevent raptor pairs from building nests on power poles and causing power outages. These large raptors and owls do not like nesting where there is human activity and will vigorously defend a chosen site or abandon it, so ensure that these sites do not have ready access by the public.

16.3 Control of Invasive Species

Invasive species are those that are not native and threaten the environmental, economic or social health of the area. Terrestrial invasive plants, insects and fungi that have landed on the Island have typically originated from importation of exotic plants for the ornamental gardening trade or agriculture. Some diseases have been imported with exotic pets. Aquatic invasive plants and marine animals have often arrived on our shores in ballast waters of ships travelling and trading throughout the world. Most invasive plants are opportunists that take hold in disturbed soils. The animals are hardy and aggressive generalists that can easily adapt to new environments. All are excellent, prolific breeders or spreaders that can quickly dominate their niche environment.

These alien invaders can influence watersheds in a number of ways. Invasive plants out-compete native plants that occupy similar habitat thereby reducing the diversity of those vegetation communities. These mono-species expanses provide poor habitat for wildlife. New research also indicates that native herbaceous insects often cannot use these aliens as food, thereby reducing insect densities in these systems and in turn the wildlife that eat them (Tallamy 2007). This can have a ripple effect on pollination and other important processes driven by insect populations. Annual invasive plants that die down every winter leave the soils bare and vulnerable to erosion. Aliens can bring disease into a system, indirectly reducing the health of closely related native species. For example, the Norway maple is more susceptible to tar spot fungus than red or sugar maples and can aid establishment of the fungus in a natural environment, where it might not have taken hold otherwise. Marine invasive species can quickly change community dynamics in coastal waters by preying or foraging on a preferred species.

The role of watershed groups in invasive species management will chiefly involve creating awareness of the risks they present in each watershed. In the case of most marine species, control is being addressed where possible at a broader spatial scale than the watershed. For some terrestrial plants, it is possible that watershed groups could initiate programs to control or eradicate invasive species, depending on the species and the level of invasion. For this reason, this chapter will focus on the invasive plants and particularly those adapted to the moist riparian or river habitats where many watershed groups are working.

The PEI Invasive Species Council was recently created to "provide leadership, expertise and advice on the management of invasive species on PEI." They are administered by Island Nature Trust, through which advice can be sought. Wherever your group suspects an invasive species has taken hold, the first step would be to contact the Invasive Species Council to arrange a site visit and verification of the species identity. Many of the alien plants have similar appearances to native plants and often share a similar habitat. Once the identity has been verified, a watershed group can work with the council to determine the best course of action. The following sections describe invasive species present on the Island and some methods of control for those that may be present in riparian ecosystems.

16.3.1 Invasive species present on PEI

PEI has a number of marine, aquatic and terrestrial invasive species. There are also many non-native organisms that are considered invasive in other parts of the continent, but that currently do not enjoy the optimal growing conditions to thrive and dominate in Island ecosystems. For example, rainbow trout is listed on the global top 100 most invasive species list; although it is present in Island waters and expanding its distribution, it as yet does not have an invasive or noxious designation. Our list may grow quickly in coming years, if a warming climate allows these non-natives to become more entrenched.

The following table describes the animal and fungal invasive species currently identified by the Nova Scotia Invasive Species Council and the PEI Departments of Agriculture and Forestry and Fisheries, Aquaculture and Rural Development.

Table 16.2 Invasive animal and fungal species in the marine and terrestrial environments of PEI

Invasive Species	Invaded Environments	Description of Impact
European green crab (*Carcinus maenus***)**	Coastal waters, estuaries Rocky shores, sandflats, tidal marshes	In top 100 list of world's worst invaders Omnivore that consumes widest array of plants and animals of any crab species in the world Alters shore community dramatically by preying heavily on mussels
Sea squirt / tunicate (*Styela clava, Botrylloides violaceus, Botryllus schlosseri***)**	Coastal waters, estuaries Sheltered subtidal water with good flow and hard substrates for attachment	Attaches to shellfish and is a major challenge to mussel aquaculture Alters shore community by out-competing for space and for food with other filter-feeders
Dead man's fingers (*Codium fragile***)**	Coastal waters, estuaries Protected to semi-exposed subtidal & intertidal zones on rocks in a wide range of salinities	Algae that out-competes native kelp where it has been grazed by sea urchins Does not provide good cover habitat for marine invertebrates and fishes, as the kelp did May inhibit foraging of lobster and suffocate oyster beds
European gypsy moth (*Lymantria dipar***)**	Forest insect with population in Charlottetown area	Defoliates hardwood trees such as maple, oak, birch and elm Limits the capacity of the tree to photosynthesize
Balsam wooly adelgid (*Adelges piceae***)**	Forest insect with widespread distribution on Island	Can kill mature balsam fir and other fir species
Dutch elm fungal disease	Fungus affecting all elm species across the Island	A fatal infection that has devastated rural and urban elm populations since it arrived in the 1970s, carried and spread by elm bark beetle
Beech bark / beech canker disease	Fungus affecting American beech stands across the Island	Can be fatal or significantly stunt beech trees Some stands appear to be developing a natural resistance
European larch canker	Fungus affecting native eastern larch and other non-native larches	A fatal infection, preceded by canker growths, sap loss and defoliation
Tar spot disease	Fungus affecting maples, particularly the introduced Norway maple (hardy competitor with advanced seed distribution mechanism)	Does not kill maples, but may impact their capacity to photosynthesize and grow Norway maples in woodland settings may increase exposure to native species of maple
Chytrid fungus	Fungus affecting frogs and toads across the Island	Can decimate frog populations Some species appear to be more susceptible than others

The PEI Invasive Species Council has developed a list of invasive plants for the Island, from a wide variety of exotic species that have the potential to become invasive. Many aggressive plants, such as goutweed (*Aegopodium podagraria*) wreak havoc in gardens across the Island but have not yet widely escaped into more natural environments. The following table lists the 13 invasive plants currently on the I.S.C. list, but expect that list to change as our climate changes.

Table 16.3 Invasive plant species in terrestrial, riparian and freshwater environments of PEI

Invasive Plant Species	Invaded Environments	Description of Impact
Garlic mustard (*Alliaria petiolata*)	Prefers rich, moist soils of riparian woodlands; shade tolerant Found in National Park, eradication program underway	Out-competes native understory vegetation in woodlands Produces a toxin that inhibits mycorrhizal fungi required for healthy root growth and nutrient uptake by native trees and shrubs
Scotch broom (*Cytisus scoparius*)	Prefers open, sunny location Few Island sightings along roadsides and in ditches	Out-competes native wildflowers and shrubs for nutrients, moisture and light Root system is extensive and difficult to contain
Glossy buckthorn (*Frangula alnus*)	Prefers open site but a habitat generalist (wetland, ditch, field, etc.) In the Charlottetown area	Aggressive tall (20') shrub that out-competes native shrubs and grasses for space and light
Giant hogweed (*Heracleum mantegazzianum*)	Prefers rich, moist riparian soils in disturbed, sunny location Contained to a few garden sites on PEI	Forms dense canopy that shades out native herbaceous vegetation and depletes their seed reserves used by wildlife Stalks die back in winter, leaving land susceptible to erosion
Common buckthorn (*Rhamnus cathartica*)	Habitat generalist tolerating forest and riparian habitats Growing in western and central PEI	Shrub forms dense canopy that shades out native understory plants Secretes toxin from roots to inhibit growth of neighbouring plants
Multiflora rose (*Rosa multiflora*)	Habitat generalist, shade tolerant Widespread across the Island	Grows in dense thickets that out-compete native herbaceous and shrub vegetation
Bittersweet nightshade (*Solanum dulcamara*)	Prefers semi-shade to shade, along tree edge or in forest In ditches, forest edges on PEI	Perennial climbing vine that can grow up and smother native vegetation
Periwinkle (*Vinca minor*)	Prefers shade of forest Widespread on PEI	Perennial creeping herb that out-competes native herbaceous vegetation on forest floor
Wild cucumber, Japanese knotweed, Himalayan balsam, yellow flag iris and purple loosestrife are described in detail below		

16.3.2 Control strategies for invasive species in riparian zones

The options for control of any invasive plant species generally fall into four basic strategies: mechanical, chemical, biological or environmental control. Mechanical control involves pulling, cutting, raking, dredging, cultivating or digging up the plants. Chemical control kills plants with a herbicide application, often glyphosate-based (Roundup™). Biological control uses a natural herbivore, usually an insect, to devour the above-ground foliage or a fungal disease organism. Environmental control involves blocking a critical condition for growth, usually sunlight, and gradual death of individual plants. Most experts advocate a multi-pronged approach to control, given the highly adaptable and resilient nature of invasive species. In riparian habitats, the use of herbicide is not recommended except in extreme situations and only with professional assistance. In some instances, Roundup™ may be injected into plant stalks, thereby limiting the surface exposure and potential for contamination of water. It is not only the active ingredient (glyphosate) in Roundup™ that is toxic to aquatic organisms, but also the surfactant (soap-like substance) that keeps it in solution as a sprayable product.

Before a watershed group embarks on any control program, they must recognize the commitment that is involved. Control of invasive species generally requires repeated application of control measures, usually over the course of a number of years. Many invasive species exude a sap that irritates the skin and care must be taken when handling plant material. Debris from control efforts should always be burned on-site (with a permit) or brought to provincial incineration facilities in closed plastic bags. There may be a cost associated with the latter for some species. These materials cannot be composted!

The assistance of a landowner or neighbour in monitoring the control area is invaluable. Their vigilance in checking for spread or re-growth can make or break the success of the project. Try to enlist their help wherever possible. Where waterways are close by, it is often helpful to ensure you do not have upstream sources of the same invasive plants that could re-invade the control area. Above all, know thine enemy! Be prepared to throw an arsenal of eradication methods at the alien. What follows is the most current advice for control of riparian invasive species present on the Island. It is always advisable to check online for updates and new strategies for these species.

Wild cucumber (*Echinocystis lobata*)

Description: Wild cucumber is an annual vine that can climb 15 – 25 feet in one season. It has alternating star-shaped leaves with 5 to 7 pointed lobes (similar to maple leaf shape), paired with cucumber-like tendrils (Figure 16.9). Flowers are pale yellow – white. The oval, spiny 2" seed pods that dangle at intervals from the vine distinguish this from other native vines.

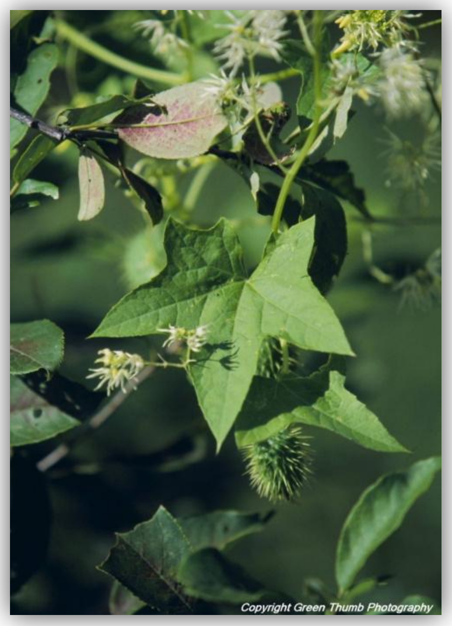


Figure 16.9 Wild cucumber (Photo courtesy of Beth Hoar)

Habit and Habitat: This weed prefers the moist soils of riparian margins, wetlands and stream-banks and full sun to part shade. It is widely spread across the Island, smothering the native trees and shrubs that it climbs, blocking light and taking soil nutrients to support its rapid growth.

Control: Because this species is an annual, the key to its control is the prevention of seed dispersal. This can be achieved by mowing or pulling the vines in spring as soon as they are found. Over several seasons, the seed bank can be eliminated or controlled, depending on the extent of the invasion. Glyphosate can also be painted on cut stalks of young plants early in the growing season, when the air temperature is between 16 – 27°C and no rain is forecast for 24 – 48 hours. Care must be exercised around waterways.

Japanese knotweed (*Fallopia japonica*)

Description: Japanese knotweed is a perennial shrub with a bamboo-like appearance. Stems are stiff and hollow when mature. Alternating leaves are dark green, smooth and elliptical in shape. Flowers are small, white or green and borne in clustered panicles.

Figure 16.10 Japanese knotweed growing into the outlet at Lewis' Pond, Schooner Creek

Habit and Habitat: This species is an opportunist, establishing in disturbed soils where there is full sun to part shade. It forms dense stands that shade out all native vegetation and spread is mostly by underground rhizomes. On the Island, it was sometimes intentionally planted to stabilize soils, but most often it has travelled along roadsides with construction equipment and cars. It can grow in water and is already known from one stream location on the Island (Figure 16.10).

Control: This highly aggressive species makes the top 100 list of the world's worst invaders. Its rhizomes can extend 7 m laterally and 3 m vertically. Be prepared for a battle! An eradication project in Victoria Park is in its 7th year with some sign that victory is near. In spring, cut the canes down, pile the cuttings on top of the patch, cover with heavy black tarp (silage tarp is a suitable thickness), pin down with heavy-duty staples, make sure the old cane has not punctured the tarp (otherwise cover again), then cover the tarp with at least 8" soil and seed it out. Constant vigilance is required to pull out any stalks creeping out around the tarp edge; monitoring and maintenance will likely be ongoing for at least 5 years and would benefit greatly from the assistance of a nearby landowner. Away from a stream edge, stalks could also be cut and painted with Roundup at the time of flowering (mid-summer).

Himalayan balsam (*Impatiens glandulifera*)

Description: Himalayan balsam or touch-me-not should not be confused with the closely related native spotted touch-me-not (*Impatiens capensis*). Although the foliage is very similar, the invasive non-native has bright pink or purple flowers (Figure 16.11) rather than orange spotted ones. This is an annual weed that can grow up to 3 m in one season. Leaves are opposite, lance-shaped with serrated edges.

Figure 16.11 Himalayan balsam in bloom (Photo courtesy of Beth Hoar)

Habit and Habitat: This annual thrives in moist, rich soils of riparian margins, particularly where some type of disturbance has left soils bare. It is tolerant of part shade and acidic conditions. Its growth habit is dense, shading out all other plants where it establishes. It dies back in the winter, leaving soil susceptible to erosion. This species can grow in streams and any growing within 7 m of a stream bank can disperse their seeds downstream to new locations.

Control: Because this is an annual species, it can be controlled by limiting the seed dispersal. Hand pull plants before they flower (mid-June) or mow them routinely over the course of the summer. The shallow root system makes hand-pulling relatively easy, but the process will likely need to be repeated for three years until the seed bank is exhausted.

Yellow flag iris (*Iris pseudacorus*)

Description: Yellow flag iris is a perennial forb with a tuberous root system. Leaves are grass-like with a mid-rib. Flowers are pale yellow. The plant looks very similar to the native blue flag iris (*Iris versicolor*) and usually needs to be seen in flower before a positive identification can be made.
Habit and Habitat: This invasive iris grows in wetlands, margins of streams and tidal freshwater or brackish reaches. It is present in several ponds and streams across the Island. Its habit is dense growth that leaves no space for native wetland plants and provides little habitat for amphibians, fishes and water birds to use.
Control: This aquatic plant is extremely difficult to eradicate once it becomes established. The best option is prevention of its spread. For groups wanting to remove it from a sensitive area, there has been some success with mechanical or environmental strategies. In standing water, plants and leaves can be cut below the water-line for some level of control, but eradication will require digging up the plants. In wet, emergent areas eradication can be achieved by covering the patch with a heavily weighted tarp for several years. The rhizomes will attempt to grow out around the tarp edges and maintenance will be required to keep these creeping roots in check.

Purple loosestrife (*Lythrum salicaria*)

Description: Purple loosestrife has woody squared stems with opposite, lance-shaped leaves that are sometimes covered in fine hairs. The flowers are purple, clustered in spikes and present from July to September (Figure 16.12). This species also makes the top 100 world's worst invaders list and is designated as a regulated weed under PEI's Weed Control Act. As such, it is illegal to intentionally bring it into the province, plant it or move it.

Figure 16.12 Purple loosestrife in bloom (Photo courtesy of Beth Hoar)

Habit and Habitat: This beautiful weed is an aquatic perennial that invades marshes, ditches, streams and irrigation ponds. Like the iris, it forms dense stands and out-competes all other native wetland vegetation while providing little habitat value for wildlife.

Figure 16.13 Purple loosestrife growing beside Matters Pond, Westmoreland River

Control: Ducks Unlimited Canada administers a biological control program for purple loosestrife in the Maritimes. This method uses two leaf-eating beetles (also non-native species) to defoliate the plants. Only a registered group can apply this method, so groups are referred to the Charlottetown DU office for more information on this strategy.

16.4 Useful Resources

Wildlife enhancement strategies are the subject of a number of excellent, informative websites. Available online

Bradley FM, 2004. *Project's for the Birder's Garden*. Yankee Books, Rodale Inc.

Simpson J, 2010. *Restoring the Acadian Forest. A Guide to Forest Stewardship for Woodlot Owners in the Maritimes*. Four East Publications, Tantallon, NS.

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

17. Methods to Track and Show Achievement of Goals

17.1 Proving Progress

Watershed restoration projects have been underway across North America for the past several decades. Some government, academic and private organizations have begun to question whether the monies directed towards these efforts have produced meaningful positive results. In many cases where project assessments were made, the conclusions were ambiguous because insufficient monitoring and record-keeping were done (Baldigo and Warren 2008; Roni et al. 2002; Smokorowski et al. 1998).

Increasingly, watershed groups will be asked to prove their progress toward achieving their management goals. Funding agencies in particular will be looking for concrete evidence of success. Without a robust monitoring program, watershed groups will have difficulty satisfying such requests. Anecdotal evidence is likely to be insufficient and opportunities to secure funding for future work may be compromised.

This chapter discusses some standard methods to monitor successes and assess challenges. Good monitoring programs typically have clearly identified *a priori* the endpoints that will be measured and have consistently measured those endpoints over appropriate scales of time and geography.

Watershed groups will have neither the time nor the financial resources to measure everything. There must be a monitoring design that identifies what takes priority for evaluation. These priorities should align with the goals described in the group’s management plan. Wherever possible, standard operating procedures (SOPs) should be used to measure the chosen endpoints. Variability in how and what is measured will diminish the power of the data compiled. In some instances SOPs may already be available, but in others a province-wide protocol could potentially be developed by collaborative efforts of watershed groups and other stakeholders.

17.2 Water Quality

Good water quality is a goal shared by most if not all watershed groups on the Island. Some common issues of concern relate to physical properties such as suspended solids and surface water temperature, while others relate to chemical properties such as groundwater nitrate concentrations and surface water pesticide concentrations.

When conducting water quality monitoring, be clear about your goals in terms of timeframes and the questions you want to answer. Choose sites carefully, recognizing possible sources of poor water quality and being realistic about your budget for water analyses. Some measurements are suited to long-term monitoring, where the intent is to assess trends over many years; for example, groundwater nitrate concentrations can be expected to change very gradually and a nitrate monitoring program would look at variability over years rather than months. In this instance, groundwater sample analysis would be required perhaps only once each year. Other measurements are important for a single point in time, to record an extreme scenario; for example, an intense rain event has occurred and suspended solids in surface water need to be measured during or immediately after the storm when they are at their peak.

Many of the physical properties are simple and reasonably inexpensive to measure. They also often have some influence on other chemical measurements, so it is a good idea to collect this information as basic background data. Surface water temperature and conductivity can be measured automatically at select locations using data loggers. Dissolved oxygen (DO) of surface water is a key parameter for aquatic organisms, but a bit more complex to measure. Automated DO equipment is expensive. However, if you have some of your monitoring sites in estuaries, DO will fluctuate naturally throughout the day and throughout the water column, and it is difficult to interpret spot measures in this context of natural cycling. It requires a greater commitment of time and resources. DO and pH can be measured using portable YSI meters that may be purchased or shared among watershed groups (Figure 17.1). In estuaries, be sure to make measurements at a standardized series of times throughout the day and, where appropriate, at a representative series of water depths. This is not as important in streams. Seasonal patterns for DO may also be useful. Portable YSI meters are notorious for needing frequent calibration. Ensure that staff is suitably trained in working with this equipment.

Figure 17.1 Digital recording of dissolved oxygen in-stream

Turbidity and suspended solids measurements provide important information on sedimentation in Island waterways. In ponds and estuaries, a Secchi depth reading will give a very crude measure of water clarity; it is not well suited to most Island surface water conditions. Analysis of total suspended solids (TSS) is a more accurate measure. The provincial government analytical lab can measure TSS in water samples brought into an Access PEI location. The complication with TSS is being on site to collect a water sample during an extreme rain event when the suspended solids are at their worst. Making this monitoring a priority for the group will involve enlisting people who live close to sampling sites and who are willing to go out in unpleasant conditions to collect the sample. There is a new automated method for measuring TSS, but it remains untested in Island waters and the equipment is very expensive (in the tens of thousands of dollars).

Water chemistry analyses can provide important information on both groundwater and surface water. Most groups will be interested in collecting data on nitrate concentrations, bacterial counts, and possibly concentrations of other compounds like phosphorus or heavy metals. These samples can also be brought to Access PEI for analysis at the provincial lab facilities. The costs for chemical analyses can add up quickly and it will be necessary to prioritize sample locations and frequencies.

To take a surface water sample for chemistry, the sample collection process must be standardized. Samples can be collected in plastic Nalgene bottles provided by the province. The water should be collected from the middle of the stream, as close to the thalweg as possible. In smaller streams, the collector can wade to the middle, rinse the bottle out three times, then walk a short distance upstream away from the disturbed stream bottom. Invert the bottle and lower it upside down into the water, turning it right side up once it is ~15 cm under the surface. This procedure will give the most accurate measure of stream water, without the variability associated with processes like volatilization that occur at the water surface. If the stream is not deep enough to accommodate this practice, a surface sample will suffice (Figure 17.2). Be sure not to touch the inside of the bottle lid; this is particularly important for bacterial assessments. It is a good idea to collect a sample for bacteria before one for chemistry. If the water is too deep to sample the middle, wade as far out as possible before taking a sample. Where possible, collect mid-channel from a canoe or bridge. Whatever your process is, be consistent with its application. Do not switch locations or sample procedures. All samples should be kept cold but unfrozen until drop-off.

Figure 17.2 Collection of a sample for water chemistry analysis

The process of collecting a sample for pesticide analysis is more logistically complex. Where a fish kill is suspected, the collection of a water sample has legal ramifications and there is a chain of custody that must be recorded. Environment Canada must collect these samples and analyse them at their own lab in Moncton. However, watershed groups can be prepared to respond rapidly in the event of an extreme rain event during the summer months. During or immediately after the rainfall, a drive of the watershed and check at all culverts for signs of dead fish can increase the frequency of detection of pesticide pulses in streams.

There may be other instances where a point source of pollution is suspected. If there is an area where you suspect organic material such as processing plant by-products or sewage is entering a stream system, ammonia concentrations upstream and downstream of the suspected point source can be measured with a Hach kit. These can be found at any pet store for the fish aquarium trade. Hach kits are not very sensitive so this sampling could be followed up with upstream and downstream water sample collection for total nitrogen and nitrate concentrations. A high ratio of total nitrogen to nitrate is an indication of a point source of organic pollution.

17.3 Riparian Zone

Monitoring the success of tree and shrub planting efforts may be the most straight-forward program to administer for watershed groups. Nonetheless, the data collected is no less important than other restoration data record-keeping. Groups currently benefit from access to the provincial tree nursery, which provides free, quality trees and shrubs for riparian zone plantings. This should not devalue the process of forest establishment but rather enhance it. Groups can use the resources that would otherwise be spent on buying plants to protect and maintain them once planted. On a semi-annual basis, all plantings should be assessed for survival (Figure 17.3). Winter breakage and browse mortality may be evaluated in April or May, while summer establishment survival may be evaluated in September. If resources permit only one monitoring session per year, the spring assessment is more important. Records could also be kept of non-fatal insect infestations, fungal infections and annual growth (in cm, of the terminal branch). Watershed groups should expect to achieve a survival success of 75 % or greater. If this is not the case, the group should re-evaluate protection and maintenance strategies as well as the mix of species planted.

Figure 17.3 Monitoring of tree plantation for over-wintering survival in spring

17.4 Fish Populations

Watershed groups should expect to have fish in even the smallest of streams, with the exception of a few streams that tumble over cliffs as they approach the sea. There are a number of different methods for monitoring fishes, depending on where the group's priorities lie. Presence or absence of some fish species (e.g., smelts, trout) can be determined by walking the stream during potential spawning seasons when individuals are congregating and more visible. Density and condition of a sample population for a species of interest can be measured by electrofishing or with fish traps. Reproductive effort can be estimated by keeping records of redd counts over a number of years.

17.4.1 Presence / absence data

In order to determine what fish are present and the habitat being used in each stream, groups should plan to walk stream reaches in all seasons, but especially during spring and autumn. Some fish, for example rainbow smelt, alewife and rainbow trout, move upstream to spawn in spring.

Others such as blue-backed herring and white perch spawn in late spring or early summer and brook trout and Atlantic salmon spawn in late autumn.

Rainbow smelt may migrate considerable distances upstream or may spawn near the head of tide if upstream access is limited. Since they lay sticky eggs that remain attached to stable objects in the stream (gravel, rocks, woody material and vegetation) and do not hatch for a couple of weeks, regular visits in April – May should detect eggs, even if the adults have left the system (Figure 17.4). Sometimes the only evidence that smelts were present is the carcasses or parts of smelts left behind on the bank. Heavy concentrations of eggs below blockages like perched culverts can lead to eggs being laid on top of one another, thereby greatly diminishing hatching success. Males often enter freshwater ahead of the females and this can be determined by netting and examining a few of the fish present (see appendix II). Groups can document timing of the run, comment on the strength of the population, identify the area of stream used by the fish and locate any blockages that may be affecting fish migration.

Figure 17.4
School of smelt and smelt eggs

Alewife (gaspereau) migrate long distances upstream and young frequently remain until August in accessible impoundments (Figure 17.5). Beaver dams may prevent adults from ascending or descending stream reaches. One can observe heavy mortality of adult alewives at beaver dams. If alewives are present in rivers in your region, it is important to document the location of any blockages that affect upstream movements, starting at the head-of-tide.

Figure 17.5 Young alewives leaving Pius MacDonald's Pond

Blue-backed herring can be expected to start their spawning run in late May to early June, depending on water temperature, and a run may last until early July. These fish move back and forth with tides and normally spawn in the lower swift water portions of streams or upper estuaries. Do not expect to see the very tiny eggs that hatch in a few days. Externally, blue-backed herring and alewives look similar, explaining why they are both commonly referred to as "gaspereau." The best way to distinguish between the two is to cut the fish open and expose the inner body wall. It will be a dark colour in blue-backed herring and lighter in the alewife. If in doubt, ask a commercial fisherman to identify the fish. Groups should determine if they have both species, only one or no gaspereau in their streams.

White perch are only present in a few Island streams but may become very abundant in some impoundments where they can tolerate warmer water than brook trout. They are also commonly found in coastal ponds and estuaries (Figure 17.6). Anglers can often tell you if white perch occur in a particular watershed.

Figure 17.6 White perch are now common in O'Keefe's Lake

Salmonids in most Island streams consist of brook and rainbow trout. Atlantic salmon still spawn in some rivers. Anglers can provide information about timing of runs and location of spawning activity.

17.4.2 Age and size distributions

Fish Traps A fish fence at the head of tide can be an excellent way to monitor upstream movement of anadromous fishes. However, they are very expensive to set up and labour intensive to monitor so are not often used (Figure 17.7). The more common means of trapping migrating fish is by installing a fish trap in a fish ladder (Figure 17.7). This can be an actual trap that is placed into one of the fish ladder cells, a trap placed in front of the final cell or a divider or screen that prevents fish from moving through a cell. All fish traps are labour intensive as they must be checked at least once per day and more frequently when some species are migrating (e.g., gaspereau). Fish traps can provide data on species present, run timing, run strength, and size ranges of fish. The set up and fish handling require experience and there are dangers when working around fish ladders. A permit is required from the Department of Fisheries and Oceans to trap and handle fish.

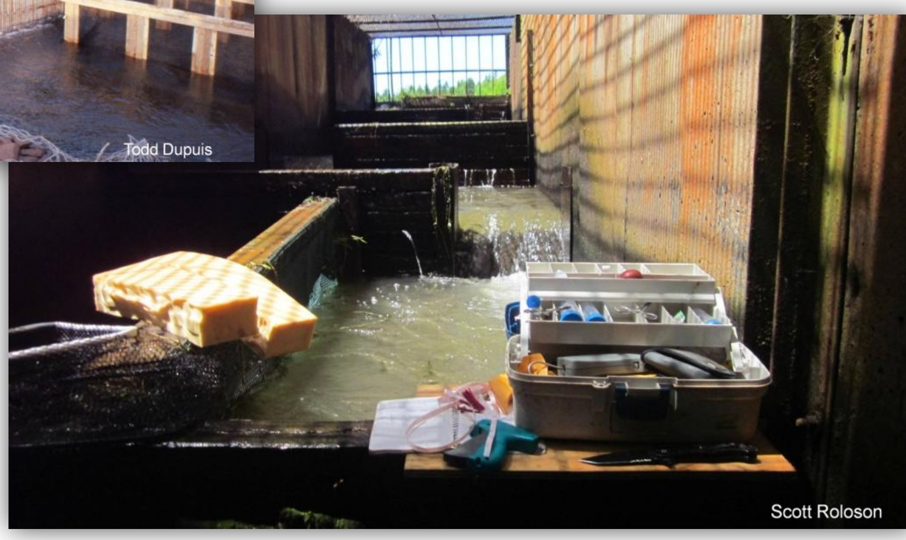


Figure 17.7 West River fish fence (above) and fish trap at Knox's Pond (right)

Electrofishing involves temporarily stunning and collecting live fish for information about species presence and size distribution, for analyses of disease incidence, chemical or mercury contamination, for marking and tracking, and for broodstock collection. It requires training in the use of a backpack electrofisher (Figure 17.8). Electrofishers are useful for carrying out spot checks of stream reaches to determine what fishes are present. As well, by isolating a defined section of stream with barrier nets and making multiple passes (normally three), removing and counting fish each time, one can determine the density of fish per habitat unit (100 m^2). This allows a comparison between sites with similar habitat within the same stream or in different rivers and comparisons among years in the same stream reach. Establishing multiple index sites can provide information on changes to fish populations over time or as a result of habitat improvement or degradation. Measuring length and weight of fish can also provide data on condition and general health of the population. Electrofishers are expensive and operators require certification before using them. A permit is required from the Department of Fisheries and Oceans before undertaking this procedure.

Figure 17.8 Department of Fisheries and Oceans staff electrofishing on Fortune River

17.4.3 Reproductive effort

Female salmonids dig depressions for egg laying in gravel/cobble substrate. Each “pocket” of eggs is covered with gravel and/or cobble. The end result is a disturbed area with a defined pile of rock and a depression at the upstream end. This is called a redd and can be located by looking for the disturbed and overturned stream substrate.

Redd surveys can be an excellent way to identify critical spawning areas and when done annually, can serve as an estimate of adult reproductive effort. The tools of the trade for doing any redd survey are polarized glasses, peaked cap, GPS unit, notepad and camera (Figure 17.9). Water conditions should be relatively low and clear to allow greatest visibility. Carry out surveys during the early part of the day when light conditions are optimal. Walking upstream is recommended, as visibility is best and it reduces the likelihood of walking on redds. Redd surveys in small streams can be done from the stream bank. The eggs under the rocks are very delicate and can die if disturbed. Timing is critical – too early will miss some redds and too late will result in some redds infilling, making them difficult to see. It is beneficial to monitor an accessible location where the fish are known to spawn on a regular basis to pinpoint the time of maximum spawning. It may take a couple of years of monitoring for a group to become comfortable with the methodology and timing for a particular river.

Figure 17.9 Carrying out a redd survey

On the Island, rainbow trout spawn in March and April when stream water can be high and turbid, making redds difficult to see. Like other trout and salmon, they appear to return to the same locations each year. With careful observation from the shoreline, you can document stream reaches that are intensively used by rainbows. However, trout redds are not as easily defined as salmon redds so the primary purpose of these surveys is to document spawning locations rather than numbers of redds.

Brook trout may spawn from late October until late December. However, the bulk of spawning appears to take place in the last three weeks of November, so redd surveys should be focused around the middle of this period. Trout prefer to spawn in springs and areas with groundwater discharge, which may not always be clearly visible. While doing the redd survey, take GPS readings of all major springs in or beside each stream reach. Trout often select areas associated with cover so look for redds along edges of overhanging vegetation or undercut banks (Figure 17.10).

Figure 17.10 Brook trout redd in spring water and with undercut bank on Morell River

Brook trout do not always pair up to spawn, rather they often form spawning groups with a number of males jockeying for prime position with the spawning female. Look for the spawning groups and try not to disturb the fish. In large springs, there may be many spawning groups active at one time. In other areas, particularly in larger springs near the head of tide where deep pools are present, the time frame for spawning can be considerably longer. Be sure to survey upper estuary areas, as we have observed redds in these locations. As with rainbow trout, it is impossible to do a quantitative survey. The principal objective is to document spawning areas.

Atlantic salmon redd counts should be scheduled for the last two weeks of November and the first week of December, depending upon water levels. A canoe can be used in larger rivers. As a rule, salmon redds are larger than trout redds, with many in excess of a metre in length from the tip of the depression to the end of the rock pile (Figure 17.11). Salmon need escape cover nearby, but the redds are usually in the open, where water circulation and oxygen are high. The tail end of a pool is a preferred location. The goals of a salmon redd survey are to identify spawning habitats and to get a count of redds. Females often produce more than one redd and these can be close together. Where there are multiple redds, count the number of depressions. You can lightly place your foot into the hole to get an indication of its size and depth if unsure. Eggs are within the gravel pile so no damage will be done when walking in the depressions. Female salmon will investigate the stream bed, and if the depth of spawning material is too shallow, will move on to another location. Surveyors will notice rocks disturbed but the rock pile will not be pronounced and there will be no obvious depression. These are considered “test redds” or “scrapes” and are not counted.

Figure 17.11 St. Peter’s salmon survey showing large salmon redd

17.4.4 Resource use: creel surveys

Watershed groups interested in monitoring angling effort on their river can carry out creel surveys (Figure 17.12). This involves interviewing anglers and recording information about their community of origin, gender, equipment and bait used, time spent fishing, as well as species, numbers and sizes of fish angled. It is an excellent opportunity to meet the people who use the river and get their input into restoration projects and angling regulations. Some creel surveys are done from a primary access point, for example a boat slip, while others have surveyors circulating around a pre-established route. Surveyors count and measure the angler's catch and complete as much information as possible on a survey sheet.

A particularly useful calculation is that of catch per unit effort. This can be an indicator of fish numbers in the river and allows comparisons of angling success in various rivers over time. Most of the current creel surveys taking place on the Island capture angling effort in the first two weeks of the angling season, a time of greatest fishing effort. However, interested groups can do the survey throughout the angling season.

Figure 17.12 Morell River creel survey

17.5 Wildlife Populations

Monitoring wildlife populations requires a well-planned study design, trained individuals and a long-term commitment. This is another area where it may be helpful to pool resources among watershed groups and work with academia, such as the wildlife conservation technology program at Holland College.

Habitat restoration will be the focus of many groups and so wildlife monitoring should reflect that focus. Surveys that evaluate communities, such as forest birds, small mammals or butterflies, will provide more valuable information on habitat use than assessments of indicator species. There is a danger in singling out indicator species, because groups may unconsciously begin to narrow their work efforts to enhance areas solely for that species, at the expense of the wildlife community as a whole. The exceptions to this general rule would be where watersheds support threatened or endangered species, or where the group has created specific structures, such as tree swallow boxes, to assist species with habitat limitations.

In many instances, national or regional monitoring programs for fish and wildlife communities already exist. Watershed groups can participate in these structured programs, rather than go through the trouble of developing their own. These include the Community Aquatics Monitoring Program (CAMP) for estuaries (administered by the Department of Fisheries and Oceans), the Breeding Bird Survey (administered by Environment Canada, with Island participants from the PEI Natural History Society), the Maritime Butterfly Atlas survey (administered by the Atlantic Canada Conservation Data Centre in Sackville, NB) and Frogwatch (administered by Nature Canada through the provincial government).

Figure 17.13 Yellow tiger swallowtail butterfly

Where groups have focused their habitat restoration efforts in a few locations and are particularly interested in habitat changes there, monitoring of reproductive effort or occupancy might prove more useful. In forest or wetland systems, bird call or nest counts could be assessed routinely throughout the summer, using a linear or block transect design.

For bird call counts, a linear transect or circular trail route would need to be established. The general method involves walking the route routinely at dawn or dusk when birds are most vocal, stopping every 400 – 500 m, waiting for 5 minutes, then listening for 5 minutes and recording the number and species of all birds seen and heard. This is known as the 5-minute-bird-count and students at Holland Collage receive training in this technique. It requires some skill in bird call recognition and reasonably good hearing, including at higher frequencies where people often experience gradual hearing loss with age.

Densities of amphibians and reptiles in riparian margins may be conducted using a linear transect with established cover stations. Salamander species on the Island include yellow-spotted and blue-spotted mole salamanders, red-backed salamanders and red-spotted newts (Figure 17.14). Red-backed salamanders in particular are indicative of undisturbed forest and are unlikely to be found in regenerating forest in old pastures. Riparian margins are a great place to set up these monitoring transects, as all amphibians require a moist environment. Artificial cover habitat can be placed at set distances along a transect, to attract salamanders in the area and make them easier to count. This habitat generally consists of untreated wood boards with lathe spacers, stacked into two levels. Amphibians will take cover in between the boards, and can be counted routinely, starting in April and ending in October.

Figure 17.14 Yellow-spotted salamander, adult and larva in process of transformation / metamorphosis

Snake occupancy may be similarly measured by creating basking sites of rock in open areas along a transect. The Island has populations of common garter snake, smooth green snake and red-bellied snake. Monitoring is constrained in this instance by the weather. Sunny days are a prerequisite for data recording.

If a group has erected nest boxes for a particular species, such as wood duck, tree swallow or barred owl, there may be an opportunity to monitor occupancy and reproductive success of breeding pairs that use the boxes. Care must be taken to observe owls and raptors from a discrete distance, as pairs may sometimes abandon broods when disturbed. Tree swallows are more accommodating, and boxes can even be opened to count eggs and chicks. Common endpoints measured in next box studies include clutch size (number of eggs), hatch success and fledge success.

In all instances of wildlife monitoring, professional advice should be sought at the experimental design stage. Training of designated staff members will also be necessary. Field notes should be transferred to an electronic medium as soon as possible, before the meaning of cryptic comments is forgotten or loose papers are lost. Despite the challenges of establishing these kinds of monitoring programs, the front-end work is well worth it when solid restoration successes can be documented.

17.6 Useful Resources

Information on national and regional wildlife monitoring programs can be found online.

Baldigo BP and Warren DR, 2008. Detecting the response of fish assemblages to stream restoration: effects of different sampling designs. North American Journal of Fisheries Management volume 28, pages 919-934.

Heyer WR, Donnelly MA, McDiarmid RW, Hayek L-AC and Foster MS, 1994. *Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians*. Smithsonian Institution Press, Washington, DC.

Roni P, Beechie TJ, Bilby RE, Leonetti FE, Pollock MM and Pess GR, 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management volume 22, pages 1-20.

Smokorowski KE, Withers KJ and Kelso JRM, 1998. Does habitat creation contribute to management goals? An evaluation of literature documenting freshwater habitat rehabilitation or enhancement projects. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2249.

Links to all online resources are provided on the Watershed Alliance website: www.peiwatershedalliance.org

18. Appendices

Appendix I. Technical Glossary

Aggradation – progressive rising of a channel bed by accumulation of sediment; occurs in areas where the supply of sediment is greater than that which the stream system is able to transport

Alluvial stream – a stream in which the bed and banks are made up of mobile sediment and/or soil

Anadromous – fish that spend part of their adult life in saltwater and return to freshwater streams and rivers to spawn

Anaerobic – lacking oxygen; where biological (microbial) processes occur and use elements other than oxygen to drive respiration

Anoxia & anoxic events – the process by which a water-body becomes so depleted in oxygen that most of the life within cannot adapt and dies; cycles of anoxia occur in several Island estuaries during the summer, when sea lettuce blooms, dies and the microbial decomposition process uses up all available oxygen in the water due to the sheer volume of materials being broken down

Aquifer – a water-bearing stratum of permeable rock, sand or gravel; the area where water is stored underground and the soils are permanently saturated

Assessment – to evaluate in relation to a pre-determined standard or objective

Bankfull flow – where heavy and/or sustained precipitation leads to maximum volumes of water in streams, when the water just begins to leave the channel and spread onto the floodplain

Bankfull height – water depth that just fills the channel to the top of its banks and at a point where the water begins to overflow onto a floodplain

Bankfull width – the width of a stream channel at the point where over-bank flow begins during a flood event; often the distance between the bases of perennial vegetation on opposite banks; the width of the 2.5 year daily peak flow channel

Barrier beach pond – brackish water, open wetlands occurring in the intermediate zone between coastal dunes and transitional upland forest

Baseflow –where the volume of water in a stream is at its seasonal low, made up mostly of discharge from groundwater springs on the Island

Bedrock – the solid rock underlying surface soils; also referred to as hardpan

Best management practices (BMPs) – standards for common-sense practices in industries such as silviculture and agriculture designed to minimize risks to the surrounding environment by preventing pollution and conserving soil, water and air quality

Bog – a class of peat-accumulating wetland having the following characteristics: has no significant outflows or inflows; kept wet by direct precipitation with a water table at or near the soil surface; supports acidophilic mosses (particularly Sphagnum); virtually unaffected by the groundwater from surrounding mineral soils, making it generally very acidic and low in nutrients; may be treed or treeless and dominated by mosses and ericaceous shrubs

Boulder – all rock over 25 cm (10”) in diameter

Braiding (of stream) – where a stretch of stream is divided into separate channels that repeatedly meet and divide

Bylaw – a document that outlines the governing rules and regulations of an organization and provides ground rules for a Board of Directors to use in developing the organization’s management structure

Canopy (forest) – the coverage of the forest floor or stream provided by leaf and branch growth of trees

Carbon sequestration − where carbon is removed from the atmosphere and stored in an area such as a forest or wetland, which naturally absorbs carbon dioxide from the air

Clay – soil particles less than 4 µm in diameter

Cobble – rock material between 6.4 and 25 cm in diameter

Covenant (land) – a legal designation for land that protects the natural values it holds in perpetuity, regardless of changes in ownership

Culvert velocity barrier – a culvert that does not allow fish passage, because it is too long or smooth, creating water flows that are too strong for the swimming capabilities of the fishes

Decommissioning (of infrastructure such as roads, dams) – the process by which all remnants and influences of a piece of infrastructure are removed, with restoration of the functional integrity of associated hillslopes, channels, and/or flood plains and their related hydrologic, geomorphic, and ecological processes and properties

Digger log – an untreated log placed across a stream channel to mimic a natural form of large woody debris that scours the stream bottom and over time creates a pool providing habitat for aquatic plants and animals

Discharge (of groundwater) – the land area where groundwater re-surfaces through springs and seeps

Dissolved oxygen – a relative measure of the amount of oxygen that is dissolved or carried in water and available for respiration of aquatic life

Drop inlet culvert – a type of outlet used at a dam structure to allow water to exit an impoundment through a vertical culvert structure

Embeddedness (of substrate) – the degree to which fine sediments such as sand, silt, and clay fill the interstitial spaces between rocks in a stream substrate

Emergent vegetation – plant species that have a part extending below the normal water level; plants adapted to periodic flooding, including sedges, reeds and cattails

Enhancement – refers to activities designed to make the present environment more habitable for a certain species or group of species; distinct from restoration in that it introduces elements that were historically absent or un-necessary (e.g., nest boxes)

Equilibrium – a state of balance between opposing forces or actions

Erosion – the weathering of soils, streams and watersheds by the forces of wind, water, ice and gravity

Estuary – a semi-enclosed coastal body of water that has a free connection with the open ocean and within which ocean water is measurably diluted with freshwater derived from land drainage

Eutrophication – the process by which a body of water acquires a high concentration of nutrients, especially phosphates and nitrates; these typically promote excessive growth of algae; also known as nutrient enrichment

Evapotranspiration – a collective term for the processes of evaporation of water from the soil surface and plant transpiration by which water is returned to the atmosphere from the land

Fen – a class of peat-accumulating wetland having the following characteristics: a high water table that is usually at or above the surface; waters are mainly nutrient-rich and minerotrophic from mineral soils, but nutrients can be highly variable across the class; dominant materials are sedge and/or brown moss peat of variable thickness; live vegetation consists dominantly of sedges, grasses, reeds, and brown mosses, with some shrub cover and, at times, a sparse tree layer

Fish ladder – a series of pools arranged like ascending steps at the side of a stream, enabling migrating fish to swim upstream around a dam or other obstruction

Fishway – see Fish ladder

Flow deflector – an engineered or natural in-stream structure that alters the flow pattern of the stream

Gabion basket – wire baskets filled with rock and used to re-direct stream flow

Gradient (of stream) – the general slope or vertical drop of a stream-per-unit of length

Gravel – rock material between 2 and 16 mm in diameter

Groundwater – water that is found under the earth's surface usually in porous rock, soil and other cavities

Habitat – the total environment (physical, chemical, biological) that is required by a plant or animal to complete all of its life processes

Head-of-tide – upstream limit of water affected by the tide

Helical flow – the rotating pattern of flow that water takes as it moves around a meander bend in a stream channel

Hydrophytic vegetation – plants that grow in hydric soils, which are those formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part

Hydrologic cycle – the water cycle describing movement of water between all phases, around the planet

Hydrology – the scientific study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere

Impermeable surface – a surface such as concrete that does not allow the entry of water

Impoundment – a body of water, such as a reservoir, that was made by damming / impounding

Incorporation (as a non-profit society) – the forming of a new corporation (a legal entity that is effectively recognised as a person under the law); may be a business, a non-profit organization, club or government

Interstitial space – the air space in between particles of soil or sediment

Large woody debris (LWD) – a general term referring to all wood in streams greater than 10 cm in diameter and 2 m in length, naturally occurring or artificially placed and including whole trees, branches, root wads, logs and log-jams

Lentic – water that is impounded or otherwise very slow-moving or stagnant; e.g., pond or lake water

Lotic – flowing waters moving in relation to gravity and gradient; e.g., stream or river water

Loam soil – soil composed of sand, silt, and clay in relatively even proportions (about 40-40-20%)

Marine-derived nutrients – elements required by living things to grow, present in the terrestrial or freshwater environments but originating from organisms that have largely spent their life at sea (e.g., anadromous fishes)

Marsh – a class of wetland having the following characteristics: periodically inundated by standing or slowly moving water; surface water levels may fluctuate seasonally, with declining levels exposing drawdown zones of matted vegetation or mud flats; waters are often eutrophic; substratum usually consists dominantly of mineral material; characteristically show a zonal pattern of pools or channels interspersed with clumps of emergent sedges, grasses, rushes and reeds; where open water areas occur, a variety of submerged and floating aquatic plants flourish

Meander bend – the bend in a stream channel generated over time as the stream changes course in response to erosion and sedimentation forces

Microbes (microbial activity) – microscopic organisms found in soils, plants and animals; generally include bacteria, fungi, protozoa and viruses

Monitoring – recording or tracking a defined set of measures that are of interest; measurements taken over space or time for the purpose of characterizing and assessing environmental conditions

Nature-like fishway – see fish ladder

Nitrate – an ion NO^{3-} originating from organic and inorganic fertilizers as well as breakdown processes that is readily dissolved in water and affects groundwater quality on the Island

Nitrogen – an element that is one of the two main nutrients that drive plant growth; see Phosphorus

Nutrient – a chemical that is an essential raw material for the growth and development of organisms

Open water wetland – a class of wetland having the following characteristics: having mid-summer water depths <2 m and open water zones occupying 75% or more of the total surface area; may have submerged and floating aquatic vegetation in the open water zone; within a complex of different wetland types, distinguished as a distinct form when >8 ha of open water is present; may be variously called ponds, lakes, impoundments on the Island

Organochlorine pesticide – a family of pesticides that are organic compounds containing at least one covalently bonded chlorine atom; generally have a high level of environmental persistence and toxicity

Organophosphate pesticide – a family of pesticides with the general structure being esters of phosphoric acid; generally high toxicity to bees

Peak flow – the maximum instantaneous discharge of a watercourse in flood

Perched culvert – a culvert with an outlet elevated above the downstream water surface, allowing a freefall condition (also referred to as a hanging culvert) requiring migrating fish to leap into the culvert from the downstream pool

Percolate – to trickle or filter through a permeable surface; the movement of water down through the soil to an aquifer

Periphyton – a complex mixture of algae, cyanobacteria, microbes and detritus that are attached to submerged surfaces in rivers, streams, ponds and lakes

Phosphorus – an element that is one of the two main nutrients that drive plant growth; see Nitrogen

Photosynthesis – the main process by which plants create energy for growth using the sun's radiation

Point bar – crescent-shaped deposit of fine sediment located on the inside of a stream bend

Policy – an expression of the will of the group, board or community drafting it, with regard to a specific issue of concern

Pool – habitat associated with water of considerable depth (> 50 cm) in relation to the average for the stream reach

Recharge (of groundwater) – the land area where surface water percolates down through the rock and soil to an underground aquifer

Refugia – areas that have escaped ecological changes occurring elsewhere and so provide a suitable habitat for native species; often referred to in relation to coldwater streams impacted by warming waters in impounded sections

Restoration – the process of restoring site conditions as they were historically, before disturbance and/or environmental degradation

Riffle – habitat characterized by shallow water (< 25 cm), moderate current and with broken surface flow, usually over gravel, cobble and boulders

Rill erosion – the formation of numerous, closely spaced rills or channels due to the uneven removal of surface soil by streamlets of running water

Riparian margin – the unique terrestrial environment adjacent to and influenced by a river or stream

Rip-rap – cobbles, boulders, broken stone or other hard materials placed along the bank of a watercourse to protect against erosion

Run – habitat characterized by rapid current flow in a deep, narrow channel, where flow is less turbulent than in a riffle

Runoff (surface) – water that drains across the surface of land in a watershed, into a stream

Sand – granular soil between 0.0625 and 2 mm in diameter

Sediment – the fine forms of soil; a term that encompasses clay, silt and some sand

Seep – an area where groundwater discharges to the surface in a dispersed pattern, often along a line of fractured rock

Sequester – see Carbon sequestration

Sheet erosion – the transport of loosened soil particles by surface runoff that is flowing downhill in thin sheets; can occur over the top of frozen soil

Shrub − a woody perennial plant differing from a tree by its low stature and by its production of several basal shoots instead of a single trunk

Silt – fine particles of soil between 4 and 62 µm in diameter, often carried along in the water column and deposited in Island rivers and estuaries

Spawning – the process where fish and amphibians reproduce via an external aquatic mixing of eggs and sperm

Split log – an untreated log split lengthwise and installed with spacers on the stream bottom to provide cover for fish

Spring – an area of groundwater discharge, where water issues from a rock or soil to the land surface

Spring lead – the channel of water that transfers spring water from the point of groundwater discharge to the point of entry to a stream

Stream bed – the bottom of the stream

Stream channel – a long, narrow, sloping trough-like depression where a natural stream flows or may flow

Stream roughness – a measure of the complexity of the stream channel bottom and sides, related to amounts of rock, large woody debris, vegetation and other materials that take up volume and slow water flow

Submergent vegetation – plant species that have no part extending above the normal water level, but that are rooted in a substrate (not floating)

Substrate – the materials making up the bed of a watercourse

Surface water (freshwater) – water flowing above-ground, in the channels of spring leads, streams and rivers

Swamp − a class of wetland having the following characteristics: a mineral wetland or a peatland with standing or gently flowing waters occurring in pools and channels; water table is usually at or near the surface; strong water movement from margin or other sources, hence the waters are nutrient-rich; the vegetation is characterized by a dense cover of coniferous or deciduous trees, tall shrubs, herbs, and some mosses

Thalweg – the path of deepest water in a river channel, and thus the line of fastest flow along a river’s course; it normally follows a meandering path along a channel

Tidal surge – occurs when storm elements such as wind and changes in barometric pressure combine with high tides to push saltwater further upstream and on-shore than is the norm

Transect – a sampling system that involves the measurement or recording of data along a line

Transpiration – the process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it evaporates and is released to the atmosphere. The amount of water released into the air through this process is significant

Undercut bank – an overhanging stream bank that is formed by the erosion that occurs when a stream channel moves horizontally

Under-sized culvert – culverts that are not sufficiently large to contain maximum water flows produced during storm events

Understory (forest) – the community of young trees, shrubs and herbaceous plants that live under the higher canopy of a forest

Water residence time – the average amount of time that a parcel of water stays within a wetland or impoundment before exiting

Water table – the upper limit of the soil or underlying rock material that is wholly saturated with water

Watershed – the area of land drained by one river, including all of its tributaries and the groundwater that discharges to them; also called a drainage basin

Appendix II. Fish Species and Their Freshwater Habitat Requirements on PEI

All fish illustrations in this appendix are provided courtesy of the New York State Department of Environmental Conservation. The photographs of brook trout and Atlantic salmon are provided courtesy of Rosie MacFarlane and The Atlantic Salmon Federation, respectively.

Brook trout - *Salvelinus fontinalis*

- Brook trout, also called speckled trout, is the primary fresh water sport fish species on PEI, appearing in all streams with any amount of continuous flowing water (exceptions are some streams that drop over cliffs along the coast).
- Some brook trout leave fresh water and spend time in the estuary. These "sea trout" feed on shrimp and other crustaceans and grow quickly, with their flesh becoming deep orange. Sea trout are the preferred target for most anglers. Our spring fed streams, short rivers, and relatively long productive estuaries provide ideal conditions for sea run brook trout.
- Spawning begins in late October and extends until the end of December. Brook trout prefer to spawn in springs or spring leads in the headwaters but have also been observed spawning at or below the head of tide, in areas of groundwater discharge.
- Trout form spawning groups, with males jockeying for position. Females lay 1,300-1,500 eggs per pound of fish in nests called "redds." Eggs usually hatch by the end of March and young-of-the-year brook trout (YOYs) can be spotted in shallow, quiet waters along the edges of the stream.
- Brook trout are a cold water fish and do best when summer water temperatures range from 13-18°C. At 20°C their ability to metabolize food is impaired, at 22°C they move into springs if possible and by 25°C, they die.
- The availability of cover, such as large and small woody debris, undercut banks and deep pools is critical for all age classes of this species.
- On PEI, brook trout populations are affected by habitat degradation - sedimentation, pesticide run-off, poor water quality (high temperature, low dissolved oxygen), fish passage blockages (particularly to preferred spawning locations) and in some regions, overfishing.

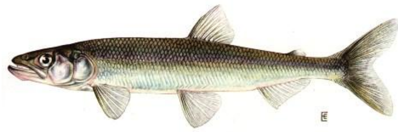
Atlantic salmon - *Salmo salar*

- The life cycle of the Atlantic salmon is well described on many websites
- Salmon were once widespread on PEI, likely present in more than 70 rivers. Currently, about two dozen rivers have Atlantic salmon present. Populations are dangerously low in a number of these systems.
- Environmental problems on the Island that may affect populations include: fish passage through culverts and over beaver impoundments, sediment impact on stream substrate, degraded water quality, pesticide run-off, competition with rainbow trout.
- Habitat restoration efforts in some rivers have been so successful that salmon runs in those systems have shown dramatic increases in recent years.
- Most Island salmon are late run fish, returning to rivers to spawn in late October/November. Adults go back to sea in spring. Juveniles stay in most streams for two years before leaving freshwater for the ocean. If they stay at sea for one year, they return as grilse weighing 3-5 lbs. If they remain at sea for two or more years, they return as very large salmon.

Rainbow Trout – *Oncorhynchus mykiss*

- Rainbows can be found in about two dozen streams and they are still expanding their range. They are especially abundant in rivers draining into south shore estuaries from Summerside to Vernon River and the eastern shore from Valleyfield River to Souris River.
- Rainbow trout occupy fresh water locations similar to Atlantic salmon: gravel areas with moderate current. They spawn everywhere conditions are acceptable from head- of- tide to headwater streams.
- Spawning takes place in April, often after spring run-off and young hatch anytime from June to late August, depending upon water temperature.
- Young rainbows grow more rapidly than brook trout during their first summer. They prefer swift water habitats rather than slow pools.
- Like Atlantic salmon and brook trout, rainbows may go to salt water. Most appear to stay in estuaries. Current research may reveal the extent of travel while in salt water.
- After rainbows have spent time in salt water, they are referred to as “steelhead.” These fish can grow quite large (5-8 lbs) and can be challenging for anglers.
- Rainbow trout are an exotic species with overlapping habitat with native salmonids (brook trout and Atlantic salmon). They can have a competitive advantage over trout and salmon, have a higher tolerance for pesticides, can tolerate warmer water temperatures and lower oxygen levels, they spawn in spring so eggs are less likely to be impacted by sediment than our native fall spawners, and in some instances, they disturb salmon redds when making their own.

Rainbow (American) Smelt - *Osmerus mordax*

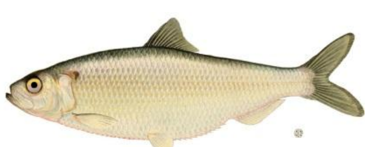


- Schooling adults inhabit inshore coastal waters
- Move to estuaries in autumn and winter where water temperature is warmer and their movements depend upon light and tides
- Water depth is used for overhead cover but in shallow streams they use any available cover
- Preferred water temperature for spawning is 6-11°C
- Smelt enter different streams in March, April or May depending upon locality and weather
- Males appear first and tend to stay the longest on the spawning grounds.
- Blockages, such as dams, prevent smelt from ascending because they cannot jump and are weak swimmers. However, they can move up fairly swift currents if adequate boulders and back eddies are present for resting. Smelt cannot ascend most fish ladders.
- In some rivers, smelt may migrate several kilometers upstream to spawn but in most streams, spawning occurs within a kilometer from the head-of-tide.
- Large females lay more eggs than smaller ones and a five year old 8" (20 cm) smelt can lay 50,000 eggs. However, over 95% of spawning smelt are 2-3 years of age and deposit an average of 10,000 eggs each.
- Most spawning occurs at night. Eggs stick to rocks, debris and vegetation and silt/sand bottoms are less suitable. Eggs are small but quite visible, live eggs are golden coloured and dead eggs are white.
- Eggs hatch best if they are not crowded e.g. a gap of one egg width separating different eggs. Flowing water with dissolved oxygen greater than 5 mg/L is desired.
- Masses of eggs, sometimes many centimeters thick, may occur below obstructions to fish passage. These areas have very poor hatching success. Sometimes eggs deposited at high spring flows are exposed when the water level drops and eggs die.
- Smelt sometimes spawn in upper estuary areas (downstream from head-of-tide). Survival rates of eggs in these locations are not known.
- Eggs hatch in 2-4 weeks, depending upon water temperature
- Young are about 5 mm long when they hatch and drift downstream to the estuary. They grow fast in estuaries and may reach 5.1 cm (2 inches) by late summer.
- A winter commercial smelt fishery exists in many estuaries.
- Many Islanders take part in a recreational fishery for smelt. Spearing smelts through the ice from darkened shacks is a favourite recreational pursuit and a dip net fishery in streams takes place each spring.

Alewife – *Alosa pseudoharengus*

- The alewife and blueback herring (*Alosa aestivalis*) look quite similar. A black spot behind the head at eye level is sometimes used to distinguish adult alewives from blueback herring. However, a more fool proof technique is to open the body cavity; the body wall of alewives is pale to whitish in colour whereas the body wall of the blueback herring is darker in colour.
- Island streams may have both species, one, or none, likely dependent upon past activities (e.g. an impassible dam near the head-of-tide, which prevented upstream movement for spawning).
- Alewives spend most of their adult lives at sea but return to fresh water to spawn in April-May.
- They are strong swimmers but do not jump. Thus, they are able to ascend some Island fish ladders but not all (see Volume I of "Impact of Impoundments and their Suitability for Resident and Anadramous Fish Species in Prince Edward Island"). Movements upstream and down may be blocked by both active and inactive beaver dams. Heavy mortality often occurs at these sites during migration.
- In large rivers, such as the Morell, Midgell and Naufrage, alewives go many kilometers upstream and spawn in impoundments.
- Females lay tens of thousands of tiny eggs about 1 mm in diameter.
- Eggs are usually shed in low to medium velocity currents (4.0-20cm/sec), sink and hatch in less than a week, depending upon water temperature. A large impoundment such as Larkins Pond on the Naufrage River, is an ideal spawning site.
- Both juveniles and adults survive well in water temperature from 12-22°C. Above 24°C, water is considered too warm.
- Juveniles descend the river to estuaries usually in late July and August when they are about 2" (5 cm) in length.
- The sheer magnitude of the juvenile numbers can be very impressive during the downstream movements to estuaries.

Blueback herring - *Alosa aestivalis*



- Looks very similar to the alewife with its laterally compressed deep body and it is also a strong swimmer;
- Spends most of its life in the sea but returns to fresh or brackish water to spawn, usually in June-July.
- At one time, many rivers had prolific runs of blueback herring.
- Like alewives, each female may lay tens of thousands of tiny eggs (1 mm). The eggs sink and stick to whatever they come into contact with.
- Eggs hatch within a few days depending upon water temperature and young bluebacks drift downstream and grow rapidly in the rich estuarine water.
- The blueback eggs are a favourite food of freshwater fish such as brook trout.
- Both bluebacks and alewives are harvested in many Island estuaries using box traps.

Striped Bass - *Morone saxatilis*

- Coastal fish with range including the Maritimes and St. Lawrence River
- Spawns at the head-of-tide. The only local confirmed spawning area is the Miramichi River in New Brunswick.
- Striped bass varying from about 2 lbs to 26 lbs have been caught on the Island, especially early in the angling season.
- Appear to be fairly common in the Midgell River but are regularly caught in many other locations around the Island.
- Since females full of eggs have been caught on the Island in May and they spawn shortly after this time, it has long been suspected that they spawn here. However, striped bass can travel long distances in a few days. Although various researchers have looked for the larvae in estuarine waters in PEI, none have been found.
- A large female could lay over 100,000 eggs, which become semi-buoyant and drift with the current. They hatch in 2-4 days depending upon water temperature. Striped bass may survive for many years and are reputed to be an excellent sport fish and very tasty. It is illegal to retain these fish on the Island.
- Numbers of striped bass in the region have been increasing in recent years.
- Adult striped bass are voracious top level predators and frequent coastal estuaries where smelt, gaspereau and sea run trout concentrate in spring.

White Perch - *Morone americana*

- Most Island anglers are unaware of how widespread white perch are on the Island. Several barrier beach ponds on the North Shore (e.g. Lake of Shining Waters), western coastline (e.g. Roseville Pond) and Eastern shore (e.g. East Lake) are known to have good populations of white perch. They are also common in estuarine ponds (e.g. Johnstons River and MacLures Pond in Murray River), rivers such as the Naufrage and in recent years, in O'Keefes Pond in Avondale.
- White perch may be anadramous or year round residents, depending upon the site but they are only abundant in warm water systems.
- Most white perch caught are in the 4-6" (8-15 cm) category but they may be fairly long lived (6+ years) and grow to be a half kilogram.
- The perch in O'Keefes Lake have high concentrations of mercury in their flesh and are not recommended for human consumption.
- White perch are considered to be a good food fish by some anglers.