Technical Information for Lot 11 and Area Watershed Managers

Dedicated to Myra Kelly

Prepared by Mark Bishop, Chairperson
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The Lot 11 & Area Watershed Management Group acknowledges and thanks the following parties for their support and input for this document:

- The PEI Department of Environment, Energy and Forestry
- Service Canada
- The Evangeline Credit Union
- Todd Dupius, Director of Regional Programs for the Atlantic Salmon Federation
- Darren Bardati, Director of Environmental Studies, University of Prince Edward Island

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I. Executive Summary and Introduction

The Lot 11 and Area Community is a special place. Relative to many parts of the Island, it is not as severely stressed by population pressure, land uses, and deforestation. Although there are many watershed enhancement opportunities, a fair portion of our mission centers on preservation. Public information is the key to appropriate community choices, both for enhancement and protection of our home.

There are several contributing factors to a well-functioning community, including gainful employment of residents, landowner freedom to enjoy and derive a living from their land, public health, property values, etc. Of no minor importance is the landscape itself. It is the setting for the community. It is what we call home.

People and the community are the focus of community-based watershed planning and watershed management. Any watershed mission or initiative that fails to consider human factors will fail. Within our community we have a balance of interests, including agriculture, forestry, tourism, residents, fishermen, sportsmen, seasonal visitors, etc. Members of these individual interest groups are called stakeholders. Most stakeholder groups share common interests in the landscape and in watershed values, but sometimes there are conflicts. The same can be said of wildlife and human populations.

In watershed planning we try to establish the common interests of all stakeholders and establish a consensus on practices to protect those interests. We also seek to discover where conflicts exist, and work to resolve our differences. This cannot be done by a watershed group. It cannot be done by government. Neither has the authority nor the qualifications to dictate to the community the nature of its best interests.

The watersheds in our area have certain characteristics that distinguish us from most other watershed areas in PEI. It is a demonstrable fact that we have fewer of the problems caused by land use and population density. The following map is taken from the 2008 Report of the Commission on Nitrates in Groundwater.

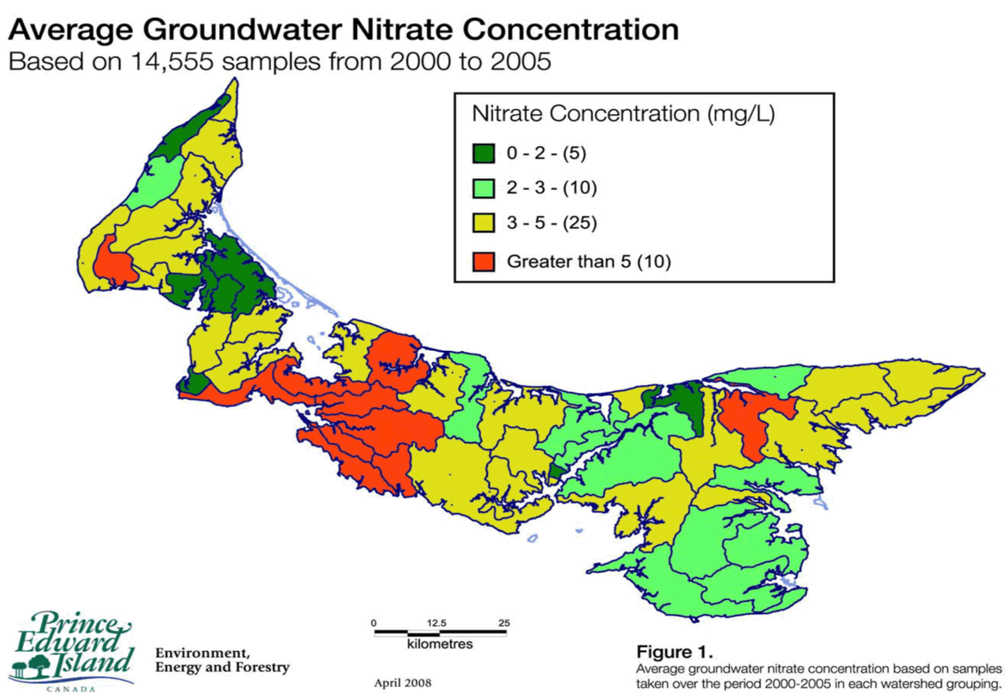


Figure 1.
Average groundwater nitrate concentration based on samples taken over the period 2000-2005 in each watershed grouping.

We have the best levels in the Province. Why? The Nitrate Commission report shows a clear correlation between nitrate levels and the number of acres of potatoes in production. Notice that we are one of the few areas on the Island with less than 3% of our land area in potatoes.

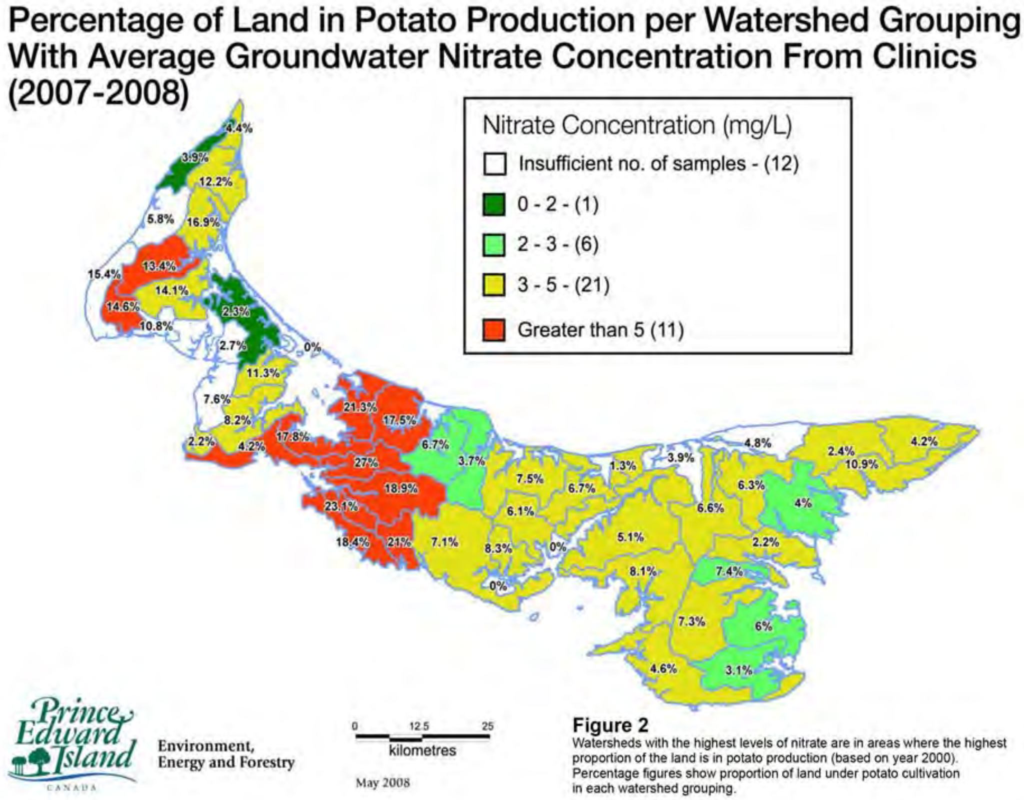
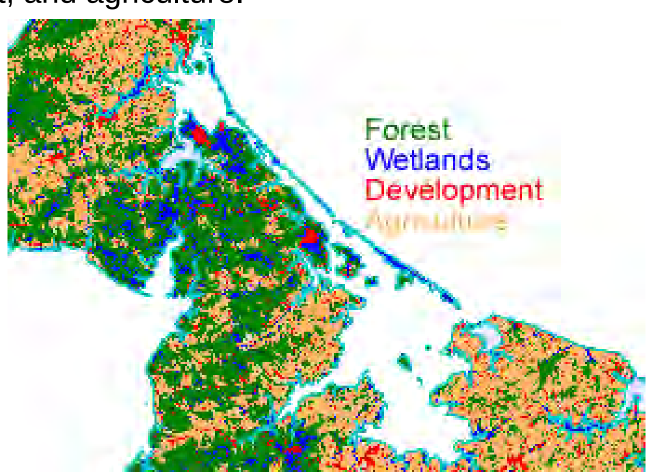


Figure 2
Watersheds with the highest levels of nitrate are in areas where the highest proportion of the land is in potato production (based on year 2000). Percentage figures show proportion of land under potato cultivation in each watershed grouping.

However, it is not just nitrate and it is not just potatoes. The nitrate levels indicate an underlying, positive condition for our area. There are other factors responsible for this. Water quality and environmental quality are directly related to forest cover. Wetlands and their distribution are very important. Other land uses like development also play a role. The next map shows land uses. Our area has a working balance of forest, wetlands, development, and agriculture.



There is a substantial band of forest and wetland between Routes 12 and 2 in our area. There are similar areas on the Gulf side of Route 12. These are marginal areas for agriculture and development, but they are not wastelands. They are responsible for the quantity and quality of our water supply. They are also responsible for the ideal environment here in the Lot 11 and Area Community. To exploit these areas for limited, short-term gain will have consequences for our community.

What we have here is a gift. Unlike other watershed groups elsewhere on the Island, we do not have to scramble and reactively correct problems caused by decades of land use problems. Rather, our primary task is to proactively preserve what we still have. However, this does not mean we are free from problems. We have identified some areas that need enhancement solutions. Beavers are a problem, both for streams and landowners. There are sedimentation and obstruction problems in our brooks. There are also opportunities for tree planting and control structures. But the fundamentals look good.

The effectiveness of the watershed planning process hinges on reliable stakeholder information. What are the important issues? What are the factors contributing to a healthy watershed? Why should certain things be done and others avoided? It is hoped that the background information provided here will help answer these questions. This document was originally prepared as a training guide for our watershed group's staff, but material in it is of fundamental value to watershed planners.

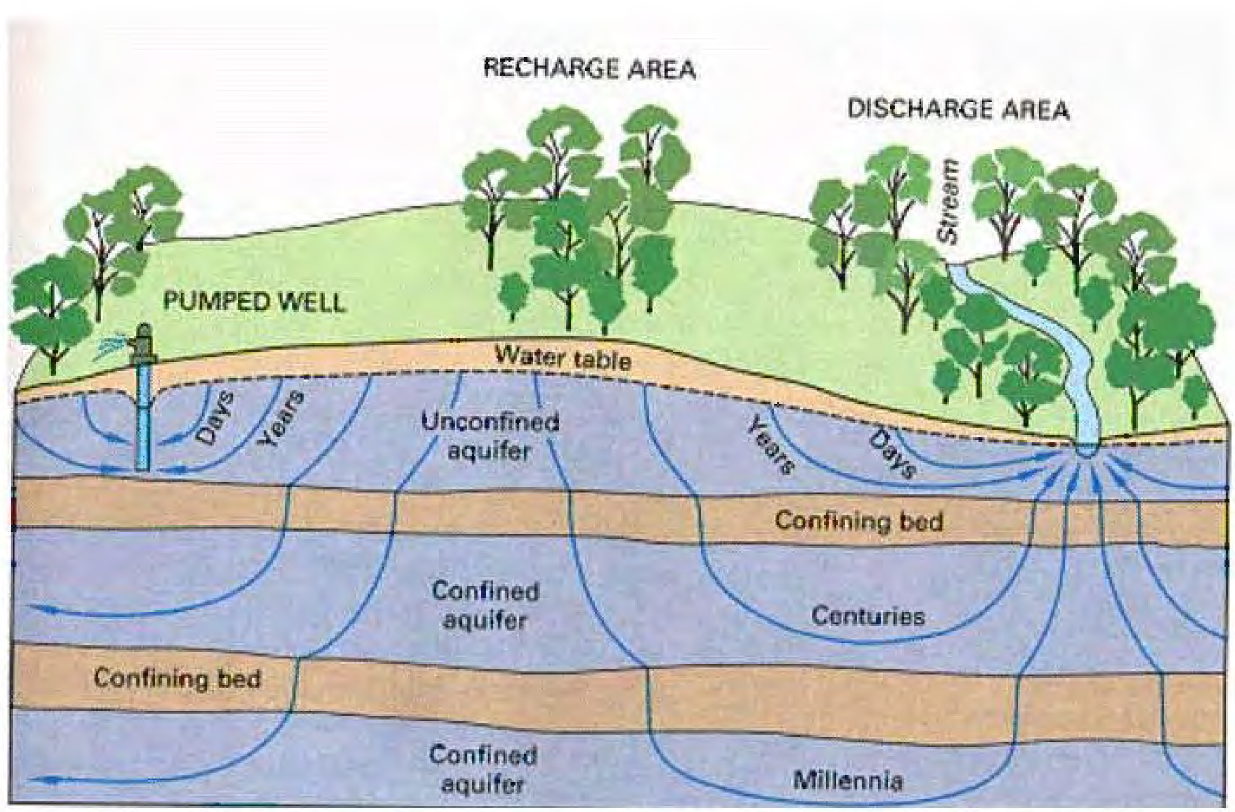
II. Private Wells and Nitrate

1. About Groundwater

Below the ground there is a water-saturated zone called an *aquifer*. The layer of soil above the aquifer is called the *zone of aeration*. When it rains, the water trickles through the zone of aeration until it reaches the aquifer at a boundary called the *water table*. This process where the rain replenishes the ground water is called *recharge*. The aquifer has a lower boundary also, which may be clay or bedrock. Usually there is another aquifer below this *uppermost aquifer* called a *secondary aquifer* or a *confined aquifer*. When the elevation of the land dips below the elevation of the water table we see *surface water* (river, stream, pond, lake, etc.).

The ground water flows, usually following the contour of the land. The contour of the land is called *topography*. A topographical region where the rain recharges a specific uppermost aquifer is closely related to the topographical region that drains to a specific river (*watershed)* in our small, divided systems on PEI.

When rain percolates through the zone of aeration it picks up contaminants from the soil. These contaminants enter the aquifer and move with its flow. Nitrate is very water-soluble and will transport quickly to the groundwater. Essentially all drinking water on PEI comes from groundwater.[42] The times on the following picture refer to the length of time the water has been in the various areas. The water in the confined aquifers will become contaminated at a slower rate than in the uppermost aquifer. However, once contaminated, the confined aquifers may take centuries to regenerate.



2. Nitrate Sources

2.1 Plant Nutrients

Plants use carbon dioxide, water, and sunlight in the photosynthesis process to make starch. They convert starch to cellulose, sugars, carbohydrates, and other biochemicals they need. At night they consume energy from their stored food in a process that uses oxygen.

To make DNA and a few other essential ingredients for life, plants need phosphorus. Plants need potassium to regulate their metabolism and for internal water management functions.

Plants also need protein and, to make protein, they need nitrogen. The plant cannot use the nitrogen from the air. Rather, it must take it from the soil in a combined form, specifically ammonium, nitrate, and nitrite ions. Combined nitrogen is essential for life.

There are several other essentials for plants. For example, they must have optimum pH and temperature conditions. They must be reasonably free of predators. Other nutrients include sulfur, magnesium, calcium, iron, manganese, boron, chlorine, zinc, copper, and molybdenum.

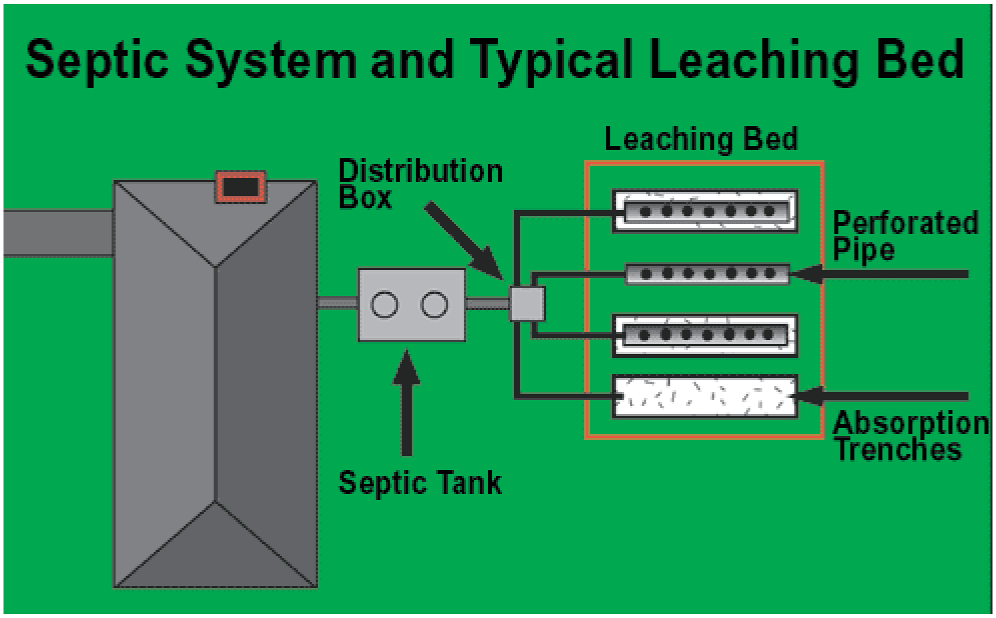
Of all the things the plant needs, there is usually one that is in the shortest supply. This is called the *limiting growth factor*. Often the limiting growth factor for plants is nitrogen or phosphorus. Farmers have long known that if they satisfy the plant's need for its limiting growth factor they will get a better crop. In the past they enriched the soil with manure, seaweed, or some other *organic*, nitrogen rich fertilizer. Synthetic fertilizers that contain ammonium nitrate, ammonium phosphate and potassium carbonate are more efficient nutrient sources. Often they are more cost-effective, easier to apply, and easier to get.

The organic fertilizers of the past (manure, etc.) released nitrogen slowly as the material decomposed. In contrast, synthetic ammonium nitrate is very, very soluble in water. After application, it immediately begins to transport with rain from the soil to the water.[*] The elusive secret is to keep the necessary but sufficient amount of nitrate on the field. The various practices for doing this are called *nutrient management*.

2.2 Septic Systems

In rural PEI, wastewater is treated by discharging it to a septic system. The pipe from the house first enters a *septic tank* where solids settle. The top of the tank overflows into a *leach field*. In the leach field the water is filtered through the soil and discharged... eventually into the uppermost aquifer. Typically there is gravel in the leach field to aid the filtering process. To keep an open flow, most systems use corrugated, semicircular channels or perforated pipe in the leach field. The organic matter in the wastewater is consumed by bacteria in a process called *biodegradation*. Many waste components – either naturally present in human waste or present in household chemicals – can pass through the system and reach the groundwater as contaminants. The waste discharged by households is high in nitrates, phosphates, and bacteria.

[*] There are (expensive) commercially available (pelletized) *slow release* fertilizers.



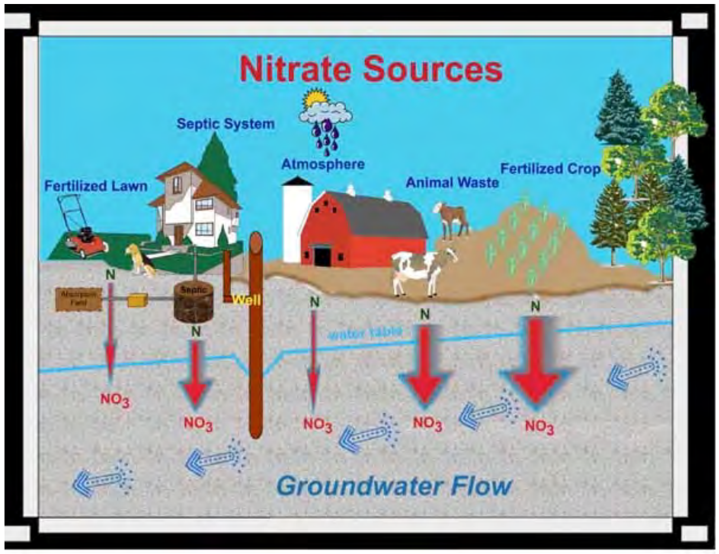
If the septic tank is not periodically pumped out to remove solids, or if the system is undersized for the home, the solids can overflow into the leach field, overload/foul the soil pores, and make the system ineffective. Septic system problems are frequently evidenced by a patch of very healthy grass over the leach field.[74]

2.3 Other Sources

Other sources for high nitrate levels on PEI are shellfish processing waste piles and landfill leachate. Also, intensive livestock operations can release nitrogen from animal wastes.[42]

Everyone who consumes food grown on farms is ultimately responsible for the effects of production-level farming. With that in mind, the nitrate contamination problem on PEI is directly related to potato production. The nitrate study[62] unambiguously demonstrates this. If you look at the maps in the nitrate study, you will see that the map for nitrate levels and the map for acres of potatoes in cultivation correlate remarkably well.

The nitrate study maps also show a very important finding for us. Lot 11 has the lowest nitrate levels in the Province. Area-wide, elevated nitrate levels from agricultural field losses are not expected in our area. If the nitrate study is accurate, we should see only isolated cases that are most likely related to septic system inadequacies or other localized circumstances.

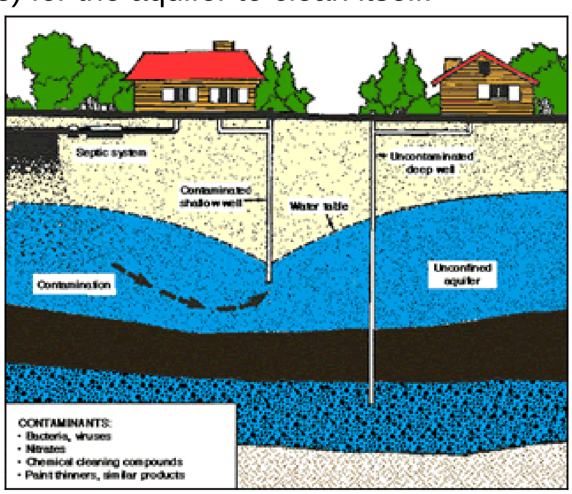


3. Drinking Water Wells

3.1 General

In the past, drinking water wells were *shallow wells* that extended only into the uppermost aquifer. They were often dug by hand. The problem with shallow wells is they are easily contaminated by runoff from activities near the well, because the contaminants the rain water picks up as it percolates through the zone of aeration may not be effectively controlled by the processes in the soil that work to purify the water. Some local residents may still use shallow wells.

Modern wells are drilled into a secondary aquifer. The secondary aquifer is often recharged somewhere else, often a considerable distance away. The water in the secondary aquifer has had more time for natural purification processes. So, provided the contaminants can be effectively broken down by natural processes, and provided the well casing does not allow the water in the uppermost aquifer to leak into it, the water is safer to drink. However, problems do occur. The secondary aquifer can become contaminated by breakdown-resistant chemicals like fuel oil, hazardous waste, landfill leachate, certain domestic/agricultural chemicals, etc. Once this happens, it can take decades (or centuries) for the aquifer to clean itself.



3.2 Testing

Testing is expensive. Tests for pesticides, for example, can cost more than $900 per sample. Homeowners do not have the resources to test for everything, but everyone wants to know their water is safe. There are two important concepts here:

- There is no such thing as zero risk
- Safety is defined as an acceptable level of risk

Once homeowners hear the prices for testing, they usually ask, "Well, what makes sense to test?" The answer lies in the question, "What are the most common problems with our wells?" Here in PEI the most common problems (so far detected) are nitrate and bacteria. (There are also some problems related to sea water intrusion in limited cases, e.g., sodium and chloride.)

<u>Nitrate</u>

Nitrate, when present at high enough levels, interferes with the blood's ability to transport oxygen. The condition is called *methemoglobenemia* or, because infants are particularly susceptible, *blue baby disease*. Guidelines for drinking water quality indicate a maximum nitrate (as N) level of 10 mg/l should not be exceeded. This action level is based on an *acceptable risk* judgment. Certain individuals may have health problems if they drink water with nitrate levels below this value. The Nitrate Commission indicates that our area (Lot 11 and Area) has very good nitrate levels in general. Localized problems can occur and homeowners should definitely test for nitrate.[61,62,64,48]

<u>Bacteria</u>

There are often harmless bacteria in drinking water. In fact, there are bacteria everywhere. There are millions of different species of bacteria, and many of them are essential to us. The bad bacteria are called *pathogenic* bacteria and there are many different species of pathogenic bacteria. In a drinking water well, the pathogenic bacteria are usually coming from a source of human or animal waste. No one can test for each and every possible pathogenic bacteria species, so they test for a single category of bacteria that is always present where there is animal or human waste present: the Fecal Coliform group (includes several species: *E. coli, Citrobacter, Enterobacter, Klebsiella*). Because the presence of the Fecal Coliform group indicates contamination, the test is called an *indicator parameter*. Although Fecal Coliform bacteria themselves can cause health problems, it is important to know that finding Fecal Coliform bacteria raises the specter of a host of other insidious threats.[59,61,64]

Although Fecal Coliform bacteria are always associated with human/animal wastes, occasionally these organisms are found in systems that are not being contaminated by an active source like a field or septic system. Some of the species detected by the test occur naturally in soil and grass. Sometimes these bacteria accumulate on the plumbing surfaces (particularly treatment systems and filters). So, when a Fecal Coliform test is positive, it is not necessarily time to panic. There are steps to take, which are discussed below.[59,61,64]

<u>Pesticides</u>

Many residents want to know about pesticides. Pesticide testing is expensive. Many modern pesticides degrade rapidly in the environment, but pesticide detections in groundwater on PEI do occur. Atrazine, Metribuzin, and Metalaxyl are the most commonly detected pesticides in PEI (I have more information as well as actual data from DEEF if you are interested). If there is immediate evidence of a potential contamination event (a spill, for example) the well at risk must not be used. The Department of Environment, Energy, and Forestry should be contacted.[71,73]

<u>Others</u>

There are several other possible contaminants that could occur in a resident's well water. Again, few have the resources to monitor their water for all of the potential problems. The owner is well advised to beware of any changes in taste, color, odor, etc. Because fuel oil is a common, dangerous problem, the owner should respond quickly if they detect a petroleum odor. Frequently the odor is first noticed in the shower.

3.3 Dealing With Problems

If testing shows a drinking water well is contaminated, then certain questions need to be asked, depending on the contaminants found. Is it a shallow well? Where is the well located? What activities are going on around the well (septic system, agriculture, etc.)? Frequently, problems can be corrected by well maintenance. When the problems cannot be corrected, the water can often be treated before use. It is always best to remove the contamination source or relocate the well rather than treat the water. Once again, because it is very important, treatment should *only* be done when corrective measures fail or are impractical. Why? Because treatment systems require ongoing maintenance. If they are not regularly serviced they not only can fail to do their job, they can cause more harm than good.

When it is a nearby septic system causing the problem, the problem can usually be corrected. Many other causes are harder to correct because they impact the entire aquifer. If the well is a shallow well, then the problem may be solved by upgrading to a modern deep well. The whole process can be overwhelming for the resident. Our role as watershed managers is to help with interpreting problems and to recommend solutions.

Nitrate

When corrective measures fail, there are two primary ways to treat elevated nitrates in the water: *reverse osmosis* and *ion exchange* (each has its advantages and shortcomings). There are whole house systems and “under the sink” units. The whole house system is by far the best approach. The reverse osmosis systems should be available for under $1200 installed. *Standard water softeners, boiling the water, and simple filters will not remove nitrates*. Standard water softeners remove calcium, magnesium, iron and manganese. There are some more expensive softeners that have additional capabilities for nitrate removal. Boiling kills bacteria. Strictly speaking, filters remove particles, but treatment systems are often called filters, even by manufacturers. So, when you hear the term *filter,* be sure to get a detailed specification for the particular system being discussed. All treatment systems require regular maintenance. If they are not maintained they will be ineffective, and may be dangerous.

Bacteria

When a Coliform test is positive, a decontamination step may correct the issue. The web site http://www.gov.pe.ca/envengfor/index.php3?number=1015749&lang=E has instruction sheets for homeowners. These sheets do not consider certain important special aspects, such as dealing with water filters and purification systems when decontaminating. Local residents with positive tests should contact a knowledgeable resource (this could be us). After a decontamination, the owner waits one week and tests again. If the retest is positive, then an active contamination source is indicated and corrective actions must be taken.

There are ways to treat bacteria contamination by sterilizing the water, but I would not recommend any. The presence of persistent Fecal Coliform bacteria indicates the water is potentially contaminated by many other hazards, only some of which may be other bacteria. (That’s why it is called an indicator.)

Petroleum Products

When the groundwater is contaminated with petroleum products an imminent, emerging hazard exists. The water must not be used. Neighbors are also substantially at risk. If the source is large, and it frequently is, an entire community water supply may be impacted. Clean-up costs are very high (typically over $20,000 and frequently over $100,000). Homeowners who have fuel oil tank leaks frequently lose their homes. It is absolutely imperative that homeowners maintain their tanks. With the high cost of fuel oil, cases where criminals have stolen fuel from a storage tank are not uncommon. Frequently these thieves will tap the tank for a few gallons and let the rest leak out. A security enclosure for a fuel oil tank may seem excessive, but when you consider the consequences of a fuel oil release, the concept begins to make sense.

4. Sampling

Samples for nitrate and bacteria must be collected using a specific procedure. Some labs provide containers for nitrate testing, but a well-rinsed plastic container (ideally one previously used for store-bought bottled water) can be used.

Samples must also be submitted to the lab within a specified time frame. They must be kept cold from the time they are taken to the time they arrive at the lab. The Provincial laboratory has sampling instruction sheets. The sample should be taken from a cold water faucet (never a hose) after the water has run for several minutes (to flush the tank).

There are special considerations for bacteria samples: They must be collected using sterilized containers. If the faucet has a screen or aerator it should be removed. Some instruction sheets advise flaming the spigot with a butane lighter. Do not rinse the bottle or touch the rim of the bottle or the inside of the cap with your fingers or with the spout of the sampling point.

5. Nitrate Results

5.1 Format

Nitrate is reported in milligrams per liter of nitrate expressed as nitrogen (mg/l NO_3-N). Occasionally you see units of parts per million (ppm). They are equal for water.

What does "as nitrogen" mean? I promise not to bog down in chemistry, but this is important. Nitrate is a *dissolved ion*. The ion consists of one nitrogen atom bound to three oxygen atoms (NO_3). It has a molecular weight of 62. In every 62 milligrams of nitrate, there are 14 milligrams of nitrogen. In the lab, technicians measure nitrate but they do not report the number of milligrams of NO_3 they found. Instead, they report the milligrams of nitrogen that are contained in the amount of NO_3 they found. This can be a confusing convention.

Why is it important to us? The acceptable level for nitrate as nitrogen is 10 mg/l. Fortunately, our Provincial lab follows the convention both in its results and its statement for acceptable levels. Some guidelines do not use this convention. For example, the Canada Guidelines for Drinking Water Quality express the maximum recommended level for nitrate as nitrate (mg/l NO_3). When expressed this way, the maximum guideline level is 45. For the most part we should not have confusion because everyone in PEI seems to be on the same page, using the NO_3-N convention. But beware. It is not uncommon for someone to challenge the maximum level statement of 10 because they saw 45 somewhere else. If this happens, you will have the explanation.

5.2 Levels

There are several different methods used to measure nitrates. Each of these methods has a minimum detectable level (typically below 1 mg/l NO_3-N). The methods also have an upper limit beyond which the nitrate can only be measured by pre-dilution at a known dilution factor. For example, say a laboratory uses a test with an upper limit of 15 mg/l NO_3-N. If a sample had a nitrate level of 50, it would be off-scale for the method, so a preliminary dilution of 5X would be used to obtain a useful reading (10 in this case). The final result is obtained by multiplying the result for the diluted sample by the dilution factor (10 × 5 = 50).

At nitrate clinics the Provincial staff use a screening method to measure nitrate. The screening test is reliable in that it does not underestimate nitrate concentrations. However, it can overestimate levels,. Also, at nitrate clinics they do not perform the preliminary dilutions for values above the upper limit for their test. Rather, they report that the nitrate was too high in the undiluted sample for the test to measure. This is not a problem because they recommend a retest when the screening method indicates high levels. The retest is done in the Provincial laboratory and an approved method is used. The lab will perform the necessary preliminary dilutions if specifically asked, so whenever levels are reported as *greater than* values, the lab should be asked to dilute as necessary on the retest sample. The retest recommendation should always be followed.

6. Regulatory Considerations

Canada does not have federal drinking water regulations. Rather, Health Canada has published drinking water *guidelines*. The federal government has an advisory role, not a regulatory role. The guidelines are non-binding and non-enforceable. Provinces may at their discretion adopt those guidelines in binding regulatory legislation. Prince Edward Island has not.[61,63]

In provinces, municipalities, and countries that do have binding drinking water quality regulations, the regulatory jurisdiction rarely extends to private wells. Instead, the regulatory standards typically apply to public water supplies.

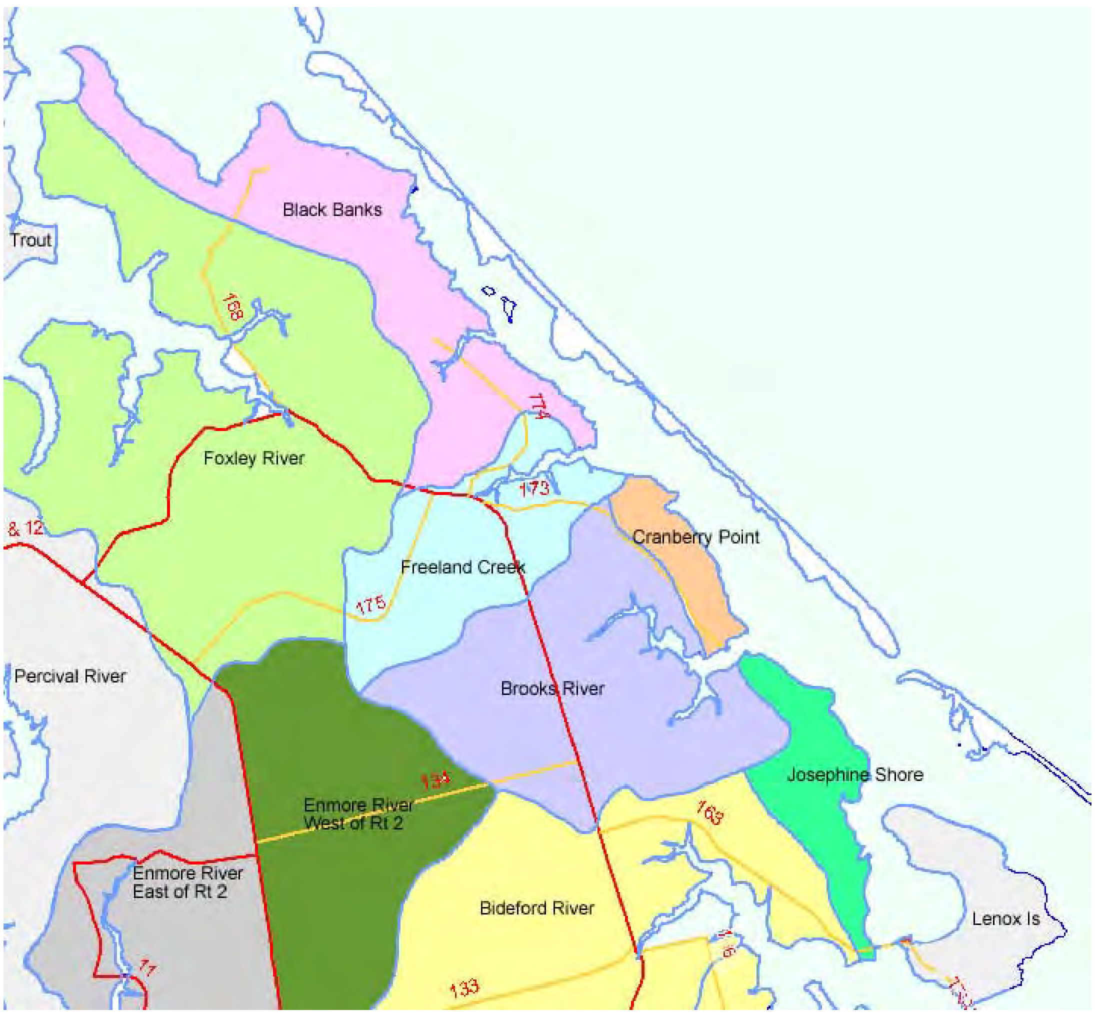
For private well owners in our area, there is no enforceable regulatory framework for water quality standards. There is no law that requires testing, and there is no evident legal pathway for a cease-and-desist order simply because a water quality parameter exceeds guidelines. However, this does not mean a well owner can ignore conditions that endanger human health with impunity. If a private well were contaminated with harmful levels of contaminant(s) and if persons (particularly infants and children) were at risk, then government intervention may be expected. If a well owner/operator knows, or has reason to know, that a hazard exists and chooses not to take action nor warn, then that person could be legally responsible for harm or damages.

Finally, if there is a likelihood that a person's actions have caused the contamination of a private well(s), then that person has an obligation to warn those who may be affected and may have an obligation to inform the Provincial Department of Environment, Energy and Forestry.

III. The Characteristics of Streams

1. About Watersheds

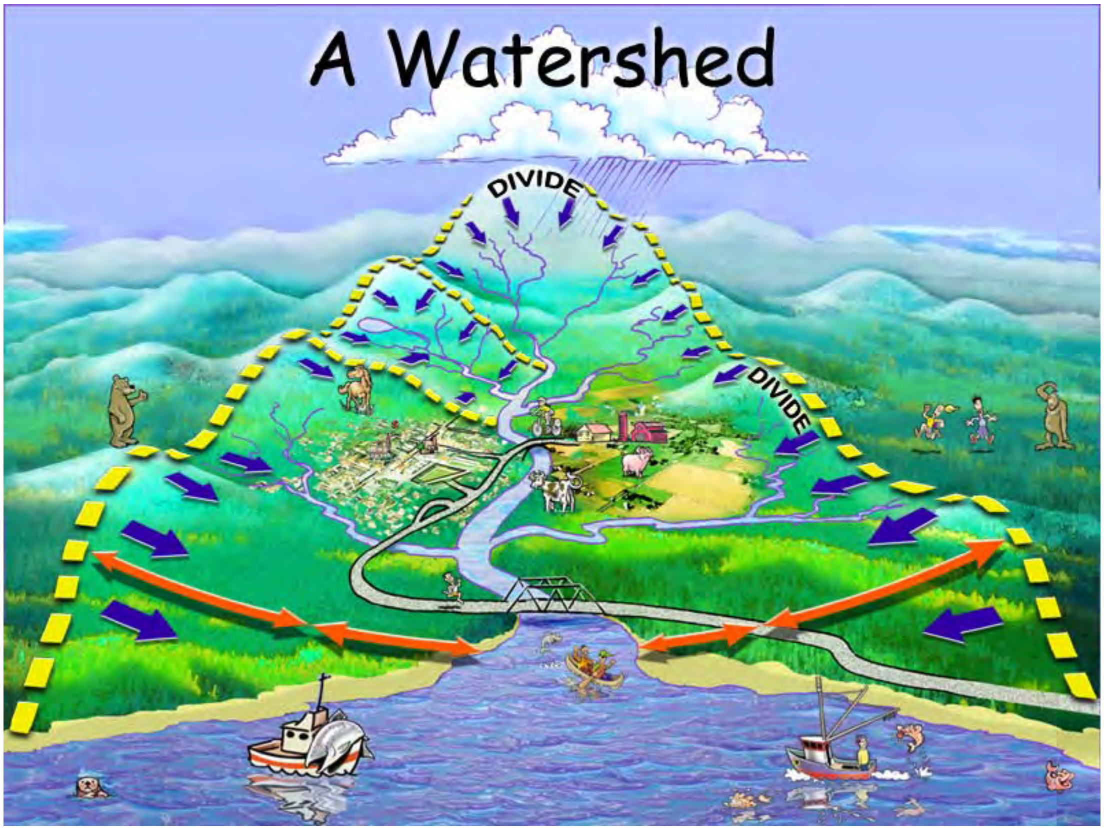
A land area drained by a specific stream system is a *watershed* or *drainage basin*. Because this definition is based on the physical characteristics of the land, it can also be called a *geophysical watershed*. A second definition for the term *watershed,* which is used by the watershed management community here in PEI, relates to the area managed by a given group. For example, our management area includes several geophysical watersheds that we refer to as the Lot 11 and Area watershed. These geophysical watersheds are shown on the following map.



For the rest of this document, the term *watershed* will be used in the geophysical sense, and our managed area will be called simply *our area*.

Watersheds are separated from one another by the contour of the land (topography). The boundary between watersheds is called a *divide*. Most Prince Edward Island watersheds drain into a transitional body of water at sea level called an *estuary*. (Some drain directly into the sea.) The water in the estuary is a mixture of salt water and fresh water called *brackish* water. Occasionally a stream will discharge directly into the ocean. The location where the stream enters the estuary or ocean is called the *head of* *tide*. The head of tide can be identified by determining where the water level begins to fluctuate with the tide.

As shown in the following picture, everything that lives within the watershed and its receiving water depends on the quality of the water in the watershed.



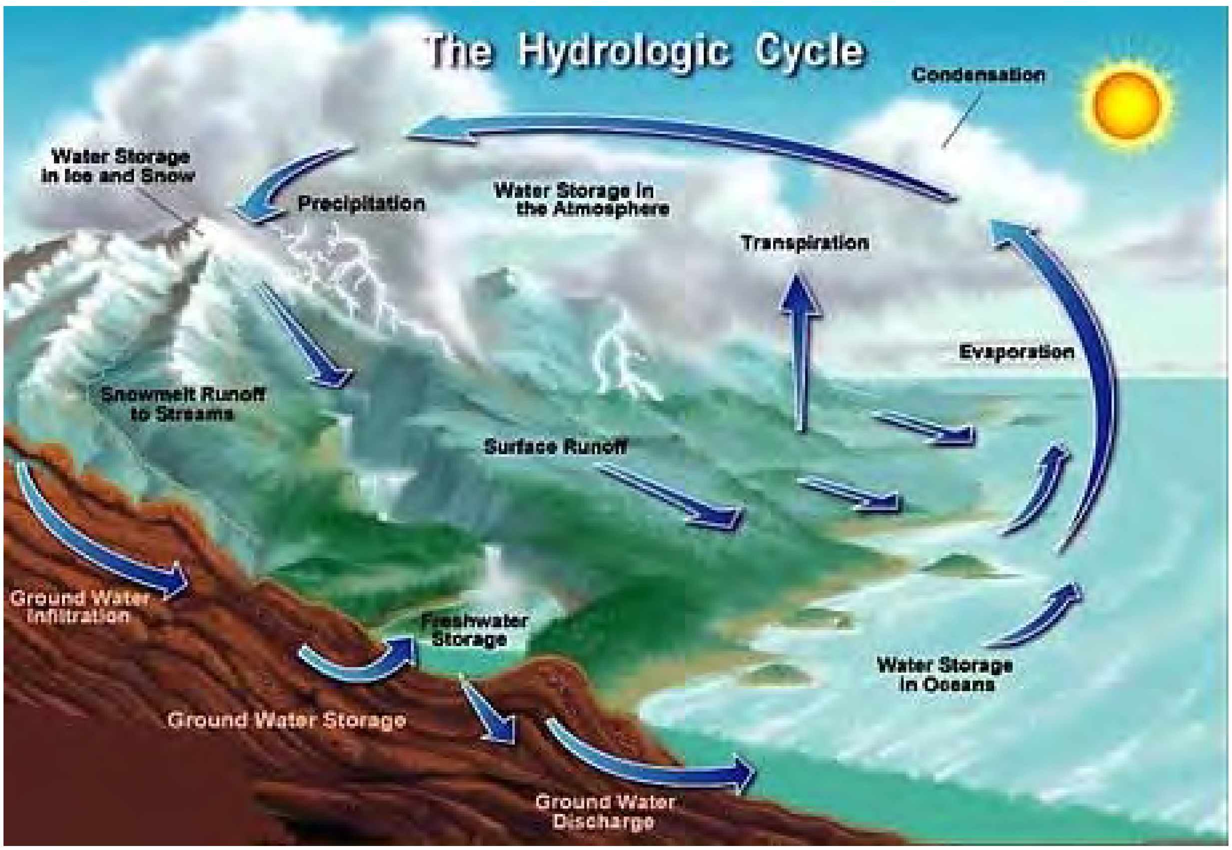
There is one more possible source of confusion concerning the definition of *watershed*. Look at the Foxley River watershed below:

It has more than one stream, so why is it only one watershed? The agency that drew the map decided that a single watershed based on the drainage basin of the eastern side of the estuary itself (also called the Foxley River) was a better choice than having several *micro-watersheds* cluttering the Island's database.

Finally, the terms *river*, *broo*k and *creek* refer to a stream's size. These are relative terms and whether a stream is called a river, brook, or creek is a local convention.

2. Hydrology

Hydrology is the study of the distribution, movement, and properties of water. A scientist who specializes in our earth's hydrology is called a *hydro-geologist*. Water has three *phases*: ice, liquid, and vapor. It is constantly being transferred in a process called the *hydrologic cycle* or, simply, the *water cycle*, pictured below.

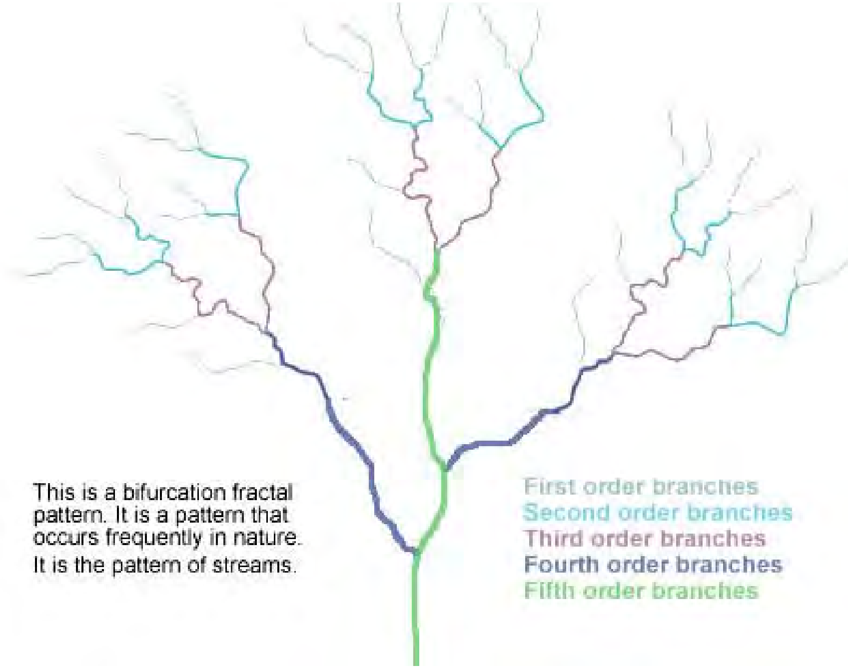


2.1 The Flow of Water in Streams

One water cycle component is the flow of water in streams. We rarely, if ever, see a single-channel stream where the water flows in a straight line. Streams are complicated systems, and a general understanding of how water moves in streams is essential when assessing the health of a stream and in designing enhancement projects. There are several important aspects of stream flow, some of which are explained below. In case you ever need a nine-syllable term, the technical name given to this discipline is *fluvial geomorphology*.

2.1.1 Stream Order

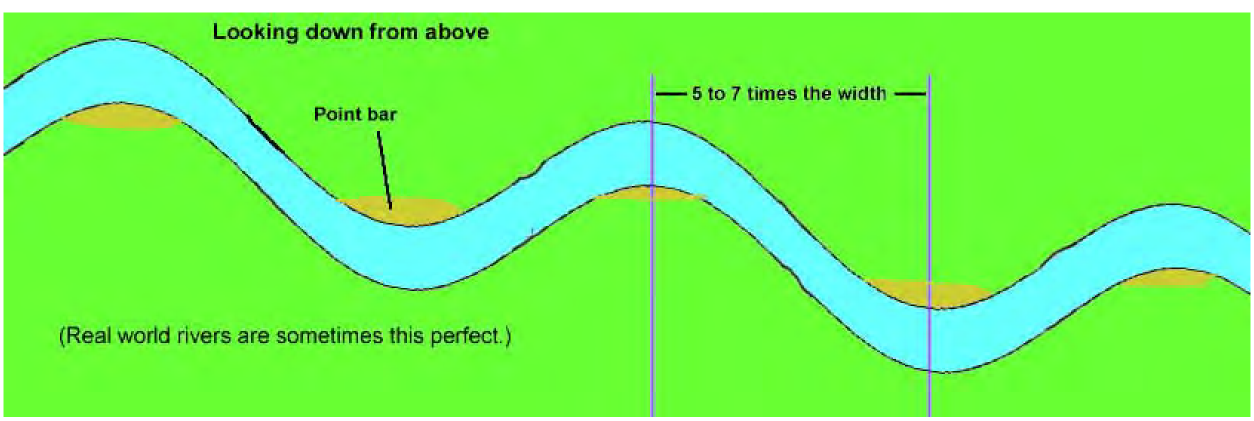
Single-channel streams are uncommon. Usually they are fed by tributaries, and usually those tributaries are in turn fed by other tributaries, etc. The overall system forms a pattern that is present throughout nature. You see it in tree growth and bird feathers, in leaf veins and blood vessels, in snowflakes and lightning. It is a fragmented pattern that can be split into many levels, each of which is approximately a smaller copy of the level just above it. This pattern is known as a *bifurcation fractal*. The following picture shows the familiar pattern.



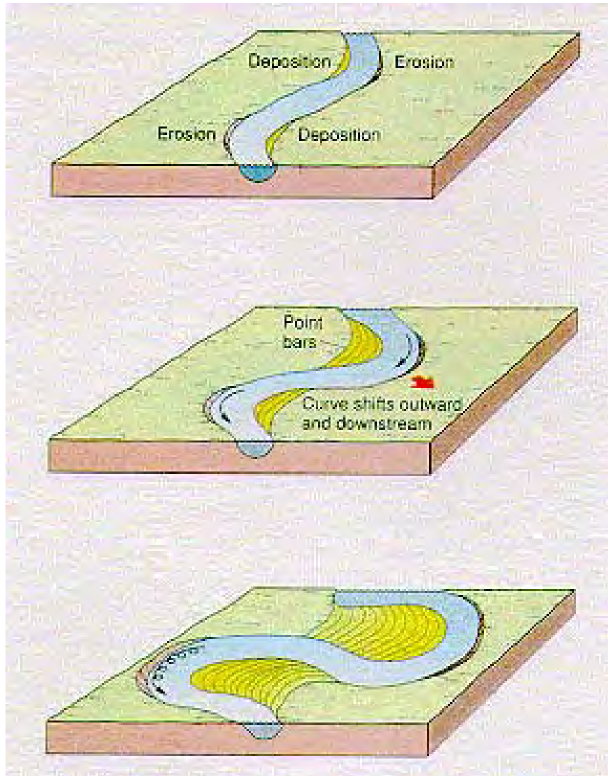
The picture above could be a stream system. Don't worry about the numbering system for the branches. Just know that for streams, the final, largest branch is referred to as the *main channel*. Because streams in PEI are short, the number of branches in the pattern for our streams is relatively low. The Amazon river is a 12th order stream!

2.1.2 Meandering

If you trickle water on an angled glass plate, it does not flow in a straight line, but instead follows a wavy, snaking pattern. Water flowing in streams follows this same wavy pattern, which is called a *meandering* pattern. The meander bends for PEI streams are typically 5 to 7 stream widths apart.[46,54]



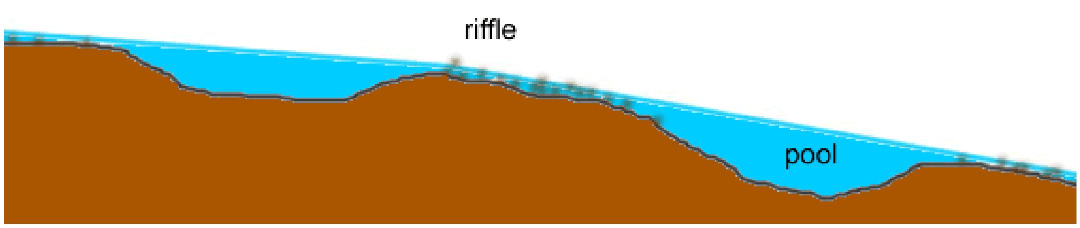
As the water enters each bend it makes a ½ turn in a corkscrew fashion, rotating towards the inside elbow of the curve. Because of this, sediment is scooped out of the outside elbow side and tossed into the inside elbow side. So, the sediment builds at the inside elbows of the bends, forming *point bars*. At the outside elbows, the bank receives the full force of the running water. Because of this erosion-deposition process, the bends become more pronounced over time, as shown in the following picture.



If we were able to view a stream in time-lapse, we would see the meanders vary over the flood plain. Certain activities (for example, beaver dams) will disrupt the meander of a stream. This disruption causes erosion and habitat problems. When a stream's flow pattern is disrupted, the stream will seek to re-establish its natural meandering pattern. Certain enhancement activities (which will be discussed later) are designed to help a damaged stream accomplish this.[46,53,54]

2.1.3 Lateral Profile

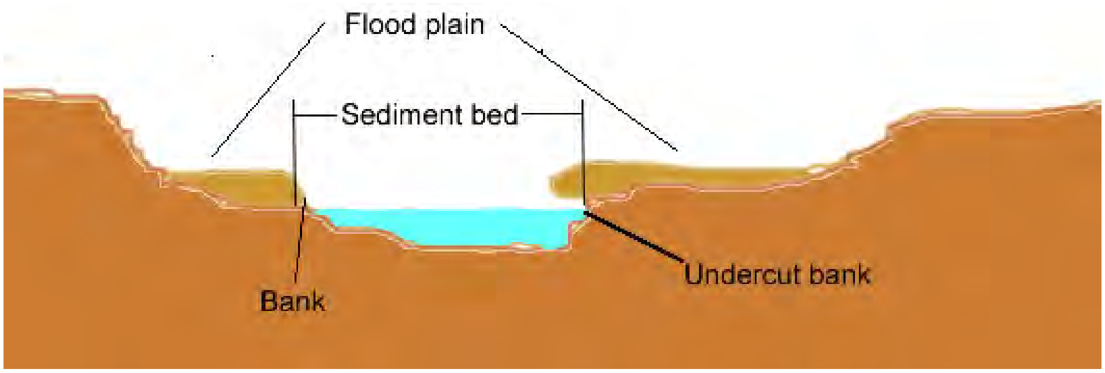
Just as it moves in a wavy fashion from side to side, a stream typically also has an undulating depth profile along its course. In PEI streams, we usually see a sequence of *pools* and *riffles*. This sequence is very important for aquatic habitat. The rate of change of the stream's elevation is called its *gradient*. Clearly, a higher gradient means faster water.



Pools often occur at meander bends, and riffles in the stretches between the bends. The water in the pools moves more slowly than water in the riffles. When the water slows, solids suspended in the water settle. Streams with high sediment loadings from land activities experience pool degradation. There are several enhancement strategies to correct pool problems and to restore the pool-riffle sequence.[46,53,54]

2.1.4 Bed Profile

The bed profile for streams varies considerably. The following picture shows a hypothetical profile. The flood plain is often absent, particularly for streams with a high gradient and for streams that have formed relatively recently.



The *sediment bed*, as defined by the PEI buffer zone regulations, is “a depression or low area of mud, silt, sand, gravel, rock or bedrock, or a combination thereof, which has a defined path” that “was formed or apparently formed by flowing water.” It is “normally to the edge of the water.”[1,46,53,54]

The banks of the stream usually define the sediment bed. The terms *right bank* and *left bank* refer to their position as you look *downstream*. The geometry of the banks and their condition are important, and these are frequently modified in stream enhancement work.

The *flood plain* is a low-lying area adjacent to the stream that is subject to flooding. The flood plain is often sediment, and the distinction between the flood plain and the sediment bed, as defined in the buffer zone regulations, is easily misunderstood.

As a stream’s meandering pattern shifts over time, it shifts within the flood plain. Aerial photographs of large rivers covering long distances not only show the river meandering, they also show the flood plain snaking through the landscape. (This is another example of a fractal in nature.)

As the stream makes its way along its course, at any given point there is a place in the bed profile where the water is deepest. If you connect these deepest points along the entire stream, you get an imaginary line that defines the stream’s deepest channel. This line is called a *thalweg*.

The stream bed and the flood plain characteristics are critical to wildlife habitat and to human use of the resources of the stream and the receiving water. A *cleaned-out* stream bed is not a good thing. Fish need in-stream cover and the spawning ground it creates. However, stream channels can be clogged by excessive debris, such as becoming tangled with alders that jam the channel and modify the flow.

2.1.5 Impoundments

When a natural or manmade obstruction blocks the flow of water in a stream, it creates an *impoundment* (pond). Are impoundments good? It depends on whether you are a duck or a trout. Certain animals need impoundment habitats and their associated vegetation. They provide cover, food, and nesting for these animals. Impoundments also provide for water storage within a watershed. In many cases, draining an impoundment (or swamp) can lead to lower groundwater tables and, in some cases, dry wells.[76,77]

Because impoundments are essentially still waters, considerable sediment settles in them. Trout need gravel bottoms for spawning. Because of high sedimentation and aquatic plant growth, ponds tend to have lower dissolved oxygen extremes and occasionally they become oxygen-starved (*anoxic)*. Still water also warms to levels that are stressful and often fatal to trout and salmon. Dams that create the impoundments frequently act as obstructions to migrating fish like trout and smelt.[17,18,54]

When an impoundment that has been in place for an extended period is suddenly removed, either deliberately of by an act of nature, the accumulated sediment is catastrophically released. This causes severe damage (consider Scales Pond). Not only is stream habitat destroyed, the sediment loading on the receiving water often impacts the estuary's habitat and commercial shellfishing. Careful planning and caution are necessary when considering the removal of a dam. Permits are also required. Unfortunately, many of the stream problems in our area are related to beaver dams. Removing these structures is not a simple procedure, and often requires a protracted engineering project.

2.2 Stream Water Supply

Streams are supplied, or *charged*, with water (and the dissolved and suspended components in it) in various ways, including surface water runoff, groundwater infiltration, wetland drainage, and direct precipitation. Contributions that occur over an undefined area of the stream are called *non-point sources*. Conversely, contributions that can be identified at a specific location are called *point sources*.

The upper reaches of a stream are called its *headwaters*. In our area, the headwaters are usually wetlands. The water drains from these wetlands in small, nested tributaries. In this way the wetlands are a reservoir for the stream. Often, beavers enhance these wetlands and expand the capacity of the stream system and the watershed in general. Beavers, it turns out, are good for something!

The stream bed is generally below the water table, and the groundwater contributes considerably to the stream's water volume along its course. Because this process occurs throughout the stream's reaches, it is an example of a non-point source. Frequently, you see areas where water flows directly out of the ground, forming or contributing to a stream or stream branch. These areas are called *springs,* and are an example of a point source. Groundwater temperature is essentially constant, with a value that is approximately the area's average temperature. The groundwater component of our streams keeps them cool in the summer and warm in the winter.

Water from storm events and melting snow and ice contribute to a stream in the form of runoff water. Sometimes this runoff is added to the stream slowly and consistently along its bank as a non-point source. Other times you may see channels of runoff from fields or roads. Runoff water is of particular interest to watershed managers, and on PEI it is the most significant source of contamination in streams. The area along the stream margin is called a *riparian* zone. Because runoff must cross this zone before reaching the stream, the properties of the riparian zone significantly impact the health of the stream. Riparian soils with high organic content and dense, diverse vegetation filter and dampen the flow of runoff water.

2.3 Stream Water Quality

There are countless components of water quality. These components are called *water quality parameters,* or simply *parameters*. It is not possible to discuss all of the parameters here, but we should look at a few of them, particularly those that are of the highest priority in our area. Some of these parameters were already discussed in Chapter 1, Private Wells.

2.3.1 Contaminants

Water quality is affected by human activities. Because PEI has a substantial agricultural economy, a focal concern is agricultural inputs to streams. For the most part, agricultural inputs are contributed to a stream by runoff. They include:

- Sediment: most important
- Nutrients: also important
- Toxins: uncommon, but often devastating
- Organic biomass
- Bacteria

Of secondary, but not insignificant, importance is contamination created by roadway runoff and construction/development activities. Sediment is the principal contaminant.

Another source of contamination is domestic waste. On PEI, domestic waste is treated and discharged to open water in only a few places. For the most part, contributions to a stream from this source are made by septic systems through the groundwater. They contribute:

- Nutrients
- Bacteria
- Dissolved organic matter (e.g., soap)
- Toxins: household chemicals

There are other contamination sources that apply to specific uncontrolled releases to a stream that cannot be ignored on PEI. Examples are waste dumps, leaking fuel storage tanks, fish processing waste piles, composting operations, gravel extraction, automobile wrecking yards, and industrial waste. They contribute:

- Nutrients (e.g., nitrate from fish processing waste piles)
- Sediment
- Toxins: fuel oil, solvents, antifreeze, heavy metals, acids, caustics, etc.
- Dissolved organic matter
- Organic biomass
- Bacteria

We hear a lot about nitrates and pesticides, and they are a problem that must be reckoned with. However, the most significant problem affecting PEI streams is sedimentation.[80] In PEI the primary inputs for sediment are agricultural runoff from potato fields, clay road erosion, and construction/development disturbances. Later we will look at methods our progressive farmers use to keep topsoil on the field, and methods construction engineers use to control erosion.

Stream contamination from human activities is a result of population pressure. Here in the Lot 11 area, we are fortunate to have experienced less impact from these factors than the residents of most other PEI communities. Even if we do nothing else as a group but make our residents aware of this gift, we will have accomplished a worthy task. Most watershed groups reactively scramble to control and correct problems that have occurred over decades of mismanagement. We have some examples in our area too, but our primary community challenge is to proactively conserve what we already have. For the most part, we have a working balance between human activities and natural resources.

2.3.2 Some Water Quality Parameters

Nutrients

As discussed in the Private Well chapter, farmers deliberately add nutrients to the soil to improve crop yields by supplying plants with their limiting growth factors. Aquatic plants also have these same nutrients as their limiting growth factors which, when satisfied, cause streams (and receiving waters) to become overgrown with aquatic plants and algae. The plants eventually die and decay, which adds organic sediment to the stream bottom. This organic sediment promotes attached plant growth, interferes with fish spawning, and demands oxygen for the decay process. The living plants and algae respire at night, dropping oxygen levels.

- Nitrate/nitrite: The human health and environmental importance of this parameter is well-known, and we discussed this parameter at length in the Private Well chapter. It should be noted that nitrate levels that would be considered safe for drinking water may be above the optimum level for surface water. Even at *very* low levels, nitrates can cause algae and weed problems in streams.
- Phosphate: Because phosphate does not have the same human toxicity as nitrate, it has not been as much in the public eye. It is often said that phosphate is less of a problem environmentally because it binds more effectively with active sites in the soil. Although this is perhaps partially true (particularly for geological areas with high iron and calcium levels), the exchange capacity of the soil is not always sufficient for trapping phosphate from bulk sources such as septic systems and phosphate-based fertilizer sources. Sand and gravel have poor anion/cation exchange capacity (relative to clay and humus) and breakthrough can and does occur – particularly in high use areas. The cation/anion exchange process is subject to exhaustive loading, and breakthrough will occur in high phosphate-input environments. Also, the erosion process transfers soil particulates to the water column and the bound phosphates are solvated. Most importantly in the environment, phosphate is often the limiting nutrient for plant and algal productivity.
- Ammonia and total nitrogen: Ammonium nitrogen is a significant plant nutrient, and elevated levels contribute to algal blooms and degrade aesthetic quality and habitat suitability. Although ammonium nitrate fertilizers, septic system failures, and landfill leachate are sources, natural decay processes are responsible for a considerable portion of this nutrient in the environment. Organically bound nitrogen in the form of plant and animal proteins, certain naturally occurring amines, and urea all degrade to ammonia. Systems with substantial organic biomass effectively fuel themselves with nutrients by this process. Organic nitrogen is rarely measured directly; instead, levels are obtained by nitrogen mass balance techniques requiring data for total nitrogen, ammonia, and – depending on the method for total nitrogen – sometimes nitrate/nitrite.
- Other nutrient/mineral factors: Certain other parameters such as potassium, iron, selenium, silica, chloride, and sulfate play a role in both plant and animal nutritive profiles. They are rarely priority factors, except in cases where special conditions prevail.

Non-nutrient Parameters and Stress Indicators

Nutrient levels are not the only part of the overall water quality profile. There are several other key water quality factors for healthy streams and productive aquatic habitat. Listed below are some of them.

- Dissolved oxygen: Trout, and salmonids in general, require relatively high, sustained dissolved oxygen levels. Algal blooms and other oxygen depletion conditions reduce oxygen to levels not suitable for these species, long before the obvious anoxic events observed by the public occur. These measurements can also be used to predict and document anoxic events. The measurement must be made in the field.
- Temperature: Oxygen solubility decreases (fairly dramatically) with increasing temperature, and aquatic biological processes are accelerated at higher temperatures, increasing demands (e.g., oxygen demand) on the system. Also, many species have narrow optimal temperature requirements (specifically trout and other salmonids). Reduced cover vegetation and impeded flow can cause temperatures to rise above acceptable levels. The measurements are useful in making predictions, evaluating habitat suitability, and documenting existing problems. This measurement must also be performed in the field.
- pH: Aquatic organisms thrive within region/species-specific pH ranges. Excursion beyond these optimum ranges disturbs their biological processes such as osmotic balance, immune response, nutrient uptake, and reproduction. Flooding and stream flow reduction caused by natural and man-made obstructions can cause local pH excursions beyond regional norms. Sharp changes in pH, perhaps caused by storm-related erosion events, can also stress aquatic organisms. Long term changes in pH caused by acid rain occur. Although this test is often performed in the laboratory, it is substantially preferable to perform the test immediately in the field.
- Alkalinity: Here we measure the system's resistance to pH changes brought on by the processes discussed above. To a degree the alkalinity of fresh water is at a fairly constant steady state within a given hydrogeological setting, unless outside stressors – such as gravel extraction, commercial-scale composting, landfill plumes, and septic plumes – exert demands on the system.
- Biological oxygen demand (BOD): This test measures biological oxygen uptake potential. BOD measurements can be used to evaluate potential for anoxic events.
- Chlorophyll A: Chlorophyll A is an algal biomass indicator. Its measurement is used to evaluate and document potential, as well as ongoing, algal bloom events.
- Dissolved solids and/or specific conductivity and hardness: Like alkalinity, these parameters are fairly stable in the absence of unusual stressors. Excursion from the ecosystem's general range-limits impacts the biological processes of the endemic organisms.
- Suspended solids and turbidity: Often brought on by storm-related erosion events, frequent, sustained, or catastrophic excursions in suspended solids can be acutely fatal to many aquatic species. Extended elevation of water column sediment loadings can substantially alter aquatic communities. Sediment deposition will degrade the suitability of the stream bed for insect and fish nesting, increase oxygen demand, and enhance eutrophication.

Bacteria

With drinking water we are concerned with pathogenic bacteria, and we use the presence of the Fecal Coliform group as an indicator of the possible presence of these harmful bacteria. In the stream, however, it is normal to have Fecal Coliform bacteria, and the presence of this group is not necessarily a problem. In fact, Canada's guidelines for recreational fresh[*] water set a maximum level for *E. coli* at 200 *E. coli* /100ml. Intrusion from domestic septic systems and runoff from livestock management areas can bring about unhealthy levels, both for aquatic animals and humans. Shellfish in receiving estuaries are particularly susceptible to bacterial contamination.

The aquatic and semi-aquatic animals themselves release bacteria and other micro-organisms into the stream. Beavers are notorious for contaminating streams with a microorganism called Giardia. Drinking the water causes an infection that is sometimes called *beaver fever*.

[*] Recreational guidelines for salt water are based on a different indicator. The guideline for marine recreational bathing water is 35 enterococci/100 ml.

Not all bacteria are bad. In fact, without them our biosphere would collapse.

Odors and Films

There are two primary odor complaints for streams: fishy and rotten egg smells. Ammonia and nitrogen-containing organic compounds (amines) are responsible to a considerable extent for the swampy, fishy odor. It is common around anoxic/hypereutrophic systems, and is primarily caused by decomposing biomass (particularly decomposing algae).

In an aerobic water system, aerobic bacteria use dissolved oxygen in their metabolic process. In an anoxic environment, anaerobic bacteria predominate (certain bacteria – *facultative anaerobes* – can adapt to anaerobic conditions) and they can take their oxygen from certain combined oxygen sources, e.g. dissolved sulfate. They release as a waste product hydrogen sulfide, which smells like rotten eggs. Often the odor is pronounced at levels well below the measurement thresholds of most tests.

Films on the water surface come from a variety of sources. Some of them are bad, like fuel oil or gasoline. Often they are harmless. The groundwater on PEI is high in dissolved iron and manganese. When the groundwater comes in contact with the air, the iron and manganese change form to an insoluble species (iron oxide and manganese oxide). We see this in the form of a black or brown stain in our plumbing fixtures after the water has stood for an extended period. In still surface water, the iron and manganese oxide form at the water's surface, creating a very thin, shinny film.

2.4 Conclusion

Understanding stream hydrology is essential for effective stream assessment and stream enhancement work. Understanding the terminology is necessary for effective communication with the watershed community and the local community. The detail and language discussed above should be adequate for most of our purposes. In some cases, the concepts and terms here may be overly technical for some residents, although you might be surprised at how knowledgeable many residents are. They often want us to explain things in plain language, but they expect us to have a sound working knowledge of the facts.

The science of stream hydrology is considerably complex. The various branches of environmental science, including hydrogeology, make productive and rewarding career choices for our young people to consider.

IV. Riparian and Riverine Ecosystems

1. Introduction

The term *wildlife* encompasses all non-domesticated plants, animals, and microorganisms. Watershed wildlife communities are an essential component for many human stakeholders. They are part of the overall global system that supports life, and they provide aesthetic and cultural enrichment. Often they have immediate economic value too. Wildlife populations are natural resources that comprise our biological wealth. Natural systems and wildlife are important on their own, independent of human values. Whatever your view of creation, they are a part of it.

We cannot effectively address here the broad subject of wildlife habitats on PEI. Instead, we will focus on certain aspects that are of special relevance to watershed managers: in-stream (*riverine*) and stream-border (*riparian*) habitats. You may ask, “Why do wildlife habitats need to be managed at all? Didn’t wildlife do just fine before people came here?” The answer is, “We are here now and we are an integral part of the landscape.” Most animals can only adapt to their environment. Humans (and beavers) have the remarkable ability to *modify* the environment to meet their needs. The advent of permanent European settlement about 300 years ago brought about wholesale modification of PEI’s wildlife habitats. In this modified landscape, the wildlife that once did quite well on their own now require special accommodations.

1.1 Carrying Capacity

The number of a given species that an area can support is called the *biological carrying capacity* for that species. We discussed the concept of limiting growth factors for plants, and this principle extends to other wildlife components. The biological carrying capacity is determined by such limiting factors as climate, access, space, shelter, food, disease, predation/harvesting, water/water quality, and den/nesting/spawning sites. There is also a *cultural carrying capacity* for each species, which refers to the number of a species that society will tolerate or permit in an area. Beavers provide a clear example of a species that frequently exceeds its cultural carrying capacity. This capacity is also frequently exceeded in a more subtle way. Land uses often inadvertently control the number of a species we permit by modifying the land’s biological carrying capacity.

1.2 Interdependence

The term *ecology* has acquired the unfortunate meaning of *the cause of environmental activists* or, sometimes, the *study of the environment*. These are not the term’s true scientific meaning. Ecology is the study of the interrelationship among living organisms (*biotic factors*) and their relationship with their physical environment (*abiotic factors*). It is a study of interactions and interdependencies. We cannot effectively understand or manage a single species in isolation. We have to more broadly consider the framework in which they live, including other plants and animals and their optimum habitats.

Examples of a species’ biotic factors include prey, predators, scavengers, parasites, competitors, symbiotic species, decomposing microorganisms, nitrogen-fixing microorganisms, etc. Examples of a species’ abiotic factors include light, air, water, climate, soil properties/composition, etc.

There a few other important terms that have broad definitions in our language but have specific biological meanings. An *organism* is a living thing (a plant, an animal, a bacteria, etc.). A *species* is a group of organisms that can interbreed and have viable offspring. A *population* is a group of the same species that lives in a given area at a given time. A *community* is a group of populations living and interacting with each other in an area. The animals in a community when considered as a group are called *fauna*. The plants in a community when considered as a group are called *flora*. An ***ecosystem*** is a community together with its physical environment. Formally, an organism's (or a population's) *habitat*[*] is the ecosystem where it lives; this ecosystem is species specific. *Critical habitat* is the set of habitat elements that the species absolutely must have to live. Certain species (*generalists*) can adapt to a variety of ecosystem characteristics, and others (*specialists*) have narrowly defined habitat requirements.

Managing an ecosystem for the benefit of a desirable species is not a novel concept and is not limited to wildlife ecosystems. It is the basis of modern agriculture. We condition the agrarian ecosystem by modifying the properties of soil, eliminating crop and animal predators, introducing pollinating insects, providing food and shelter for animals, etc. In fact, the overall systematic interrelationships on a farm are an excellent conceptual model for the term *ecosystem*. Note that as with wildlife ecosystems here on PEI, humans are a critical element in the farm ecosystem.

Biodiversity is the variety and variability among living organisms within a given ecosystem. It is not simply the number of different species present in a community (species diversity). Biodiversity also includes the genetic variations within those species (genetic diversity) and other variations within a species (subspecies diversity), along with the variety of interactions and levels of dependence of the organisms with one another and with their physical environment (ecosystem diversity). A biodiverse ecosystem is a healthy ecosystem. It is resilient, adaptable, and disease resistant. A stand of trees does not a forest make.

There are curiosity products that claim to be self-sufficient ecosystems, and there are technologies that target isolated ecosystems in space. However, there are precious few independent ecosystems in nature. The ecosystems themselves interact with and influence one another. Ecosystems are defined at many scales. Globally, there is an ultimate-scale ecosystem called the *biosphere*.

2. Riparian Ecosystems

It is appropriate that the last section ended on the interdependence of ecosystems, since the riverine ecosystem is inseparably connected to the riparian ecosystem. You cannot have a healthy stream without a healthy, adequate riparian zone. In fact, managing a stream is more often better accomplished by managing the riparian zone than by doing in-stream enhancements. The riparian zone provides countless critical requirements for a stream's ecosystems, including cover, shade/temperature regulation, food for aquatic animals, bank stabilization, in-stream debris for aquatic habitat, nutrient uptake, water storage, etc. Finally, and of predominant importance in PEI watershed management, the riparian zone attenuates runoff from human activities. Riparian zones capture sediment and trap pollutants, and they mediate catastrophic rain events.

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[*] There are other definitions for the term *habitat*. Some relate simply to the area where a species lives. Another is: *a combination of food, water, cover and space all arranged in a way that the organism can access them within its territor*y. Our definition above encompasses these definitions but it more comprehensively considers the relevant factors.

Riparian zones are the stream's shock absorbers.[12,14,19] Although *buffer* is a perfect descriptive term for the riparian zone, avoid using this term. It has acquired negative connotations in PEI and should only be used in its regulatory definition.

The riparian zone has profound importance beyond the considerations of the stream; it is a critical wildlife habitat as well.

2.1 Soils

Because it is the life support system for vegetation, soil is a most important element in the riparian ecosystem. It supports and anchors the plant, provides moisture and nutrients, holds microorganisms that fix nitrogen and decay organic matter, and presents oxygen to the root hairs. In addition to being a primary factor for effective plant cover, optimum soil conditions provide several other critical benefits, including the stability of stream banks, the effectiveness of the riparian zone in dissipating runoff, the ability of the riparian zone to absorb nutrients and filter water, and habitat for a variety of beneficial flora and fauna (e.g., insects, nematodes, fungi, etc).

Soil science is a complex, diverse study. It has two general branches: *pedology* (geological, chemical and physical properties) and *edaphology* (study of soil as a habitat for organisms, including crops). We will consider a few simple concepts.

2.1.1 Phases

Soil is made up of three *phases* of matter: solid, liquid, and gas. The solid phase is a mixture of mineral and organic matter. The liquid is primarily moisture, and the gas is simply air.

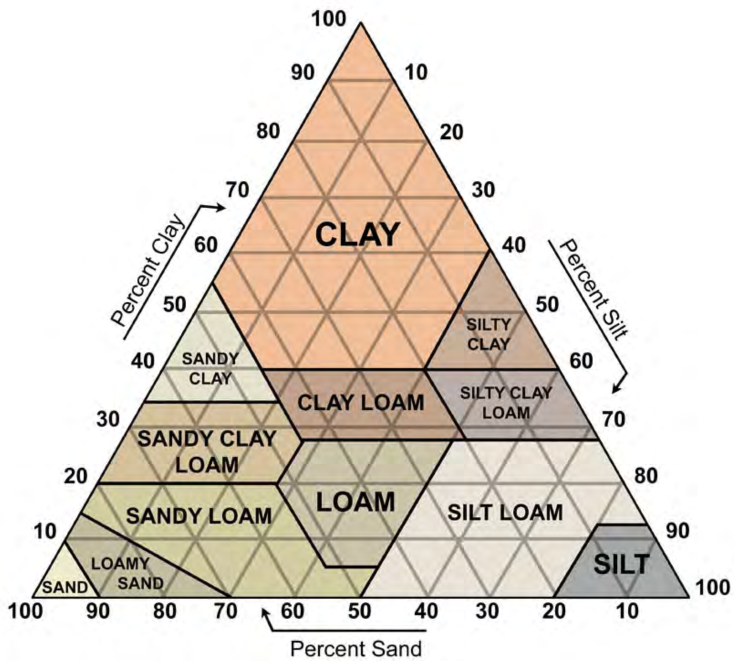
2.1.2 Organic Content

The solid phase of soil consists of organic matter and mineral particles. The organic matter consists of dead plant and animal tissues in various stages of decay. Microorganisms in the soil are responsible for the decay processes. After considerable decomposition, the organic matter forms a stable mass called *humus*. The humus is extremely porous and is very effective in holding moisture, trapping nutrients, absorbing contaminants, and stabilizing pH. Because it is dark, organic content absorbs light and warms efficiently for plant production. The organic matter is networked with fungi and sticky secretions of bacteria that promote cohesion of the soil mass. (Soils with less than 5% organic content are easily eroded by wind and water.) Finally, organic content is food for a complex soil ecosystem.

2.1.3 Soil Texture

Soil texture refers to the particle size distribution of the mineral content of the soil. Soil scientists divide mineral particles into three primary classes called separates: sand, silt, and clay. Sand is coarse (0.05 to 2 mm in diameter); silt is finer than sand (0.002 to 0.05 mm); and clay is very fine (less than 0.002 mm). These three separates occur in a soil at some percentage. Knowing the percentages of the separates enables classification of the soil into one of twelve texture groups. The chart on the following page is used in the classification process. Gravel and rock (pieces over 2 mm) are not considered part of texture.

The texture of the soil controls its porosity and affects the soil's ability to absorb water, hold water, and present oxygen to the roots. The clay and silt have a very high, reactive surface area and they efficiently absorb nutrients and contaminants and hold water. However, soils with high clay/silt content are less permeable.



Soil texture classification

2.1.4 Soil Structure

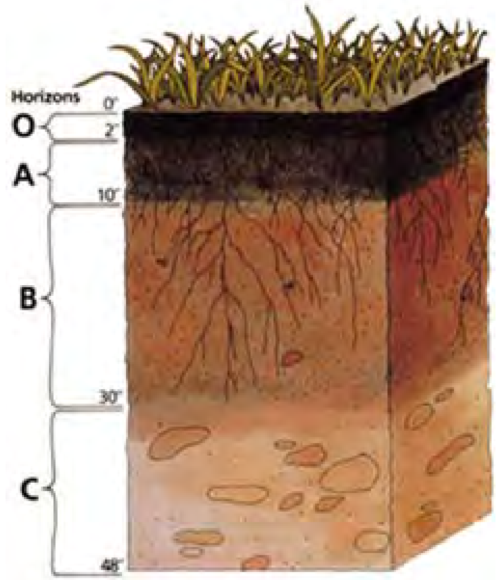
The composition of the soil dictates how well it holds together as a unit. Soil particles clump together cohesively in structural units called *aggregates*. Strong aggregates are more erosion resistant and provide better anchorage for plants. Clay, iron oxide, and organic matter promote strong aggregates. In general, sandy soils form weak aggregates. Soil compaction is another element of soil structure. Compaction de-aerates the soil, reduces its permeability, and crushes aggregates. Frequently, heavily used foot paths along stream banks become compacted and unsuitable for plant growth. This destabilizes the bank and causes erosion and catastrophic failures.

2.1.5 Soil Profile

If you dig a hole in a riparian soil you will see layers. The boundaries between the layers are called *horizons*. The arrangement of these horizons is called soil *profile*.

Typically, riparian soils have five or more horizons. Here are the common ones:

- O: Un-decomposed organic litter.
- (Sometimes P: Peat, in flood plains and areas where there is considerable water saturation).
- A: High organic top soil. Most diverse soil ecosystem. Highly effective erosion control and nutrient/contaminant trapping properties. Ideal plant habitat.
- B: Sub-soil. Deep root penetration. Low organic content. Transitional layer.
- C: Substratum. Unconsolidated mineral. Weathered bedrock.
- R: Bedrock.



An example of a soil profile

One special soil type that deserves mention is *hydric* soil, which is a soil that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic (oxygen-starved) conditions. Wetland vegetation (e.g., cattails) grows on this type of soil. Identifying a hydric soil is a complicated process and often requires the trained eye of a professional soil scientist. The buffer zone regulations define a wetland (and actions that are regulated within a wetland) based in part on whether the area has hydric soils. (See Chapter V, Section 2 for more detail.)

What is the ideal riparian soil? What is the optimum organic content, porosity/texture, structure and profile? There is no simple, quick answer. Ideally, it is the soil that has evolved with the stream over the millennia. Most of the land on PEI has been altered to some degree by human activities. Disturbance of the riparian soil and introduction of sediments from elsewhere are common problems. Compaction and disruption of the soil profile/texture – particularly by stripping or covering the O and A horizons – causes dramatic degradation of a steam's riparian shock absorber. A change in soil suitability degrades plant cover and results in a chain reaction of riparian zone failures.

2.2 Vegetation

Vegetation performs several critical functions in the riparian ecosystem and the riverine ecosystem, including:

Bank stabilization – The roots of riparian trees and shrubs help consolidate the stream bank.

Absorption & filtering – The network of plant matter (both living and dead) traps sediment and absorbs nutrients and pollutants.

Terrestrial food source – All riparian wildlife either eat plants or eat something that does.

Stream food source – Salmon and trout eat aquatic insects. Aquatic insects spend most of their life in water. They feed on leaves and woody material such as logs, stumps and branches that fall into the water from stream banks. Standing riparian vegetation is habitat for other insects that sometimes drop into the water, providing another food source for fish.

Temperature control – Riparian vegetation provides shade that moderates summer temperatures that are stressful/fatal to fish and riparian wildlife.

Energy dissipation – During high stream flows, riparian vegetation slows and dissipates floodwaters. This prevents erosion that damages fish spawning areas and aquatic insect habitats and may cause bank failures.

Fish habitat – When trees fall into a stream they sculpture the stream bottom by focusing the flow of water, forming structure for fish habitat. (*Digger* logs are sometimes deliberately placed in the stream by watershed managers for this purpose.) The woody debris that falls into the water is ideal spawning habitat for trout.

Fish cover – Predatory birds (e.g., cormorants) spot trout in pools from the air. Tree and shrub cover shields the fish.

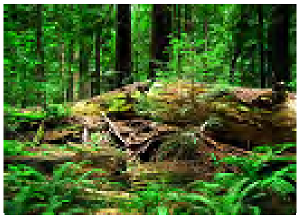
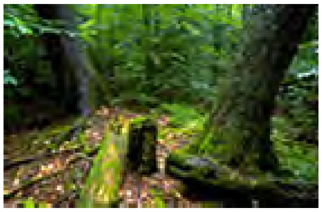
Wildlife habitat – Riparian vegetation provides food, nesting, and hiding places for terrestrial animals.

Riparian vegetation management is a primary concern for watershed managers. Some important principles need to be understood before assessing a riparian zone or designing riparian zone enhancement projects.

2.2.1 Old Growth

What is the ideal vegetation pattern for a riparian zone? We need a benchmark, a model to mimic when performing riparian zone management. One benchmark is *old growth forest*. Old growth forest has several characteristics:[35]

- Assorted trees, shrubs, and plants (not just a single-species plantation)
- Vertical structure (green at every level)
- Random spacing
- Includes large, mature trees
- Climax species (explained below)
- Minimal disturbance
- Biodiverse plant and animal communities
- Some standing and fallen dead trees
- A high percentage of canopy cover (*crown closure*)

2.2.2 Succession

When a disturbance in a riparian zone destroys vegetation, a process of regeneration begins. These disturbances can occur naturally (fires, floods, beavers), but frequently human activity causes the destruction. The regeneration occurs in a sequence of stages called *succession*. In the first stage, shade-intolerant plants grow.

Usually the mix of species that initially begins to grow after the disturbance (called the *pioneer species*) is predominated by grasses and alders in PEI, but some others do occur, such as willows and aspens. Deforested areas (whether by flood, fire, bulldozer, chain saw, tractor, or beavers) quickly become densely vegetated with these pioneer species. The land does not necessarily have to be cleared. Heavy sediment deposits or soil profile erosion will also bare ground for these pioneer species. We are fortunate that alders quickly infest riparian zones after disturbances. They form dense networks of anchoring roots and branch tangles that stabilize a potentially disastrous situation for the stream.

If disturbances do not frequently re-occur, then the second stage of succession begins. Somewhat more shade-tolerant species begin to grow in the (albeit sparse) canopy of the pioneer species. These second-order species include black spruce, eastern white pine, ash, and birches. Slowly they begin to replace the majority of pioneers. Then shade-tolerant species (cedars, maples, white spruce, balsams, beech) take hold. The species in this final group are called *climax* species.[38]

Once the process has completed, the riparian forest remains in equilibrium at the climax stage. Some trees die and others grow in their place. This final stage is a mix that includes representatives from all the previous stages and the climax species. Over time, the forest begins to resemble old growth.

As stated above, succession will occur if the disturbances do not frequently re-occur. Areas that are under repeated stress – whether by human activity or natural conditions – will remain at the pioneer stage indefinitely. If the re-occurring disturbance is from a natural cause, then it is best left alone. When the disturbance is manmade, it should be corrected.

Frequently our streams become infested with alders that interfere with enjoyment of the stream. The problem is compounded when there are continuous disturbances. Because the climax stage has not been reached, the diverse plants and animals that require it are not supported. In some cases, narrow stream channels become impacted with alder stems, destroying stream habitat. It is possible to assist the succession process to a limited degree. Isolated patches of alders can be removed (with a permit), and subsequent stage species can be planted. However, it is unwise to do this in the case of a re-occurring disturbance.

2.2.3 Planting

One very important aspect of watershed management is planting vegetation in the riparian zone. The Department of Environment, Energy and Forestry is a substantial resource for this work. The trees and shrubs are provided at no charge to watershed groups through the Greening Spaces Program. The staff at the J. Frank Gaudet Nursery are a resource for species selection and planting advice. They have provided us with a detailed chart of recommended trees and shrubs for the riparian zone. The chart details how the different plants should be intermingled.

2.2.4 Invasive Plants

Roughly one third of the Island’s plants are introduced species. Thousands of postcards from PEI showing lupines reach readers around the globe. According to Kate MacQuarrie (Director Forests, Fish and Wildlife, PEI DEEP), lupines are not native to PEI. Invasive plants become a problem when they displace species that are native. Frequently, native wildlife depend upon native plants. Purple loosestrife has public recognition. Japanese knotweed is another very problematic invader. Norway maple and buckthorn are also common. Dealing with infestations is complicated and frequently involves the use of herbicides that are substantially risky in riparian zones.

2.3 Riparian Animal Communities

There are thousands of species and subspecies of terrestrial and semi-aquatic animals that live in, and/or depend on, the riparian ecosystem. There are mammals, birds, insects, reptiles, amphibians, mollusks (snails), etc. We can only consider a few important aspects of this topic.

The Macphail Woods Forestry project has comprehensive lists of mammals, birds, reptiles and amphibians on PEI. They have a brief, incomplete list of insects as well. Their web site is http://www.macphailwoods.org

2.3.1 Beavers

There is considerable controversy – at several levels – over beavers. One controversial question is whether they are native to PEI. The experts disagree. Most believe they were not here for the past 6000 years. They were absent when the Europeans arrived. American beavers were introduced to PEI in 1949. When beavers were introduced, their predators were not introduced with them. At present there are only three beaver predators on PEI: humans, coyotes, and a few bobcats. Beavers eat bark, leaves, stems, buds, aquatic plants, and roots of trees and aquatic plants. Their preferred tree is the aspen, but they also eat several others, including the ubiquitous alder. The result is a beaver population explosion.

Beavers and beaver impoundments have benefits. They provide critical habitat for a variety of waterfowl. Also, the impoundments create a massive storage structure for fresh water. Killing the beavers and draining the vast swamps they have created will lower the water table and could lead to dry wells in areas like ours.[76,77,78]

Beaver dams and beaver impoundments are not good for trout, smelt, gaspereau, and salmon. They warm the water, lower oxygen content, modify the stream bed, and create migratory blockages in the stream.[54,53] Also, beaver impoundments flood property and access roads.

The secret is to implement a balance. Each stream should have a beaver management strategy. The most common strategy is to establish beaver-free zones, typically in the main channel starting at the head of tide. Trappers are the only viable resource for controlling beavers. Removing a beaver dam is not a simple task. Tons of sediment accumulate in beaver impoundments and removing the dam requires engineering to prevent the sediment from killing the river (and shellfish populations in the receiving estuary).

2.3.2 Insects

Most people don't like insects. Mosquitoes and biting flies make our riparian zones intolerable for many. But, insects are good (most of the time). They are near the base of the food chain and they fuel the riverine/riparian ecosystem. In an ideal riparian ecosystem there are population controls for biting insects: dragonflies, bats, swallows and other birds, fish, frogs, salamanders, etc. Although it is unlikely that our plague of mosquitoes would be eliminated, it is certain that targeting a balanced riparian zone is part of the solution.

2.3.3 Birds

Take a walk through the demonstration woodlot in Foxley River and listen for birds. There is almost complete silence. Then take a walk along the MacDonald's river just next to the woodlot, where there is a diverse riparian ecosystem. It is alive with sounds of countless different species of birds. They not only prefer the rich, old-growth–like environment, they need it.

A final note on riparian ecosystems and forest habitats in our area. Lot 11 and Area is a good place to find most of the species appearing in the species lists for PEI. Even the endangered species have been spotted here. We owe this to substantial undeveloped, forested areas in our community. We also owe our superior water quality to these areas. Most of our nitrate results are at background, natural levels.[62] If you look at the topographic maps for our area you will see huge areas of undeveloped land between Route 12 and Route 2. You will also see similar areas north and east of Route 12. There are some who believe this is wasteland. Some may think it should be clear-cut, drained, and exploited. If that happens we could lose what makes Lot 11 and Area special. Again, if we do nothing else as a group but make people aware of their gift, then we have accomplished a worthy task.

3. Riverine Ecosystems

We devoted Chapter 2 to the hydrology of streams; in this section, we will consider the role of streams as wildlife habitats. There are three primary freshwater aquatic ecosystems in our area: marsh/wetland, impoundments, and free flowing streams. For now we will focus on free flowing streams. There are many aquatic and semi aquatic species in riverine ecosystems, including aquatic plants and algae, insects, birds, amphibians, mammals, and fish. Populations of various fish species are typically the primary interest of watershed managers. We will also focus on fish, but bear in mind that fish do not live in isolation. They require insects as food and so require everything the insects require. In many streams in the spring, trout rely on smelt eggs and so require everything the smelt require. The list of interdependencies goes on, forming a complex network. Also, because these different species evolve in the same natural setting, optimal conditions for fish in free flowing streams match the optimal conditions for other species populations there.

It should be noted that sea run brook trout are dependent on the riverine ecosystem. Sea trout anglers are sometimes under the false impression that their fishery is not affected by stream problems. Our estuaries are nurseries and habitats for a variety of species that comprise, and make food for, marine ecosystems. They are also the source point of our aquaculture economy. Stream inputs directly impact estuarine ecosystems.

Ultimately, the streams are part of our natural wealth. Trout and salmon are not on everyone's list of priorities, but most people want the benefits of healthy streams and the healthy communities they are a part of. Trout and salmon are particularly sensitive to stream problems. They are fussy. Therefore, they are stream-health barometers here in PEI. If they are not flourishing and abundant, then something is wrong.

When we consider the riverine ecosystems on PEI, we are considering ecosystems that are in trouble. As we review the elements of riverine habitat it is easy to become pessimistic and negative. When the facts are explained to the public, some become resentful and angry. They are impatient with the *environmental scoldings* they frequently hear from activists. We will stick to the science. Many of the problems we will look at are directly related to land use practices. Landowner understanding of the facts is the key to solutions. Communicating the facts without a defensive response is a challenge in watershed management.

Fortunately, we live in the Lot 11 area. We do not have the severity of problems that other, more developed communities have. We do not have the magnitude of population, agricultural, forestry, development, and commercial/industrial pressures of other areas. We have a better balance of land uses. Most of our landowners and farmers are progressive and responsible. There is cause for optimism in our area. Our job is to keep what we have. We can have confidence that the problems we do have can be corrected with management actions and landowner practices.

3.1 Elements of Riverine Habitat

Like the communities that live in riparian ecosystems, the communities that live in streams have biotic and abiotic factors that affect their carrying capacity. Some of these factors were discussed in the stream hydrology section. The important factors include:

3.1.1 Trophic State

Technically*, trophic* state refers to the relative amount of biomass (attached plants, algae, insects, fish, dead/decaying plants and animals) in the water course. In practice, the trophic state is based on the level of plant productivity (or, more specifically, algae productivity) in the water. It is directly related to nutrient levels. The nutrients (ammonia, nitrate, phosphate, etc.) can be either natural or human inputs. There are various approaches to measuring trophic state, including: measuring chlorophyll concentrations, measuring nutrient levels, measuring water clarity, qualitative observation, and measuring oxygen concentrations. The are several trophic states, but we will consider only three: *oligotrophic, mesotrophic* and *eutrophic*. It is important to remember that any given stream is not necessarily one or the other. There is a progression from one state to the other, and a stream can be at any point in the progression.

Oligotrophic streams have low nutrient levels, low algae content and few attached plants. Usually the water is clear and oxygen rich. The stream bed is primarily mineral.

Conversely, eutrophic streams have high nutrient levels and considerable algae and plant content. The water is colored and turbid from algae. There is considerable organic sediment from dead organisms is various states of decay on the bottom. The organic material exerts an oxygen demand on the system. Oxygen is further depleted at night when the plant matter is respiring. Occasionally, still waters (ponds and poorly flushed estuaries) will become *hypereutrophic.* A hypereutrophic water course has extreme over-productivity and is characterized by a dramatic algal bloom, very colored/turbid water, and foul odors. Occasionally, the term eutrophic is used to describe the hypereutrophic state to laypersons.

A mesotrophic stream has a trophic state between oligotrophic and eutrophic.

A stream with a sterile stone bottom and distilled water flowing in it will not support life. Nutrients, algae, and decaying organic debris are necessary at some level for aquatic communities. But as streams become increasingly eutrophic, the oxygen content of the water can fall below acceptable levels for many valued species in our streams. Also, colored, turbid water absorbs sunlight more efficiently than clear water, and our riverine communities are intolerant of the resulting warmer temperatures. Nutrient inputs from agriculture, domestic waste, fish processing, landfill leachate, etc. will accelerate eutrophication.

3.1.2 Substrate

The bottom of the stream is called the *substrate*. There are several types of substrates, and many can occur along different sections of the stream (*reaches*). They include: bedrock, boulder (>600 mm), stone (250 to 600 mm), cobble (75 to 250 mm), gravel (2 to 75 mm), sand (0.05 to 2 mm), silt (0.002 to 0.05 mm), and organic sediment. The types and distribution of substrates are critical habitat parameters for aquatic animals. Of particular importance, sand and silt substrates are not suitable for aquatic insects and the types of fish inhabiting our streams. Appropriate substrate for trout is gravel with some organic/woody debris present.[7,11,13,39,54]

Sedimentation is the most serious limiting factor for trout and other aquatic populations in PEI streams.[80] In the news we hear the reports of pesticide-related fish kills and nutrient-related anoxic events, but sedimentation is the predominant stream problem in PEI. Sediment enters the stream channel when running water carries it from the landscape. The primary sources of this eroded soil on PEI are potato fields, runoff from clay roads, and construction/development operations. Some of this sediment arrives in the big rainstorms of the summer when the fields are full; however, when snow melts from bare soil on fields in the spring, enormous quantities of topsoil erode to the streams.

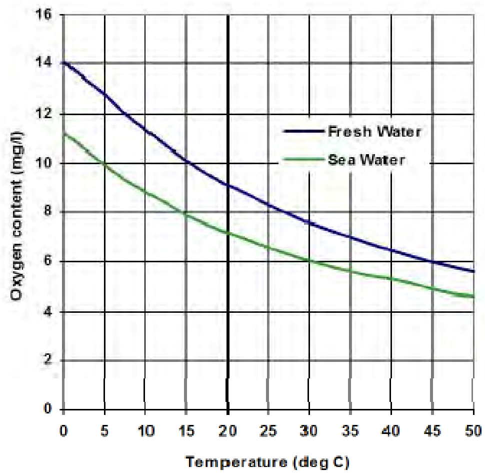
There are other consequences to this erosion. Our fields lose topsoil faster than it regenerates. This is not a sustainable practice, and tomorrow's farmers will inherit our mistake. It also impacts aquaculture. Frequent, catastrophic erosion is not a natural phenomenon here in PEI. When a stream runs brown from erosion from a land activity, something is wrong.

3.1.3 Temperature

Because the source of our streams is 60 to 70% groundwater, the temperature of the water is moderated. The groundwater's temperature is fairly constant at about 8˚C. The water in the streams remains a few degrees above freezing (below the ice) in the winter and (ideally) below 20˚C in the summer. The wildlife communities that inhabit our streams have evolved in this environment and are not tolerant of temperatures outside of these ranges. Impoundments (beaver or manmade) and degraded canopy cover cause warming of the water. Trout do best when the temperature is between 13˚C and 18˚C. Their metabolism changes at around 20˚C. They become stressed at 23˚C. They die at around 25˚C.[53 (5/19)]

3.1.4 Dissolved Oxygen

Oxygen in the air dissolves in water to a limited degree that is temperature-dependent. The following chart shows the maximum amount of oxygen that can dissolve in water at any given temperature.



For example, at 20˚C the dissolved oxygen content can be no higher than about 9 mg/l. This does not mean that at 20˚C it will be that high. It could be lower. In fact, because there are various processes occurring in the stream that use oxygen, often it is lower (particularly in mesotrophic to eutrophic streams). When the water is entrained with air, say in a riffle, the oxygen level increases.

The level of dissolved oxygen that trout require depends on their metabolic rate, which is determined by a variety of factors like age, activity/water-velocity, and temperature. When temperatures rise, the animal's oxygen requirements increase; but, as the chart shows, the dissolved oxygen decreases. Results in the literature are not well-documented, but optimum levels appear to be above 7 mg/l at temperatures below 15°C and above 9 mg/l at temperatures above 15° C.[11]

3.1.5 Other Water Quality Factors

Suspended sediment from erosion not only degrades the stream substrate as it settles, it is acutely harmful to fish while it is in the water column. High suspended solids, even in short-term events, abrade and clog gills, resulting in suffocation. Fish feeding and access (migration) are also affected by chronic turbidity.[13]

Eroding sediment also carries phosphates and other contaminants into the stream. Phosphates are a plant nutrient and they are often the limiting factor for aquatic plant/algae growth. The conventional wisdom is that phosphates – because they bind more effectively with the soil – are less of a problem than other nutrients. Although this is true, the phosphates are released when the soil gets in the water.

There are events where other chemicals (e.g., pesticides) enter the stream. Fish kills are often the result. Recently, mercury contamination in fish in O'Keefe's Lake has reached the news. There is a constant mercury input to streams from the atmosphere. O'Keefe's lake is landlocked (it has no surface inlet or outlet), and mercury accumulates in landlocked systems. It stands to reason that mercury and other accumulating contaminants like PCBs may also build to some degree in the wetlands that are common in our area.

3.1.6 Stream Flow and Velocity

The quantity of water that is flowing in the stream is called *stream flow*. Again, because our streams are primarily fed by groundwater, stream flow is reasonably consistent. Even in dry periods there is adequate flow to support the riverine communities. High-capacity agricultural wells and other high-volume groundwater withdrawals can cause inadequate flows. In fact, any activity that lowers the groundwater table, such as wetland draining, will impact both streams and private wells.

The amount of water that passes through any given cross-section of the stream bed in one second is the *flow rate* of the stream at that point. The velocity of the water is dependent on the flow rate and the cross-sectional area of the stream at any given spot. For a given flow rate in a reach of a stream, if the channel is deep and wide the water will move more slowly than it would in a section where the channel is shallow and narrow. Within any cross-section of the stream the water velocity will vary considerably, depending on the geometry of the channel, the meander of the stream, and the topology of the bed.

Adult trout inhabit the slower moving water in pools. Young trout also require slower moving water, but avoid larger fish by staying near the bank, often in partially submerged grass. To get good growth of grasses, alders can be cut back at limited stretches along the bank. Springs are very important spawning areas for trout. It is important when doing stream enhancement work to limit flow velocity in sections where springs join the channel.[53]

Salmon inhabit faster moving water in riffles. They have a biological adaptation that allows them to stay in the riffle without exhaustive swimming by anchoring to the substrate with their pectoral fins. The disturbed water of the riffles provides cover.[53]

3.1.7 In-stream Cover

Various riverine animals need structural elements in the watercourse for cover. Examples of in-stream structures include woody debris (e.g., logs and branches), undercut banks, rocks, etc. Large, woody debris is a very important component of trout habitat. *Cleaning out* a stream is an impulse to resist. Because our fish are migratory and because their predators are opportunistic, it is preferable that there be cover in each stream reach.

3.1.8 Canopy

Vegetation at the bank in the riparian zone provides cover, temperature control, and food for aquatic animals. Predatory birds (e.g., double-crested cormorants) spot trout in pools from the air. Overhanging vegetation provides shade for temperature control and habitat for terrestrial insects that fall into the water and feed the fish.

3.1.9 Access

Many of our fish are migratory. They must be able to access a sufficient area of the stream to live and spawn. Many obstructions can block fish passage, including beaver dams, hanging culverts, and manmade dams. Large salmon and trout are able to jump obstructions to a certain degree, but dams frequently require enhancement structures to enable passage. Smaller trout, gaspereau, and smelt are substantially limited by obstructions.[53]

3.1.10 Predation/Harvesting

When a species' predators remove individuals faster than they reproduce, the population declines. Here in PEI, fish are the target of over-predation. Often exacerbated by degraded habitat suitability, this predation can exhaust populations. Anglers prefer larger fish, but a trout produces about 1600 eggs per pound of fish, so the larger fish are proportionately more important for population support. Also, the larger fish are the fittest, most viable individuals and preferentially culling them leads to a survival-impeded population[53, (5/20)]. For these reasons there are creel limit and size limit regulations.

Trout also have natural predators, primarily birds and mink on PEI (and perhaps seals for sea run brook trout). The double-crested cormorant has a particularly bad reputation with anglers. Provincial wildlife biologists have acknowledged the problem, and permits have been granted for controlling their numbers. The practice is controversial.[6]

When a river's trout (or salmon) are severely depleted, many areas often introduce hatchery fish to restore populations. (In PEI this is more often done after fish kills.) Using hatchery fish to restore depleted populations degrades genetic variability in the species. The practice is also expensive and may soon be discontinued in PEI. Some regions (rare in PEI) restock fish annually for anglers to re-deplete each season, forming a *put and take fishery.* A put and take fishery is not a viable natural ecosystem.

Some endangered or heavily angled rivers have modified creel limits. Although this makes some anglers angry, it may be the only way to save a native trout population in a stressed stream.

3.1.11 Depth Profile

As we saw in the hydrology section, a stream has a varying depth profile. It takes the form of alternating pools and riffles. Aquatic species preferentially utilize these features, often changing their locations at their different life stages. To be effective habitat, a stream must present the entire range of depth profiles required by the species throughout its lifecycle. Trout do best in streams with a 1:1 pool-riffle ratio.[53]

3.2 Fish Populations

Frequently, the focus of stream ecology is on the populations of fish. There are comparatively few species of fish occurring in freshwater streams on PEI. Primarily they are *anadromous* fish: migratory fish that live part of their live in salt water and spawn in fresh water. These fish include brook trout, salmon, gaspereau, smelt and white perch. Brook trout need not migrate to salt water and are called *facultative* anadromous species. Sometimes brook trout become landlocked by stream barriers. Locally, landlocked trout occurring in murky water are called *mud trout*. There are also *catadromous* fish that migrate to salt water to spawn. PEI's catadromous fish is the eel. There are a few streams with striped bass. Rainbow trout were introduced in the early 1900s and can still be found in some rivers. There are also some accidental introductions, like bullhead catfish and arctic char. Some brown trout have been reported and they are believed to have migrated from Nova Scotia (where they were introduced).[53,54] We will focus on brook trout here, but some other fish will be discussed as well.

3.2.1 Brook Trout

Also known as speckled trout, brook trout often migrate to sea; when they do, they are called sea trout or sea-run brook trout. When they migrate to sea they undergo a physiological change. Their markings become lighter and their flesh turns pink. Some refer to this change as *cleaning out*. Scientists are uncertain of the factors influencing migration to sea, but they may include genetics, population size, and habitat limitations.

Brook trout lay their eggs in the fall (late September to December in PEI) in gravel or gravel/organic litter. The eggs are laid in one to two foot diameter, saucer-shaped structures called *redds*. Often the fish pick spots where groundwater is upwelling into the stream. The eggs incubate in the gravel during the winter and hatch in about 530 degree-days after they are laid, typically in late February or March.[53 (5/19)] Shortly after they emerge from the gravel, the *fry* swim to the surface to fill their air bladders. The fry prefer quiet, shallow edges of the stream. When the fry mature to 2 to 5 inches in length they are called fingerlings. Fingerlings utilize the flats at the exits of pools and the quieter sections of riffles. As the juveniles mature, they move between pools and riffles but prefer the slower water and deeper cover of pools. Usually, they become sexually mature adults in two years. They have a maximum life expectancy of eight years. Because spawning, incubation, hatching, and early life stages generally occur between late September and early April, it is necessary to stay out of the stream during this time.

Brook trout eat primarily insects, insect larvae, fish eggs, and other fish (including smaller trout). They also eat worms, mollusks (snails), and crustaceans such as water fleas. Larger animals will eat mice and frogs.

Most of the brook trout's critical habitat was discussed above. Their optimal pH range is 6.5 to 8; Island streams have ideal alkalinity and dissolved mineral levels for them.[7,11,53,54]

3.2.2 Rainbow Smelt

Rainbow smelt are not uncommon in our area. They enter the estuaries in late fall and winter. In spring they migrate upstream (often in very small streams) and spawn. Each female lays thousands of eggs that adhere to rocks and gravel. They quickly hatch and flush back to brackish water. The eggs provide a substantial food source for trout at a time when insect activity is low. Smelt migration/spawning is easily blocked by obstructions that present only minor blockages for trout.[53,54]

3.2.3 Gaspereau

Gaspereau is a name for two fish: alewives and blue-backed herring. They have similar spawning behavior. At around three years of age they migrate a considerable distance from the head of tide (I have seen them more than one kilometer inland). The females sometimes lay more than 100,000 eggs each. The alewives spawn in May to June, and the blue-back herring in June to July. The eggs hatch quickly and the fry return to the estuary, where they grow to about 2 inches by August.[53,54] I have seen gaspereau in streams near Lot 11.

3.2.4 American Eels

American eels spawn in the Sargasso Sea (vicinity of Bermuda). The larvae drift with the Gulf Stream and arrive at estuaries and streams in North America in about one year as juveniles. *Until very recently, scientists considered the American eel to be a freshwater eel. The latest information shows that some American eels swim up freshwater streams to mature, others remain and mature in both estuarine and marine waters, and still others move between habitats (US F&W)*. They are active at night and often hide in mud, sand, and gravel in the daytime. They eat fish, dead fish and carrion, insects, and other invertebrates. They are very long lived (perhaps more than 20 years). They are important elements in the food chain and have economic value.[8, 9, US Fish & Wildlife website]

3.2.5 Atlantic Salmon

The current estimate for rivers that have Atlantic salmon activity in PEI is about 22. There could be some in our area.[18]

From late spring to fall, salmon return from the sea to spawn. They spawn in late October to November, in a gravel/cobble substrate in areas where there is good stream flow (often in the tail end of a pool). The redd is typically about one square meter in size and is often elongated. Unlike Pacific salmon, Atlantic salmon live after spawning and they typically remain in the river until spring. The eggs hatch in spring (in April commonly) and the alevin remain in the gravel for two to five weeks. In late May to early June, the alevin emerge as fry. The alevin stage extends further into the spring than it does for trout, and in-stream activities should be postponed longer in salmon streams. By fall the fry develop dark bars and are called parr. They stay in the stream for two to three years, preferring the riffle environment. Then they undergo physiological changes and migrate to sea as *smolts*. This migration typically occurs in May during high water periods. When they return the following year they are called *grilse*. Later they develop to a stage where they remain at sea for longer than one year and are called *multi-sea-winter adults*.[53,54]

V. Wetlands and Tidal Estuaries

1. The Value of Wetlands

Although sometimes viewed as wastelands, wetlands are probably the most important feature of our watershed area. In some mainland systems, the uppermost aquifer is massive and seasonal variations in groundwater levels are fairly stable. Also, sometimes these wetlands are isolated from surrounding groundwater resources by an impermeable layer. In our narrow, lowland, island setting, wetlands store substantial quantities of water and act to stabilize groundwater elevations. Our permeable geology enables these wetlands to steadily contribute to the groundwater. Stable groundwater elevations **result in a stable water supply for drinking water, irrigation needs, and stream flow**.[77]

Wetlands are valuable in several other critical ways:

- "Wetlands are among the most productive ecosystems in the world, comparable to rain forests and coral reefs. An immense variety of species of microbes, plants, insects, amphibians, reptiles, birds, fish, and mammals can be part of a wetland ecosystem." [78]
- They provide nurseries for commercially important fish and/or their food sources.[78]
- They provide critical habitat for various life stages of fish/shellfish.[78]
- They act as water purification systems by treating potentially harmful products in runoff from terrestrial sources by removing bacteria, assimilating nutrients (nitrates, phosphates, ammonia), and accumulating and retaining suspended sediments (silt).[77]
- They contribute to the global recycling of carbon, nitrogen and sulfur through anaerobic reduction, which occurs in the wetland bottoms.[77]
- They accumulate organic matter and contribute to carbon sequestration, thus acting as "carbon sinks" that aid in reducing the "greenhouse effect."[77]
- They stabilize shorelines of rivers and coast.[77]
- They provide areas for recreation (hunting, trapping, etc.)[77]
- They provide erosion attenuation.[20]
- They have aesthetic and cultural value.[20]

2. The Wetland Environment

The definition of *wetland* uses the concept of *hydric* soils. The full meaning of the term *hydric soils* and the methods used to identify these soils is beyond the scope of this report. Briefly, when the soil is saturated with water for a while, aerobic bacteria deplete the available oxygen and anaerobic processes predominate. The biological and geochemical processes that result create a specialized soil environment.[4]

"A wetland is defined as land that has the water table at, near, or above the land's surface or which is saturated for a long enough period to promote certain characteristic natural processes. These processes are identified by the presence of *hydric soils* and the vegetation that grows in them (*hydrophytic* vegetation), and the various kinds of biological activity that are adapted to the wet environment."[76] Some of the vegetation (aquatic and semi-aquatic plants) will only grow in wetlands. Certain upland species (alders) can adapt to the wetland environment.

The Canadian Wetland Classification System recognizes five wetland classes: bog, fen, swamp, marsh and shallow open water.[20] The buffer zone regulations expand and qualify the definitions provided by the Canadian Wetland Classification System, and add two more classes: seasonally flooded flats and meadows.

2.1 Bogs and Fens

Bogs are peat-covered wetlands in which the vegetation shows the effects of a high water table and a general lack of nutrients. They exhibit cushion-forming sphagnum mosses and heath shrub vegetation, both with and without trees.[20] Two of the Island's largest bogs at Black Banks and East Bideford are being mined commercially for peat moss.[77]

Fens are similar to bogs but have higher mineral and nutrient levels and are less acidic.

The buffer zone regulations define *bog* as a wetland covered by *sphagnum* mosses, with peat underneath.[1] These regulations do not explicitly define fen, but the generalized definition provided for *bogs* captures the fens category.

2.2 Marsh and Meadows

Marshes are wetlands that are periodically or permanently inundated by standing or slowly moving water and hence are rich in nutrients. Marshes are mainly wet, mineral soil areas. Water remains within the rooting zone of the plants for most of the growing season. Marshes are characterized by an emergent vegetation of reeds, rushes, cattails, ferns, and sedges.[20]

Tidal marshes are normally categorized into two distinct zones, the lower or inter-tidal marsh and the upper or high marsh. Tidal marshes serve many important functions. They buffer stormy seas, slow shoreline erosion, and are able to absorb excess nutrients before they reach the oceans and estuaries. This ability to absorb nutrients can be an important factor in attenuating estuarine eutrophication. Tidal marshes also provide vital food and habitat for shellfish, crabs, and juvenile fish, as well as offering shelter and nesting sites for many species of marine and semi-marine animals.

The buffer zone regulations list four classes of marshes: brackish marshes, salt marshes, shallow marshes, and deep marshes.

The buffer zone regulations further define *meadow* as a wetland that has fluctuating water tables, lacks trees, and is covered in water-tolerant *Graminoid (*grass like*)* vegetation.[1]

2.3 Swamps

Swamps are wetlands where standing or gently moving water occurs seasonally or persists for long periods, leaving the subsurface continuously waterlogged. The water table may seasonally drop below the rooting zone of vegetation, creating aerated conditions at the surface. Swamps are nutrient-rich, productive sites. Vegetation may consist of dense coniferous or deciduous forest or shrub thickets.[20]

The buffer zone regulations define two types of swamp:

- Shrub swamp: A wetland containing nutrient-rich, highly decomposed woody plant and organic material that has as its dominant cover shrubs and herbaceous vegetation, including but not limited to alders.[1]
- Wooded swamp: A wetland dominated by water-tolerant trees or shrubs growing in a muck soil and covered by a moss layer at least 30 centimeters thick.[1]

2.4 Open Water

This class of wetland is self-explanatory. In our area it frequently takes the form of shallow ponds upstream from beaver dams and impoundments associated with lowland marsh/swamp.

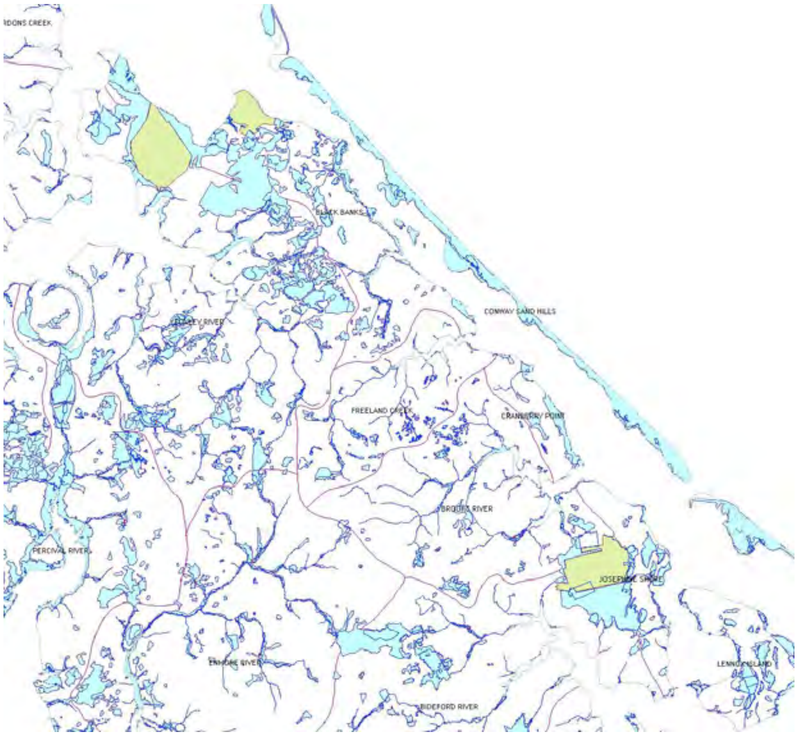
The buffer zone regulations refer to this class of wetlands simply as *open water*. The regulations also define *watercourse*: an area which has a sediment bed and may or may not contain water, and without limiting the generality of the foregoing, includes the full length and width of the sediment bed, bank and shore of any stream, spring, creek, brook, river, lake, pond, bay, estuary or coastal body, any water therein, and any part thereof, up to and including the watercourse boundary.[1]

2.5 Seasonally Flooded Flats

The buffer zone regulations include the additional wetland category of seasonally flooded flats: a wetland formed by rivers overflowing their banks to a depth of at least 12 inches annually during spring, winter and late fall.[1]

2.6 Lot 11 and Area Wetlands

The following map shows the PEI Wetlands map layer in pale blue. Three large peat harvesting areas are shown in green. Note that the sand hills are classified as wetlands in the map layer. There is an official database of Island wetlands, entitled *Prince Edward Island Wetland Inventory,* which is maintained by the Department of Environment, Energy, and Forestry. As can be seen on the map, our area has wetland resources, but they are not unlimited.



A fair amount of the land associated with these wetlands is marginal (presumably this is why we still have them). Because these wetlands are the underpinning of our stable water supply and because of other previously mentioned wetland values, short-term gains from developing these lands are substantially offset by the potential losses. However, when beavers create local problems for existing land uses, those problems should be corrected.

3. Estuaries

An estuary is a partially enclosed body of water along the coast where fresh water from rivers and streams meets and mixes with salt water from the ocean. Estuaries and the lands surrounding them are places of transition from land to sea, and although influenced by the tides, they are protected from the full force of ocean waves, winds, and storms by such landforms as barrier islands or peninsulas.[79]

Like wetlands, estuarine environments are among the most productive on earth. The tidal, sheltered waters of estuaries also support unique communities of plants and animals, specially adapted for life at the margin of the sea. Many different habitat types are found in and around estuaries. The productivity and variety of estuarine habitats foster an abundance and diversity of wildlife. Shore/sea birds, fish, crabs and lobsters, marine mammals and shellfish are just some of the animals that make their homes in and around estuaries.[79]

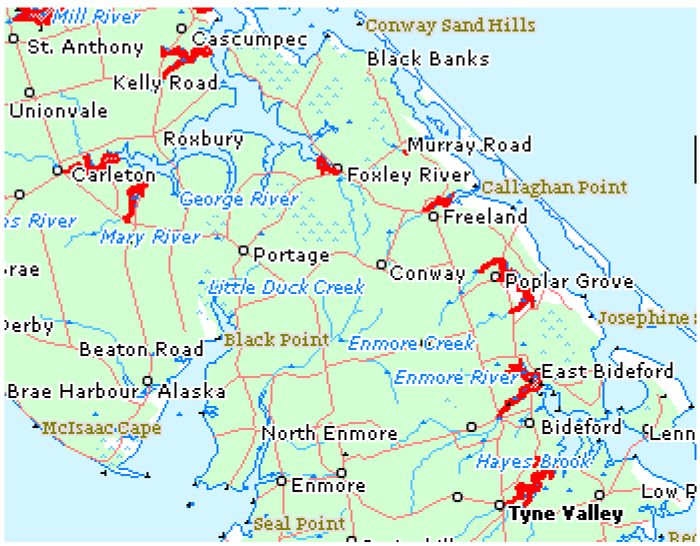
Estuaries are of substantial economic importance in PEI. The aquaculture sector is centered on them. They are a big part of the attraction for the tourism industry. Many fish of commercial value rely on the estuaries as nursery habitat. Many others rely on estuary-dependent species for food.[43,53]

Estuaries are a source of recreation, education, and aesthetic value. Boating, fishing, swimming, and bird-watching are just a few of the many activities people enjoy in estuaries. They also have cultural and social value.

Fresh water enters the estuary and mixes with salt water. The estuary discharges to a greater saltwater body such as a bay or the ocean. The rate at which the water in the estuary is discharged from the estuary is called the flushing rate. This rate is dependent on a variety of factors, including tidal variations, currents, and the complexity of the discharge route. Relative flushing rates for our Gulf-side estuaries are lower than on other parts of the Island.[53] Because the changeover is reduced, nutrient/contaminant build-up is a problem. Fortunately for us, the estuaries in our immediate area have lower nutrient inputs. Also, adjacent wetlands act as nutrient sinks. Still, we have considerable algal blooms and sea lettuce clogging our estuaries. Neighboring estuaries within the greater Cascumpec system have had anoxic events (Mill River).

Sediment loading is a potential hazard for estuaries. Agriculture, forestry, development, road/construction-related erosion events, and dam failures can cause catastrophic sediment inputs. The shellfishing sector is rightfully wary of these hazards.

Another estuarine water quality parameter of specific interest to shellfishers is bacterial contamination. The following map from the DFO website shows shellfish closures in our area in red. They usually occur in the uppermost reaches of estuaries and predominate in populated areas. There are several possible input vectors for shellfish bacterial contamination, including domestic waste releases, animal waste–related releases, fish processing waste piles, landfill leachate, and releases related to septic system maintenance wastes.



DFO November 2009

[http://www.glf.dfo-mpo.gc.ca/shellfish-coquillages/map-carte.asp?Language=en]

Our estuaries are complex systems that have profound importance. Although watershed group activities do ultimately improve estuarine health, many aspects of their direct assessment, protection, and enhancement are beyond the resources of most groups. However, watershed groups can raise public awareness of issues and solutions for estuarine health, since public information and public awareness are key. When a landowner understands how his activities can harm an estuary and endanger another person's livelihood, conscience and responsibility are better able to guide his actions.

Shellfish are an indicator of estuarine health, and there are some government and private shellfish monitoring efforts. The PEI Shellfish Association has initiatives related to production-focused evaluation and enhancement. There are federal and academic assessment/research projects related to estuarine health. The DFO's Community Aquatic Monitoring Program (CAMP) is collecting baseline data (aquatic animal population surveys, aquatic plant characterization, and water quality measurements).

They partner with watershed groups. The nearest locations of CAMP projects are the Mill River and Malpeque Bay. Bringing this program to our area may be possible but would probably require a combined lobbying effort of multiple groups, including trade associations and our watershed group.

VI. Preventive Measures and Corrective Actions

The primary problems with watershed resources on Prince Edward Island are related to water quality and riparian/riverine habitat. Primary sources of those problems are agricultural losses of topsoil and applied chemical enhancements, highway construction, unpaved road runoff, large-scale forest clearing, and wetland exploitation. Various other land uses have consequences in some areas, including: recreational facilities (e.g., golf courses), food processing operations, and waste management activities.

At one time, the primary activity of many watershed management groups was to address the problems of streams affected by those problems with in-stream enhancement activities. This is still an important component of watershed management, but the role of watershed management groups has widened to better address causative factors. **It is more cost-effective, efficient, and beneficial to proactively modify a problem's source point than to reactively correct the problem as it re-occurs.** Watershed groups increasingly target land use practices and landowner awareness. Community-based planning and public information are key strategies in proactive watershed management. Because they are a primary source of watershed group funding, the PEI Department of Environment, Energy, and Forestry has been the primary driving force for the evolution of this expanded role of watershed managers. Their publication, *A Guide to Watershed Planning on Prince Edward Island*, explicitly details the benefits of a proactive approach on a watershed basis over a reactive approach on a stream basis. They have unambiguously stated that community-based watershed planning is a prerequisite for their support.

1. Community Planning and Public Awareness

In the absence of formal community planning and the sense of ownership it creates, watershed managers are doomed to a reactive, losing battle with recurring land-use problems. The planning process requires more than casual lip service. It should not be a secondary activity that we tinker with in winter months.

A formal planning process involves members of various interest groups (stakeholders) within the watershed management jurisdiction. These representatives seek to understand one another's priorities as well as to understand the specific, local issues associated with servicing those priorities. An overall mission, a set of goals, strategies for realizing those goals, and a means of measuring effectiveness of the strategies is developed through ongoing stakeholder consensus.

What does all of this planning have to do with preventive measures and corrective actions?

- Individual involvement has tremendous value in improving success of any human effort. Simply being involved stimulates awareness. Planning raises individual consciousness of watershed health factors by directly engaging the public.
- Planning is an avenue for communication of facts, ideas, values, and interests. Watershed stakeholders are rarely insensitive to the values of their neighbors or wildlife. However, they are sometimes not fully aware of the impacts their land use practices have on the needs of others. With a planning forum, stakeholders come to understand the dynamics of watershed resource sharing. Trout populations are not a priority for everyone, but the

livelihoods and health of other community members are. The watershed planning table is where these interests are explained. Direct exchange, discussion, and specific requests for action are needed.

- Planning is a forum for the resolution of conflicts. Most differences can be resolved through negotiation. Compromises can be discovered that serve both parties' interests effectively, but only if the parties are at the table together.
- Community planning imparts a sense of community ownership of objectives. It's no longer "*the things the watershed people want*," it's "*the things we want*."

2. Community Information

Public information equips the community with the facts they need to make informed land use decisions. In fact, that is the purpose of this document. Other public information such as water quality data, stream assessment reports, relevant publications from government and academic contributors, etc. all have value in promoting an awareness and understanding of our assets, issues, and solution options.

3. Land Use Practices

Planning, public awareness, and public information are of value in identifying, focusing, prioritizing, and directing watershed management activities. Also, they promote the spirit of resource protection. Ideally they result in explicit actions to protect and enhance our watershed. In the end, it is the explicit actions that we seek. We want results, not a pretty plan document. What are some of these actions?

3.1 Agriculture

The primary inputs from agriculture to the drinking water supply are in the form of dissolved nutrients and other agricultural chemicals that trickle into the groundwater through the soil. The primary agricultural impacts on streams are sedimentation, nutrient enrichment, toxic releases, and bacterial contamination. Farmers use a variety of controls to minimize these losses. The best strategy for protecting drinking water quality and for stream enhancement is to keep the soil and chemical inputs *on the field*. This is also the best practice for economical, sustainable farming.

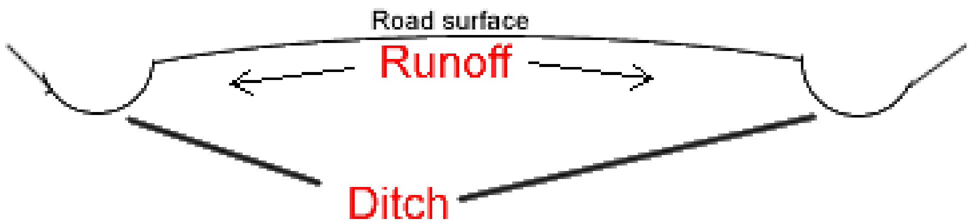
Keeping fertilizer input out of the groundwater can be improved through a strategy called nutrient management, which is a set of practices that seek to have an optimum level of nutrients for the farmer's targeted yield available in the soil uniformly throughout the growing season. In other words, the right amount of the right product in the right place at the right time. Nutrient management also extends to other farm operations like waste storage and handling. The practices are fairly involved and they are farm-specific. They are compiled in a nutrient management plan.[42,52,62,70]

Keeping nutrients out of the stream is partly accomplished though keeping them out of the groundwater. However, streams have a substantial nutrient input from runoff, particularly from potato fields. More importantly, agricultural runoff is a primary source of sediment input for streams. Again, there are management practices that seek to control these inputs from runoff. They are called soil conservation practices, and here on PEI they are of critical importance as they apply to potato production. They include crop rotation, conservation tillage, winter cover/mulch, cross-slope and strip cropping, and erosion control structures like diversion terraces, grass waterways, surface inlets, and buffer strips.[55,57]

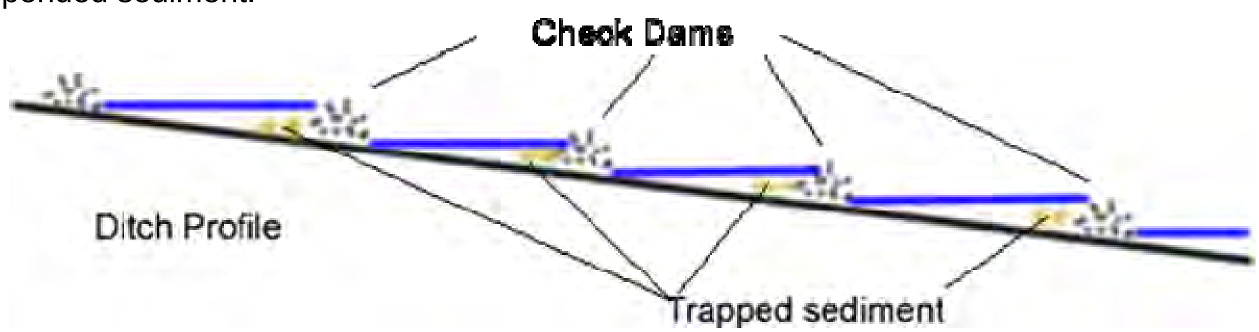
In the Lot 11 and Area community we have farmers with a substantial understanding of the details and implementation strategies for nutrient management and soil conservation. Their knowledge goes well beyond the generalities discussed above. They are a resource for bringing these mutually beneficial practices to others in the community. Beyond recognizing the issues and possible solutions, it is best for watershed managers to let the experts work with the experts.

3.2 Unpaved Roads

Unpaved roads have unanchored soil available for erosion. They are corridors for sediment-laden runoff to streams. It is best to avoid runoff along the path of the road by directing the runoff into the ditch through proper grading of the road.

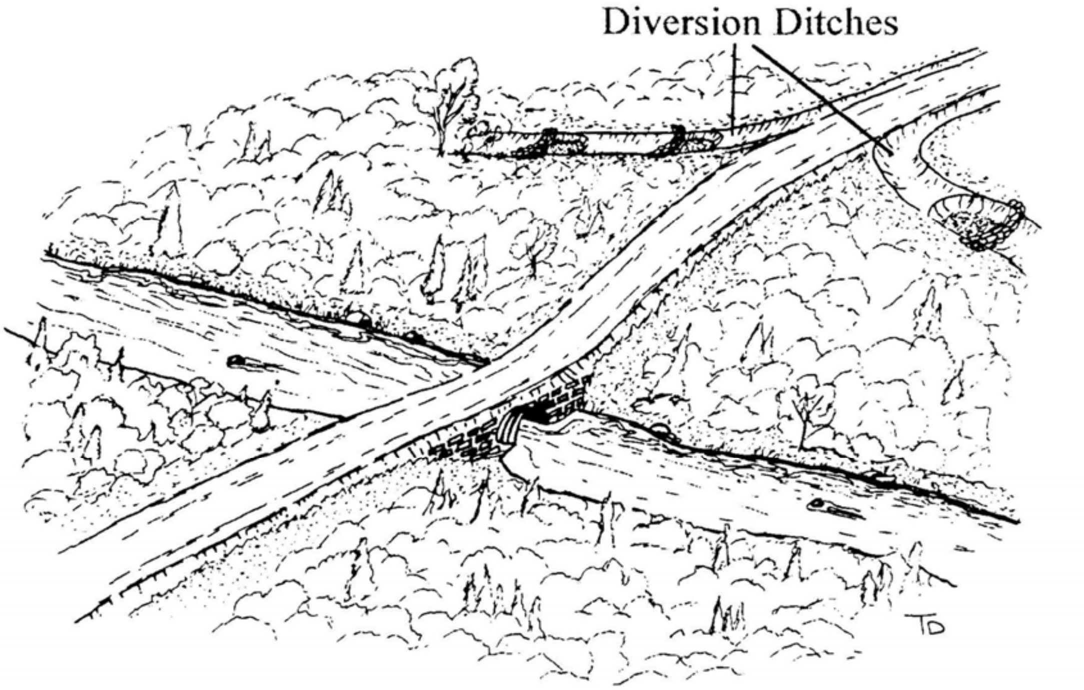


Of course, once the sediment-laden water reaches the ditch it may still travel to a nearby stream. In low gradient areas, vegetation in the ditch is sometimes sufficient. When it isn't, there are control structures for trapping the sediment. One common method is to use check dams and settling basins. They slow the water and allow the sediment to drop out. It is best to space the dams so that the top of each is level with the base of the prior up-gradient dam. The sediment must be periodically removed from the traps. In PEI, stone dams are preferred over straw bales. There are some new, enhanced natural fiber dam materials (PAM) that claim to be effective at clumping suspended sediment.



A pair of check dams

Another approach is to divert the ditch inland from the road, allowing the surroundings to trap the sediment. This method often works when simple check dams fail on steep slopes[54]. There is an example at the Freeland Creek – Route 12 crossing.



Finally, spreading crushed asphalt millings over the road stabilizes the road bed during erosion events. Improving the road in this fashion has an initial expense, but subsequent maintenance is reduced.

3.3 Construction

Excavation for building construction and road work loosens and bares soil. The loose soil erodes and transports to streams. Silt fences are often used to trap sediment from these operations.

A silt fence

When silt fences are installed, they need to be solidly staked frequently along the down gradient side of the fence. Anchor the bottom edge well below the surface. Control structures like sediment collection ponds at construction sites may be needed when silt fences cannot adequately manage the runoff.[53]

Quickly vegetating (e.g., hydroseeding) the exposed soil at construction sites is essential. Jute mesh and other mulch can stabilize the soil while the vegetation grows.[53]

When construction is at a stream crossing, additional controls like floating booms should be used. Sometimes temporarily diverting the stream is the best strategy.[53]

3.4 Forestry Considerations

Tree harvesting exposes soil. The same problems associated with bare soil at construction sites occur at logging sites. The controls that are used for construction sites apply to forest harvesting as well.

Natural forest is a dramatically more productive wildlife habitat than plantation. Large natural forests are not common on PEI. Sometimes these areas are set aside through trusts and other conservancy efforts.[37,38] We have natural forests in our area.

A large clear-cut operation exposes substantially more ground than a highway repair. It eliminates habitat. It has aesthetic impact. Because the succession process is restarted and because of our moist lowland soil, the dreaded alder frequently infests the area. Where forested land has been effective in trapping sediment and nutrients, the clear-cut may be ineffective. Often the land uses that follow clear-cuts are at odds with community values. Managed approaches to harvesting, like patch cutting and strip cutting, are by far preferable to clear-cutting.

Plantation harvesting is part of our economy. It provides employment and revenue. Private woodlot harvesting is provides family income and energy needs. Our forested areas are also of fundamental importance to us. They are a primary factor for a healthy watershed and a clean water supply. Avoiding clear-cut operations wherever possible is a responsible compromise.

3.5 Wetland Protection

Development of wetlands is regulated but not strictly prohibited. Development projects from agriculture to landfills are (perhaps remotely) possible. The Provincial policy is that wetlands should be avoided unless the project is in the greater public interest. Understanding the importance of wetlands to this community is key when interpreting this policy. We have a limited water supply aquifer. The wetlands preserve the quality and quantity of this supply. Wetlands have several other critical values (detailed in Chapter V, Section 1). It is difficult to imagine a greater public interest. Protecting our resources depends upon government understanding of the compelling, region-specific values of our wetlands.

4. Stream Enhancements

4.1 General

Deliberate alterations of streams and riparian zones to address stream problems are called *stream enhancements*. Frequently enhancements are done to correct problems that interfere with fish habitat, but alterations to protect human interests sometimes occur. Beaver management is a prime example. Certain enhancements are designed to mitigate problems created by land uses. It is unwise to conduct these enhancements when land use problems are ongoing. Sometimes, however, it is the only option.

Stream improvement is an engineering process. Enhancement strategies have scientific underpinnings. There are many resources for conducting effective projects.[54,56,58]. Perhaps the best one for work on PEI is: *A Technical Manual for Stream Improvement on Prince Edward Island.*[54]. Its authors have extensive training and experience in stream improvement that is Island-specific. It provides the following project timetable (pp. 59, 60):

Project Timetable

Year 1, June - September Stream Habitat Surveys
Year 1, Fall - Winter Develop Work Plan
Year 2, Spring Prepare to Implement Plan
Year 2, June - September Implementation
Subsequent Monitor, Assess, Maintain

4.2 Surveys

Stream surveys are essential. To dash into installing digger logs and brush mats with the simple objective of *getting things going* is irresponsible and ill-advised. Stream enhancements are performed to correct problems. The problems must be known and understood. When several streams (perhaps some with several problems) are in an area, establishing cost-effective priorities requires surveys at several sites. Stream surveys can vary in complexity and detail. Watershed groups rarely have the resources for in-depth scientific studies. Excessive studying uses resources better spent making improvements. One strategy is to restrict initial surveys to the level of detail needed to understand the overall condition of various reaches of the stream, specifically noting problem areas. More data can always be collected once specific enhancement sites are selected.

One survey approach is to divide the stream into reaches with similar characteristics and record observations for critical parameters. Reach observations should include:

- Channel characteristics
- Depth range
- Flow characteristics (pool-riffle structure)
- Estimated trophic state
- Substrate
- Cover (in-stream, overhang, and canopy)
- Access for fish migration
- Appropriate water temperature when problems are suspected
- Riparian zone characteristics

- Surrounding land uses

Additionally, there are stream-health checklists that have been developed for streams in Atlantic Canada, and one should be completed for each reach. We prefer the checklist provided in *Beneficial Management Practices for the Management of Riparian Zones in Atlantic Canada*. Documentary photographs and GPS readings are very important. Specific opportunities for enhancement work should be noted. A final report for each stream should be prepared.

Landowner permission must be obtained prior to accessing private property.

4.3 Work Plans

After completing surveys for a majority of streams in our management zone, priorities for stream improvement can be evaluated. When a collective decision is reached on which projects to conduct, work plans are prepared for each enhancement project. These plans should address:

- What is to be done
- Why it is needed
- Labor and special skills requirements
- Health and safety considerations
- Project design and logistics (technical input from others)
- Materials requirements
- Timeframes
- Regulatory requirements
- Project budget

Some additional measurements and data may be required. Specific projects may need more detailed field measurements than the overall stream surveys provide. In addition to a detailed work plan, the Department of Environment, Energy and Forestry requires individual beaver management plans for any stream where beaver controls are planned. The plans should include:

- The section of the stream to be designated beaver-free (coordinates)
- Justification (fish passage, temperature control, etc.)
- Location of active and inactive dams
- Procedures for achieving beaver-free zones
- Inspection and maintenance procedures

4.4 Preparing to Implement

Prior to conducting the project, land owner permission is required, not only from the site abutters but also from owners of access routes. Funding must be secured, permits must be filed and approved, and materials and equipment must be obtained. A crew supervisor needs to be informed of work plan specifics. A crew must be hired and work schedules arranged. Finally, work can begin.

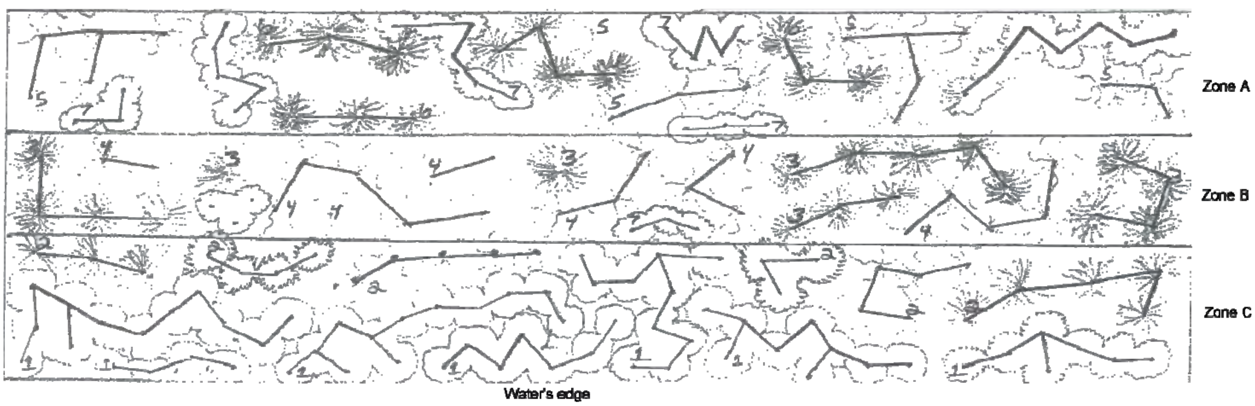
4.5 Common Stream Improvements (permits required)

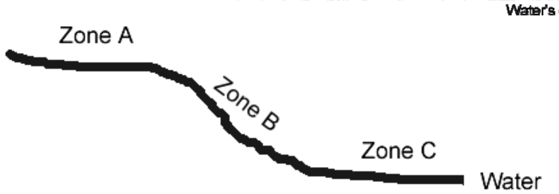
The Lot 11 & Area Watershed management Group gives special thanks to Todd Dupuis of the Atlantic Salmon Federation for his careful review of this sub-section.

4.5.1 Riparian Zone Planting[58]

Improving the riparian zone through planting is a low-impact, high-value enhancement. The overwhelming importance of riparian vegetation is discussed in Chapter IV, Section 2.2.

The trees and shrubs are provided at no charge to watershed groups through the Greening Spaces Program. The staff at the J. Frank Gaudet Nursery are a resource for species selection and planting advice. They have provided us with a detailed chart of recommended trees and shrubs for the riparian zone.





Zone	Key	Plants
C	1	Wild Rose, Spiraea, Red Osier Dogwood, Winterberry, Willow, Chokeberry
C	2	Serviceberry, Elderberry, Cedar, Balsam Fir, Aspen, Red Maple, Elm, Black Ash, Black Spruce, Larch
B	3	Hemlock, White Pine, Balsam Fir, Dogwood, Red Spruce
B	4	Sugar Maple, Yellow Birch, White Birch, Aspen, Elm, Ironwood, Red Oak, Serviceberry
A	5	Serviceberry, Red Maple, Sugar Maple, Ironwood, Red Oak, White Ash, Yellow Birch, White Birch
A	6	Balsam Fir, White Spruce, White Pine
A & B	7	High Bush Cranberry, Wild Rose, Serviceberry, Willow, Spiraea, Bayberry, False Holly, Elderberry, Red Osier Dogwood, Black Cherry

4.5.2 Brushmats[54]

Use

Brushmats capture and retain sediment. They are frequently needed as part of other enhancement projects to trap sediment released by the work. They are also used in streams that have abnormal sediment loadings from nearby land uses. They have been used to narrow and deepen stream sections. They can help to restore bank vegetation. They are most often installed at the point bars at meander bends.

<u>Advantages</u>

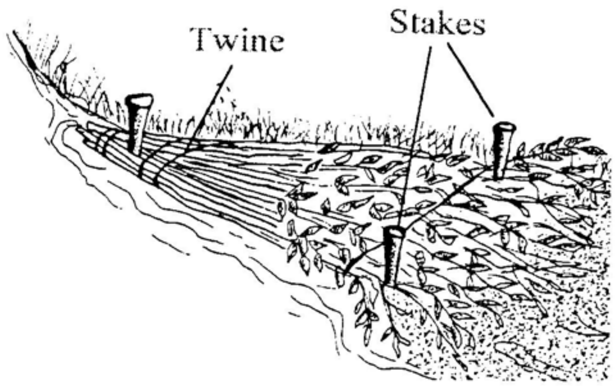
They are natural in appearance. The materials are inexpensive and easy to obtain. They can be quickly installed. They are effective, often in a short time frame.

<u>Problems</u>

If not properly installed the material can break loose and cause blockages downstream. Healthy streams have some sediment loading during high flow events and installing brushmats unnecessarily – or in the wrong places – will cause unnatural sediment accumulation.

<u>General Construction</u>

The brush is typically shrub (alder) branches. The brush is assembled at the location by tying it with bailing twine to firmly anchored stakes. The butts of the branches are faced upstream. The entire mat is stabilized and compacted by networking twine around the branches and stakes.



A brushmat

4.5.3 In-stream Sediment Traps[54]

<u>Use</u>

In-stream sediment traps are used to collect sediment from the water column by slowing the water in an excavated basin. They are also effective for removing sediment as it migrates along the channel bottom (bed load). The accumulated sediment is removed later by excavation. Using sediment traps is a heavy-handed approach to remediating sediment loading from pronounced erosion inputs. This method can also be used to intercept sediment from other upstream enhancement projects in process. For example, it can be used downstream from a beaver dam removal.

<u>Advantages</u>

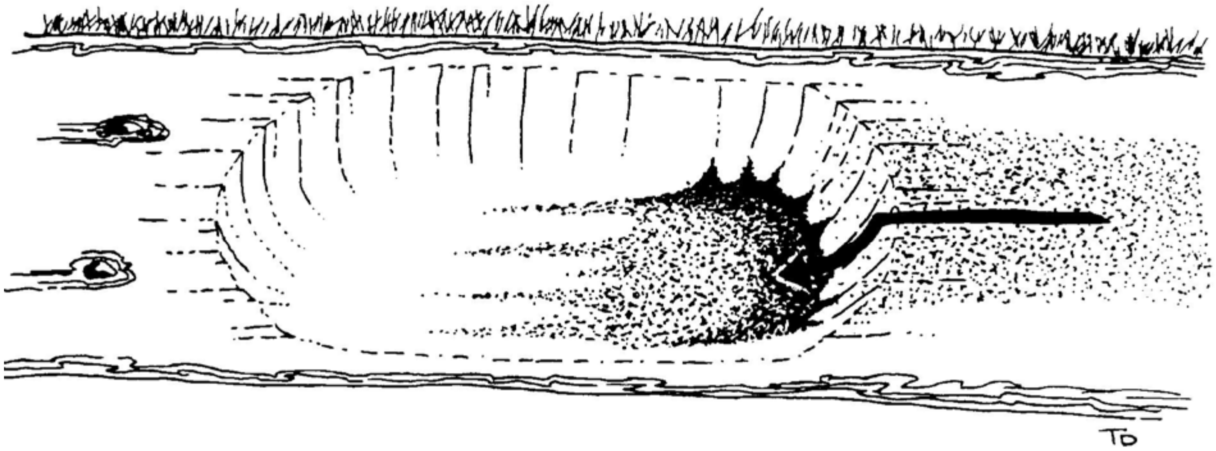
Sediment traps are superior to simple brushmats for large-scale sediment control. They can help create and restore pools.

<u>Problems</u>

This method has a large impact on both the stream and the riparian zone. It requires heavy equipment at the stream bank to dig the trap and empty it. It requires active, ongoing maintenance, and it is relatively expensive.

<u>General Construction</u>

Requires site-specific design and implementation. Work should be scheduled during low flow. During excavation, downstream sediment controls are necessary. Also, straw bales lined with filter fabric are needed on the bank near the point of excavation to filter sediment from water draining back to the stream. The depth of the basin should be about ½ the width of the stream. The excavated soils can be deposited on-site but must be permanently stabilized to prevent erosion.



An in-stream sediment trap

4.5.4 Bypass Sediment Trap[54]

Use

The bypass sediment trap is a variant of the in-stream trap. It is more effective where very heavy sediment loadings occur. It is a candidate for sediment control when large beaver dams are dismantled.

Advantages

It can be designed to trap considerably more sediment than an in-stream trap. The sediment accumulated in the trap can be left in place when the trap has served its purpose and the stream channel is restored.

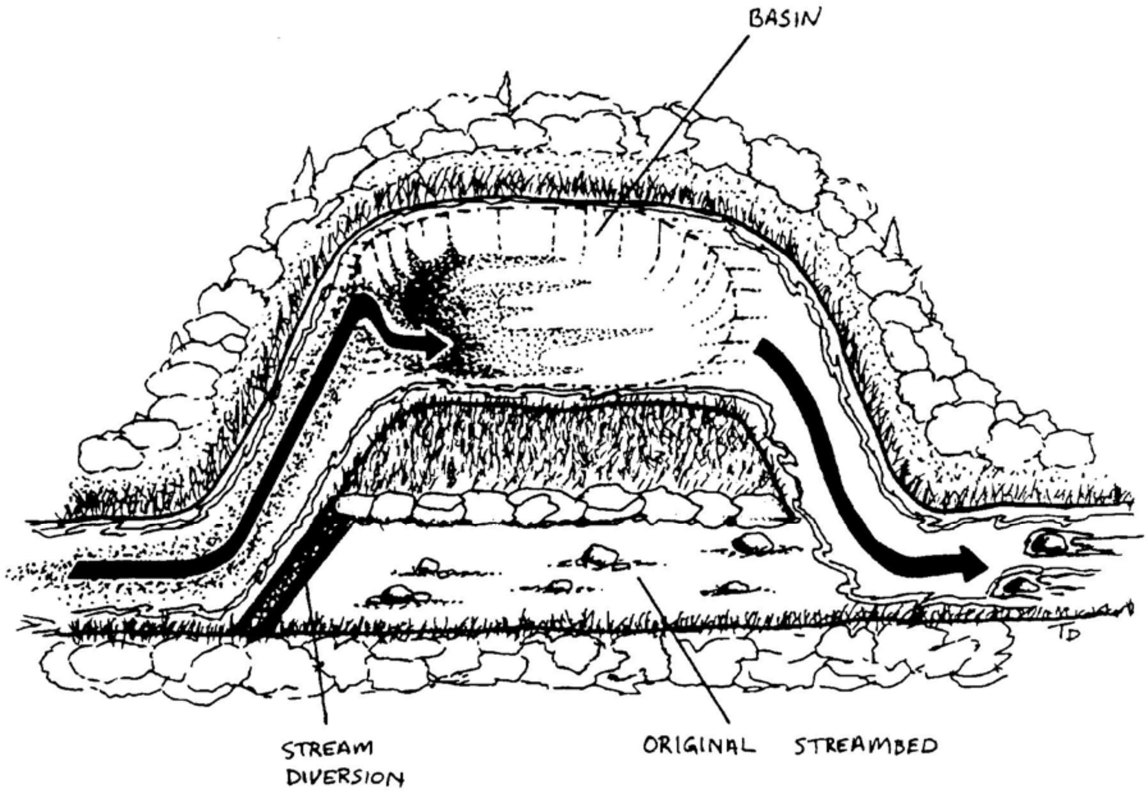
Problems

Same as the in-stream trap.

General Construction

Requires site-specific design and implementation. Work should be scheduled during low flow. During excavation, downstream sediment controls are necessary. Also, straw bales lined with filter fabric are needed on the bank near the point of excavation to filter sediment from water draining back to the stream. The depth of the basin should be about ½ the width of the stream. The excavated soil can be deposited on-site but must be permanently stabilized to prevent erosion.

A pit is excavated at one side of the stream and channels leading to the pit from the stream are excavated. The channels should enter and leave the pit at the same relative point in the meander pattern. That is, if the channel to the pit leaves the stream at a bend, then the returning channel should rejoin the stream at another bend. A diversion barrier is placed to direct the water through the pit. After the pit is filled with sediment, the original stream course can be reestablished. The pit can then be cleaned for re-use or seeded and abandoned.



A Bypass Sediment Trap

4.5.5 Bank Stabilizers[54]

Use

These structures protect banks where erosion is occurring. They can be used on turns where excessive erosion occurs, on steep slopes where gullies lead to the stream, and where unstable banks are falling into the water. They are effective where planting cannot do the job or gain a foothold. There are three types: gabion baskets, logs, and rock.

Gabion Baskets

Advantages

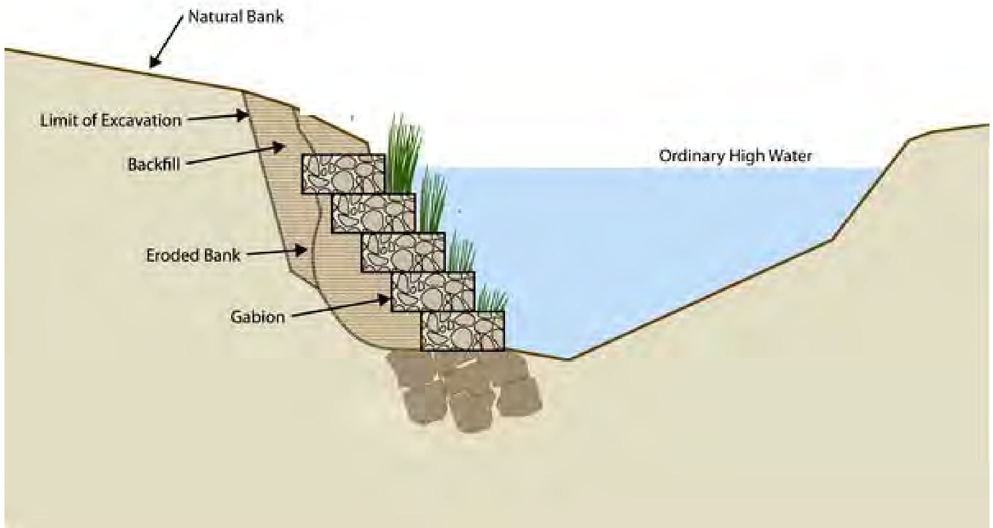
They are relatively permanent and maintenance free. They can be used to terrace the approach to the stream on a steep bank.

Problems

They are unnatural, labor-intensive and expensive.

General Construction

The footing for the structure is leveled and the basket, with the sides assembled, is keyed into the bank. The basket is packed tightly with rock of various sizes then laced closed. Sod can be placed on the structure.



A Gabion Bank

Logs

Advantages

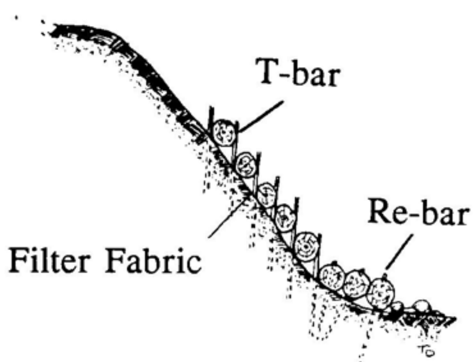
Logs are more natural than gabions and they can provide cover for bank-dwelling animals and fish. The logs can be obtained onsite.

Problems

They are labor-intensive and will eventually rot.

General Construction

The base log is drilled and then spiked into position with rebar. The logs are placed in tiers over filter fabric on the bank. The tiers above are locked in place with rebar retainers and secured with gabion wire.



A Log Bank

Rocks

Advantages

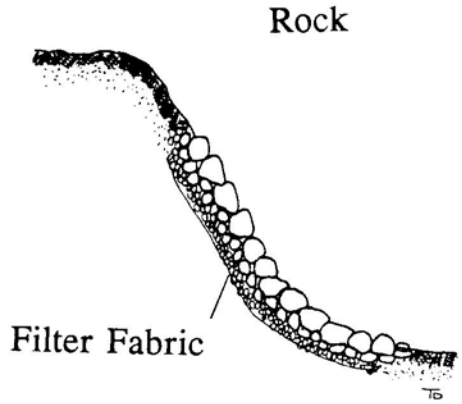
They are more natural than gabions and they can provide cover for bank-dwelling animals and fish. They do not rot.

Problems

They are labor-intensive and expensive.

General Construction

The rocks are placed in multiple layers over filter fabric, starting with gravel, then cobble, then boulders. The completed structure should be 30˚ to 45˚ up the bank.



A Rock Bank

4.5.6 Beaver Dam Removal[54]

Use

To restore fish passage, control water temperature, eliminate land use impacts, and restore canopy. To enforce a beaver-free zone specified in an approved beaver management plan.

Advantages

Restores stream habitat.

Problems

Destroys impoundment habitat. Drains wetlands.

General Implementation

The dam must be inactive. Beavers must be trapped and removed prior to removing the dam. Beaver dams can hold substantial volumes of sediment, and improper design and implementation of site-specific protocols can be disastrous. Downstream brushmats and sometimes sediment traps are required to capture sediment. Carefully breach the dam and slowly draw down the water. Implement restoration in the former impoundment area to re-establish the meander and stabilize the banks. Plant the newly exposed stream banks.

4.5.7 In-stream Cover Placements[54]

Use

To provide cover for fish.

Half Logs

Advantages

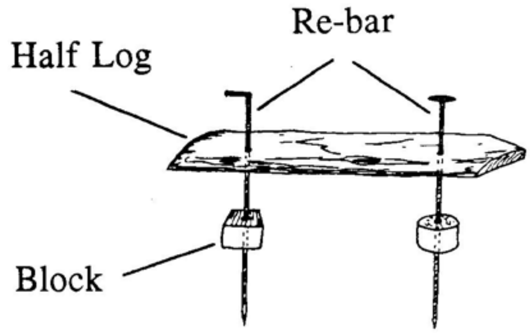
Natural appearance. Simple, inexpensive, low maintenance.

Problems

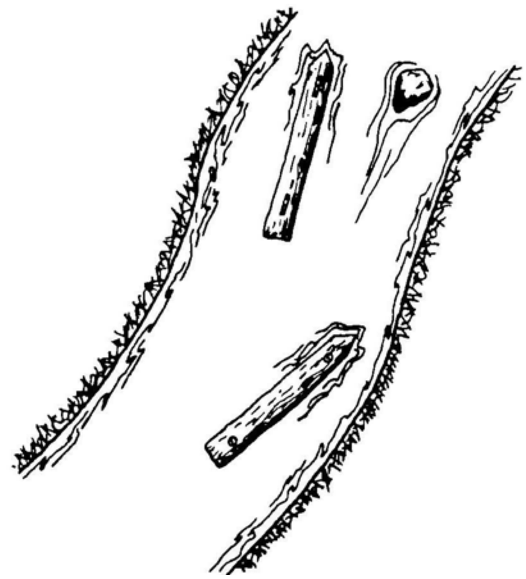
Catch debris. Difficult to install in some substrates.

General Construction

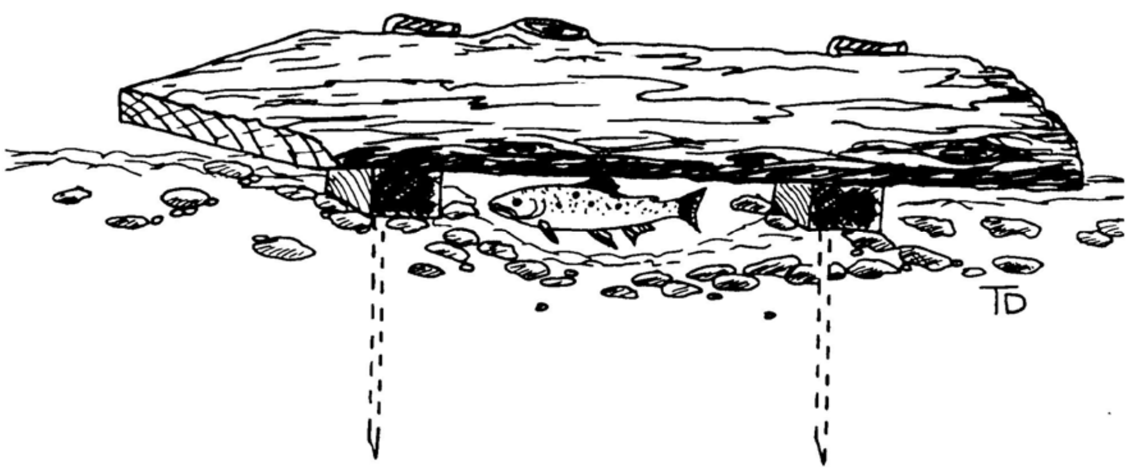
Install near the bank. Locate at the outside edges of turns or below a riffle.



Construction



Placement



A Half-log Cover Structure

Bottom Anchored Whole Logs

Advantages

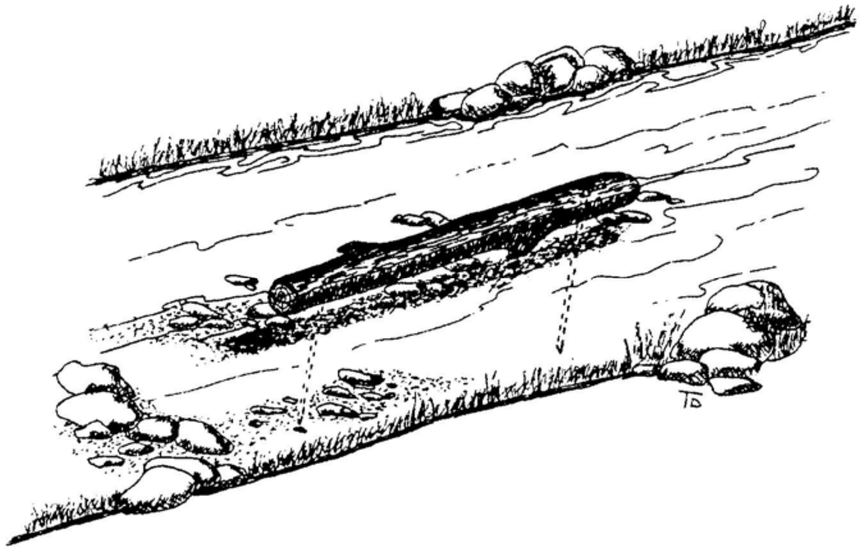
Natural appearance. Simple, inexpensive, low maintenance.

Problems

Catch debris. Difficult to install in some substrates.

General Construction

Locate parallel to the bank. Trim the branches from the log, leaving stubs on the bottom side. Drill pilot holes 25 cm from each end. Secure the log to the bottom with rebar spikes.



A Bottom-anchored Whole Log

Floating Logs

Advantages

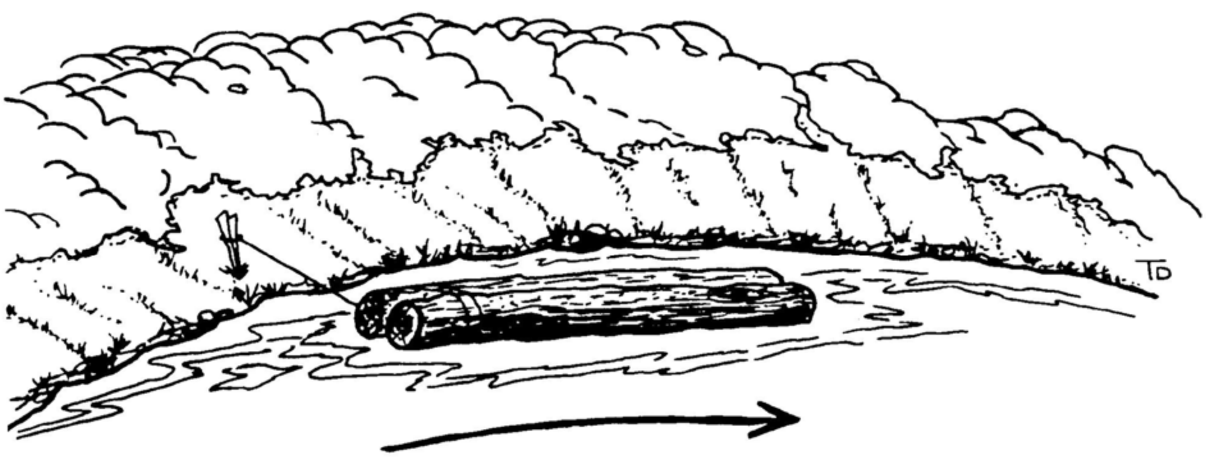
Natural appearance. Simple, inexpensive, low maintenance. Good for short-term applications. Should be considered when cover has been disrupted by other enhancements. Can be installed in water that is too deep for bottom anchored logs.

Problems

Can be displaced by ice or high water. Can snag debris.

General Construction

Locate parallel to the bank. Trim the branches from the logs and attach together with rustproof wire and staples. Position the log on the outside of a meander bend, and tie with wire to a stable structure on the bank.



Floating Log Cover

Boulder Placements

Advantages

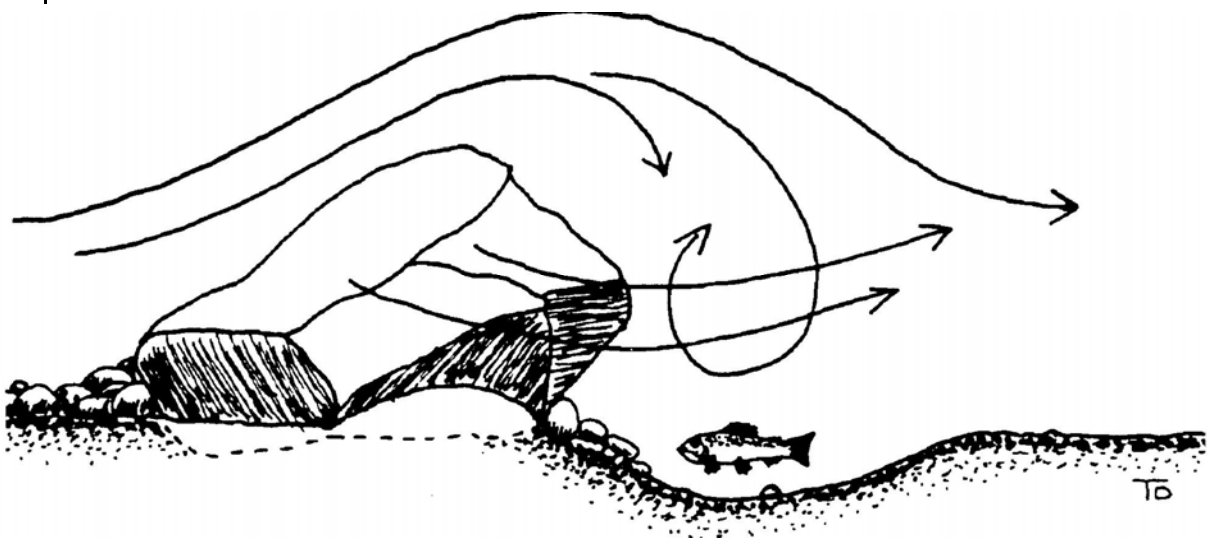
Natural appearance. Inexpensive, low maintenance. Simple when boulders are available at the site.

Problems

Sediment can build around the boulder.

General Construction

The boulder should not be larger than 20% of the stream width. Install in the deepest ⅓rd of the stream.



An In-stream Boulder

4.5.8 Digger Logs[54]

Use

Digger logs use directed water flow to preferentially scour the channel on one side of the stream, forming a pool and promoting a meander bend. Used to re-establish proper meander and riffle-pool sequence in a stream where they have been disturbed (e.g., by a beaver impoundment). Used to create, restore, or maintain a pool.

Advantages

Natural. Inexpensive, use local materials. Very effective.

Problems

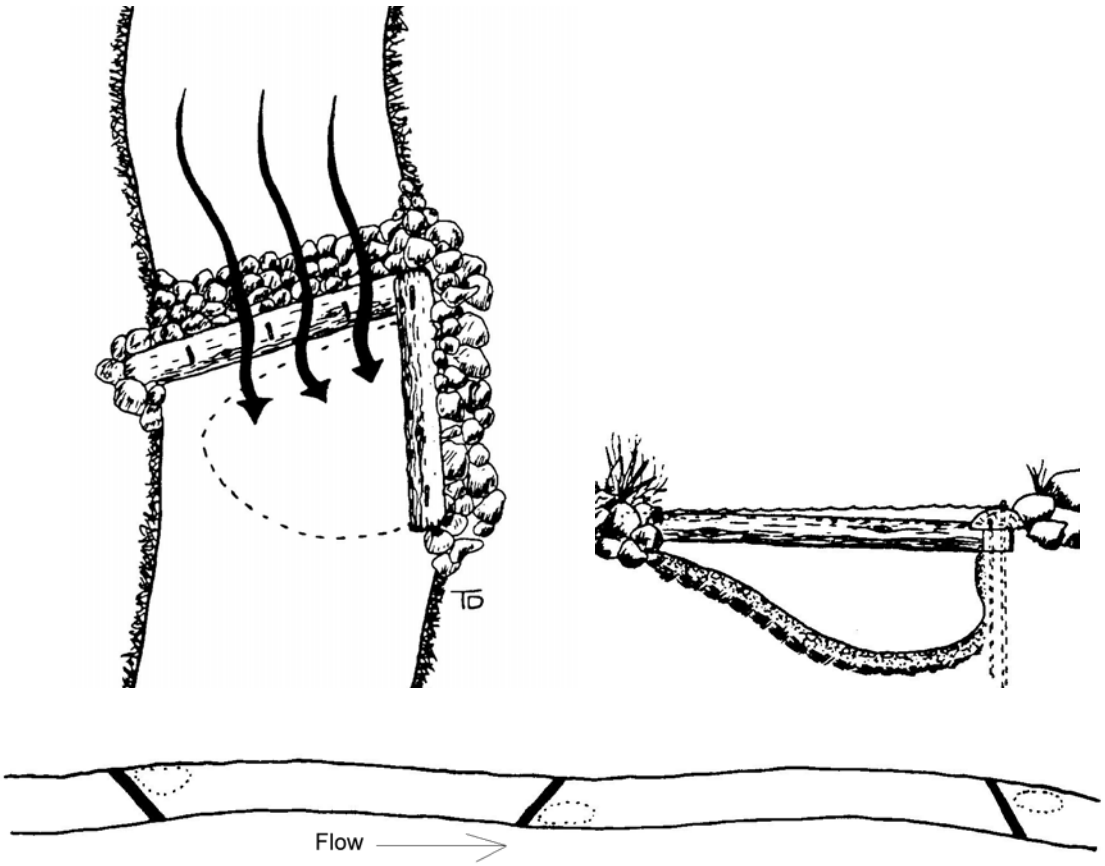
They can catch debris. Could create a migration barrier. Fairly labor intensive. Do not use in heavily silted sections of the stream or in tidal zones. Digger logs do not work well in low gradient streams or in streams with substrates that do not scour effectively.

General Construction

The digger log should be installed immediately upstream of where the pool/meander bend is to be created or improved. If the log is being installed at an existing pool/bend, it should be positioned so that the scouring effect it creates occurs at the pool. If the log is being installed to restore meander pattern, the river's meander period must be determined by making several measurements at nearby locations where the pattern is intact. If a series of digger logs are being installed in a reach where no meander pattern exists, then they should be placed 5 to 7 channel widths apart, starting from a road crossing or a well-formed pool. The placement of these digger logs should be done by a trained individual as misplacement can result in stream damage.

The log is installed at a 30˚ angle with the bank and it should key into the banks by ½ meter on both sides. Cut the log to a length that allows for these design conditions. Keys are dug into the bank and the log is set (at 30˚) so that the narrow end points upstream. The log is also vertically angled in the channel. The wider end is propped up so that it is at or above the water line and the narrow end is well submerged. Fish need to be able to swim over the narrow end. The log is anchored with rebar spikes through equally spaced drilled holes along the log’s length. Stones are piled on the upstream side of the log, keeping the channel open at the narrow end. The water should not run under the log. Filter fabric stapled to the log can be used under the stones. Sometimes another log is anchored along the bank on the pool side to stabilize the bank.

When a series of logs are being installed, the targeted side for the pool must alternate.



Digger Log Details

4.5.9 Managing In-stream Debris

The rule of thumb with in-stream debris is: leave it alone. It is human nature to make a tidy, park-like environment, but that is not ideal riverine habitat. The fish need the structure provided by the debris... and lots of it. Disrupting debris dislodges natural sediment accumulations and degrades gravel spawning areas when the sediment drops out downstream. This dislodged sediment can also degrade pools. Be wary of the term *clean out* when used in conjunction with stream management.

When fish passage is impeded, or is soon to be impeded, by debris jams, surgical removal of the blockage is appropriate. When unnatural placements (e.g., car wrecks) scar the stream, they should be removed. When the stream channel is being adversely affected by congested alder stems, or when alder stems are excessively trapping floating debris, the stems should be trimmed out of the stream. Sometimes limited removal of alders and the planting of grasses or grasses with trees/shrubs is advantageous. Beware of removing cover, especially over pools.

When doing debris removal, limit the number of places in the stream where the work is being done; i.e., stagger the work over a few seasons. If sediment migration is possible (it usually is), downstream controls (brushmats or traps) are needed.

Some nearby areas have park-like streams for leisurely, overhead fly-casting. Sometimes these streams are put-and-take fisheries. They serve a purpose. Our smaller, scrappier streams are more natural. Perhaps one may be a candidate for nature trails and easy fishing, but for the most part – if they are well managed – they can be a fine example of how streams like ours should be.

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