

Setbacks & Vegetated Buffers in Nova Scotia

A review and analysis of current practices and management options

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Executive Summary

This report presents a summary of the relevant scientific literature on riparian and coastal zone ecosystem functioning, the approaches to coastal and riparian management used in other North American jurisdictions, the management options available to the Province, as well as challenges of implementing a vegetated buffer or setback policy. A ten step decision-making framework for designating vegetated buffers and setbacks is also presented. This report is intended to clarify the complex issues related to use of vegetated buffers and setbacks in coastal and riparian zones, and to provide guidance to government staff as a basis for policy design recommendations.

Several provincial strategies and policies, such as the future Coastal Strategy, Natural Resources Strategy, Water Resources Management Strategy, the Wetland Policy and the Climate Change Action Plan, call for some type of vegetated buffer or setback for development from watercourses in order to protect and enhance water quality, habitat, livelihoods, access, property, and infrastructure. Public consultations conducted over the past three years as part of strategy development processes, and ongoing media coverage demonstrates growing public interest and expectations around buffers and setbacks from watercourses. The goal of this research is to investigate potential management options for setbacks and vegetated buffers that will protect ecosystem processes, people and property.

Nova Scotia Environment and Nova Scotia Fisheries and Aquaculture initiated the *Setbacks & Vegetated Buffers in Nova Scotia Report* in June 2011 in order to facilitate the development of a coordinated and consistent approach to riparian buffers and coastal setbacks across provincial government by performing the following tasks:

1. Review, inventory and summarize current policies in place or planned across all departments in Nova Scotia, including legislation, regulations, and guidelines;
2. Conduct a review of scientific literature to determine science-supported minimum buffer widths needed to maintain particular ecosystem services as well as to protect people and property from hazards such as flooding and erosion;
3. Identify the Province's management priorities in the areas of water quality, habitat protection, and flooding hazards, and assess the potential effectiveness of buffers/setbacks in addressing these priorities. This involves:
   a) Working with provincial government staff to clearly define the management "problem(s)" (e.g., habitat conservation, reduced sedimentation, flooding, etc.);
   b) Assessing the available regulatory tools that can be used to implement buffers and setbacks to address identified management problems/priorities;
4. Summarize policies implemented in other jurisdictions and describe the range of management approaches available to the Government of Nova Scotia;
5. Convene meetings with representatives from government, academia, stewardship groups, and industry sectors to:
   a) Review the current policies and problems and discuss the merits of buffers/setbacks as the appropriate regulatory tool; and
   b) Identify the goals and objectives of buffers/setbacks to help determine whether more than one type of approach is needed to attain them (for instance, protect water quality and habitat vs. protect people and property, or coastal setting vs. inland setting).

The approach for this report consisted of five steps: problem definition, interviews, and a review of scientific literature as well as international policies, and analysis. The problem was defined by exploring the literature regarding riparian and coastal management, and through interviews. Interviews were conducted with 48 representatives of industry, stewardship, business associations, academia, and provincial and municipal government staff. Feedback was collected via email, phone conversations and in face-to-face meetings. Existing legislation in Nova Scotia was examined to gain an understanding of the current regulatory context regarding the use of vegetated buffers and setbacks in coastal and riparian zones. One hundred and fifteen riparian and coastal policies from Canada, the U.S. and some international jurisdictions were reviewed. Policies from Nova Scotian municipalities were explored, but were not systematically examined due to the project scope. The scientific and management literature regarding riparian and coastal zones was also examined to gain an understanding of the vegetated buffer or setback width necessary to protect ecosystem services and protect property from natural hazards.

Many jurisdictions and researchers use the terms ‘buffer’, ‘vegetated buffer’, ‘setback’ and ‘riparian zone’ or ‘coastal zone’ interchangeably, however, it is important to distinguish between the terms because setbacks and vegetated buffers serve very different management functions. When writing policy, it is important to define and differentiate terms in order to promote a higher degree of understanding and compliance. A ‘vegetated buffer’ is a management term and refers to the strip of vegetation immediately adjacent to a watercourse in which activities are limited. A ‘setback’ is a separation distance designed to reduce conflict or minimize impact between a land use, structure, property line, or natural feature. A setback does not need to be vegetated; it is merely a separation distance. Both vegetated buffers and setbacks can be used in either riparian zones (i.e., adjacent to a river or lake) or in coastal zones.

Vegetated buffers and setbacks are two simple, yet powerful resource and risk management tools available to the Government of Nova Scotia. Specifically, vegetated buffers have low to moderate complexity (e.g., number of divergent public opinions, technical difficulty, physical and policy challenges to implementation), low cost, and high value as a planning tool (Fisher & Fischenich, 2000). The same can be said of setbacks (Bernd-Cohen & Gordon, 1999). Generally speaking, vegetated buffers provide more ecological services than setbacks due to the ability of vegetation to filter nonpoint source pollution contained in overland runoff, to increase infiltration and reduce peak flows during storms, and to provide terrestrial and aquatic habitat and wildlife movement corridors – functions that setbacks cannot provide (Figure 3. 1; Mellina & Hinch, 2009; Semlitsch *et al.*, 2009; Rideout & Sterling, 2012).

The use of one or both of these two management tools can achieve multiple government objectives, including the protection of water quality, biodiversity, private and public property and infrastructure, the provision of recreational and tourism-related spaces, and balancing economic and environmental values. Presently, there are some regulated and voluntary buffers and setbacks in place in Nova Scotia. For example, the forestry sector is subject to 20 m wide vegetated riparian buffers, and septic systems must be set back 30.5 m from watercourses. Some Nova Scotian municipalities have by-laws requiring vegetated buffers or setbacks ranging from 4 - 30.5 m; however, at this time Nova Scotia does not have a province-wide vegetated buffer or setback policy for all land uses similar to the policies and legislation in place in New Brunswick, Prince Edward Island, and many U.S. states. This piecemeal approach in Nova Scotia results in uneven and likely inadequate, protection of freshwater and coastal resources province-wide.

International case studies illustrate the effectiveness of “special management zones” in riparian and coastal zones in protecting water quality and biodiversity (see Neary *et al.*, 2011). The policy review found that many North American and international jurisdictions, including municipal, provincial/state, and federal governments, have implemented vegetated buffer and/or setback requirements for some or all land uses. The increasing popularity of these management tools can be attributed to the potential savings they can produce (e.g., avoided disaster repair costs and relief payments, avoided costs of armouring). While the use of these management tools is becoming increasingly popular, no standard approach was found amongst jurisdictions. Further, few jurisdictions use one vegetated buffer or setback design to the exclusion of all others; most use a combination of approaches.

There have been many studies on the effectiveness of riparian buffers to provide ecosystem services. There is a wide variation in effectiveness of riparian buffer widths to protect ecosystem functions, due to the individual nature of the sites. Studies indicate a 20 m vegetated buffer can capture 60% of the nutrients for most site types (Figure 3.6). Further, for most sites studied, a 20-30 m vegetated buffer captures most of the aquatic habitat services; a wider buffer (e.g., ≥50 m) is needed to provide terrestrial habitat services (Figure 3.7).

In contrast, there are far fewer studies on the effectiveness of different vegetated buffer and setback widths to provide coastal zone services. Instead, the scientific literature as well as the policy review revealed that setback or buffer widths are often based on local erosion rates or some other method of quantifying coastal hazards (Table 3.4). Unfortunately, erosion rates can be difficult and expensive to determine, and may have a large margin of error depending on the mapping and estimation methods used. According to Bernd-Cohen & Gordon (1999), 22 U.S. states and territories (e.g., Guam, Virgin Islands) use setbacks in coastal zones. Of these, 10 states delineate their setbacks based on an arbitrary distance from the shoreline, four use erosion rate data (Florida, Michigan, Pennsylvania, Virginia), three delineate setbacks according to distinct coastal features (New York, Oregon, South Carolina), and five use a combination of arbitrary distance, erosion rates, and coastal features (Maine, New Jersey, North Carolina, Rhode Island, Virgin Islands) (Bernd-Cohen & Gordon, 1999).

This review identifies options for choosing an approach to implement a vegetated buffer or setback policy. Analysis reveals that the process to decide which approach is most suitable can be broken down into ten sequential stages (Figure 4.1 and Figure 4.2). Three key elements of the decision-making process are the determination of the policy objectives, appropriate design, and regulatory approach. This review also identifies challenges that exist in the implementation of a vegetated buffers and setback policy.

This review indicates that:
1. There is no provincial-level vegetated buffer or setback policy in Nova Scotia for all land uses for either riparian or coastal zones;
2. Different vegetated buffer and setback widths are required to protect different ecosystem services, and a wider buffer is needed to provide terrestrial habitat services. The literature review did not reveal the minimum setback distance needed to protect property or ecosystems in riparian or coastal zones;
3. Ecological, hydrological and geological processes occur differently in coastal zones than riparian zones, therefore separate policies should be developed for each zone;
4. In order to determine an appropriate setback or vegetated buffer width in coastal zones, LIDAR data and tidal flood modeling are recommended to create coastal hazard maps, or alternatively, site specific assessments could be used; and
5. There are ten key management decisions required to establish a vegetated buffer or setback policy in riparian or coastal zones.

It is apparent from the scientific literature and interviews that riparian and coastal zones provide valuable services to Nova Scotians. There is a clear scientific consensus that vegetated buffers, particularly in riparian zones, are one of the most effective tools for reducing nonpoint source pollution in both inland and coastal waters. The literature review did not reveal the minimum setback distance needed to protect property or ecosystems in riparian or coastal zones, however, the literature review showed that riparian and coastal zones are ecologically, hydrologically and geologically distinct and therefore separate policies should be developed for each zone.

Policy objectives will determine whether vegetated buffers or setbacks are applied in coastal and/or riparian zones, and how they are designed. Interviews and policies from multiple jurisdictions suggest that water-dependent infrastructure including wharves, docks, boat ramps, pump stations and supporting pipes for the purposes of accessing water should be exempt from (but encouraged to comply with where possible) setback or vegetated buffer requirements. Vegetated buffers and setbacks are two management tools that are relatively simple, cost effective, have great value as planning tools and can produce multiple benefits to both the provincial government and the people of Nova Scotia.

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Acknowledgements

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1. Introduction

1.1. *Need for a vegetated buffer and setback policy in Nova Scotia*

Coastal and freshwater zones and resources play important roles in the economy and identity of Nova Scotians. Healthy ecosystems adjacent to these aquatic areas provide many services that are vital to residents and government alike and attract approximately two million non-resident tourists to our province every year (Nova Scotia Tourism, Culture and Heritage, 2009). However, these coastal and freshwater resources are facing increased threats from development, climate change, unsustainable harvesting of resources, and land-based pollution (CBCL Ltd., 2009; Theobald *et al*., 2010).

Presently, there are a number of regulated and voluntary vegetated buffers and setbacks in place in Nova Scotia to protect and conserve coastal and freshwater resources from human activities. There is however, no consistent, province-wide vegetated buffer or setback policy in place for all land uses. For example, the forestry industry is subject to legislated vegetated buffers, and on-site septic systems, mining pits and quarries are required to be set back from watercourses. Many members of the agriculture sector have voluntarily implemented vegetated buffers either independently or through the Environmental Farm Plan program (Nova Scotia Federation of Agriculture, 2011). Some municipalities have land use by-laws which require setbacks from watercourses (Table 3.6). The uneven application of vegetated buffers and setbacks (e.g., application to different land uses, different widths and conditions) means that many activities and siting practices are permitted that reduce ecosystem health and jeopardize waterfront development.

A coordinated approach to the management of riparian and coastal zones is needed. The recent *Nova Scotia Watershed Assessment Program* shows that most streams in Nova Scotia are bordered by an anthropogenic land use (Horne *et al*., 2011). Public consultation conducted for the development of the Coastal Strategy highlighted a number of concerns about Nova Scotia's coast including the number and location of permanent and seasonal residential developments, decreasing access to the coast due to private land ownership, land-based and marine pollution, and damage to property by erosion, storm surge, and sea level rise (Nova Scotia Fisheries & Aquaculture, 2010).

The need for a comprehensive approach to buffers and setbacks in Nova Scotia is underscored by existing government policies and strategies. Multiple provincial strategies and policies such as the Coastal Strategy, Natural Resources Strategy, and Water Resource Management Strategy, the Wetland Policy and the Climate Change Action Plan all discuss or commit to researching or implementing some type of buffer or setback from watercourses in order to protect and enhance water quality, habitat, livelihoods, public access, and property (Nova Scotia Environment, 2009, 2010 & 2011; Nova Scotia Fisheries & Aquaculture, 2011; Nova Scotia Natural Resources, 2011). Specifically, the Nova Scotia *Water for Life Water Resource Management Strategy* commits the Province to "Assess the current and future use of setbacks from fresh and coastal water resources" (Nova Scotia Environment, 2010). Similarly, a key action proposed under the draft *Coastal Strategy* is to "establish coastal development standards", and makes explicit reference to setbacks (Nova Scotia Fisheries & Aquaculture, 2011). *The Path we Share Natural Resources Strategy* recognizes a number of ecosystems and ecological processes which may be protected or affected by the establishment of vegetated buffers or setbacks (Nova Scotia Natural Resources, 2011). Despite the emphasis across provincial government departments, no province-wide vegetated buffer or setback policies have been implemented to date.

There is growing public interest in addressing the absence of a consistent, province-wide vegetated buffer or setback policy, as demonstrated in the public consultations conducted over the past three years for the aforementioned strategies. Ongoing media coverage demonstrates growing public interest and expectations around vegetated buffers and setbacks from watercourses (e.g., "Algae showing up on lakes", 2011; "Queens County watercourse setbacks moving forward", 2008).

1.2. Research objectives & tasks

Nova Scotia Environment and Nova Scotia Fisheries and Aquaculture initiated the *Setbacks & Vegetated Buffers in Nova Scotia Report* in March 2011 in order to facilitate the development of a coordinated and consistent approach to vegetated buffers and setbacks across provincial government by performing the following tasks:

1. Review, inventory and summarize current policies in place or planned across all departments in Nova Scotia, including legislation, regulations, and guidelines;
2. Conduct a review of scientific literature to determine science-supported minimum buffer widths needed to maintain particular ecosystem services as well as to protect people and property from hazards such as flooding and erosion;
3. Identify the Province's management priorities in the areas of water quality, habitat protection, and flooding hazards, and assess the potential effectiveness of buffers/setbacks in addressing these priorities. This involves:
    a) Working with provincial government staff to clearly define the management "problem(s)" (e.g., habitat conservation, reduced sedimentation, flooding, etc.);
    b) Assessing the available regulatory tools that can be used to implement buffers and setbacks to address identified management problems/priorities;
4. Summarize policies implemented in other jurisdictions and describe the range of management approaches available to the Government of Nova Scotia;
5. Convene meetings with representatives from government, academia, stewardship groups, and industry sectors to:
    a) Review the current policies and problems and discuss the merits of buffers/setbacks as the appropriate regulatory tool; and
    b) Identify the goals and objectives of buffers/setbacks to help determine whether more than one type of approach is needed to attain them (for instance, protect water quality and habitat vs. protect people and property, or coastal setting vs. inland setting).

1.3. Scope

This report focuses specifically on the use of setbacks and vegetated buffers, and summarizes the findings for the above tasks. Research was focused on rivers, streams and the coast; wetlands and estuaries were only investigated to the extent that they can be associated with or classified as a freshwater body (wetlands) or as a coastal water body (salt marshes and estuaries). The physical delineation of riparian and coastal zones has not been explored in this report; instead, research was focused on the delineation of these zones for management purposes. The use of shoreline armouring has not been explored in depth in this report; further research regarding the use of shoreline armouring should be undertaken. In conducting the policy review, provincial and state government policies were favoured over municipal or federal government policies in order to gain an understanding of how provincial-level governments approach the issue of land use planning near watercourses.

1.4. Project team

Name	Affiliation	Role
Emily Rideout	Hydrologic Systems Research Group, Environmental Science, Dalhousie University	-Primary researcher. -Wrote and produced the report
Dr. Shannon Sterling	Hydrologic Systems Research Group, Environmental Science & Earth Science, Dalhousie University	-Advisor for research analysis and report
Justin Huston	Nova Scotia Fisheries & Aquaculture	-Advisor on coastal research & overall project -Provision of government contacts -Reviewer
Krista Hilchey	Nova Scotia Environment	-Advisor on freshwater research & overall project -Provision of government contacts -Reviewer

2. Research methods

This research consists of five steps: problem definition, stakeholder interviews, riparian and coastal zone science literature review, policy literature review, and analysis.

2.1. Problem identification

Problem definition is a common step in policy development processes; defining the ‘problem’ helps to ensure that the proposed policy solutions will directly address the problem and produces the desired results (Government of Nova Scotia, 2009). A review of the literature reveals four key issues of concern for riparian and coastal zones without buffers and or setbacks:

- Property damage (from erosion, storm surge and freshwater flooding & sea level rise)
- Loss of aquatic and terrestrial wildlife habitat (aquatic & terrestrial)
- Reduction in water quality (contaminants and increased sediment)
- Loss of public access

2.2. Stakeholder and government interviews

Input was sought from non-governmental stakeholders (including industry, associations and stewardship associations and academia) and from government staff. The author conducted interviews with and received feedback from 48 individuals or groups (Table 2.1).

Table 2.1. List of government staff and non-government stakeholders interviewed between July and December 2011 by Emily Rideout.

Department or Organization	Name
South Shore Wildlife Association	Stephen Joudrey
Canoe Kayak Nova Scotia	Dusan Soudek
Sackville Rivers Association	Walter Regan
Ecology Action Centre	Jen Graham, Fred Wendt, Raymond Plourde, Jen Powley
NS Boat Builders Association	Tim Edwards
NS Federation of Agriculture	Henry Vissers, Kathryn Bremner
NS Home Builders Association	Paul Petitpas
HRM Water Commission	Barry Geddes
DFO Small Craft Harbours	Paul MacDonald
NS Association of Anglers & Hunters	Sheldon Ryan
Tourism Association of NS	Tanya Poulton
Dalhousie University	Dr. Peter Duinker, Dr. Patricia Manuel
NS Fisheries & Aquaculture	John MacMillan, David Mitchell
Region of Queens Municipality	John Leefe - Mayor
Saint Mary’s University	Dr. Danika van Proosdij
HRM	John Charles, Rob Jahnke
NS Environment	Cheryl Benjamin, Krista Hilchey, Cory Mooney, Darell Taylor, Kevin Garroway, Dawn McNeil, David Hopper, Kermit Degooyer, Norma Bennett, Will Green, Kyla Milne, Sophia Foley, John Brazner
Service Nova Scotia & Municipal Relations	Andrew Paton, Dave Smith
NS Natural Resources	Garth Demont, Rob Naylor, Dan Utting, Sean Basquill, Sherman Boates, Reg Newell, Randy Milton, Bill English
NS Agriculture	Brian MacCulloch, Laurie Cochrane
NS Transportation and Infrastructure Renewal	Ian MacCallum, Sylvie Colomb

Stakeholders were asked for their input on four questions:

1. What issues does your organization see as being important to coastal and riparian buffer and setback policy development?
2. What values and uses should be protected related to watercourses and coastal areas? For example, clean water for drinking or recreation, healthy fish habitat, ecosystem values, protection of property, wildlife corridors, aesthetics, access to natural resources, development, ocean-dependent industries, tourism, etc.
3. Does your organization support the restriction of certain activities within freshwater buffer zones and/or along coasts?
4. What types of activities should be permitted or prohibited in these zones?

Feedback was collected via email, phone conversations and in face-to-face meetings. The interviews, including the selection of interviewees as well as the content of the interview were not formally structured. Interviews were conducted with individuals or groups who responded to a request for feedback and discussions were free flowing. The results of these interviews have been incorporated into the content of this report. Expert opinions have been cited as personal communication, however non-expert opinions have not been cited, and instead have served to guide the author towards research topics and resources, and to help with “problem definition”.

2.3. Literature reviews

2.3.1. Scientific literature review on riparian and coastal zone hazards

Of the key issues identified during the problem definition stage of this project, the following were researched in scientific or management literature:

- Drivers and effects of erosion (e.g., bank collapse & sedimentation),
- Threats to ecosystem health and wildlife habitat (e.g., sea level rise, storms, development),
- Flooding (e.g., storm surge & storm water management), and
- Effectiveness of different vegetation types and buffer/setback widths at absorbing overland pollution and sediment

2.3.2. Policy literature review

Over 115 riparian and coastal policies were examined from every Canadian province and territory, many US states, and some international jurisdictions. Table 3.6 lists some Nova Scotian municipal setback bylaws, Table 3.7 lists some U.S. coastal setback policies, Table 3.8 lists some U.S. riparian policies for the forestry sector, and Table 3.9 lists some U.S. non-forestry riparian policies. Existing legislation in Nova Scotia was examined in an attempt to identify policies that permit or prohibit activities in riparian and coastal zones. Nova Scotian municipal land use by-laws were examined using a summary document created by Indeera Wimaladharma (2010), an intern working under Nova Scotia Environment’s Wetland Specialist, John Brazner. Research was undertaken to confirm the data in this document and to seek updated information, however a comprehensive study of all municipal approaches to riparian and coastal zone protection was not undertaken. Riparian policies were examined in every Canadian province and territory, and coastal policies were examined in all coastal Canadian provinces and territories (NL, PE, NB, QC, BC, YK, NU, and NT).

When reviewing non-Nova Scotian policies, provincial/state-level jurisdictions were selected over municipal or federal–level jurisdictions to allow for comparisons to the Nova Scotia context. U.S. State policies, particularly on the Atlantic coast, were actively sought and several articles reviewing policies from multiple U.S. jurisdictions were used extensively (e.g., Bernd-Cohen & Gordon, 1998; Kean, 2010; Vermont Legislative Research Center, 2008; Lee, Smyth & Boutin, 2003; Blinn & Kilgore, 2001). Some international policies were examined including Sweden, Mediterranean nations, Australia and New Zealand based on suggestions from stakeholders.

2.4. Analysis

Once the policy data was collected, it was analyzed for trends. Several policy objective, design options and regulatory pathways were identified (Section 4.1) and are presented as part of a decision making framework that has been developed for the Province (Figure 4.1 and Figure 4.2). Challenges to implementation of vegetated and/or setback policies identified in the literature review are discussed, and additional recommendations to support the development of a vegetated buffer and/or setback policy are presented.

3. Summary of literature reviews

3.1. Definitions

Vegetated buffer: The term "vegetated buffer" refers to a vegetated strip immediately adjacent to a watercourse in which activities are limited (Fischer & Fischenich, 2000; Wenger, 1999). In the literature two types of vegetated buffers are often studied: a mix of species including trees, shrubs and grasses that can be naturally occurring or planted during restoration and that provide multiple ecosystem functions, or planted grass filter strips located at the edge of cropland designed to trap runoff from agricultural lands (Dillaha *et al*., 1988). Both types of vegetated buffer provide some of the same functions (e.g., filtration of pollutants and sediment), however grass filter strips cannot provide the same habitat functions as mixed species vegetated buffers, nor can they moderate stream temperature. For the purpose of this report, the term vegetated buffer refers to mixed-species vegetation along watercourses, whether naturally occurring or planted. The term "vegetated buffer" can be used more narrowly to clarify its application, for example, a vegetated riparian buffer or a vegetated coastal buffer.

Setback: In the context of this research, a "setback" is a construction control line that separates a land use, structure, property line, or natural feature, which is designed to minimize conflict (e.g. residential housing and wind turbines), or minimize impact (e.g., industrial development and a watercourse) (NOAA, 2007; West's Encyclopedia of American Law, 2005; University of Nevada Co-operative Extension, 2008). A setback does not need to be vegetated; it is merely a separation distance. Like vegetated buffers, the term setback can be used more narrowly, for example, a coastal setback or a riparian setback.

All vegetated buffers are setbacks, but not all setbacks are vegetated buffers

The terms "setback" and "vegetated buffer" are different than coastal or riparian "zones" or "areas". The term "zone", whether riparian or coastal, refers to the ecotone or naturally occurring ecosystem comprised of the interface of land and water (Figures 3.1 and 3.2) (Wenger, 1999; USEPA, 2009b; Rose, 2004; Nova Scotia Environment, 2002; Schueler *et al*., 2009; Desbonnet *et al.*, 1994). The term "vegetated buffer" is a management practice, rather than an ecological unit, and refers to the deliberate protection of vegetation which is designed to capture some, if not all, of the functions provided by the natural riparian or coastal "zone" or ecotone. Many jurisdictions and researchers use the terms "buffer", "vegetated buffer", "setback" and "riparian/coastal zone" interchangeably, however, when writing policy, it is important to define and differentiate terms in order to promote a higher degree of understanding and compliance. For the purposes of this report, precise definition and delineation of coastal and riparian zones is not necessary.

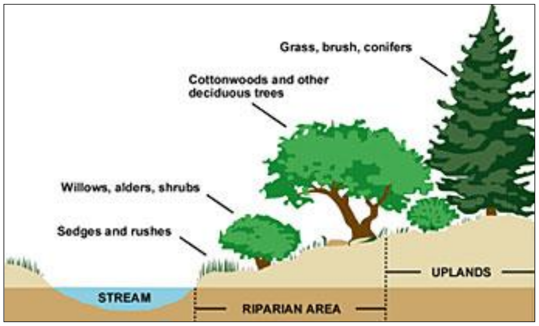

Figure 3.1. Cross section of a riparian zone (University of Nevada Cooperative Extension, 2011)

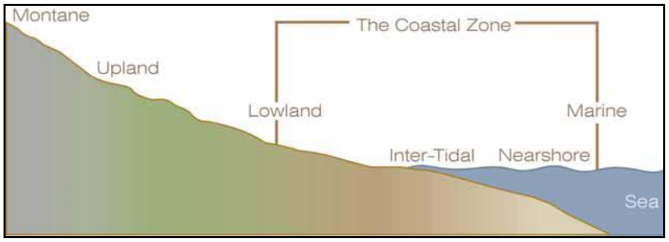

Figure 3.2. Cross section of a coastal zone (CBCL Limited, 2009)

3.2. Ecosystem services of riparian zones and coastal setbacks

3.2.1. Ecosystem services

Coastal and riparian zones play an important role in the ecology of the province. The services provided by ecosystems form the life-support system of the planet; constantly acting to filter air and water, sequester carbon, cycle nitrogen and phosphorous, form soil layers, produce food, etc. In order to effect meaningful protection of natural resources, proper attention must be paid to water and its myriad interactions with the natural environment in the form of streams, rivers, marshland, estuaries, lakes, wetlands, and the underlying water-table.

Vegetated buffers and setbacks help protect different ecosystem services and can also protect different services depending on whether they are used in riparian or coastal zones. The ecosystem services protected by vegetated buffers used in riparian and coastal zones, by vegetated buffers in riparian zones, and by setbacks in riparian and coastal zones are summarized in Figure 3.3 and discussed below.

- Filtering of pollution in overland runoff
- Promotion of bank stability and erosion reduction
- Delivery of nutrients and nutrient cycling
- Provision of terrestrial & aquatic habitat
- Support of riffle-pool stream morphology
- Enhancement of habitat connectivity & biodiversity
- Moderation of peak flow during storms
- Protection of property from flooding
- Protection of property from erosion

Vegetated Buffers

Setbacks

Figure 3. 1. Services provided by vegetated buffers vs. setbacks (Rideout & Sterling, 2012).

Vegetated buffers in riparian and coastal zones: Riparian and coastal vegetation can filter surface runoff from agriculture, construction sites, forestry operations, leaking septic systems and urban areas which can deposit nutrients, bacteria, pharmaceuticals, salt, and toxins (hereafter called "pollutants") into watercourses (Poletika *et al*., 2009; Lowrance & Sheridan, 2005; Robbins *et al*., 2001). These pollutants can reduce water quality and make unsuitable for uses such as drinking water, agriculture, industry, recreation, and for aquatic habitat (Wright, 2007; Poletika *et al*., 2009; Botkin *et al*., 2006; Limburg & Schmidt, 1990; Woodcock *et al*., 2006).

Riparian and coastal vegetation helps to hold soils in place, preventing bank and shoreline erosion (Gran & Paola, 2001; Abernethy & Rutherfurd, 2004, Desbonnet *et al*., 1994). Both riparian and coastal vegetation can reduce bank erosion which in turn limits sedimentation. Excessive sedimentation in freshwater streams can harm fish populations by depositing sediment in gravel beds where fish lay their eggs, by clogging gills, and by disrupting feeding (Sullivan & Watzin, 2010; Jones *et al*., 1999).

Riparian and coastal vegetation provides habitat and food for terrestrial and aquatic species by providing physical habitat, food sources and micro-climate moderation, which can in turn contribute significantly to provincial biodiversity. Biodiversity helps ecosystems to be more resilient and enduring in the face of disturbances such as storm-related flooding and blown-down (Petit & Naiman, 2007).

Riparian and coastal vegetated buffers can enhance habitat connectivity in fragmented landscapes (Harper *et al.*, 2005; MacDonald, 2003; Hannon *et al.*, 2002). Landscapes are often a patchwork of land uses that result in habitat fragmentation, forcing species to move across open areas and threatening populations. Vegetated buffers can provide important refuge habitat when primary habitat is damaged and can serve as corridors along which terrestrial species can migrate when foraging for food (Darveau *et al.*, 2001; Macdonald, 2003). The proximity of riparian zones to fresh water provides ideal corridors for terrestrial species (Stoffyn-Egli & Willison, 2011).

Riparian and coastal zones act as a sink for nutrients because a portion of dissolved nutrients entering streams through surface or subsurface runoff can be removed by riparian vegetation and by microbial processes in the riparian soil (Komor & Magner, 1996; Pinay *et al*., 1992, Haycock & Pinay, 1993; Hill, 1996; Mayer *et al*., 2007).

Riparian and coastal vegetation produces oxygen and improve air quality, and act as carbon sinks. Trees in particular filter air pollution maintaining and improving air quality (Nowak *et al*., 2006).

Vegetated buffers in riparian zones: Riparian vegetation provides and enhances aquatic habit by such things as contributing large woody debris (LWD), organic matter (i.e., leaf litter), and by shading the water. Many fish species, including Atlantic salmon, depend on the riffle-pool structures created by LWD (Mossop & Bradford, 2004; Crooks & Robertson, 1999; Bisson & Bilby, 1998). Organic matter inputs provide food to fish and invertebrate species (Johnson & Covich, 1997; Fisher & Fischenich, 2000; Bisson & Bilby, 1998). Fish species require cool water temperatures to thrive (MacMillan *et al.*, 2008; Macdonald *et al.*, 2003; Jackson *et al.*, 2001; Poole & Berman, 2001).

Riparian vegetation can maintain river morphology (e.g., pool riffle sequences) by stabilizing the channel-widening effects of bank erosion (Gran & Paola, 2001) and by providing LWD inputs (Mossop & Bradford, 2004) which can be important for fish habitat in small streams.

Vegetation adjacent to watercourses helps to control infiltration rates. A high infiltration capacity enables rain to be absorbed by the riparian soils before reaching the watercourse, resulting in moderated peak flows and a reduced likelihood of flooding (Walsh *et al.*, 2005).

Setbacks in riparian and coastal zones: Damage to property, infrastructure, and valuable habitat causes millions of dollars' worth of economic damage every year (Marchand *et al.*, 2011). Setbacks can allow space for naturally occurring coastal and riverine processes including erosion, deposition, flooding (French, 2006; Palmer *et al.*, 2009). The use of setbacks in riparian and coastal zones can protect property from these naturally occurring process, flooding and erosion in particular, by separating structures and activities away from coastal and riparian hazards (Hayes, 1985). Setbacks can also provide privacy for property owners, and improve access for beach users (Fish *et al.*, 2008).

3.2.2. Benefits of intact riparian and coastal ecosystems

The literature review and interviews showed that coastal and riparian zones provide Nova Scotians with a wide range of goods and services including fisheries, aquaculture, tourism, commercial, and recreational opportunities from which directly benefit the economy (CBCL Ltd., 2009; Gardner Pinfold Consultants Inc., 2011; NRC, 2002; Covich *et al.*, 2004; Giller *et al.*, 2004). The economic value of water can be viewed in terms of the direct extractive and non-extractive benefits, such as tourism, sanitation, irrigation, public drinking water, and animal habitat (Table 3. 1). In addition to direct economic benefits derived from extracting goods, these ecosystems provide important services including nutrient cycling, flood control, pollution absorption, wildlife habitat, genetic resources, and recreational and cultural activities (Scavia *et al*., 2002). Some industries (e.g., fisheries, recreation/tourism), rely upon healthy riparian and coastal zones, and good water quality in particular. We define "healthy" riparian and coastal zones as those which are "stable and sustainable – that is if it is active and maintains its organization, and autonomy over time and is resilient to stress" (Costanza, 1992).

Table 3. 1. Profits related to ecosystem services in Nova Scotia (GPI Atlantic, 2000, 2008; CBCL Ltd., 2009; Gardner Pinfold Consultants Inc., 2011; Gardner et al., 2009). It should be noted that the precise economic worth of ecosystem services can be considered incalculable due to their complexity and inter-connectedness. These values are 'incalculable' in the sense that, should their functioning cease, society would have no alternative for their services (Boyd, 2010).

Riparian or Coastal Activity/Function	Annual Value ($)
Ecosystem services provided by water based ecosystems (lakes, rivers & wetlands)	$11.2 billion
Water filtration and retention provided by uncut forested lands	$2,750/hectare
Contribution of non-recreational fisheries to GDP (2006)	$536 million
Contribution of aquaculture to GDP (2006)	$33.5 million
Recreational fishing (including estuarine and salt-water fishing)	$20 million
Coastal recreation (including whale watching, sight-seeing, hiking, kayaking, sailing, & beach visits)	$270-300 million

A review of the literature highlights three key functions and services provided by coastal and riparian zones (beyond benefits to wildlife and biodiversity discussed above) and their contributions to Nova Scotia's economy: protection of water quality, protection of property, and recreation, aesthetics and identity.

3.2.2.1.Water quality protection

The availability of clean fresh and coastal waters are of great importance for human health, ecosystem needs, economic activities such as fishing and aquaculture, livelihoods, and recreation and tourism activities (Millennium Ecosystem Assessment Board, 2005; Butler & Oluoch-Kosura, 2006; United Nations Development Programme *et al*., 2000). Nova Scotia's coastal economy, and to a lesser extent its riparian economy, is heavily dependent on two factors: water quality and access.

Vegetated buffers in riparian and coastal zones protect freshwater quality (Desbonnet *et al*., 1994; Lowrance & Sheridan, 2005). Healthy riparian vegetation (e.g., trees, shrubs, grass) and coastal features (e.g., salt marshes) act as natural filters of pollutants including sediment, nutrients, bacteria, pharmaceuticals, salt and toxins, and therefore protect inland and coastal water quality (Borin *et al.*, 2005).

Vegetated buffers can also protect water quality by mitigating stormwater. An increase in annual rainfall may result in decreased water quality due to sewage overflow events. Some Nova Scotian municipalities that provide centralized wastewater collection have "combined" systems which collect sanitary wastewater as well as stormwater in the same pipe (Canadian Council of Ministers of the Environment, 2009). When a large rainfall event occurs, the wastewater volume can exceed the capacity of the sewer system or treatment plant and is often re-routed and discharged directly into watercourses unfiltered (USEPA, 2011a) . The use of vegetated buffers in riparian zones can increase the infiltration capacity of lands adjacent to watercourses resulting in moderated peak flows and a reduced likelihood of combined sewer overflow (USEPA, 2011a).

The value of clean water to Nova Scotia's economy is very high; clean water brings direct financial benefits to the economy, and can result in financial savings when protected from degradation. For example, the success of Nova Scotia's fishing, agriculture, tourism sectors is closely linked to water quality (Freeman, 1995; CBCL Ltd., 2009, Lotze *et al.*, 2006).

The preservation of fresh water has direct benefits in terms of Nova Scotia's agricultural yield. The majority of Nova Scotia's agricultural irrigation needs are met by lakes and rivers (GPI Atlantic, 2000), and damage to these resources (e.g., through eutrophication resulting from runoff carrying excess nutrients) may lead to the loss of these water resources, and therefore to reduced agricultural output. For example, livestock that is watered directly from a polluted watercourse will decrease its water intake which often causes a reduction in feed intake, resulting in reduced "animal performance" (Wright, 2007).

By enhancing habitat quality for invertebrates, freshwater fisheries, marine fisheries, aquaculture operations and the harvesting of beach resources such as clams and seaweeds, commercial and recreational fisheries can benefit from larger and more consistent catches that are safe for human consumption. As shown in Table 3.1, significant revenue is derived from these industries. Clean water also plays an important role in enhancing the quality of waterfront tourism opportunities, such as kayaking, fishing, surfing, cruise ships, marine and freshwater recreational fishing, and swimming. Table 3.1 shows the value of these activities to the economy.

When water is cleaner, it requires less processing to ensure its safety which reduces the financial and energy cost of water purification for residents, agriculture and industry (GPI Atlantic, 2008). Vegetated riparian buffers can also help maintain groundwater quality as vegetation filters pollutants and slows infiltration rates (Le Maitre *et al.*, 1999). Keeping freshwater resources clean may reduce burdens on the health care system. The value of aquatic resources to the agriculture, fishing and tourism sectors necessitates steps to preserve and enhance these regions from pollution and degradation. Riparian or coastal vegetation should be maintained as much as possible to filter nonpoint source pollution and protect water quality.

3.2.2.2. Property protection

It is important to protect public and private property in Nova Scotia. The Province is responsible for the provision and maintenance of public infrastructure and property including highways, bridges and provincial government buildings (Nova Scotia Transportation & Infrastructure Renewal, 2012). Municipalities are responsible for roads, municipal government buildings, and water and wastewater infrastructure (Service Nova Scotia & Municipal Relations, 1998). Private property owners (e.g., individuals or corporations) are responsible for roads, residences, seasonal housing, businesses, industrial infrastructure, secondary structures (e.g., garages, sheds, and boat houses), etc.

Damage to private and public property and infrastructure caused by storm surge, freshwater flooding, and erosion can have significant costs to individuals, municipalities, the Province, and the economy (Table 3. 2), and are often not covered by insurance companies (Insurance Bureau of Canada, 2008). Setbacks and vegetated buffers can protect property from damages caused by storm surge, freshwater flooding, sea level rise and erosion by siting development away from hazardous impacts of these phenomena (USFEMA, 2011; Palmer *et al*., 2009).

There is an increasing risk to property in Canada due to increased development in floodplains and climate change (Jakob & Church, 2011). Although storms, erosion and flooding have always been a part of life in Nova Scotia, climate change will produce new patterns for these phenomena. Coastal flooding hazards are projected to worsen with a changing climate, as sea level in Nova Scotia is projected to rise an average of 1.07 m by 2100 (Richards & Daigle, 2011).The Intergovernmental Panel on Climate Change (IPCC) also predicts a widespread increase in annual precipitation across Canada (IPCC, 2007). The increased frequency of extreme storm events will result in increased frequency of storm surge, inland flooding, and accelerated erosion rates (IPCC, 2007).

Erosion can threaten waterfront development. Along the coast, more frequent storms will accelerate erosion via storm surge. After large rainfall events or spring snow melt, inland flooding can increase erosion of streambanks (Rose, 2004). In some areas, this will result in an increased annual erosion rate and in other areas storms could cause several metres of land at a time to fall into the ocean, destroying structures, and reducing property size, appearance, and value (USFEMA, 2011).

In coastal zones, setbacks and vegetated buffers can be used to separate property from coastal hazards, and slow gradual erosion. By siting structures away from the shore, erosion is less likely to damage public and private property and infrastructure.

There is an increasing risk of flooding to property in Canada due to land cover change and increased development in floodplains (Jakob & Church, 2011; Pottier *et al*., 2005; Wheater & Evans, 2009). When vegetated soils are replaced with impermeable surfaces such as roads, parking lots and areas of development, rain water is unable to permeate the soil. Instead, large volumes of stormwater enter watercourses via stormwater drainage systems in a shorter amount of time, causing intense peak flows which produce flooding (Lee & Heaney, 2003; Wheater & Evans, 2009; Schueler, 1994). The use of vegetated buffers in riparian zones can increase the infiltration capacity of lands adjacent to watercourses resulting in moderated peak flows and a reduced likelihood of flooding, and therefore, property damage (Walsh *et al.*, 2005).

The increasing risk to property from climate change and floodplain development are scenarios that neither the Province, nor individuals, are adequately equipped to address given the absence of a province-wide watercourse setback or vegetated buffer policy and the immediate proximity of so many properties to both inland and coastal waters.

A common approach to protecting property against rapid erosion is to armour the river bank or coastline with coarse material. This method is effective at protecting individual stretches of shoreline and may be useful in cases where the use of buffers or setbacks is not possible due to the immediate threat of erosion. However armouring often deflects wave action and river power, and therefore erosion, further along the shoreline onto un-armoured stretches where erosion can occur more rapidly than before armouring was installed (USFEMA, 2011). Armouring also prevents the coast or riverbank from behaving dynamically, as it is naturally prone to do, particularly on highly erodible stretches, and destroys coastal and riparian ecosystems (Trenhaile, 2007).

3.2.2.3. Recreation, aesthetics & identity

Much of Nova Scotia's cultural identity has been founded on a relationship with marine and aquatic environments. With 125 salt and freshwater beaches, unique geological formations (e.g., Five Islands Provincial Park), the highest tides in the world, and numerous beach resorts and opportunities for water sports, fishing and whale watching, the coasts and watercourses of Nova Scotia are popular destinations for locals and tourists alike (Nova Scotia Economic & Rural Development & Tourism, 2011; Novascotia.com, 2011).

Access to clean coastal water and healthy coastal ecosystems provide recreational opportunities which can promote a sense of stewardship and healthy lifestyles that include physical activity. The aesthetics of clean inland and coastal water and healthy ecosystems contribute to a sense of place which is highly valued by Nova Scotians. Clean water, mature trees and other vegetation, and healthy ecosystems can also enhance property values (Michael *et al.*, 1996; McMahon, 1994; Arbour Day Foundation, n.d.).

The environmental, social and economic function and beauty of many coastal destinations for tourism and recreation are sensitive to the impacts of development and climate change as well as the impacts of coastal industries such as aquaculture, quarries, and oil and gas activities (Nova Scotia Economic & Rural Development & Tourism, 2011).

According to Nova Scotia Economic & Rural Development & Tourism (2011), “key coastal considerations for destination development planners include:

- The loss of traditional coastal access points due to development pressures;
- Increasing percentages of privately owned coastal land (approximately 95% in Nova Scotia);
- Liability concerns related to coastal land use and access;
- Increases in storm surge flooding;
- Accelerated erosion of beaches and coastal dunes; and
- Degradation of coastal wetlands and increasing saltwater intrusion.”

3.2.3. Costs to Government of damaged riparian and coastal zones

The use of vegetated buffers and setbacks in riparian and coastal zones can separate human activities from natural processes and sensitive ecosystems, and can help government and communities proactively manage resources and protect people and property from harm, rather than trying to manage in a reactive manner – generally the more costly approach. We define “proactive management” as a management framework that aims to anticipate naturally occurring threats/risks to ecosystem functioning, people and property in order to reduce damage before they occur.

Failure to proactively manage coastal and riparian resources can be expensive, particularly when dealing with the aftermath of significant storm events (Marchand *et al*., 2011). According to the National Round Table on the Environment and the Economy (NRTEE, 2011) “flooding damages to coastal dwellings, resulting from climate change-induced sea-level rise and storm surges, could cost between $1 billion to $8 billion per year with higher than average cost impacts in Atlantic Canada.” Table 3.2 summarizes the total cost of damages from major storms in Nova Scotia over the past 11 years. According to CBCL Ltd. (2009) “Gross repair costs to provincial coastal infrastructure (mostly roads and shoreline structures) after hurricane Juan (2003) and post-tropical storm Noel (2007) were $2 million and $580,000, respectively (Shawn Ramey, Financial Services, NSTIR, pers. comm., 2009).” Total disaster relief estimates for hurricanes Juan and Noel respectively are $37.5 million and $2.6 million (Table 3.2). In addition, Canadian insurance companies in general only cover sewer-back-up related flooding and not coastal flooding, or gradual erosion damage (Insurance Bureau of Canada, 2008). It should be noted that even with a province-wide vegetated buffer or setback policy, not all these costs would be avoided, since much development has already occurred, however buffer/setback policies would help to minimize future costs.

It is clear that major storm events are both common and expensive for the Province. According to the IPCC (2011), we can expect this expensive trend to increase as climate change is projected to produce more frequent storm events; however the use of vegetated buffers and setbacks can help protect property from storm damage. If both vegetated buffers and setbacks in riparian and coastal zones are implemented, the Province stands to save a significant amount of money on disaster relief payments over time as older structures are dismantled, re-located or destroyed, and as new structures are set further inland than previous developments. If a setback is implemented there will be fewer structures to be destroyed and therefore fewer disaster relief payments to be made.

Likewise, if the Province’s Department of Transportation and Infrastructure Renewal and rail companies begin to move their at-risk road and rail infrastructure (Figure 3.4 and Figure 3.) away from watercourses and coasts in recognition of the risks posed by a changing climate, even greater financial savings could be achieved. Preventing damage to infrastructure can also reduce the economic costs resulting from delayed delivery of services. By reducing damage to dwellings and infrastructure, costs to home owners, municipalities, and the Province can be reduced.

> “Policies designed to minimize adverse ecological impacts of human activities on coastal ecosystems in the mid-Atlantic, such as decreases in nutrient loading of watersheds, could help mitigate some of the risks associated with future climate variability and change in this region.”
> -Najjar *et al.* (2000)

Table 3. 2. Summary of provincial and federal expenditures for disaster relief programs between 1999 and 2010 (Nova Scotia Emergency Management Office, 2011)

Event	Cost of Program (estimate)	Provincial Expenditure (to date)	Estimated Federal Recovery Due	Federal Recovery (to date)	Cost of Program minus Federal Contributions
Tropical Storm Harvey (1999)	**$2,231,000**	$2,231,000	0	$401,000	**$1,830,000**
Cape Breton Flood (2000)	**$2,419,000**	$2,419,000	0	$449,218	**$1,969,782**
March Flood (2003)	**$28,151,000**	$28,151,000	0	$21,065,353	**$7,085,647**
May South Shore Floods (2005)	**$1,963,000**	$1,963,000	0	$510,004	**$1,452,996**
Hurricane Juan (2003)	**$37,537,170**	$32,550,000	$17,031,184	$8,000,000	**$12,505,986**
Blizzard (2004)	**$7,080,239**	$4,361,123	$4,500,215	$0	**$2,580,024**
Tropical Storm Noel (2007)	**$2,552,413**	$2,552,413	$808,206	$0	**$1,744,207**
Labour Day Flood (2008)	**$2,362,106**	$1,652,106	$713,053	$0	**$1,649,053**
Meat Cove Flash Floods (2010)	**$7,743,032**	$1,598,753	$5,096,728	$0	**$2,646,304**
November 2010 Floods	**$5,669,408**	$3,251,408	$3,230,467	$0	**$2,438,941**
Dec. 12-15, 2010 Floods	**$2,385,024**	$1,023,050	$724,512	$0	**$1,660,512**
Dec. 20-22, 2010 Floods	**$1,706,419**	$131,046	$385,209	$0	**$1,321,210**
Total	**$101,799,811**	**$81,883,899**	**$32,489,574**	**$30,425,575**	**$38,884,662**

Figure 3.4. Examples of flood damage in Yarmouth, Nova Scotia (left) and Quinan, Nova Scotia (right) (Insurance Bureau of Canada, 2011)

Figure 3.5. Examples rail infrastructure vulnerable to coastal erosion near Antigonish, NS (Nova Scotia Department of Natural Resources, 2011)

Failure to protect water quality can have negative environmental and economic impacts. For example, shellfish closures have been on the rise and are linked to poor water quality mainly due to high levels of coliform bacteria (Potter, 2004). “Since 1985, there has been a rapid increase in the number of shellfish closures [in Nova Scotia]...In 2000, for example, there were 278 shellfish closures” (CBCL Ltd., 2009), the highest rate of closures in Atlantic Canada (CBCL Ltd., 2009). In August 2009, the entire coastline of Nova Scotia was closed to shellfish harvesting (“Major closure of Nova Scotia coastline to shellfish harvesting”, 2009). As recently as November 13, 2011, heavy rains caused the waters within 3 km of the shores of Halifax, Digby, Queens and Lunenburg counties to exceed acceptable water quality criteria and resulted in the closure of shellfish fisheries in these regions (“Shellfish harvesting closed in some areas of N.S., N.B.”, 2011).

Water quality can also have direct economic impacts. GPI Atlantic (2000) has calculated the total municipal expenditure on Nova Scotian drinking water at $8.1 million annually and an estimated $4.2 million spent by residents on home filtration.

The decline in Atlantic salmon returns over the past 25 years has been estimated at 80% by the Atlantic Salmon Federation and has been linked to contamination of aquatic habitat by industrial and domestic runoff, and increased sediment loads from neighbouring agriculture and forestry operations (GPI Atlantic, 2000).

Nova Scotia stands to preserve substantial economic benefits from actions that protect water quality and quantity as an integral part of larger ecosystems due to the significant financial and social benefits provided by coastal and riparian ecosystem services, including the protection of water quality, property, habitat, etc. (Marchand *et al.*, 2011). The restoration of damaged ecosystems to their former levels of productivity is costly. For example, a study of 11 salt marsh restoration projects in the U.S. showed that restoration costs ranged from approximately $900 to almost $90,000 per acre ($0.22 to $22 per hectare) for planning, construction, and monitoring (price levels adjusted to reflect 2001 dollars. Louis Berger & Associates Inc., 1997). Typical costs for restoration of Nova Scotia salt marshes are within this range (i.e., ~$50,000 per hectare) but also provide significant community and economic benefits (see Nova Scotia Transportation & Infrastructure Renewal, 2006; B. Pett, Nova Scotia Transportation & Infrastructure Renewal, personal communication, April 1, 2012).

The preceding monetary estimates suggest that it would be in the interest of the Province to follow the Global Water Partnership's guide to Integrated Water Resources Management by managing water resources "to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (United Nations Environment Programme, 2009).

3.3. Land use activities that impact riparian & coastal zones

Different land use types can impact riparian area functioning to varying degrees and in different ways (Sterling & Rideout, 2012). Numerous studies have shown that surface water quality is affected by the land cover characteristics found within the watershed drainage areas of streams (Limburg & Schmidt, 1990; Bis *et al.*, 2000; Riva-Murray *et al.*, 2002). Land use adjacent to a watercourse can have a large impact on riparian ecosystem functioning as it can determine how vegetation is managed. Some land uses require access to watercourses whereas others may have more freedom to protect riparian zones. Land use types with clear impacts on coastal and riparian zones include residential, industrial or commercial developments, agriculture, and forestry operations.

Residential waterfront property, be it along a river, lake or the ocean, is often seen as the ideal location for residential, cottage or tourism development, however these properties can have large impacts on riparian and coastal zones. These developments can cause vegetation to be removed which results in lost habitat, increased erosion, decreased filtration of pollutants, decreased water quality, and increases in water temperature (Sterling & Rideout, 2012). Malfunctioning or poorly sited septic systems can drastically reduce water quality. Certain areas of the province are unsuitable for residential homes and permanent infrastructure due to their ecological, social, cultural or recreational significance, or their sensitivity to sea-level rise and coastal erosion. Some waterfront developments may exacerbate erosion if they use poor construction practices. Private development can limit public access to watercourses, a concern that was repeatedly raised in the “What We Heard” Coastal Strategy consultation summary document (Nova Scotia Fisheries & Aquaculture, 2010).

Industrial or commercial developments can also produce negative impacts on riparian integrity and water quality, particularly if an industry requires access to the waterfront for water intake, effluent dumping, or shipping. A recent study of the Sackville River watershed found that industrial and commercial land uses had the third most severe impacts on riparian vegetation after energy infrastructure and transportation land uses (Sterling & Rideout, 2012).

Energy infrastructure (e.g., utility pole corridors) and transportation (e.g., roads, highways and rail tracks) were found to be responsible for the most severe riparian deforestation in the Sackville River Watershed (Sterling & Rideout, 2012). Energy infrastructure corridors are kept clear of vegetation (other than grass and shrubs) to allow for access to utility poles and maintenance. The complete removal of riparian trees can lead to an increase in stream temperature from lack of shade (Wilkerson *et al.,* 2006) which negatively impacts fish habitat (Mossop & Bradford, 2004). Damage to streams caused by maintenance and recreational vehicles in these corridors is also an issue (Sterling & Rideout, 2012). Transportation-related land uses must at times cross streams and will necessarily remove a portion of a riparian zone and often introduce pollutants into the watercourse via runoff from the road surface. It should be noted that while energy infrastructure and transportation land uses have the most severe impact per unit area, this impact is normalized by area. The impact of these two linear land uses can be reduced if they cross streams on a perpendicular manner rather than at an oblique angle (Sterling & Rideout, 2012). Impacts can also be reduced by preventing the parallel siting of linear land uses immediately adjacent to watercourses, and instead requiring that they be setback from watercourses (Sterling & Rideout, 2012).

Agriculture can have an impact on riparian, stream, and human health, as well as coastal water quality when agricultural processes cause pollutants (e.g., fertilizers, pesticides, manure, and sediment) to enter streams adjacent to fields or pastures (Broadmeadow & Nisbet, 2004; UNFAO, 1996; World Resources Institute,1992). Habitat is heavily impacted when farmers use all available land right to the stream edge (Morris, 1998). Streams are often used for watering livestock which can damage bank stability, increase erosion and add fecal matter to the watercourse (Soil & Crop Improvement Association of Nova Scotia, 2006). Without a buffer to remove runoff, fertilizers and pesticides enter streams unfiltered (Zhang *et al.*, 2010). There can be downstream health impacts if contaminated water is used for drinking (World Health Organization, 2003).

Awareness about the benefits of riparian vegetation for mitigating chemical-laden agricultural runoff has become more widespread, and vegetated riparian buffers are used more widely now than in the past (Bentrup & Kellerman, 2004; de la Crétaz & Barten, 2007; Greenland-Smith, unpublished data; L. Cochrane, Nova Scotia Agriculture, personal communication, October 28, 2011). This new awareness can be attributed to the high uptake level of the Nova Scotia Department of Agriculture's Environmental Farm Plan program and the dissemination of educational material and workshops by the Nova Scotia Federation of Agriculture (L. Cochrane, Nova Scotia Agriculture, personal communication, October 28, 2011).

In a recent study, Greenland-Smith (unpublished data) found that many farmers in Nova Scotia already maintain a vegetated buffer along watercourses, however in general, they are too narrow (5 m on average) to provide many riparian functions beyond bank stability and some degree of pollution filtration (e.g., provision of shade, large woody debris, leaf litter, terrestrial habitat). Of the 31 streams and 39 wetlands surveyed in the Annapolis Valley, only eight streams and two wetlands had vegetated buffers wider than 15 m (Greenland-Smith, unpublished data).

The forestry sector also has impacts on water quality and habitat, such as increased sediment deposits, habitat destruction, soil compaction and changes to wind and heat patterns (Broadmeadow & Nisbet, 2004), despite being the only sector in Nova Scotia to be subject to vegetated buffer requirements. While the forestry sector does impact riparian zones, the *Wildlife Habitat & Watercourse Protection Regulations* have likely reduced the impact of this sector on water quality and habitat.

3.4. Economic consequences of establishing vegetated buffers or setbacks

The establishment, maintenance, and land opportunity costs associated with vegetated buffers and setbacks are difficult to quantify due to the difficulty of quantifying the non-economic (i.e., social and environmental) costs and benefits of these management tools (Ice *et al.*, 2006; Roberts *et al.*, 2009). Much of the debate about appropriate minimum buffer widths and setback distances stems from the effect of these zones on land use and the landowner's ability to use or modify their property. Some types of costs associated with implementing setbacks and buffers include opportunity costs, tree or grass planting costs, and livestock exclusion costs, although livestock exclusion is less necessary for vegetated buffers than for setbacks. Opportunity costs resulting from the establishment of vegetated buffers or setbacks include the loss of earnings from crops that could have been grown, or trees that could have been harvested in the buffer or setback zone (Lynch & Tjaden, 2000). According to Lynch and Tjaden (2000), "opportunity costs include the net changes in current and future income that will result from establishing the buffer. Factors such as the productivity of the land nearest the stream and the type of crop grown will affect these costs. In some areas, the streamside will be the grower's most productive land, in others, the least productive."

In a study of riparian grassed buffer strips on agricultural land in the Harpeth River watershed in Tennessee, Roberts *et al.* (2009) found that grassed buffers 45.7 m wide on all agricultural land throughout the watershed would 'consume' 8% of the agricultural land. The cost of implementing 45.7 m-wide buffers was found to be $192.54 to $291.26 per hectare of crop land, and $128.03 to $867.34 per hectare of pasture land, "thus, pasture buffers would cost 13% more than cropland buffers on average as livestock exclusion expenses are more than enough to offset the greater opportunity costs associated with cropland acres" (Roberts *et al.*, 2009). Table 3.3 lists some costs associated with restoring treed or grassed buffers and excluding livestock in riparian zones. Lynch & Tjaden (2000) provide some examples of budget worksheets showing the costs and benefits to landowners of different buffer types over a 15 year period.

Table 3.3. Costs of establishing treed or grassed riparian buffers, or livestock exclusion zone. These costs are not applicable to already forested or grassed buffers. The buffer width is not specified (Lynch & Tjaden, 2000).

Treed Buffer Expense (436-550 trees)	Cost Per Acre	Grassed Buffer Expense	Cost Per Acre	Livestock Exclusion Expense	Cost Per Acre
Plant by machine	$75-130	**Planting**	$10-50	**Fencing**	$2.15-2.60 (per ft)
Plant by hand	$60-174	**Seeds**	$100-225	**Solar powered water source**	$4,000-10,000
Plant material	$60-275	**Site preparation**	$18-40	**Gravity powered water source**	$2,000-7,000
Replanting	$56-100			**Stone crossings**	$2,000-6,000
				Culverts/bridges for crossing	$4,000-10,000

A comprehensive study of the costs of riparian and coastal zone protection was beyond the scope of this report, however general costs for different sectors are listed in Table 3.4. It may be of interest to the Province to determine how much land would be included in a vegetated buffer or a setback policy; using GIS, the Province could see how much land would be captured by a vegetated buffer or setback 15 m, 30 m, 50 m etc. wide. This data may also help to calculate opportunity costs on agricultural or forested lands. See Roberts *et al.* (2009), the Chesapeake Bay Program's Chesapeake Bay Riparian Handbook (1998), and Lynch & Tjaden (2000) for analyses of the economic costs (e.g., cropland opportunity costs, pasture opportunity and exclusion costs, total annualized buffer costs, planting costs) associated with the use of riparian vegetated buffers.

Table 3.4. Economic consequences of implementation of vegetated buffers and setbacks in riparian and/or coastal zones. Exemptions could be made for any of these sectors (Rideout & Sterling, 2012).

Land Use	Potential Economic Costs
Forestry	Unable to move timber across streams - financial & labour costs of constructing longer access roads, reduced area available for harvest (often the biggest trees are in the riparian zones)
Residential	Loss of partial or entire property, loss of scenic views, loss of ability to alter property
Agriculture	Loss of productive land or pastures, limited access to water for livestock
Urban	Loss of high-value real estate, loss of views
Transportation	Financial & labour costs of constructing roads around streams, could limit access for recreational vehicles and access for transportation of goods to coast for shipping
Coastal Industries (e.g., aquaculture, wharves, boat building facilities)	Reduced accessibility, Some new operations unable to open,
Power lines	Increased cost in siting and maintenance, increased length of transmission lines

3.5. Summary of riparian & coastal zone science

This review found that there is a distinct difference between the scientific literature regarding coastal and riparian zones. Riparian zone literature has a strong scientific emphasis on evaluating the ability of different vegetated buffer widths to protect ecosystem functions. On the other hand, coastal zone literature focuses more on determining a setback or vegetated buffer width based on localized coastal processes, and provides little guidance regarding specific distances, or potential regional-scale approaches.

The sparseness of the literature regarding ecosystem services and appropriate setback or buffer widths in coastal zones can likely be attributed to the fact that it is harder to generalize ecosystem type for vegetated coastal zones; for example, some may be forest, coastal plains, cliff, or wetland.

Riparian vegetation is defined by a higher water availability and productivity by plants, almost always treed in Nova Scotia. This is not necessarily the case for coastal zones therefore it is much harder to define a width of a vegetated coastal zone that will provide a particular ecosystem service.

It is also much harder to define a setback distance that will protect property in coastal zones because there is a wider range of erosion rates in coastal zones than alluvial riparian zones (due to alluvial material was deposited by the river and is a function of the erodibilty of the stream itself). In coastal zones, erosion rates depend upon the geology and the local ocean processes, and can be extremely variable from region to region, ranging from centimetres to metres per year.

Another reason it is more difficult to determine an appropriate setback or buffer width in coastal zones than in riparian zones is because in riparian zones, the watershed has a buffering capacity because it has integrated many storms over the history of the land surface, whereas coastal erosion often exposes new material that is in disequilibrium. Because of this, hazard mapping or site-specific assessments are an important component of decisions regarding setback or vegetated buffer in coastal zones. Both hazard mapping and site-specific assessments depend on knowledge of erosion rates and storm incidence, both of which are challenging to predict; the determination of erosion rates requires time-consuming studies by experts. Regarding hazard mapping in coastal zones, there are some general principles that can be followed related to elevation and erodibility (Figure 4.3).

In short, a single setback or vegetated buffer width in coastal zones for the province is not scientifically defensible. *Appendix C* and *Appendix D* contain detailed summaries of the scientific literature regarding multiple ecosystem functions for riparian and coastal zones respectively.

3.5.1. Riparian zone science

A great deal of research, both theoretical and empirical, has been conducted about the vegetated riparian buffer widths necessary to protect a broad range of ecosystem functions including wildlife habitat, bank stability, and water quality and quantity (e.g., Neary *et al.*, 2011Akerman & Staicer, 2008; Bennett, 1999; Cody, 2007; Stoffyn-Egli & Willison, 2011; Decamps *et al.*, 2004; Dunn *et al.*, 2011). Vegetated riparian buffers have been used in forestry and agriculture for many decades (Comerford *et al.*, 1992). In recent years, there has been a shift from one-size-fits-all vegetated buffers and setbacks towards more complicated policies that include modifying factors such as watercourse type and size, slope, and presence of fish (Lee *et al*., 2004).

Of the ecosystem functions provided by riparian zones, filtration of nonpoint source pollution has been extensively studied (e.g., Weller *et al.*, 2011, Dillaha *et al*., 1988, 1989, Dosskey *et al*., 2010, Lee *et al.*, 2000). Figure 3.6 summarizes 25 studies that investigated the effectiveness of riparian vegetation, whether grassed, forested or mixed species, at removing a range of pollutants. Figure 3.7 summarizes the vegetated riparian buffers required to protect various ecosystem services including pollutant filtration and wildlife habitat.

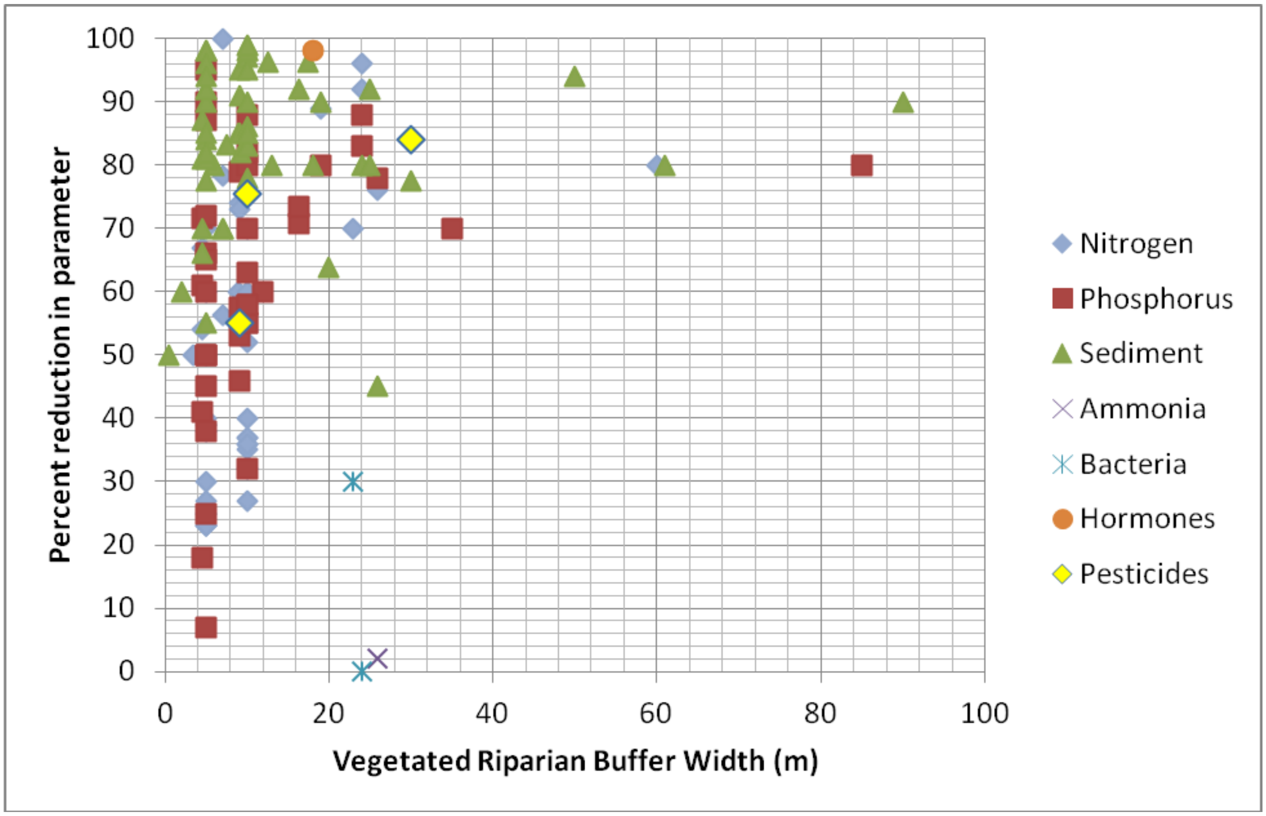

Figure 3.6. Effectiveness of various buffer widths at removing sediment, nitrogen, phosphorus, ammonia, bacteria, hormones and pesticides (Rideout & Sterling, 2012).

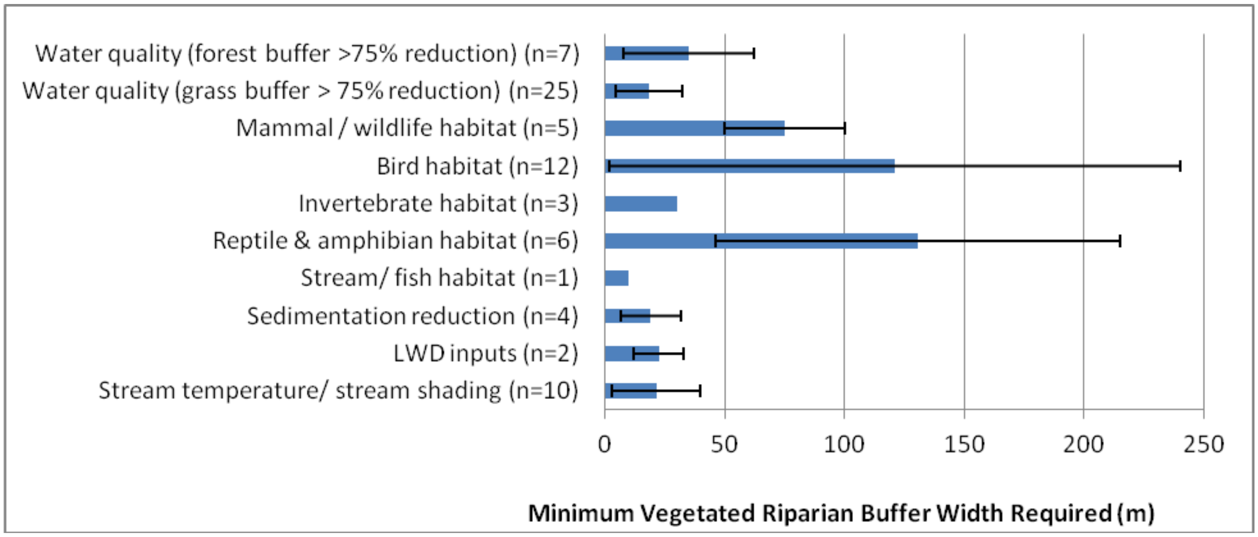

Figure 3.7. Summary of vegetated riparian buffer widths required to protect various ecosystem functions from published studies. Error bars represent the standard deviation in the estimates. Studies for which there are a several widths estimated the narrowest width to achieve the ecological is used. For most sites studied, a 20-30 m vegetated buffer captures most of the aquatic habitat services; a wider buffer (≥50 m) is needed to provide terrestrial habitat services (Rideout & Sterling, 2012).

In summary, wider buffers provide more ecosystem services. Larger buffers are required to filter nonpoint source pollution, protect wildlife habitat and serve as wildlife corridors, however narrower vegetated buffer widths will allow for bank stabilization, filtration of sediment contained in overland runoff, and the provision of shade, LWD and organic litter (Figure 3.7). According to Walter *et al.* (2009), some of the most scientifically consistent riparian buffer research has shown that relatively thin (<20 m) buffers can have remarkably positive impacts on stream water temperature, bank stabilization, and sediment trapping.

Castelle and Johnson (1994) summarize their review of riparian literature in a similar way:

> “From the literature, it appears that buffers less than 5-10 m provide little protection of aquatic resources under most conditions. Based on existing literature, buffers necessary to protect wetlands and streams should be a minimum of 15 to 30 m in width under most circumstances. Generally, minimum buffer widths toward the lower end of this range may provide for the maintenance of the natural physical and chemical characteristics of aquatic resources. Buffer widths towards the upper end of this range appear to be the minimum necessary for the maintenance of the biological components of many wetlands and streams.”

Essentially, the Province must prioritize ecosystems functions and select a vegetated buffer width which captures the functions that Government values most.

3.5.2. Coastal zone science

The coast is always changing: it is a naturally dynamic entity (Klein *et al.*, 1998). It is important to remember that coastal processes such as erosion are natural and only become problematic when these natural processes interact with human activities. While property can be damaged by nature, the reverse is also true: coastal ecosystems can be damaged by human activities. Setbacks and vegetated buffers in coastal zones must be designed to take into account episodic storm induced erosion events, long term erosion rates, and flooding from storm surge and sea level rise (Zhang *et al*., 2002).

The scientific literature regarding processes specific to coastal zones were examined, including erosion, storm surge flooding, sea level rise, pollutant filtration, and provision of habitat and wildlife corridors. Damage to property caused by coastal erosion and storm surge are the two most relevant and commonly researched short-term coastal hazards. Sea level rise is the most relevant and commonly researched long-term coastal hazard. Extreme weather events occur frequently in predictable locations. In Nova Scotia, low-lying areas, such as the Northumberland Shore, upper Bay of Fundy, and dykeland areas, are vulnerable to the impacts of storms (e.g., storm surge). Both private property and municipal, provincial, and federal infrastructure may be damaged or destroyed by the episodic or cumulative effects of coastal erosion, storm surge and sea level rise. Habitat loss and alteration caused by sea level rise and development threaten coastal ecosystems which are home to a number of endangered species in Nova Scotia (Mersey Tobeatic Research Institute, 2008; Burger, 1994; Flemming *et al.*, 1988).

While there is ample literature about coastal ecosystems and the threats they face (e.g., habitat loss, climate change, erosion, flooding (Defeo *et al*., 2009; Scavia, 2002; Erwin, 1996)), there is very little literature that connects the ability of various setback distances to protect different ecosystem functions in the same way that the riparian literature does. Instead, the literature focuses primarily on advancing the understanding of physical coastal processes, in particular, erosion, flooding, and sea level rise, the phenomena which are commonly seen to pose the greatest threat to people and property. The author found only three papers that suggest specific setback distances for different coastal geology types (e.g., cliffs, low rocky beaches, sandy beaches, the Bras d’Or Lakes), however the recommendations made in one of these are for Caribbean islands and only cover 3-4 coarse geological types (Table 3.5) (Fish *et al.*, 2008; Cambers, 1997).

Table 3.5. Summary of available literature on coastal setback distances required to protect property from erosion, flooding and sea level rise, and to protect water quality and terrestrial habitat (Rideout and Sterling, 2012).

Coastal Ecosystem Function	Minimum Width	Source
Erosion prevention	• Slowly eroding cliffs: 15 m • Low rocky beaches: 30 m • Sandy beaches: ○ case by case basis ○ >100 m to be safe ○ 1 m of erosion per 1cm in sea level rise	Cambers (1997); Zhang (1998); IPCC (1998), Bruun (1962)
Flood protection (storm surge, sea level rise)	• Low lying shores: 30 m • 50% of effects: 20 m • 90-98% of effects: 75 m Vertical setback: 2-2.5 m	T. Webster, personal communication, November 4, 2011; J. Charles, personal communication, November 4, 2011; Richards & Daigle (2011; Environmental Design and Management Ltd. (2008); Cambers (1997);
Pollution absorption (50-99% removal)	5 – 550 m	Magette *et al.* (1989); Desbonnet *et al.* (1994); Dillaha *et al.* (1988); Lowrance (1992); Daniels & Gilliam (1996); Lee *et al.* (1999); Chaubey *et al.* (1994)
Terrestrial habitat	50-1000 m	Erwin (1996); Fish *et al.* (2008); Defeo *et al.* (2004)

Literature regarding nonpoint source pollution filtration in coastal zones is also sparse. This may be because water quality in coastal zones is usually dominated by riverine inputs, and therefore implementing vegetated riparian buffers is key. Although in theory vegetated coastal buffers could filter some overland runoff, this ability is highly site dependent; for example, where there is a large flow of groundwater through vegetated coastal buffers into the ocean. Wetlands in coastal zones are expected to play an important filtering and nutrient supply to the local coastal zones (Najjar *et al*., 2000). This review found one paper that proposes specific coastal vegetated buffer widths that will provide wildlife habitat and filter pollutants from runoff (Desbonnet *et al.*, 1994). Although the pollutant filtration research contained in Figure 3.6 does not deal specifically with coastal zones (with the exception of Desbonnet *et al*., 1994), it may nevertheless provide some guidance on appropriate setback or vegetated buffer widths in the absence of coastal zone-specific literature (i.e., a 30 m vegetated buffer will provide adequate filtration functions).

According to Marchand *et al.* (2011), “a review of the main body of coastal scientific literature since 2004 has provided little or no publication on the strategic management of erosion” and that the majority of peer-reviewed papers on coastal erosion are limited to operational responses primarily at local scales. Marchand *et al.* (2011) also show that papers exploring the implications of climate change and sea level rise dominate the literature which emphasizes the need for an integrated management approach to climate change.

The *Bras D’Or Lakes Development Standards Report* by Environmental Design and Management Ltd. (2008) provides some guidance on the vegetated buffer width required to adapt to the effects of sea level rise and storm surge. The report suggests that a 20 m vegetated buffer will accommodate 50% of the combined effect of sea level rise plus storm surge in the Bras d’Or Lakes region, and 90-98% will be accommodated by a 75 m vegetated buffer. They also suggest that sea level rise should be addressed separately from watercourse protection due to the different functions they serve (i.e., vegetated buffers mitigate the impacts of land use, while the concern with sea level rise and storm surge is the potential of water to invade the land). It should be noted that sea level rise and storm surge may occur differently in this inland brackish system than on the exposed coast.

3.6. Policy review

The pressing need to protect freshwater ecosystems from damaging human activities has prompted many jurisdictions in North America to adopt guidelines – either mandatory (regulations) or recommended (best management practices) – controlling land use along watercourses (Young, 2000; Blinn & Kilgore, 2001; Lee *et al*., 2004; Olson *et al*., 2007). International case studies illustrate the effectiveness of "special management zones" in riparian and coastal zones in protecting water quality and biodiversity (see Neary *et al.*, 2011).

The increasingly widespread protection of riparian areas in North American policy can be attributed to the increased use of the watershed as management unit and the emergence of integrated water resource management strategies across Canada and the U.S. in recent decades (Lee *et al*., 2004; USEPA, 2009b; Young, 2000). Riparian zones produce far-reaching watershed-wide benefits for ecological functioning and drinking water and that are exponentially larger than the relatively simple measures necessary to maintain them (Fisher & Fischenich, 2000).

Likewise, coastal zones have been ecological units of interests for decades, and coastal setbacks are becoming the norm for many coastal jurisdictions, particularly in the U.S. As storm events begin to occur more frequently, sea level rises due to climate change, and coastal erosion and flooding pose ever greater risks to coastal property owners, coastal setbacks are seen as a relatively simple way for governments to mitigate risk and harm to residents. Just as coastal setbacks have been identified as a way to protect people from the sea, so too are they a way to protect the sea from people.

Over 115 policies were examined from every Canadian province and territory, many U.S. states and some international jurisdictions.

3.6.1. Federal legislation

The federal government has jurisdictional power over marine waters and fish-bearing inland waters; whereas coastal zones and the remainder of freshwater resources are under provincial jurisdiction. Land use planning has been delegated by provinces to municipalities. Due to the jurisdictional breakdown of management responsibilities, there are no federal policies which explicitly require vegetated buffers or setbacks in either riparian or coastal zones.

The main federal legislation affecting Nova Scotia's inland and coastal waters includes the *Canadian Environmental Protection Act*, the *Fisheries Act,* and the *Oceans Act.*

[1]The *Canadian Environmental Protection Act (CEPA)*, administered by Environment Canada, provides a framework for environmental protection in Canada, particularly with regard to pollution control. The Act prohibits the disposal of wastes and other matter at sea within Canadian jurisdiction and by Canadian ships in international waters and waters under foreign jurisdiction, unless the disposal is done under a permit issued by the Minister.

The *Fisheries Act* was established to manage and protect Canada's fisheries resources (Fisheries and Oceans Canada, 2009). It applies to all fishing zones, territorial seas and inland waters of Canada (Fisheries and Oceans Canada, 2009). Of particular note are the habitat provisions of the Act which state that a "harmful alteration, disruption or destruction of fish habitat" (HADD) cannot occur without authorization pursuant to the Act. The Act also prohibits the unauthorized killing of fish by means other than fishing, makes provisions for ensuring fish passage, particularly for migratory species, and prohibits

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[1] Adapted from the State of Nova Scotia's Coast Technical Report (CBCL Ltd., 2009)

the release of substances deleterious to fish. It is possible that the Fisheries Act will be revised, and the HADD provisions altered in the coming months ("Ottawa eyes changes to Fisheries Act", 2012).

The *Oceans Act*, which operates in coastal waters from the low water mark seawards to 200 nautical miles offshore, and is administered by Fisheries and Oceans Canada (DFO), defines Canada's international jurisdiction over its ocean area. Under the Act, *Canada's Ocean Strategy* is based on the three principles of sustainable development, integrated management and the precautionary approach. It makes commitments to integrated management of Canada's estuaries, coastal waters and marine waters and recognizes that ocean governance is a collective responsibility, not just a federal responsibility (Fisheries and Oceans Canada, 2002).

Other relevant federal statutes include:

- *Species at Risk Act*, which protects endangered and vulnerable plants, animals and birds;
- *Migratory Birds Convention Act*, which protects birds and their habitats along migration routes;
- *Navigable Waters Protection Act*, which protects the public right of navigation;
- *Canadian Environmental Assessment Act*, which sets out federal requirements for environment assessment of scheduled activities; and
- *Fishing and Recreational Harbours Act*, which involves the management of small craft harbours including the divestiture of harbours to local authorities, a process which began in 1995.
- *Canada Water Act*, which protects water resources and promotes sustainable management of water use, contains provisions for formal consultation and agreements with the provinces for the protection of water through comprehensive water resources management programs.

3.6.2. Provincial legislation and policies

Presently, there are a number of regulated and voluntary vegetated buffers and setbacks in place in Nova Scotia to protect and conserve coastal and freshwater resources from human activities. There are, however, no consistent, province-wide vegetated buffer or setback requirements in place. For example, the forestry industry is subject to legislated vegetated buffers (20 m), and on-site septic systems are required to be set back from watercourses (30.5 m). Other industries such as mining are not required to have a specific setback, but are regulated under the *Environment Act*. Many members of the agriculture sector have voluntarily retained vegetated buffers either independently or through the Department of Agriculture's Environmental Farm Plan program. Some municipalities have land use by-laws which require setbacks from watercourses generally ranging from 4-30.5 m in width, but can be up to 100 m for certain industries (Table 3.6). This sector-based approach results in a patchwork of management approaches across the province and inadequate protection of freshwater and coastal resources as well as people, property and infrastructure.

In spite of the absence of province-wide vegetated buffer or setback policies, several government departments have committed to collaborating on cross-cutting natural resource management issues with other departments. Interdepartmental collaboration will be necessary for the development of vegetated buffer or setback policies – complex, cross-cutting management tools that can accomplish many outcomes stated in these above mentioned strategies (e.g., protection of clean water, biodiversity, public and private property, etc.).

3.6.2.1. Government-wide activities

Environmental Goals and Sustainable Prosperity Act: "The *Environmental Goals and Sustainable Prosperity Act* [EGSPA] promotes environmentally sustainable economic development that recognizes the economic value of the Province's environmental assets is essential to the long-term prosperity of the Province…The Act also gives the Governor in Council authority to establish or participate in programs including those related to adaptation to the effects of climate change" (CBCL Ltd., 2009).

The goal of EGPA is to have “one of the cleanest and most sustainable environments in the world by the year 2020” (Government of Nova Scotia, 2007). EGSPA outlines 23 targets and provides the foundation for several government strategies which have been developed since its creation including the Water Strategy, the Climate Change Action Plan, the Wetlands Policy and the Natural Resources Strategy. The principles underlying EGSPA are as follows:

- The health of the economy, the health of the environment and the health of the people of the Province are interconnected;
- Environmentally sustainable economic development that recognizes the economic value of the Province's environmental assets is essential to the long-term prosperity of the Province;
- The environment and the economy of the Province are a shared responsibility of all levels of government, the private sector and all people of the Province;
- The environment and economy must be managed for the benefit of present and future generations;
- Innovative solutions are necessary to mutually reinforce the environment and the economy;
- A long-term approach to planning and decision-making is necessary to harmonize the Province's goals of economic prosperity and environmental sustainability;
- The management of goals for sustainable prosperity, such as emission reduction, energy efficiency programs and increasing the amount of legally protected land will preserve and improve the Province's environment and economy for future generations.

Climate Change Action Plan: The Climate Change Action Plan was released in 2009 and recognizes that “Nova Scotia is particularly susceptible to these changes because most of our population lives along the coastline, and much of our infrastructure is located in vulnerable areas.” In order to address this vulnerability, the Action Plan outline 68 actions intended to help Nova Scotians adapt to climate change. The following actions are of relevance to the use of vegetated buffers and setbacks in riparian and coastal zones:

- Using funds from the federal Gas Tax Agreement provide funding in 2009 to help municipal governments plan for climate change. A key focus will be the impacts of sea-level rise on land-use planning and on the design of wastewater treatment plants.
- In 2009, work with the Union of Nova Scotia Municipalities on a memorandum of understanding that will address climate change mitigation and adaptation.
- Amend funding agreements with municipalities by 2010 to require climate change strategies in municipal Integrated Community Sustainability Plans.
- Develop statements of provincial interest on adaptation by 2010 to provide guidance on land-use planning.
- Incorporate climate change impacts and adaptation response plans into the strategies and initiatives of all provincial departments by 2012.
- Establish criteria in 2009 for the consideration of climate change during Nova Scotia Environment’s Environmental Assessment process and develop a guide to climate change for project proponents.
- Release a Sustainable Coastal Development Strategy by 2010. A major part of the strategy will focus on strengthening our resiliency to climate change impacts along our coast.

Water Strategy: The 2010 *Water for Life Water Resources Strategy* aims to “protect the health of Nova Scotians, our province’s natural beauty, and the companies, industries, and organizations that contribute to our economic prosperity.” The Water Strategy commits the Province to working within an Integrated Water Management (IWM) framework (Nova Scotia Environment, 2010). IWM is “a comprehensive approach to managing water resources, including human activities and their effects on watersheds and ecosystems. It means we should work with other departments, levels of government, stakeholders and other organizations to pool our knowledge, and to ensure water resources are managed most effectively” (Nova Scotia Environment, 2010). Specifically, the Water Strategy commits the Province to “Assess the current and future use of setbacks from fresh and coastal water resources” (Nova Scotia Environment, 2010). During the public consolations for the Water Strategy, vegetated buffers or development setbacks from watercourses were suggested many times as a way to protect water quality, public access and ecosystem health.

Coastal Strategy**:** In recent years, the provincial government recognized that it needed a way to focus efforts to tackle complex coastal issues. A detailed *State of Nova Scotia's Coast* technical report was produced, public consultations were undertaken and a draft Coastal Strategy was released in 2011. This report draws heavily on the technical report. A key action proposed in Draft Coastal Strategy is to "Establish coastal development standards", with explicit reference to setbacks. Similar to Water Strategy consultations, in the consultations for this strategy, the public suggested that coastal setbacks or development standards would be an effective means to protect people and property, as well as vulnerable coastal ecosystems while also maintaining public access. Leadership and collaboration is a guiding principle of the draft Coastal Strategy (Nova Scotia Fisheries & Aquaculture, 2011).

Atlantic Climate Adaptation Solutions Projects: The Atlantic Climate Adaptation Solutions (ACAS) projects "are part of a larger national program developed by Natural Resources Canada (NRCan) to cost-share efforts to improve climate change adaptation decision-making. The program was designed to support a regional focus on the most pressing issues in each of six areas across Canada. The ACAS projects will undertake research that will assess coastal and inland vulnerability to climate impacts and develop guidelines for the siting and protection of groundwater resources from the intrusion of saltwater" (ACAS, 2011).

The following ACAS projects of relevance to this research are currently occurring in Nova Scotia:

- Shore zone characterization and coastal change analysis
- Vulnerability of the Nova Scotia coastline to erosion
- Construction and analysis of flood risk maps for select coastal communities in Nova Scotia
- An evaluation of flood risk to infrastructure across the Chignecto Isthmus
- Inventory of the physical infrastructure at risk of flooding due to climate change-induced sea level incursion in three Nova Scotian ACAS communities
- An assessment of coastal infrastructure relevant to the fishing and aquaculture industries in ACAS study areas
- An evaluation of social vulnerability and social assets at risk to climate change impacts in three Nova Scotian ACAS communities
- Development of an urban forest canopy model for input into a LIDAR-based stormwater runoff model for Halifax harbour watersheds
- Climate scenario development for ACAS communities in Nova Scotia
- Increasing the capacity of Nova Scotia municipalities to prepare adaptation focused municipal climate change action plans
- Municipal preparedness for climate change in Nova Scotia: evaluating municipal capacity to respond to climate change through adaptation

Participants in Nova Scotian ACAS projects include:

- Natural Resources Canada
- Environment Canada
- Fisheries & Oceans Canada
- Nova Scotia Departments of Environment, Natural Resources, Agriculture, Transportation and Infrastructure Renewal, and Fisheries & Aquaculture
- Nova Scotia Emergency Management Office
- Union of Nova Scotia Municipalities
- Municipal councils
- Dalhousie University
- Nova Scotia Community College
- Saint Mary's University
- Atlantic Planners Institute
- Atlantic Engineering Association

By providing new tools and maps to decision makers, the results of ACAS projects could play an important role in helping the Province to determine an appropriate approach to coastal setbacks and vegetated buffers. In particular, the projects involving the characterization of coasts and coastal erosion could inform the width of coastal setbacks. Details about the ACAS projects in Nova Scotia can be found at http://atlanticadaptation.ca/ns_projects.

3.6.2.2. Department of Natural Resources

Wildlife Habitat and Watercourses Protection Regulations: The most significant piece of provincial legislation pertaining to riparian buffers is the 2002 Nova Scotia Natural Resources *Wildlife Habitat and Watercourses Protection Regulations*. This piece of legislation requires forestry operations on public or private land to create "Special Management Zones" (SMZ's). SMZ's are "an area of forest required to be established adjacent to a watercourse… to protect the watercourse and bordering wildlife habitat from the effects of forestry operations".

This regulation requires the following from forestry operators:

- Maintain a buffer of 20 m on either side of the length of every stream wider than 50 cm and around lakes, marshes and salt water bodies.
- Within this buffer forestry operators must not conduct any activities that would result in sediment being deposited in the watercourse.
- When the average slope of a streambank within the 20 m buffer is greater than 20%, 1 m of buffer must be added for every 2% of slope increase up to a maximum of 60 m.
- No vehicles may be operated within 7 m of the watercourse.
- Partial clearing is permitted within the buffer zone, however, $20m^2$/ha of basal area must be retained and small and non-harvestable trees, shrubs and ground cover should be maintained to the fullest extent possible.
- Canopy openings may not exceed 15 m in width.
- For streams smaller than 50 cm, no vehicles may be operated within 5 m of the watercourse, sediment must not enter the water course and small trees and shrubs must be retained when possible.

In their research addendum for the Nova Scotia Natural Resources forest panel report, Bancroft and Crossland (2009) make the following statement about this regulation:

> "The Wildlife Habitat and Watercourses Regulations have made an ineffective attempt to compensate for the damage of clearcutting by legislating 20-metre riparian zones and small legacy clumps (10 trees/ha). These stipulations fall short on meeting the requirements to maintain all affected ecosystem components. The idea is that under a shifting mosaic of stand-replacement events, the components will simply move to other patches on the landscape. Many species have limited dispersal capacity (e.g., some lichens and bryophytes). Highway beauty strips may please members of the tourism industry, but serve little ecological function."

Beaches Act: The goals of the *Beaches Act* are to:

- Provide for the protection of beaches and associated dune systems as significant and sensitive environmental and recreational resources;
- Provide for the regulation and enforcement of the full range of land-use activities on beaches, including aggregate removal, so as to leave them unimpaired for the benefit and enjoyment of future generations; and
- Control recreational and other uses of beaches that may cause undesirable impacts on beach and associated dune systems.

This *Act* prohibits development on beaches, removal of beach aggregates, removal or destruction of natural objects (e.g., vegetation, minerals), alteration or destruction of watercourses, or operation of vehicles without the approval of the Minister of Natural Resources. This *Act* empowers the Minister to enter into a management agreement with the owner or occupier of land adjacent to a beach.

Natural Resources Strategy: The Path we Share Natural Resources Strategy recognizes that in the past, "managing Nova Scotia's natural resources meant promoting forestry and mining" and that "Our natural environment is threatened, and traditional practices in many resource based industries are not sustainable." The Natural Resources Strategy is a departure from traditional ways of managing natural resources and commits government to "Work together to maintain and restore healthy wildlife populations, ecosystems, and ecosystem processes." The strategy focuses on biodiversity, minerals, parks and forests and recognizes a number of ecosystems and ecological processes which are of relevance to the establishment of buffers or setbacks.

This strategy includes a number of goals and commitments of relevance to this project including the following:

- Integrate biodiversity values into planning and decision making, including the economic valuation of ecosystem goods and services.
- Collaborate with others to complete a network of conservation areas to support the protection of biodiversity and the connectivity of landscapes.
- Support action on priority issues, including alien invasive species, climate change, species at risk, habitat protection, wildlife management, and protected areas.
- Continue to map Nova Scotia's coastal geology and advise communities about adapting to and mitigating the effects of sea-level rise, coastal erosion, and flooding.
- Provide information about the geology of the province to help in provincial and municipal land-use planning and decision making.

Specifically related to forestry, the strategy commits to:

- Reduce clearcutting and establish a harvest tracking system.
- Review and redesign silviculture programs.
- Limit herbicide use.
- Clarify the use of forest biomass for energy.
- Establish the rules for whole-tree harvesting, and incorporate this into the Code of Forest Practice.
- Evaluate the effects of implementing an Annual Allowable Cut (AAC)—the amount of wood permitted to be harvested—to ensure the sustainability and productivity of Nova Scotia's forests.

Collaborative leadership is a guiding principle of the Natural Resources Strategy (Nova Scotia Natural Resources, 2011). The implementation of vegetated buffers or setbacks will require leadership and collaboration, and if these two principles are adhered to, vegetated buffers or setback may help the Province achieve many of the goals outlined in this strategy.

3.6.2.3. Nova Scotia Environment

Environment Act: [2] The *Environment Act* encourages and promotes the protection, enhancement and prudent use of the environment, including water resource management. Water resources in the *Act* include all fresh and marine waters comprising all surface water, groundwater and coastal water. The *Act* gives the Minster of the Environment authority to classify water resources according to their sensitivity or uses, develop sensitivity indices for the Province, adopt water quality guidelines, and indicators.

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[2] Adapted from the State of Nova Scotia's Coast Technical Report (CBCL Ltd., 2009)

The Minister also has the authority to establish or adopt goals for effluent reduction and establish total allowable waste-loads for water bodies. The Governor in Council is given authority in the *Act* to make regulations including those regarding the infilling or alteration of wetlands, swamps, marshes, ravines or gulches. Under the *Environment Act*, no wetland, including salt marshes, can be altered without approval from Nova Scotia Environment. It is worth noting that the *Environment Act* applies to all land uses and sectors and can therefore be a powerful tool when applying new regulations.

There are many regulations under the Environment Act but only a few are relevant to activities occurring in riparian or coastal zones including:

- **Activities Designation Regulations:** The *Activities Designation Regulations* require an approval for any industry to install or maintain a dam, culvert, bridge, causeway, wharf, weir or fishway, or erosion protection material. The regulations do not however require an approval for residential or cottage development or landscaping that may involve tree removal.
- **Environmental Assessment Regulations:** Environmental Assessments are required for large-scale industrial developments such as pulp and paper mills, highways, and mines. Impacts on water quality and endangered species for example are considered in an Environmental Assessment.
- **On-site Sewage Disposal Systems Regulations:** The *On-site Sewage Disposal Systems Regulations* require a 30.5 m setback from all watercourses and wetlands; however these regulations only apply to the septic system and not to any other development such as residential housing.

Wetlands Policy: The 2011 Nova Scotia Wetland Conservation Policy includes the following statement regarding vegetated buffers:

"Government will encourage buffers between wetlands and developments and between wetlands and agricultural operations that are similar to those required as "special management zones" for forestry operations under the Wildlife Habitat and Watercourses Protection Regulations. To this end, the variety of tools available includes:

- Educating private landowners, land developers, municipal land-use planners and farmers about beneficial management practices (e.g., the Environmental Farm Stewardship Program) for various development activities adjacent to wetlands.
- Incorporating the use of buffers and Wetland Protection Plans in Environmental Assessment approvals for projects with a high potential to have a negative impact on wetlands." (Nova Scotia Environment, 2011)

3.6.2.4. Department of Agriculture

Nova Scotia Eastern Habitat Joint Venture Wetland Stewardship Program: The Department of Natural Resources, the Department of Agriculture and several national conservancy groups administered the Nova Scotia Eastern Habitat Joint Venture Wetland Stewardship Program. This program attempted to address provincial wetland conservation and management needs through the development of conservation and stewardship objectives and the application of stewardship techniques. The program provided approximately $19,500,000 in funding to over 60 participants through habitat securement (36,700 hectares), enhancement (10,400 hectares) and management (13,200 hectares) of wetland in Nova Scotia. The program included a riparian zone management system for wetlands and waterways to control agricultural runoff, protect waterfowl habitat and biodiversity in general (Wildlife Habitat Canada, 2009).

- ***Agricultural Biodiversity Conservation (ABC) Plan Project:*** The ABC Plan Project was the primary focus of the Nova Scotia Eastern Habitat Joint Venture Wetland Stewardship Program for 2008/2009. ABC Plans were used to support the conservation and restoration of wetlands, riparian edges and biodiversity on Nova Scotia farms (Wildlife Habitat Canada, 2009).

- ***Riparian Health Assessment Project:*** The *Riparian Health Assessment Project* involves the use of a GPS and GIS tool which can be used to assess the state of riparian zones in a watershed. The user walks the desired streams answering question about riparian health. The data is entered into GIS to produce a colour coded map indicating the relative health of stream reaches using the categories such as "healthy", "healthy with problems" and "unhealthy". Although the Riparian Health Assessment Project was completed in 2007/2008, Brian MacCulloch of Nova Scotia Agriculture continues to provide support to community stewardship groups such as the Bluenose Coastal Action foundation (B. MacCulloch, Nova Scotia Agriculture, personal communication, October 21, 2011).

Environmental Farm Plan: The Environmental Farm Plan (EFP) Program "helps farmers identify and assess environmental risk on their property. It enables farmers to incorporate environmental considerations into their everyday business decisions" (Nova Scotia Federation of Agriculture, 2011).

Specifically, the EFP Program helps to identify environmental concerns related to:

- Water sources
- Watercourses and ditches
- Nutrient management
- Manure storage and handling
- Fertilizer storage and use
- Pesticide storage and handling
- Waste handling and disposal
- Fuel storage and handling
- Soil management
- Irrigation management
- Commodity specific issues
- Wildlife habitat

The EFP Program is the only provincially funded, province-wide program designed to promote the use of vegetated riparian buffers, however at the time of writing, the federal funding for this program is scheduled to end in March 2013. This program has assessed approximately 80% of Nova Scotian farms and approximately 50% of these have undertaken the major recommendations made by the assessors (L. Cochrane, Nova Scotia Agriculture, personal communication, October 28, 2011).

3.6.2.5. Service Nova Scotia and Municipal Relations

Municipal Government Act: The Province has delegated land use zoning powers to the municipalities and does not require municipalities to adopt official planning documents (e.g., a Municipal Planning Strategy (MPS) or Land Use By-law). It can, however, require that any new planning conform to the Statements of Provincial Interest (SPI) set out in the Municipal Government Act (MGA). Municipalities do no have powers over crown land or environmental issues regulated by the Province (e.g., quarries) (Hynes & Graham, 2005).

The MGA contains five SPIs regarding issues of importance to the Province. The five statements cover the issues of flood risk areas, drinking water supply, housing, agricultural land and infrastructure. MPSs must be "reasonably consistent" with the statements (Service Nova Scotia & Municipal Relations, 2011). Of particular relevance to riparian and coastal management are the SPIs regarding flood risk areas (designed to protect public safety and property and to reduce the requirement for flood control works and flood damage restoration in five identified floodplains), and drinking water supply (designed to promote wise land use practices in water supply watersheds) (Service Nova Scotia & Municipal Relations, 2011). There is currently no specific SPI regarding coastal or riparian development.

Under the Canada-Nova Scotia Flood Damage Reduction Program, the 100-year flood plain is delineated and "a two zone approach has been used where future development is prohibited in the floodway, defined by the 20-year flood, but is permitted in the flood fringe if adequate flood proofing is carried out" (Environment Canada, 2010).

There are five participating communities in Nova Scotia:

- East River, Pictou County,
- Little Sackville River, Halifax County,
- Sackville River, Halifax County,
- Salmon and North Rivers, Colchester County, and
- West and Rights Rivers and Brierly Brook, Antigonish County (Environment Canada, 2010; Service Nova Scotia & Municipal Relations, 2011).

In is important to note that the SPIs are not designed to protect the environment, instead, they are intended to protect people and property (CBCL Ltd., 2009). In addition, The Minister of Service Nova Scotia and Municipal Relations has the power to establish an interim planning area if a municipality permits development that is inconsistent with the SPIs (Service Nova Scotia & Municipal Relations, 1998).

Municipalities are only expected to comply with SPIs when an existing MPS is amended or a new MPS is implemented. Given the frequency with which MPS are created and amended, the ability of an SPI requiring buffers or setbacks to create province-wide change is limited. In addition, approximately half of the provincial land area is regulated through MPSs (Service Nova Scotia and Municipal Relations, 2009). The municipalities of the counties of Colchester, East Hants, Victoria, Inverness, Richmond and Shelburne do not have comprehensive MPSs and only have planning document which apply to urbanized or water supply areas, or to wind turbines. This means that a portion of the province is unplanned, other than the province-wide standards set out by provincial subdivision regulations, building codes, and the *Environment Act* (Baccardax, 2008). The uneven nature of municipal planning in Nova Scotia further limits the ability of an SPI requiring buffers or setbacks to create province-wide change.

3.6.3. Municipal government

Under the Nova Scotia *Municipal Government Act*, municipalities are tasked with developing land use by-laws; vegetated buffer and setback requirements are generally enacted at this level. A comprehensive study of all municipal approaches to riparian and coastal zone protection was not undertaken due to the scope of this report; however the author drew heavily on a summary document created by Indeera Wimaladharma, an intern working under Nova Scotia Environment's Wetland Specialist, John Brazner in 2010.

Nova Scotian municipalities have adopted a range of setback by-laws. Setbacks are used more frequently than vegetated buffers in Nova Scotian municipalities. Only a few municipalities require setbacks or vegetated buffers for all or most land uses, or on all watercourse types. All of these include exemptions, conditions or variances which allow for a degree of flexibility during implementation. Many other municipalities require a setback for specific land uses or activities or around specific types of watercourses.

The most broadly applicable setbacks or vegetated buffers (i.e., those which apply to all or most watercourses) used by Nova Scotian municipalities range from 4.5-30.5 m in width. The setbacks which apply to agricultural and livestock-related structures and activities are approximately 100 m, however it should be noted that no municipality requires setbacks or vegetated buffers for row crops. Only two municipalities (HRM and Cumberland County) require a vertical setback of 2.5 m. In summary, while several Nova Scotian municipalities have implemented setbacks or vegetated buffers along watercourses, their application at the municipal level is inconsistent.

Table 3.6. A sample of municipal setback and vegetated buffer by-laws in Nova Scotia.

Municipality	Setback Distance & Land Use	Restrictions & Exemptions
Cumberland County	-30.5 m setback to be retained or restored along all coastlines and wetlands and areas prone to seasonal flooding or flooding due to high tides or storm surges. -15.24 m setback to retained or restored along all lakes, rivers (not prone to flooding), streams and intermittent streams. -2.5 m vertical elevation for residential dwellings -100 m setback for animal housing or manure storage facilities	**Restrictions:** within 30.5 m and 15.24 m shoreline buffers, all development and outdoor storage shall be prohibited. **Exemptions**: necessary "hard" shoreline stabilization works, one accessory building or structure or one attached deck which not larger than 20 m^2, small scale safety and security fences or structures, shoreline or water access facilities, docks, boardwalks, walkways and trails for non-motorized vehicles, traditional marine uses or the on-shore components of water based uses and other marine dependent uses, parks, conservation and historic uses and public roads and infrastructure.
Kings County	-15.24 m setback from the top bank of any watercourse for all permitted structures in all zones - No development in Coastal Shoreland Zones -No development in Environmental Open Space Zones (lands subject to flooding or otherwise posing a hazard & environmentally sensitive areas) -91 m setback for agricultural structures such as manure storage facilities -61 m setback for storage facilities of petroleum products or hazardous materials	**Exemptions**: (Growth centre of Port Williams only) driveways, paths, decks, patios, outdoor amenities and bridges. - (coastal shoreland zones only) agricultural uses, fish sheds, forestry uses, parks and recreation uses, seasonal dwellings, single detached dwellings, small-scale wind turbines, wind monitoring (meteorological) towers. - (environmental open space zones only) agricultural uses, flood control facilities, fishing & forestry uses, radio controlled aircraft fields.
Town of Yarmouth	No development in Flood Plain Zones or Environmentally Sensitive Zones	
Halifax Regional Municipality	-20 m vegetated buffer from all watercourses & coastlines -2.5 m vertical setback -61m vegetated buffer from the ordinary highwater mark of the Atlantic Ocean, Cow Bay or Barrier Pond, on the Cow Bay River, the 20 m vegetated buffer will be increased by 1 m per 2% increase in slope up to a maximum of 60 m (Eastern Passage-Cow Bay only)	**Restrictions:** no alteration of land levels or the removal of vegetation in relation to development. **Exemptions:** board walks, walkways and trails of limited width, fences, public road crossings, driveway crossings, wastewater, storm and water infrastructure, marine dependent uses, fisheries uses, boat ramps, wharfs, small-scale accessory buildings or structures and attached decks, conservation uses, parks on public lands and historical sites and monuments.
Queen's County	-15.24 m vegetated buffer from all the ordinary high water mark of all watercourses -100 m setback from watercourses for intensive livestock buildings	**Restrictions**: vegetation must be retained except 25% of vegetation along watercourse frontage to provide a view plane. **Exemptions:** boat houses, fishing gear sheds, Docks, wharves, piers, slipways, boardwalks, walkways and trails with a maximum width of 3.05 m, erosion control and flood control structures, removal of windblown, diseased, or dead trees, and limbing of tree branches.
Lunenburg County	-20 m setback from the ordinary high water mark of significant watercourses (Riverport & District Planning Area only) -7 m setback from the ordinary high water mark of significant watercourses (Osprey Village Planning Area only)	**Exemptions:** wharves and slipways, private boathouse/fishing gear, boat building and boat repair shops.
Town of Wolfville	-8 m setback from top of banks of all watercourses	**Restrictions:** Erosion and sedimentation control plans prepared by a licensed professional required for lots containing or adjacent to watercourses.

3.6.4. Canadian provincial case studies

Of the provincial coastal and riparian policies reviewed, five provinces were examined in detail. Newfoundland, New Brunswick, PEI, and British Columbia were chosen because they are coastal provinces with both setback and vegetated buffer policies in both coastal and riparian zones. Manitoba was chosen for its financial incentives, unique to Canadian provinces. It is interesting to note that approximately two-thirds of U.S. states bordering the coast or the great lakes have some type of setback (few have vegetated buffers) and of those that do not have state-mandated setbacks, most have delegated the task of establishing setbacks to municipal governments.

3.6.4.1. Newfoundland

Newfoundland's *Policy for Flood Plain Management* under the *Water Resources Act* applies to all lands and states that ideally floodplains and a 15 m buffer zone should "be preserved and left in their natural state" (the policy equates the 15 m buffer with the 100-year floodplain). Three floodplains are delineated: the 20-year and 100-year flood zones, and the climate change flood zone (the area likely to be impacted due to the forecasted effects of climate change). Activities are either permitted, permitted with conditions (e.g., that the ground floor be above the 100-year flood level or the climate change flood zone where designated), or prohibited in one or more of the three zones.

- Temporary alterations, non-structural uses and hydraulic structures are permitted in all three zones.
- Institutional developments are prohibited in all three zones.
- Non-residential structures and industrial uses related to shipping are permitted with conditions in all three zones.
- Residential development is not permitted in the 20-year zone but is permitted with conditions in the 100-year and climate change flood zones.
- Industrial and commercial development is not permitted in the 20-year zone but is permitted with conditions in the 100-year and climate change flood zones.

Any vulnerable development placed in a flood plain or designated flood risk area after the designation and not in conformance with this policy is not be eligible for provincial disaster relief funds.

3.6.4.2. New Brunswick

The 2003 *Watercourse and Wetland Alteration Regulation* under *the Clean Water Act* requires a permit be issued to carry out activities deemed an 'alteration' (e.g., remove vegetation, build or renovate structures within 30 m of a watercourse or wetland). Two types of permits are issued: the "standard permit" applies to projects large enough to involve design or investigation by a professional engineer (e.g., bridges, dams or large culvert installations), and the "provisional permit" applies to smaller projects such (e.g., landscaping or non-merchantable vegetation removal). The *Watercourse and Wetland Alteration Regulation* does allow for permitted activities (with conditions) within the 30 m regulated buffer of mapped watercourses, and within 30 m of wetlands that are not 'Provincially Significant Wetlands' (PSWs). Only a very limited amount of new activities, alterations, or development are permitted within 30 m of a wetland designated as a PSW; this directive is a result of the objectives of the New Brunswick *Wetlands Conservation Policy* which identifies acceptable activities within 30 m of PSWs. PSWs includes all coastal wetlands and all wetlands associated within the floodplain of the lower Saint John River located below the Mactaquac Dam.

Where a regulated watercourse or wetland exists, the directives of the *Coastal Areas Protection Policy for New Brunswick* require a 30 m setback for all new activities/alterations/development from the landward edge of the "coastal feature" (beaches, dunes, rock platforms, coastal marshes and dyked lands – see Figure 3. and Figure 3.). Along the coastline, where open sea exists, but no regulated watercourse or wetland exist, the directives of the *Coastal Areas Protection Policy for New Brunswick* (no new development within 30 m of the landward edge of the coastal feature or ‘coastal buffer’) would be conveyed to planning authorities by New Brunswick Environment’s review process. In the case of dwellings or other permanent infrastructure the Policy directives would not recommend installation of any permanent infrastructure within the 30 m coastal buffer and New Brunswick Environment would not issue any approval or permit for development in this zone. (R. Capozi, personal communication, November 25, 2011).

Existing structures located within the 30 m zone are allowed to expand the building footprint by 40% (one time only), and the expansion must be done on the landward side of the structure; if an expansion greater than 40% is desired, it must be added vertically. Whereas the *Watercourse and Wetland Alteration Regulation* allows tree cutting with a permit, no alteration of vegetation is permitted in the 30 m coastal setback zone. Approximately 600-700 coastal development projects are assessed annually (R. Capozi, personal communication, November 25, 2011).

New Brunswick has taken a novel approach to defining what activities are permitted and prohibited in the vegetated riparian and coastal buffers. Instead of listing the prohibited activities the permitted activities are listed. This shift in language was intended to enhance the legal foundation of the policy by clarifying the specific allowable activities; any activity not found on the list is not permitted.

Presently, the Government of New Brunswick is reviewing their approach to disaster relief payments. Under the present system of disaster relief a property owner can make a single disaster relief claim of up to $80,000 if their principle residence is flooded, damaged or destroyed (R. Capozi, personal communication, November 25, 2011).

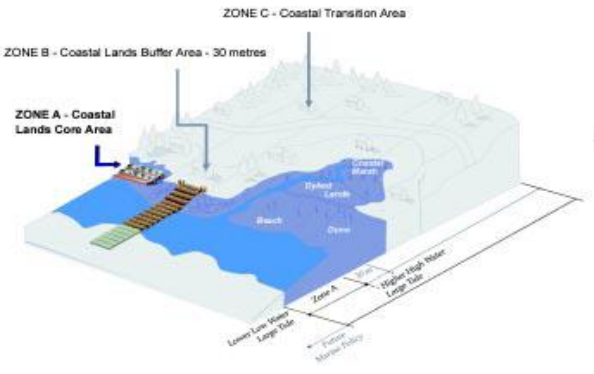

Figure 3.8. New Brunswick Coastal Policy Zone A, coastal lands core area. The most sensitive zone includes beaches, dunes, rock platforms, coastal marshes and dyked lands (NB Department of Environment & Local Government, 2002).

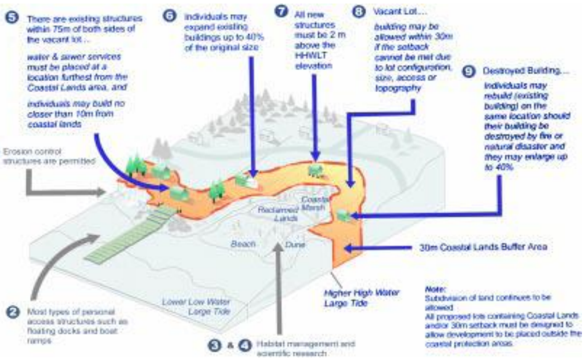

Figure 3.9. New Brunswick Coastal Policy Zone B, coastal lands buffer area. Consists of an area 30 m landward from the inland edge of Zone A (NB Department of Environment & Local Government, 2002).

3.6.4.3. Prince Edward Island

The 2008 *Watercourse & Wetland Protection Regulations* under the *Environmental Protection Act* require a 15 m vegetated buffer along all watercourses and wetlands for all land uses (including existing properties). A permit is required to undertake certain activities within the vegetated buffer including tree removal and construction. Permits are tracked in a central database which helps prevent cumulative impacts by multiple permits. New permitting and licensing systems have been implemented to deal with the increased administrative burden. If farmers allow the planting of trees in the first 5 m of riparian vegetation, they receive an annual payment under the province’s Alternative Land Use Services program (B. Raymond, PEI Department of Environment, personal communication, November 9, 2011).

PEI provides an Alternative Land Use Services (ALUS) program which financially compensates farmers if they remove additional land from agricultural production beyond the 15 m required by law.

Activities eligible for compensation include taking land out of production to establish soil conservation structures, planting native trees in the 15 m vegetated buffer, planting grassed headlands, expanding the vegetated buffer, retiring high-sloped land and erecting fencing to exclude livestock. Compensation rages from $100 - $250/hectare per year or $0.30/metre per year.

PEI combines coastal setbacks and vegetated buffers in an approach that is somewhat complex but rigorous. As mentioned above, the *Watercourse & Wetland Protection Regulations* require a 15 m vegetated buffer along all watercourses (including the ocean). In addition, the *Planning Act* requires that structures be set back 23 m, or 60 times the annual erosion rate, or 23 m from the top of sand dunes, whichever is larger. The annual erosion rate is derived from aerial photographs and is provided to developers upon request.

3.6.4.4. Manitoba

The *Water Protection Act* has the protection of riparian zones as an objective and requires that watershed management plans must contain prescriptions for protecting riparian zones. Manitoba's *Forest Management Guidelines for Terrestrial Buffers* (valid from 2010 to 2015) require that forestry operation remove only merchantable timber from riparian zones, retain all shrubs and understory vegetation, prohibits the use of heavy machinery within 7 m of watercourses. These guidelines must be adhered to when forestry operators develop their annual operating plans which must be approved by Manitoba Conservation.

Manitoba has a Riparian Tax Credit program that allows farmers who make a 5 year commitment (between 2011 and 2015) to claim $20-$28 per year per acre for farmers if they restore a 30 m vegetated riparian buffer and exclude cattle from watercourses. Although not specifically related to riparian zones, the Government of Manitoba partnered with Manitoba Water Stewardship, Ducks Unlimited Canada, and the Manitoba Habitat Heritage Corporation to provide a Wetland Restoration Incentive Program which pays land owners $200 per acre to restore 40 acres of wetlands drained before 2006. The use of financial incentives in Manitoba and PEI is unique in Canada.

3.6.4.5. British Columbia

The Government of BC delegates the management of riparian and coastal zones to local governments. The *Riparian Areas Regulation* states that municipalities must not allow developments in riparian areas to proceed until the Ministry of Environment and DFO have received a site assessment from a Qualified Environmental Professional (QEP), or until DFO has authorized a harmful alteration of fish habitat. QEPs assess the effects of the proposed development within 30 m of a stream and then suggest a vegetated buffer width and conditions that will protect "natural features, functions and conditions" of the riparian zone. This regulation only applies to 14 municipal governments. It does not apply to agricultural or institutional developments.

BC requires that forestry operators on crown land retain a vegetated riparian buffer in the *Forest Planning and Practices Regulation* under the *Forest and Range Practices Act.* These regulations classify rivers into seven categories based on the size of the stream and whether or not it is fish-bearing. As a rule, wider vegetated buffers are required on wider rivers. Specifically, the regulation requires a "Reserve Zone" immediately adjacent to the river in which herbicides, mechanized site preparation, spacing or thinning are prohibited, and a "Management Zone" in which a minimum of 10-20% of the basal area must be retained (percentage depends on stream classifications).

BC is in the process of consulting the public on its draft *Guidelines for Management of Coastal Flood Hazard Land Use*, which if approved, will provide local governments with a set of BMPs based around sea level rise projections for 2100 and 2200. Municipalities that have chosen to adopt flood management plans have acquired LIDAR data for their regions in order to delineate 2100 and 2200 sea levels. Local governments must undertake their own mapping to determine and plan for the local effects of the 2100 and 2200 year sea levels. The *Guidelines* build upon an existing coastal setback of 15 m (or more depending on erodibility of the coastal feature) from the visible high water mark in the 1996 *Land Act*. If a development is approved by local government but doesn't meet the standards set out in the *Guideline*, the developer is ineligible for provincial disaster relief.

In summary, several Canadian provinces have riparian and/or coastal buffer policies, and many place conditions on disaster relief funding and/or provide financial incentives as a mechanism to control waterfront development. Compared to Newfoundland, New Brunswick, PEI, Manitoba, and BC, Nova Scotia is somewhat of a laggard: legislated province-wide vegetated buffers and setbacks are only required for forestry operations and for on-site septic systems respectively, and the federal funding for the one program offering financial incentives for riparian restoration– the Environmental Farm Plan – is slated to end in 2013. Other industries are subject to permit-based setbacks, such as the mining industry, however, there is no province-wide legislation, regulation or policy for vegetated buffers or setbacks in Nova Scotia.

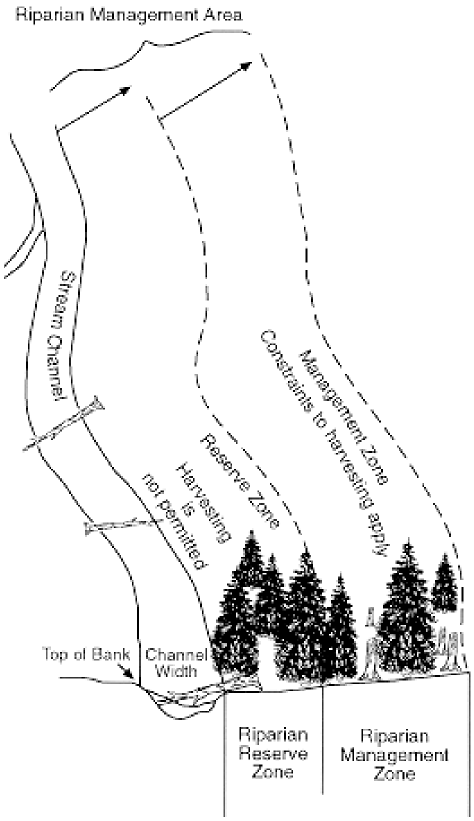

Figure 3.10. A hypothetical layout of a management zone and a riparian reserve zone along a stream channel in BC (Government of British Columbia, 1995).

3.6.5. Riparian & coastal regulations and policies in the U.S.

Many US states have riparian and/or coastal policies regarding vegetated buffers and setbacks (Blinn & Kilgore, 2001; Lee *et al*., 2004; Bernd-Cohen & Gordon, 1999). In the U.S., the 'public trust doctrine' has played a central role in the development of federal and state coastal and riparian management efforts (Sterrett Isely & Pebbles, 2009). The public trust doctrine is a legal principle that holds that certain natural resources and spaces (e.g., oceans, beaches, rivers, lakes, wildlife) should not be privately owned and/or should be protected for the benefit of the whole community, often for the purposes of public access, navigation, fishing, recreation and aesthetics (Pentland, 2009; Sterrett Isely & Pebbles, 2009). In general, financial incentives and market-based approaches are used more frequently in the U.S. than in Canada, particularly for riparian management. Setbacks are more popular in coastal zones than vegetated buffers, and setbacks tend to be based on annual erosion rates. Table 3.7, 3.8 and 3.9 list the policies and programs in place in the U.S. for coastal zones, forestry operation in riparian zones, and non-forestry riparian zones respectively.

Coastal Zones

U.S. law relinquishes coastal management to states but provides no requirements or incentives for states to adopt consistent regulations or to collaborate in coastal management (Sterrett Isely & Pebbles, 2009). In 1972, the U.S. federal government established the *Coastal Zone Management Act*. Under this Act, the national Coastal Zone Management Program was established. Administered by the National Oceanic and

Atmospheric Administration (NOAA), the Coastal Zone Management Program - a federal–state partnership - provides financial and technical assistance to states that create their own coastal zone management programs (Sterrett Isely & Pebbles, 2009). The *Coastal Zone Management Act* gives states flexibility for state-level coastal management while also acting as a mechanism to promote consistency between state-level plans and the federal Act (Sterrett Isely & Pebbles, 2009).

In the U.S., all 100-year coastal floodplains are designated as coastal hazard zones (USFEMA, 2010). Through the U.S. Federal emergency Management Agency (USFEMA), the U.S. federal government created the National Flood Insurance Program (NFIP) in 1968 which provides flood insurance in areas known to experience frequent flooding (e.g., in 100-year floodplains; USFEMA, 2012; Harris et al., 2010; Keeler *et al.*, 2003). In order to qualify for flood insurance, a community must agree to enforce sound floodplain management standards (USFEMA, 2012). The NFIP does not provide insurance for erosion-based damage unless the erosion is caused by a storm (Keeler *et al.*, 2003).

According to Bernd-Cohen & Gordon (1999), 22 U.S. states and territories (e.g., Guam, Virgin Islands) use setbacks in coastal zones (the Great Lakes are included as coastal zones). Of these, 10 states delineate their setbacks based on an arbitrary distance from the shoreline, four delineate setbacks using erosion rate data (Florida, Michigan, Pennsylvania, Virginia), three delineate setbacks according to distinct coastal features (New York, Oregon, South Carolina), and five delineate setbacks using a combination of arbitrary distance, erosion rates, and coastal features (Maine, New Jersey, North Carolina, Rhode Island, Virgin Islands) (Bernd-Cohen & Gordon, 1999). Bernd-Cohen & Gordon (1999) argue that North Carolina and Pennsylvania have the most sophisticated and information-based methods for delineating coastal setbacks – these are described in detail below. Table 3.7 lists several coastal setback policies in the U.S.

[3] *“***North Carolina’s Oceanfront Setback Law:** This strong law uses erosion rates to determine setbacks and keep development out of ocean hazard areas. Within the “Ocean Hazard Areas of Environmental Concern”—sand dunes, ocean beaches, and other areas exhibiting substantial possibility of excessive erosion—setbacks are based on average annual erosion rates, natural site features, and the nature of the proposed development. The setback is measured from the first line of stable natural vegetation or from aerial photos and ground survey where there is no stable vegetation. New structures smaller than 5,000 square feet [465 square metres] and fewer than five residential units must be set back the farthest landward of the following:

- a distance equal to 30 times the long-term annual erosion rate;
- the crest of the primary dune;
- the landward toe of the frontal dune; or
- 60 feet [18.3 m] landward of the vegetation line.

The law requires that larger structures be set back 60 times the average annual erosion rate, or 120 feet [36 m] landward of the vegetation line. Where erosion rates exceed 3.5 feet [1.1 m] per year, the setback line for larger structures is 30 times the erosion rate plus 105 feet [32 m]. This law was passed in 1974, made part of the coastal program in 1978, and amended in 1981 to make additional allowances for single family residences. The coastal program supports studies of erosion rates used in determining setbacks (North Carolina State Statute 113A and Coastal Area Management Act, Areas of Critical Concern Administrative Guidelines).

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[3] From Bernd-Cohen and Gordon’s (1999) *State Coastal Program Effectiveness in Protecting Natural Beaches, Dunes, Bluffs, and Rocky Shores.*

Pennsylvania Bluff Recession and Setback Act: This act provides a long-term regulatory approach to reducing property losses from bluff recession along Lake Erie. The act requires municipalities in bluff recession hazard areas to administer bluff setback ordinances that restrict new development from bluff areas and limit improvements to existing structures within the minimum bluff setback. Setback distance is based on the rate of erosion (feet per year) multiplied by the life span of the structure and is a minimum of at least 50 feet [15 m] from the crest of the bluff. The life span for residential development is 50 years, for commercial is 75 years, and for industrial is 100 years. The major effect of this program has been to keep new development a safe distance from bluff recession hazard areas. [The Coastal Resources Management Program] provides technical assistance to Lake Erie property owners affected by bluff recession; this assistance consists of on-site inspections and recommendations for surface and groundwater control, bluff stabilization, and the role of vegetation to stabilize loose soil conditions. In the first seven years of the service (1981–1988), approximately 75% of the surveyed property owners followed [The Coastal Resources Management Program's] recommendations, resulting in an estimated property damage savings and property value enhancement of $5.2 million. Pennsylvania is the only Great Lakes state to offer this service (S. Malone, phone interview and correspondence, September–October, 1996)."

Table 3.7. Examples of U.S. state coastal setback approaches. Feet converted to metres (Friis, 2006 in Sterrett Isely & Pebbles, 2009; NOAA, 2010; Bernd-Cohen and Gordon, 1999; Maine Department of Environmental Protection, 1993; Maui Planning Commission, 2007; Burbidge, 2008; State of California, 2010).

State	Setback Policy
Michigan	Vary based on a number of factors, including the average annual rate of erosion, the presence of stabilizing vegetation, and the characteristics of the proposed building (footprint size, foundation type, wall construction materials); these are applied to both new construction and modifications to existing structures. Nonconforming structures are allowed to remain, but limits are placed on repairs and modification.
Minnesota	Identifies coastal erosion hazard areas for which setbacks are required. Minnesota requires a site development plan for new construction, and setbacks vary depending on the established long-term erosion rate. Nonconforming structures are allowed to remain, but limits are placed on repairs and modification.
New York	Identifies coastal erosion hazard areas for which setbacks are required, prohibits new construction or other land disturbances in Natural Protective Feature Areas, and requires setbacks for Structural Hazard Areas that depend on the Long Term Average Annual Recession Rate. Nonconforming structures are allowed to remain, but limits are placed on repairs and modification.
South Carolina	Setback line for ocean-front property of 40 times the annual erosion rate (minimum setback is 6.1m). The baseline and setback lines are revised every 8-10 years. Lots seaward of the setback line can be developed but no hard shoreline stabilization structures can be used to protect the property. However, some "soft" erosion control methods can be used including beach re-nourishment, building up artificial dunes, and temporarily placing small sandbags around a home. If homes are damaged or destroyed during a storm, they are allowed to rebuild as long as high ground still exists. If the lot is submerged during high tide, rebuilding/repairing is no longer allowed.
Wisconsin	Fixed setbacks. May require removal of a structure if it is not in the public interest to remain or if it impacts certain public rights, such as scenic beauty.
Maine	All development projects are prohibited in areas of the coastal sand dune systems that may reasonably be expected to erode within 100 years, after allowing for a 0.9 m rise in sea level. No new structures or additions to existing structures are permitted seaward of a frontal dune or in the 100-year floodplain. Shoreline setback 23 m for residential; 7.6 m for general development/commercial; 76 m from normal high water line in Resource Protection Areas. There is also a building size restriction of 10.6 m in height and 232.3 m^2 in area within a coastal sand dune system. A permit is not required for maintenance and repairs unless the repair is to more than 50% of a structure or results in an additional intrusion into the sand dune system. The reconstruction of buildings severely damaged by wave action from a coastal storm must meet certain setback requirements and buildings located within the most hazard-prone areas cannot be reconstructed more than once.

New Hampshire	There are two coastal setback lines designated under the *Comprehensive Shoreland Protection Act*, known as the primary building line and the accessory building line: Primary building line - 15.2 metres landward from highest observable tide line Accessory building line - 6.1 metres landward from highest observable tide. A permit is required for the construction of water-dependent structures in the shoreland zone, including shoreline protection structures. Non-conforming structures are allowed to be repaired, renovated, or replaced provided the result is a "functionally equivalent use" and that there is no expansion of the existing footprint or outside dimensions. Municipalities are encouraged to adopt land-use control ordinances which are more stringent than the minimum standards contained in the *Comprehensive Shoreland Protection Act*.
California	New development shall do all of the following: • Minimize risks to life and property in areas of high geologic, flood, and fire hazard • Assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs
Massachusetts	While there are no specific state-wide standards for land-use and development in coastal areas, local governments have the authority and responsibility to manage development in hazard-prone coastal areas. For this reason, the Massachusetts Office of Coastal Zone Management encourages municipalities to adopt a "No Adverse Impact" approach to land management in the coastal zone.
Island of Maui, Hawaii	All lots shall have a shoreline setback line that is the greater of the distances from the shoreline as calculated under the methods listed below or the overlay of such distances: (a) 7.62 m plus a distance of fifty times the annual erosion hazard rate from the shoreline; (b) Based on the lot's depth as follows: (i) A lot with an average lot depth of 30.5 m or less shall have a shoreline setback line 7.62 m from the shoreline; (ii) A lot with an average lot depth of more than 30.5 m but less than 49 m shall have a shoreline setback line 12.2 m from the shoreline; and (iii) A lot with an average lot depth of 49 m or more shall have a shoreline setback line located at a distance from the shoreline equal to twenty-five percent of the average lot depth, but not more than 46 m (c) For irregularly shaped lots, or where cliffs, bluffs, or other topographic features inhibit the safe measurement of boundaries and/or the shoreline, the shoreline setback line will be equivalent to twenty-five percent of the lot's depth as determined by the Director, to a maximum of 46 m from the shoreline

Riparian zones

As in Canada, riparian zone management is widely used in the U.S. forestry sector (Table 3.8). Many U.S. states use financial incentives to encourage the retention of riparian vegetation in non-forestry sectors, particularly for agricultural lands. The U.S. Department of Agriculture has created a number of programs to encourage the protection or restoration of riparian vegetation. For example, the Conservation Reserve Enhancement Program is a voluntary land retirement program that helps agricultural producers protect environmentally sensitive land, decrease erosion, restore wildlife habitat, and safeguard ground and surface water. The Stewardship Incentive Program provides up to 65% cost share for forest management plan development, tree planting, riparian and wetland improvement, and recreation and wildlife habitat improvement. The Wildlife Habitat Incentives Program helps private landowners improve fish and wildlife habitat by sharing 75% of costs of installing approved practices. Table 3.9 lists several non-forestry riparian zone policies in the U.S.

Table 3.8. Regional differences in total vegetated buffer widths for forestry operations in the U.S. and Canada for permanent streams (Large = > 5m wide, Small = <5m wide), intermittent streams, and lakes (Small = < 4ha, large > 4 ha) (Adapted from *Lee et al.,* 2004 in Neary *et al.*, 2011).

Watercourse Type	**Northeast**	**Rocky Mountain**	**Pacific**	**Midwest**	**South**	**Boreal**
Number of Jurisdictions	16	9	6	9	11	13
Size (m)						
Streams						
Large	29.7	24.4	24.3	25.7	19.4	39.1
Small	23.7	24.2	22.7	14.4	17.5	26.3
Intermittent	13.1	24.2	21.7	11.5	12.1	13.9
Lakes						
Small	30.6	23	22.7	21.7	17.4	45.8
Large	30.2	23	22.7	21.7	17.4	52.2

Table 3.9. Examples of U.S. state riparian zone management policies. Feet converted to metres (University of Vermont-Vermont Legislative Research Shop, 2008; Maryland Department of Natural Resources - Conservation & Restoration Services, 2003; Minnesota Forest Resources Council, 2005; State of Washington, 2005).

State	**Buffer Policy**
Maine	The *Shoreland Zoning Act* requires municipalities to adopt shoreland zoning maps and ordinances in order to protect the state's water resources. The law considers shorelands to be all areas 76.2m from the high water lines of great ponds, rivers, saltwater bodies, and coastal wetlands, and 23m from a stream. The municipalities are required to have zoning ordinances for all land that this law considers shoreland. The state publishes guidelines for municipalities, but does not necessarily require that they abide by the guidelines. There are also additional state laws that designate specific waterways as "significant river segments" that deserve additional protection.
Georgia	Georgia's Conservation and Natural Resources Act of 2007 mandates that "a natural vegetative buffer area shall be maintained for a distance of 30.5 m on both sides of the stream as measured from the stream banks." The act requires local governments to map the areas surrounding rivers and streams and create zoning laws in accordance with the act. There is a significant exception to the act, which is that it cannot prohibit the building of a single-family home on a property of at least two acres.
Massachusetts	The Massachusetts Rivers Protection Act creates a protected area extending 60 m on both sides of most rivers and streams in the Commonwealth. The designated area is only 7.6 m in certain urban areas. The state defines a river as "any natural flowing body of water that empties into any ocean, lake, or other river and that flows throughout the year." Structures existing before the implementation of the act are exempted.
Virginia	The "Riparian Buffer Tax Credit" Program enacted in 2000 provides a tax incentive to landowners to leave a riparian forest buffer strip from [10.6 m] up to [91.5 m] wide. The credit may only be claimed in the first year of this fifteen year period, after which the land is again eligible for the credit. Additionally, the tract of land (timber harvesting area and buffers together) must be at least ten acres in size. The credit is worth 25% of the value of the timber retained as a buffer, up to a maximum value of $17,500, and must be claimed in the year in which timber on the adjacent land was harvested.
Maryland	The purpose of the Maryland State Buffer Incentive Program is to establish and maintain streamside forested buffers around the Chesapeake Bay and its tributaries; it is administered by the Maryland DNR Forest Service. A one-time incentive payment of $300 per acre on acres planted [converted] to forested buffers upon verification of 65% seedling survival rate after 1 year. A reduced payment of 50% is payable for a survival rate of 50% to 65%. Maximum payment $15,000. Property must meet one of the following three criteria: 1) be within 300 ft. of a stream, river, pond or non-tidal wetland; or 2) be with 300 ft. plus 4 ft. for every 1% slope for slopes averaging greater than 6%; or 3) be within the 100-year floodplain. - Private landowner must have 1 to 50 acres which is cropland, pastureland, or open or bare ground with early successional vegetation.

Vermont	•Under Vermont's *Act 250*, no development is permitted that will -cause undue pollution to headwaters, floodways, streams, wetlands or shorelines, erosion or the capacity of the land to hold water, -not tax water supplies. Proposed developments must apply for a permit, not have an undue adverse effect on aesthetics, scenic beauty, historic sites or natural areas, and will not imperil necessary wildlife habitat or endangered species in the immediate area. •Under Vermont's *Accepted Agricultural Practice Regulations*, a vegetative buffer zone of perennial vegetation shall be maintained between annual croplands and the top of the bank of adjoining surface waters consistent with (a) through (f) below, in order to filter out sediments, nutrients, and agricultural chemicals and to protect the surface waters from erosion of streambanks due to excessive tillage. Vegetative buffer zones are not required along intermittent stream channels such as those occurring in annual croplands or along drainage ditches. (a) adjoining surface waters shall be buffered from annual crop lands by at least 3.1 m of perennial vegetation. (b) an additional 4.5 m of perennial vegetation shall be established at points of runoff to adjoining surface waters. (c) no manure shall be applied within vegetative buffers. (d) use of fertilizer for the establishment and maintenance of the vegetative buffer is allowed. (e) tillage shall not occur in a vegetative buffer except for the establishment or maintenance of the vegetative buffer. (f) harvesting the vegetative buffer as a perennial crop is allowed.
Minnesota	The recommended Special Management Zones [SMZs – i.e., vegetated riparian buffers] widths are greater for trout waters (45.7 to 61.0 m), larger water bodies (30.5 to 61.0 m), and uneven-aged forest management. No SMZ widths are recommended for intermittent streams and drainages. -Width and residual basal area guidelines are recommendations not mandates and it is acceptable to vary above and below width and basal area guidelines - SMZ boundaries can be straight or irregular and slope aspect should not govern SMZ locations -Trees left as residuals should be relatively evenly distributed but can be in even or in gap-bunch distributions and cleared areas in the SMZ should be minimized -The best professional judgment should be used to determine species and distributions of residual trees considering site conditions, tree species, wildlife needs, clumps needed to reduce wind-throw hazard, gaps needed for regeneration of shade-intolerant species, needs to retain trees near waterbody banks, and other management objectives needs. -Distributions of individual trees should consider species distributions and arrangements, regeneration requirements, species-specific crown sizes, wind-firmness, the presence of insect and disease stressors, and needs to retain conifers near trout water bodies. -Tradeoffs need to be recognized.
Washington	The State of Washington uses three riparian management zones – a Core, Inner and Outer zone - (i.e., a "feathered" approach) for forestry operation on large of fish-bearing streams. The core zone must be 15.3 m wide, however the width of the Inner and Outer zones are based on site class, bankfull width and the management option selected by the landowner. Different harvesting practices are permitted in each zone, with no harvesting permitted in the Core zone. There are different prescriptions in the Western Washington region than in the Eastern Washington region.

4. Analysis

4.1. Decisions necessary for implementation of setbacks and vegetated buffers

Analysis reveals that the process to decide which strategy is most suitable for implementing a vegetated buffer or setback can be broken down into ten sequential stages, or questions to be answered (for riparian zones see Figure 4.1, for coastal zones see Figure 4.2 – both figures are similar but not identical). Three key elements of the decision-making process are the determination of the policy objectives, appropriate design of vegetated buffers or setbacks, and the appropriate regulatory approach. Identifying policy objectives will help determine the appropriate management tool (i.e., vegetated buffer or setback). The design element of the decision-making process involves choosing whether setbacks or vegetated buffers will apply to all land uses or only some, to all or only certain types of stream or coast, the width of the vegetated buffer or setback, etc. One or more regulatory approaches must be identified; for example, best management practices, legislation, education campaign, permits, etc. The contents of Figure 4.1 and 4.2 are described in detail in the following section.

Research of different jurisdictions shows that vegetated buffers are most frequently used in riparian zones and setbacks are most frequently used in coastal zones, however, it is important to remember that vegetated buffers and setbacks can be used separately or together in either riparian or coastal zones. While the use of vegetated buffers and setbacks is becoming increasingly popular, there is no 'standard' approach amongst jurisdictions. Few jurisdictions use one design to the exclusion of all others; this would constitute an over-simplified approach which fails to address the complexity of coastal and riparian zones as well as the regulatory or political environment.

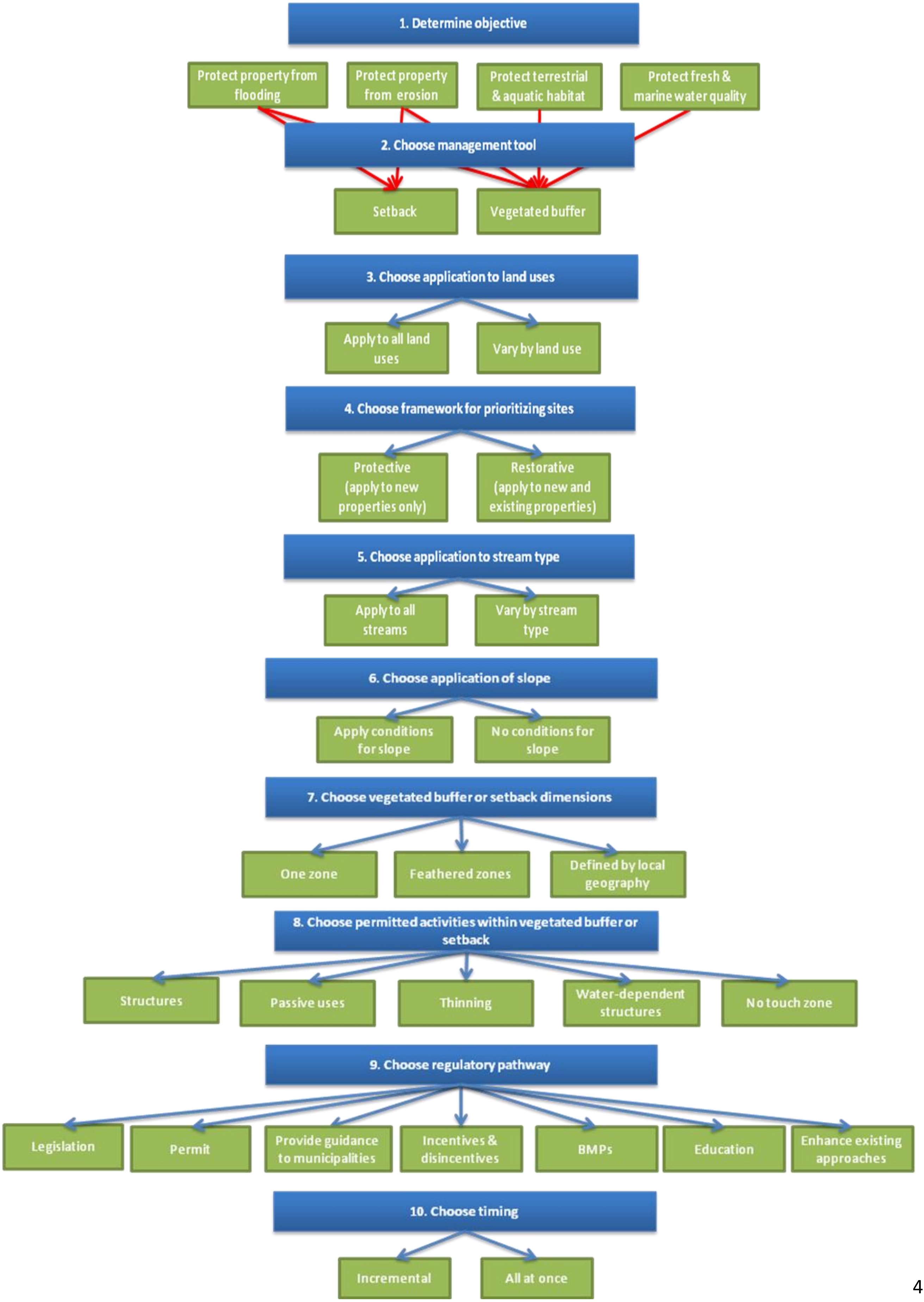

Figure 4.1. Decision making framework for designing vegetated buffers or setbacks in riparian zones.

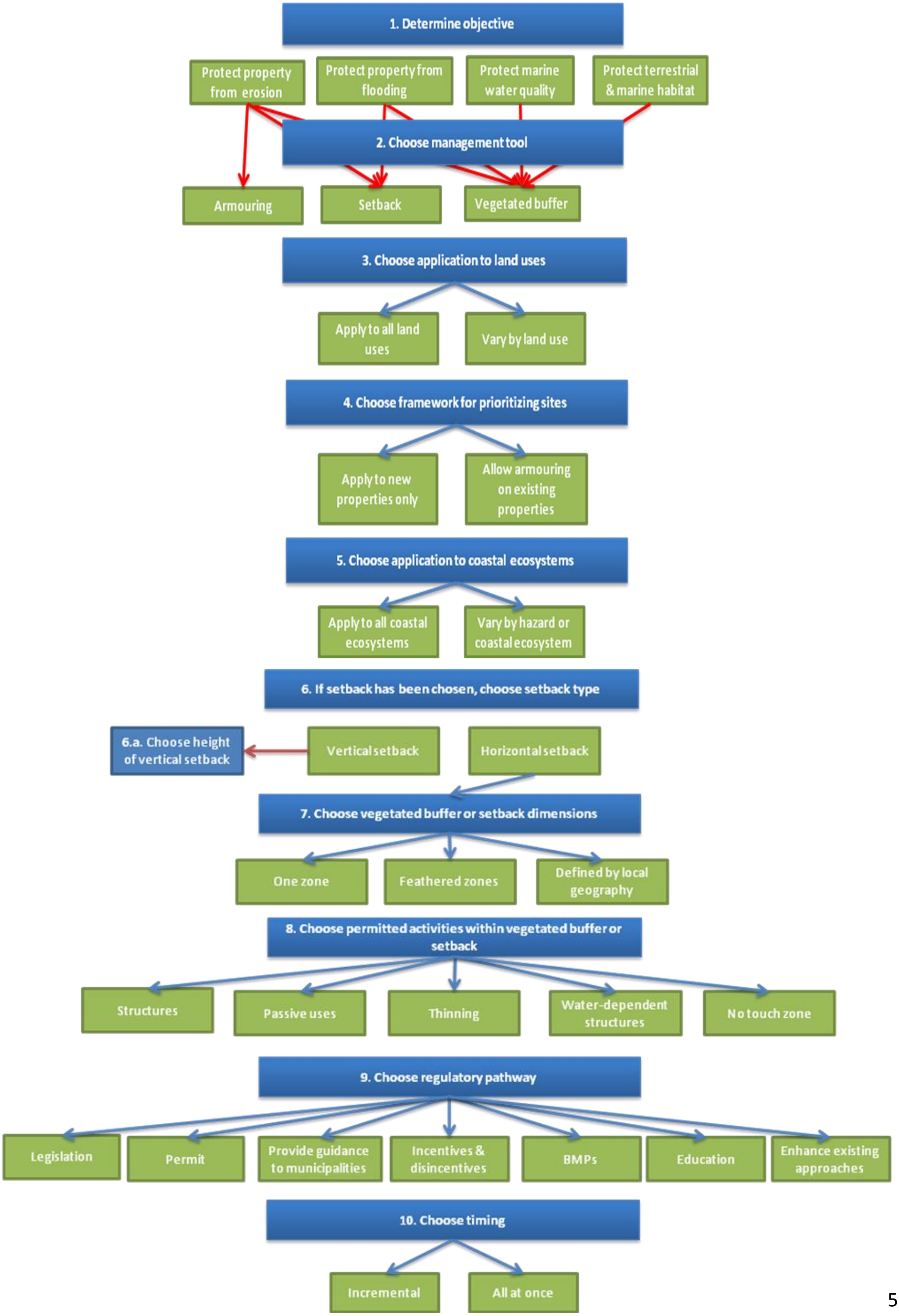

Figure 4.2. Decision making framework for designing vegetated buffers or setbacks in coastal zones.

4.1.1. Policy objectives

The first and most important step in the decision of where, how and when to use vegetated buffers or setbacks, is to determine the desired policy outcome. Before the Province can decide whether to use vegetated buffers or setbacks, which land uses will be subject to new programs, or a setback width is chosen, the Province must clearly articulate what its objectives are for the use of vegetated buffers or setbacks in riparian and/or coastal zones. Vegetated buffers and setbacks are management tools that perform very different functions in riparian and coastal zones; different tools are required to address different policy objectives.

Riparian zones

Four policy objectives which can be addressed by vegetated buffers or setbacks in riparian zones have been identified. They are:

- Protect property from flooding
- Protect property from erosion
- Protect fresh and marine water quality
- Protect terrestrial and aquatic habitat

As discussed in *Appendix C*, riparian vegetation, particularly when there is a very wide vegetated buffer, can slow the flow of water over land, promotes infiltration and reduces peak flows which can cause flooding. Riparian vegetation filters pollutants (sediment, nutrients, bacteria, pharmaceuticals, salt, and toxins) from overland runoff and improves water quality, both in inland watercourses and marine waters. Riparian vegetation provides habitat for terrestrial and aquatic species. A setback will protect property from flooding and erosion by separating human activities from immediate impacts of these processes. Flooding and erosion will still occur, but will pose less of a threat to people and property.

Coastal zones

Four policy objectives which can be addressed by vegetated buffers or setbacks in coastal zones have been identified. They are:

- Protect property from flooding
- Protect property from erosion
- Protect marine water quality
- Protect terrestrial and marine habitat

Setbacks in coastal zones protect property from flooding and erosion by separating human activities from immediate impacts of these processes. As in riparian zones, flooding and erosion will still occur, but will pose less of a threat to people and property. Vegetated buffers along the coast can trap nonpoint source pollution and enhance marine water quality, which can in turn benefit marine habitat. Vegetated buffers also provide habitat for terrestrial species.

The author recommends that the Province undertake discussions to determine which of these objectives (or others) are of importance to government, and which should be prioritized or if they are all determined to be important. Once the selection and prioritization of policy objectives is completed, the Province can proceed to the next step: determining the appropriate management tool; vegetated buffers or setbacks.

4.1.2. Appropriate management tool

The literature shows that it is the vegetation along watercourses which provides most of the value derived from coastal and riparian zones (e.g., water quality control, protection from flooding and erosion, habitat provision, bank stability) whereas setbacks provide fewer, but important, functions (e.g., protection from flooding and erosion) (see Figure 3.1).

Setbacks: As defined in Section 3.1 a setback is a separation distance between two activities or features in order to reduce conflict (e.g., residential housing and wind turbines), or minimize impact (e.g., industrial development and a watercourse). A setback does not require the retention of vegetation; it is merely a separation distance. As such, setbacks can be used to separate development from natural processes such as erosion and flooding. They are used more frequently in coastal zones where storm induced erosion and wave action causes significant damage on a regular basis, however they can also be used in riparian zones as flooding and smaller scale erosion still pose threats to people and property.

Vegetated Buffers: It is very important to note that many benefits are derived from the vegetation adjacent to watercourses that cannot be provided by setbacks. In particular, the filtration function of riparian and coastal vegetation can enhance water quality whereas setbacks have a neutral or even negative impact on water quality. Stormwater mitigation and habitat and connectivity values are also provided by vegetation and not by setbacks.

To reiterate, setbacks can most certainly protect people and property from flooding and erosion, but they cannot provide the same or as many benefits as vegetated buffers. If the priority policy objectives are to protect property from flooding and erosion, then setbacks will suffice. If the priority policy objectives are to protect marine water quality or terrestrial and marine habitat, then vegetated buffers will be required (see steps 1 and 2 in Figure 4.1 and Figure 4.2).

4.1.3. Application to land use

The province must determine which land uses or activities will be subject to any new vegetated buffer or setback programs. There are two approaches involved in this step: setbacks or vegetated buffers can be applied to all land uses and activities, or they can be applied to one or more specific land uses or activities.

Apply to all land uses ("Universal" approach): A universal approach is one in which a vegetated buffer or setback policy is applied to all sectors and land uses. Many jurisdictions, including New Brunswick and PEI, use this approach in order to ensure that riparian and/or coastal zones are uniformly protected. However, it is possible that larger buffer/setback widths would be unpopular with certain sectors and that smaller widths may be the only politically feasible option, which would result in reduced protection of ecosystem functions. Likewise, the use of a universal approach means that a policy would not be tailored to address the different ecosystem impacts of specific sectors.

> ***Pros:*** Simple for government to implement, and for the public to understand. Could be perceived as fair in the sense that a "universal" policy would apply to everyone and not target or exclude specific sectors.
> ***Cons:*** May place restrictive requirements on certain industries which would result in the loss of revenue. Not able to focus restrictions on land uses responsible for the most impact. Could be seen as unfair because it may unnecessarily restrict sectors that have little or no impact. Difficult to apply to situations with existing development in riparian/coastal zones.

Vary by land use ("Sectoral" approach): A sectoral approach requires setbacks for certain land uses or sectors. For example, setbacks may be required for forestry operations but not for residential developments or agriculture. Or different land uses may be required to comply with different types of vegetated buffer or setbacks. For example, farmers may be required to retain a 15 m vegetated buffer along riparian zones, forestry operations may require a 20 m vegetated buffer, and residential development may require a 30 m coastal setback.

> ***Pros:*** Allows government to focus restrictions on land uses that cause the most impact, to protect the most vulnerable sectors from erosion and flooding, or to exempt certain sectors from restrictive setback or vegetated buffer requirements that may hamper their economic viability.
> ***Cons:*** Can result in uneven protection of watercourses. May be perceived as unfairly targeting or exempting certain sectors.

4.1.4. Framework for prioritizing sites

It must be determined whether the chosen tool will be applied only to new developments such as a new subdivision, forestry operation, land clearing for agriculture, new business etc., or if the tool will apply to existing properties as well.

Apply to new properties only (a "Protective" approach): The protective approach - the more common of the two approaches – seeks to protect undeveloped lands (in the case of vegetated buffers) and properties (in the case of setbacks) before they are developed. A protective approach can help ensure that new development occurs in a way that minimizes risk to both property and ecosystem functions; however, simply protecting the coastal and riparian zones which remain undeveloped will not automatically produce healthy ecosystems. This approach does nothing to address the ecosystem impacts of, and risks to existing development which may include vulnerability to storm damage and erosion, limited filtration of nonpoint source pollution, and reduced wildlife habitat.

> ***Pros:*** This approach is proactive and will slow or stop the advance of riparian and coastal deforestation and/or the damage caused to development, particularly residential development, by storms.
> ***Cons:*** Fails to address the lack of vegetation and proximity of structures to the water of existing riparian or coastal developments, only protects ecosystem functions, and people and property in a portion of the province; will not necessarily produce healthy ecosystems.

Apply to new and existing properties (a "Restorative" approach): The restorative approach seeks to restore ecological function in riparian or coastal zones by requiring or encouraging the regeneration of the vegetation that was disturbed when the site was originally developed. This approach primarily applies to vegetated buffers as opposed to setbacks. Unless a structure is destroyed or sufficiently damaged during a storm, it is extremely challenging and unreasonable to require that structures be relocated to comply with setback regulations. One option is to designate all existing structures in the vegetated buffer or setback as "non-conforming" and limit or deny expansions to these properties.

In many cases, properties may not be sufficiently large to accommodate a setback or vegetated buffer. For this reason, the Province must clarify how shoreline armouring may be used in relation to setbacks. For example, if a property cannot relocate structures to comply with setback requirements, should armouring be permitted as an alternative?

While the restorative approach is superior in terms of protecting ecological integrity and reducing risk, it can be very hard to develop, implement and enforce. It can also lead to legal challenges if legislation appropriates coastal or riparian lands from landowners by making it a "no touch" zone. New Brunswick policy and PEI's legislation for riparian and coastal zones involved land appropriation, and to date, neither jurisdiction has been to court over the issue. A voluntary approach may be more politically popular and may successfully avoid legal challenges. Enforcement can also be challenging due to limited human resource capacity within provincial government.

Land owners could be offered the opportunity to obtain a variance from a legislated setback or vegetated buffer by paying "reverse compensation" to the Province. Reverse compensation occurs when a land owner wants to implement a vegetated buffer or setback that is smaller than what is required by law, and must pay the government for the right to do so. For example, Rhode Island's Urban Coastal Greenways Policy requires a standard width Urban Coastal Greenway for different zones along significant watercourses. Whenever an applicant reduces a standard Urban Coastal Greenway width or requests a variance, the applicant is required to compensate the state by paying a fee into the Urban Coastal Greenways Trust, creating non-stormwater management wetlands, restoring an existing degraded wetland, increasing opportunities for public recreational use of coastal waters, or by increasing amenities for public access pathways within the Urban Coastal Greenway.

Despite the challenges inherent in legislatively appropriating lands, some jurisdictions have chosen to pursue this route. For example, when PEI passed its original buffer zone legislation in 1999, no compensation was offered landowners. When the *Watercourse & Wetland Protection Regulations* were created in 2008 (which increased the 10 m vegetated buffer to 15 m), farmers became eligible to receive an annual payment from the Alternative Land Use Services program when they allow the first 5 m of the 15 m to be planted in trees (B. Raymond, PEI Department of Environment, personal communication, November 9, 2011). If a regulatory approach is chosen, legislation should clearly state what activities, harvesting, and thinning practices are permitted in the regenerating vegetated buffer, particularly if they are applied to the agricultural sector.

Many jurisdictions encourage the voluntary re-growth of vegetation, primarily in riparian zones and often for farmers. For example, the Maryland State Buffer Incentive Program offers a one-time incentive payment on acres planted with forested buffers at $300 per acre upon verification of 65% seedling survival rate after 1 year. A reduced payment of 50% is payable for a survival rate of 50% to 65%; the maximum payment $15,000.

Species choice is particularly important in re-forestation. In both coastal and riparian zones, fast growing, early successional species are well adapted to growth in exposed areas with little vegetation (Cramer *et al.*, 2008; Young *et al.*, 2005; del Moral *et al.*, 2007). In both coastal and riparian zones, shallow root systems will aid bank stability by holding soils in place, and deep rooted species aid in water and nutrient cycling (Vidon *et al.*, 2010; McClain *et al.*, 2003; Polster, 2010; U.S. Department of Agriculture-Natural Resources Conservation Service, n.d.; Massachusetts Office of Coastal Zone Management, 2011). In coastal zones, salt water-tolerant species with shallow root systems should be used such as American Beachgrass (*Ammophila breviligulata*) or Beach Pea (*Lathyrus japonicus*) (U.S. Department of Agriculture-Natural Resources Conservation Service, n.d.; Massachusetts Office of Coastal Zone Management, 2011). In riparian zones, early successional species with shallow roots such as grasses, sedges, cattails and wildflowers , and species with deep roots such as willow, alder, and poplar should be used (Polster, 2010; NSTIR, 2007). Native species should be chosen over non-native species in order to promote successful re-growth, avoid invasive species and reduce the need for maintenance (McClain *et al.*, 2011). An in-depth exploration of the species options available to the Province is beyond the scope of this project.

> ***Pros:*** Addresses deforestation and siting issues on existing properties, works to restore ecological functioning across the entire province. Can act as an educational tool for property owners who would not otherwise learn about new programs under a protective approach (e.g., by purchasing new property).
> ***Cons:*** Difficult to implement. Legislative appropriation of lands can result in legal challenges and political unpopularity. May be difficult to enforce.

4.1.5. Application to stream or coastal type

The next step is to determine which environmental characteristics should be subject to setback or vegetated buffer requirements. For example, vegetated buffers could be required on streams of a certain width, or on certain coastal ecosystems, or in high risk areas.

Coastal zones

In coastal zones, setbacks or vegetated buffers can be applied to all coastal types or to one or more different coastal types.

Apply to all coastal ecosystems: This approach would require that any setback or vegetated buffer program apply to all coastal ecosystems (e.g., cliffs, beaches, dunes, estuaries, salt marshes, rocky shores etc.) or all types of coastal hazard. For example, while a setback or vegetated buffer policy may only apply to certain land uses, it would apply to any and all coastal ecosystems or hazard type underlying the selected land use.

> ***Pros:*** Provides uniform protection along entre coast (depending on which land uses are covered). Recognizes that all coastal ecosystems provide important functions. Protects property on all coastal types.
> ***Cons:*** May require setbacks or vegetated buffers on coastal ecosystems which are not at risk of erosion or flooding.

Vary by hazard or coastal type: Alternatively, a setback or vegetated buffer policy could be applied to one or more specific coastal ecosystems, or types of hazard.

- **Ecological features of value:** The Province could identify specific ecological features of value, such as cliffs, beaches, dunes, estuaries, salt marshes, rocky shores, endangered species habitat etc., which require vegetated buffers or setbacks.

  Pros: Allows government to focus effort and resources on vulnerable ecosystems or ecosystems that provide key services such as storm surge absorption, or recreation and tourism activities.
  Cons: Fails to address damage occurring outside of selected ecosystems which may still have ecological impacts and/or may impact the selected ecosystem type indirectly.

- **Hazard Classification:** In coastal zones, setback or vegetated buffer distances could differ to match different levels of risk according to geology, wave action, storm history etc. Development would be required to locate farther inland in high hazard areas than in low hazard areas. In some jurisdictions the setback distance in high hazard areas is often determined by a multiple of the recession rate for the particular shoreline reach where the development is proposed (see Minnesota's North Shore Management Plan). This approach requires mapping to delineate hazard areas and levels for both regulators and property owners. For example, in Nova Scotia, the Northumberland shore might qualify as a high risk area requiring a larger setback than less erodible areas.

  There are two options for mapping hazard categories that the Province may wish to consider:

  1. **Map coastal hazard categories**
     Each coastal hazard category would require a different setback distance appropriate to the geology and geography of the region and therefore risk. High, medium and low risk zones could be identified on a map that is both easy to access and understand. Ideally a map should be as detailed as possible; however, even fairly coarse categories could help guide the development of setbacks, especially if they tended to over-estimate the required setback size. Hazard categories should be based on both risk of erosion and flooding. For example, the annual erosion rate, elevation, predicted sea level rise, highest recorded storm surge, potential

Higher High Water Large Tide (HHWLT), and the extent and type of vegetation could be used to create a formula or point-system that would indicate risk. Once the risk level was determined, setback distances could be assigned. For example, setbacks could range from 20-30 m in low risk areas, 50-60 m in areas with moderate erosion and 100-150 m in high risk areas. Alternately, landowners in high risk regions could be required to have a professional determine an appropriate setback distance. Coarsely mapped hazard zones could also be combined with a ground-truthing exercise in high risk areas to validate mapping.

2. **Create two setback distances based on coastal hazards**
   Similar to the above mentioned approach, the Province could create one 'default' setback for the 'average' situation (e.g., moderate erosion rates), and one for high risk zones experiencing erosion more rapidly than the remainder of the coast (e.g., on the Northumberland shore). Landowners in high risk regions could be required to have a certified professional determine an appropriate setback distance. High risk zones could be identified on a map. In place of delineating low risk zones, property owners living outside of high risk zones could be allowed to apply for a variance to permit a smaller setback than the default distance if they could demonstrate that erosion and flooding would not pose a threat to proposed development, and that damage to coastal ecosystems would be limited. A site assessment by a certified professional could be required to obtain a variance. This arrangement places the onus on the landowner to demonstrate that the "default" setback is larger than necessary. The option of a variance prevents the unfair practice of applying a blanket requirement for all coastal development regardless of geology geography and other relevant conditions. For example, parts of the South Shore are composed primarily of granite and are at low risk of erosion, and structures could likely be located slightly closer to the coast (assuming a reasonable elevation), than in areas with high erosion rates or low elevation. A minimum vertical setback could also be required for all situations without the option to apply for a variance.

An alternative to legislating different setbacks or vegetated buffers in different hazard zones is to allow the hazard data to act as a disincentive for inappropriate coastal development. By distributing hazard maps to concerned parties (e.g., real estate agencies, developers, insurers and the public), the market may determine coastal development patterns. This would reduce the need for enforcement.

One challenge with hazard mapping is the issue of distribution and how to ensure that concerned parties have access to this information, particularly if a market-based approach (rather than a regulatory one) is used. Distributing maps through real estate agencies could be a way to ensure that potential buyers have all the information required to make appropriate decisions about buying or developing next to watercourses.

Pros: Allows governments to focus management and financial resources on the more dynamic high hazard areas of its coastline.
Cons: Requires extensive aerial photography and mapping to determine extent of hazards. There is some debate about the accuracy of erosion-rate mapping using aerial photographs: the margin of error can be as much as the annual erosion rate.

- **Erosion Rates:** Setbacks are often based on annual recession rates, particularly in the U.S., and an erosion rate multiplier is generally used to determine the actual setback distance. The multiplier is linked to the predicted lifespan of a structure, which in the U.S. varies from 30 to 100 years, the assumption being that the structure should last long enough to pay off a 30-year mortgage. However, a setback line based on erosion rates may not be adequate as average annual erosion rates cannot factor in episodic erosion caused by severe storm events, such as Hurricane Juan that hit the Atlantic coast in 2003. As well, erosion rates are based on historical data, which may not accurately reflect future erosion rates that may be accelerated due to climate change impacts.

> ***Pros:*** A simple number that captures regional variation. If the annual erosion rate is known, it is an easy distance for landowners to calculate.
> ***Cons:*** Difficult to calculate (requires aerial photography and mapping), margin of error may be equivalent to annual erosion rate. Annual erosion rate will not capture major episodic erosion events caused by storms or naturally-occurring bank collapse.

- **Climate Change Projections:** Sea level rise projections for future dates (e.g., 2050, 2100, and 2200) are mapped and setbacks established based on future sea levels and the lifespan of the proposed structure. This is a long term approach to coastal planning.

> ***Pros:*** Taking a long-term view of coastal planning can reduce waste and costs when developments are damaged by coastal hazards or need to be destroyed or relocated as sea level rises. This approach can minimize the initial costs of considering sea level rise; adaptation costs are distributed over time.
> ***Cons:*** Climate change projection mapping is costly and time consuming, and the margin of error can be significant due to the uncertainty in global and local sea-level rise projections.

Riparian zones

In riparian zones, setbacks or vegetated buffers can be applied to all stream types, or to one or more different stream types.

Apply to all streams: This approach would require that any setback or vegetated buffer programs apply to all stream types, regardless of local physical or ecological characteristics.

> ***Pros:*** Provides uniform protection along all streams (depending on which land uses are covered). Recognizes that all riparian zones provide important functions. Protects property on all stream types.
> ***Cons:*** Vegetated buffers or setbacks on small streams (<1 m) may be un-popular.

Vary by stream type: Alternatively, a program could be applied to one or more specific types of stream or types or extent of hazard. For example, setbacks or vegetated buffer application and design could be based on stream width, flood risk, or whether streams are fish-bearing or not.

- **Fish bearing:** Setbacks or vegetated buffers could be applied to streams carrying certain fish species of interest to the Province. For example, British Columbia's *Forest Planning and Practices Regulation* (2010) stipulates different vegetated buffer prescriptions for streams frequented by listed species of fish, species at risk, a species identified as regionally important wildlife, or has a slope gradient of less than 20%, unless the watercourse:
    - Does not contain any of the listed species of fish,
    - Is located upstream of a barrier to fish passage and all reaches upstream of the barrier are simultaneously dry at any time during the year, or
    - Is located upstream of a barrier to fish passage and no perennial fish habitat exists upstream of the barrier.

> ***Pros:*** Focuses effort and funds on specific ecological values. By protecting fish habitat, other ecological functions can also be protected (bank stability, filtration and infiltration, protection of property from flooding and erosion, provision of terrestrial habitat)

Cons: Focusing protection on specific ecological features of streams may ignore other ecological features of importance or non-ecological threats to property. This approach will only protect a portion of the province unless species of importance exist in all streams.

- **Vary by stream size:** This approach requires that the vegetated buffer or setback width increases in proportion to stream width: wider streams require wider vegetated buffers or setbacks. For example, British Columbia's *Forest Planning and Practices Regulation* (2010) stipulates different vegetated buffer prescriptions for different stream widths and lengths (e.g., greater than 1 km long, wider than 20 m, between 5 m- 20 m, between 1.5 m – 5 m, less than 1.5 m, etc.). The *Forest Planning and Practices Regulation* requires these widths on "fish bearing" streams (see above), but a stream size-based approach need not be tied to the presence of fish. This approach addresses the tendency for bigger rivers to experience more severe flooding and may ensure that development is protected from flooding. In order to best protect water quality and fish habitat, however, the literature suggests that smaller headwater streams should have wider buffer than on bigger streams (Freeman *et al*., 2007; Hubbard & Lowrance, 1994, Lowrance *et al.*, 1997).

  Pros: Achieves policy objective of protecting property from flooding. Wider vegetated buffers will provide many ecological services (filtration, infiltration, terrestrial habitat etc.).
  Cons: Difficult to apply the largest buffers in areas that tend to have existing development (e.g., estuaries)

- **Flood prone areas:** Another option is to base setback or vegetated buffer widths on the frequency and extent of seasonal flooding. For example, the Municipality of the County of Cumberland's Land Use By-law requires a 30.5 m setback for areas prone to seasonal flooding, and a 15.24 m setback on rivers that are not prone to flooding.

  Pros: Will protect property from seasonal damage. A common sense approach that would likely be supported by the public.
  Cons: Setbacks or vegetated buffers widths based on seasonal flooding may not be large enough to protect property from major storm events which can produce higher flood levels than occur seasonally. Mapping of flood prone areas may be difficult at the provincial level (expensive and time consuming) – may be better administered by municipalities. Will not protect ecological functioning in non-flood prone areas or the province.

Both riparian and coastal zones

***Lot or structure size*:** This approach requires that setback or vegetated buffer distance increases in proportion to the depth of a lot or the footprint of a proposed structure. As it is difficult to require a 30 m setback on a lot that is only 40 m deep for example, smaller lots are accorded smaller setback distances. Maui's Shoreline Rules require different setback distances for different lot sizes (Table 4.1).

Table 4.1. Setback distances based on lot size under the Island of Maui's Shoreline Rules (feet converted to metres). Setback distance must be the greater of the distances listed below (Maui Planning Commission, 2007).

Lot Depth (m)	Setback Distance (m)
All lots	7.62 m plus 50 times the annual erosion rate
<30.5 m	7.62 m
30.5 - 49 m	12.2 m
>49 m	25% of the average lot depth, up to a maximum of 46 m

The standards in deciding a setback or vegetated buffer width based on structure size rest on the structure's expected physical life-span, the average mortgage length, and how easily the structure can be relocated. Under Pennsylvania's *Bluff Recession and Setback Act*, residential, commercial, and industrial structures are considered to have appropriate lifespans of 50 years, 75 years, and 100 years respectively.

> ***Pros:*** Allows smaller lots to have accordingly small setbacks, doesn't penalize small property owners over large property owners. Matches setback to lifespan of structure
> ***Cons:*** A small setback may be ineffective at protecting property from flooding or from erosion depending on the local relief and geological composition. For example in Maui, lots smaller than 30 m in depth are only required to have a 7.6 m setback, a distance that is unlikely to avoid the damages caused by storm surge during a significant storm event. Incorrectly calculated lifespans may result in flooding or land eroding away under a structure before the end of its functional life.

Site specific assessments: This approach would require a site assessment to be conducted by a professional to determine the appropriate setback distance based on geology, vegetation type, elevation, flood risk and other factors. This method would be the most scientifically rigorous, detailed, legally defensible and fair. Site assessments could be conducted for all proposed waterfront developments or only in specific areas of known flooding and/or erosion. A certified professional would complete a site assessment of proposed developments examining relevant local conditions. For example, the annual erosion rate, elevation, predicted sea level rise, highest recorded storm surge, potential HHWL, and the extent and type of vegetation could be used to create a formula or point-system that would indicate an appropriate setback distance in either specific or broad terms.

Some capacity building would likely be required in order to create this type of program as there are not currently enough certified professionals trained specifically in coastal and/or riparian processes. Professionals in this field could receive specialized training about coastal processes through a professional organization. Having a third party certify a setback distance means that much of the effort, cost and risk would be outsourced outside of government. Professionals routinely make assessments and provide certifications for various services such as building construction, well installation and other services, thus it is possible to assume that a coastal risk assessment would not be overly onerous. In addition, assessors could enter collected data into a central database which could help the Province to acquire coastal data in order to aid with coastal characterization, and better understand changes to the coastline over time.

> ***Pros:*** Site-specific, scientifically rigorous. Easily defensible in court. Province-wide data collection and database-building increases knowledge base. Effort and risk can be outsourced.
> ***Cons:*** Would likely require a great deal of time, effort and resources by the private and public sectors to create such a system. There is a cost to the homeowner to hire an assessor.

4.1.6. Application to slope

The next step is to determine whether conditions for slope will be applied to a vegetated buffer. Slope is not applicable to setbacks as the relationship between slope, and absorption of pollutants by vegetation is irrelevant. For example, the Nova Scotia *Wildlife Habitat & Watercourse Protection Regulations* require that on slopes greater than 20%, 1 m in buffer width must be added to the minimum of 20 m for each additional 2% of slope, up to a maximum of 60 m.

Many North American jurisdictions include a condition for slope in their vegetated riparian buffer regulations (Lee *et al*., 2004) and it is commonly recommended that vegetated riparian buffers on sloped land be wider than the buffer width required for flat land to provide more rough vegetated surface over which runoff may flow (Fischer & Fischenich, 2000). The results of a review of riparian buffer width guidelines from Canada and the United States by Lee *et al.* (2004) suggest that "jurisdictions that do not incorporate shoreline slope as a modifying factor had wider baseline buffers to account for the potential presence of a sloped shoreline." If conditions for slope are included in a vegetated buffer requirement, a maximum width should be defined to limit the burden placed on landowners on steeply sloped land.

One drawback to the use of slope conditions is that it can be difficult for landowners to delineate and may require a surveyor to do so. The Government of PEI's original vegetated buffer legislation used to contain a condition for slope which was removed when the legislation was amended in 2008; the slope was too difficult to enforce both in legal and practical terms (B. Raymond, PEI Department of Environment, personal communication, November 9, 2011).

> ***Pros:*** Applying conditions for slope (i.e., requiring wider vegetated buffers on sloped land) can improve water quality by promoting the filtration of sediment and other pollutants. Can facilitate the application of appropriate vegetated buffer widths to local conditions.
> ***Cons:*** Can be difficult to delineate and enforce.

4.1.7. Setback type

If setbacks have been identified as the most appropriate management tool in coastal zones, the next step is to determine whether a setback will be delineated horizontally or vertically, or both. Vertical setbacks are often referred to simply as required elevations. There are two main hazards related to coastal development: flooding (from storm surge, wave run-up and sea level rise) and erosion; geographical relief, or elevation, is the most relevant element when determining flood risk, and geological type, or resistance to erosion, is the most relevant element when determining erosion risk. In some areas only flooding is a risk, for example, in low lying areas with solid rocky shores such as Peggy's Cove, and in others erosion is the only risk, for example, in highly elevated but rapidly eroding areas such as the Blomidon area. A single fixed distance horizontal or vertical setback distance, however, may be too large in some areas and too small in others, depending on whether flooding or erosion is the primary threat. If setbacks are larger than what is required by local geology and elevation, some landowners may feel that their ability to develop their property is being unnecessarily restricted.

Horizontal setbacks: Horizontal setbacks are more common and intuitively understood than vertical setbacks. They are measured horizontally from the chosen boundary (e.g., mean high water mark, line of permanent vegetation, inland edge of coastal feature such as a sand dune). Horizontal setbacks will better protect property from erosion than from flooding if a property is located on a low lying shore.

Vertical setbacks: Vertical setbacks, or elevation distances, are measured vertically from the chosen boundary (e.g., mean high water mark, line of permanent vegetation). Vertical setbacks should be large enough to accommodate the average or the highest recorded storm surge as well as predicted sea level rise. Vertical setbacks should be delineated by a professional surveyor. Figure 4.3 provides a framework for assessing whether flooding or erosion poses the greatest threat and assigns a horizontal and/or vertical setback appropriate to the risk.

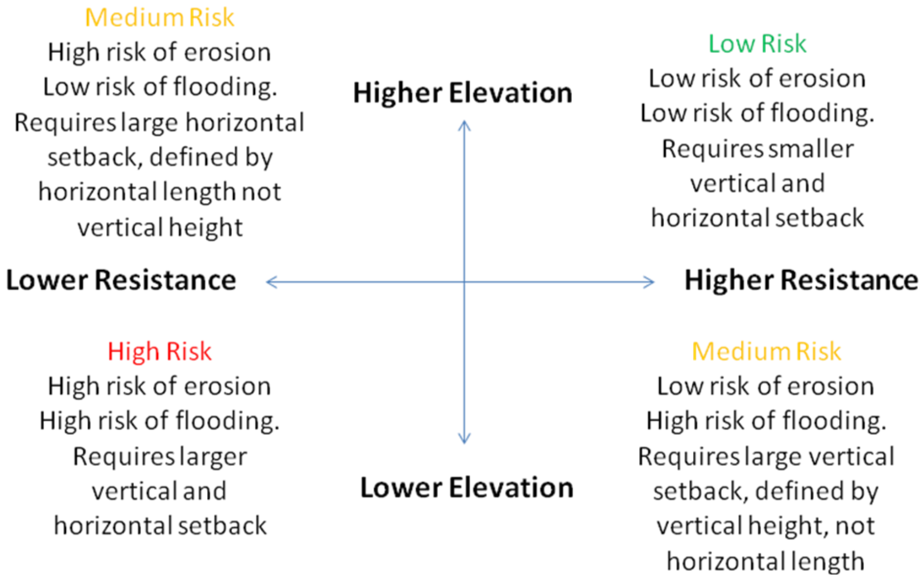

Figure 4.3. A matrix comparing different coastal types, using the characteristics of local topography and geological resistance to erosion of the coastal material, to aid decision making in coastal zones. Horizontal and vertical setback distances based on elevation and resistance to erosion (Rideout & Sterling, 2012).

4.1.8. Dimensions

The dimensions of setbacks and vegetated buffers must be determined. Dimensions refer to the number of zones within a setback or vegetated buffer in which different activities are permitted. Alternately, dimensions can be determined by geographic characteristics such as elevation (i.e., floodplains).

Single zone: The single zone approach requires that vegetated buffers or setbacks be a single width, for example, 30 m along the watercourses and land uses chosen. This is an attractive approach due to its simplicity; however this simplicity may fail to take diverse landscapes, and geology, complex land use patterns, and risk into account. This approach can tend to require a wide setback or buffer width in order to ensure that high risk areas are captured. For example, if a smaller buffer was required, some properties would be protected but others located on rapidly eroding coastlines would not. The Province may open itself up to legal challenges if damage occurs to properties that have followed the guidelines provided by the Province, unless a disclaimer regarding liability is clearly communicated. If the Province is advised that it is not legally liable, however, then a single zone setback or vegetated buffer width could be smaller. Information regarding liability and funding for storm damage should be clearly communicated under all potential policy scenarios. This approach could likely be made more palatable to the public if it is aligned with existing setback or vegetated buffer requirements such as the *Wildlife Habitat & Watercourse Protection Regulations* or the *On-site Sewage Disposal Systems Regulations.*

Pros: This approach is the simplest for government as it requires less mapping, assessments or creation of complex policies. Easy for the public to understand.
Cons: Does not take into account local conditions; setbacks or buffers may be too small for some areas with rapid erosion rates and low elevations, and too large for others with slow erosion rates and high elevations. In coastal zones, land owners may feel that large setbacks are unfair if they live on a rocky coast with a high elevation. If the chosen setback or vegetated buffer distance is too small to capture the highest risk level, land owners may sue the government for requiring an “unsafe” setback or vegetated buffer width, unless the Province specifically divests itself of the legal responsibility for damages resulting from inappropriately sized setback or buffer widths.

Multiple zones: Some jurisdictions divide setbacks or vegetated buffers into several zones in which different activities are permitted. Usually the area immediately adjacent to the watercourse is a no-touch zone where no or few activities are permitted, and a longer list of activities is permitted in the remaining zones. For example, a “feathered approach” combines setbacks and vegetated buffers. A “core” vegetated buffer is required immediately adjacent to the shoreline in which all activities are prohibited. In the intermediate vegetated buffer, thinning of vegetation and small, movable or temporary structures are permitted. An overall setback distance is established that is the sum of (or greater than) the widths of these two vegetated buffers. For example, the core vegetated buffer could be 5-20 m wide and the intermediate buffer could be 10-20 m wide resulting in an overall setback distance of 15-40 m. In riparian zones, this design maintains vegetation along the banks which provides water temperature control, bank stability contributes LWD and leaf litter. In riparian and coastal zone, this design provides some (although not all) requirements for wildlife and nonpoint source pollution absorption. The intermediate area would provide flexibility to the land owner to modify the property while still retaining vegetation for habitat and pollution absorption. The overall setback distance ensures that properties are safe from flooding.

> ***Pros:*** Allows landowners more flexibility to modify their property. The overall setback distance ensures that structures are well back from watercourses providing excellent flood protection. The intermediate zone provides some riparian functions (e.g., such as nonpoint source pollution absorption and habitat provision) despite thinning and small structures. The vegetated buffer along the bank provides erosion prevention.
> ***Cons:*** Can place a burden on landowners and enforcement staff when delineating the different zones. Can be challenging for enforcement staff to assess the degree of thinning that has occurred, an issue that could make legal challenges difficult. Reduced loss of trees due to wind-throw.

Coastal floodplains: Setbacks or vegetated buffers could be based on the extent of coastal flooding during storm events. Using digital elevation models and storm history, the inland boundary of flooding from storm surges of a 100-year flood level during a high tide could be delineated for an area of the coast. Long term sea level rise could also be incorporated. Although this can be an information-intensive and expensive approach, it would be one of the most technically rigorous methods available. Only the “site assessment” approach would provide a similar level of technical certainty in the establishment of setback or vegetated buffer widths.

This research has already begun in Nova Scotia as part of the Atlantic Climate Adaptation Solutions project. Using LIDAR-derived elevation data, Webster *et al.* (2011) of the Applied Geomatics Research Group have developed flood risk maps for the District of Lunenburg, Chignecto Isthmus, District and Town of Yarmouth, and the Wolfville-Windsor area of the Minas Basin (Figure 4.4). The model incorporates elevation, storm history (e.g., benchmark storms such as the 1869 Saxby Gale, the 1976 Groundhog Day storm, and the 2003 Hurricane Juan), and projected sea level rise to display flood risk levels.

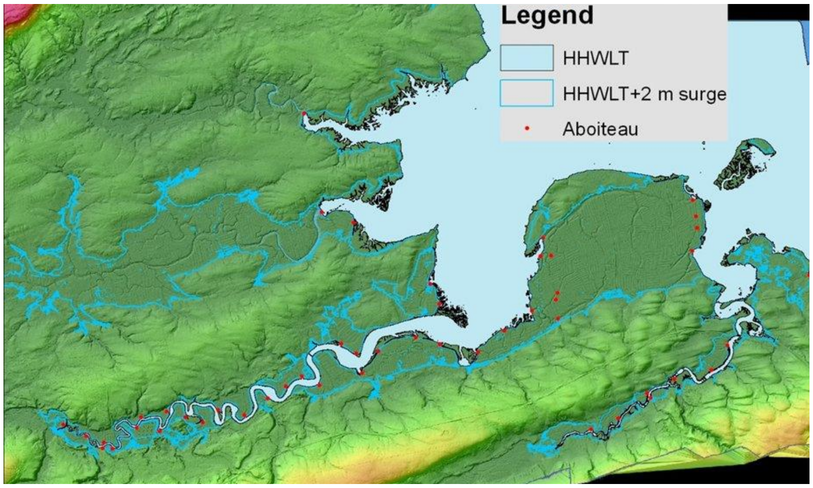

Figure 4.4. Minas Basin colour shaded relief map with HHWLT in solid light blue and the areas inundated by an additional 2 m storm surge (blue outlines). This is a water level similar to that estimated during the Saxby Gale which occurred in 1869 (Webster, McGuigan & Candace MacDonald, 2011).

The Province could partner with municipalities, the federal government, NGOs, industry and academia to obtain LIDAR data and produce maps for communities. Data collection and map production could be prioritized for high risk, and densely populated or developed areas of the province.

> ***Pros:*** Technically rigorous, easily defensible in court. Allows governments, industry and the public to site coastal development appropriately. Takes into account elevation and can be easily modified when new predictions of sea level rise become available. Does not subject landowners unfairly with blanket requirements which are unjustified by local relief and geology. Provides excellent visual materials for the public.
> ***Cons:*** Does not take erosion risk into account. Financially and labour intensive. Maps would not be detailed enough to provide property-level information.

Riparian floodplains: Some jurisdictions use the 100-year floodplain. This approach requires mapping to delineate the floodplain for both regulators and property owners. Retention of floodplain vegetation can also be required. “Soft” or “passive” uses could be permitted in the floodplain including agriculture, recreational facilities such as parks and walking trails, and small moveable or temporary structures. The Nova Scotia *Municipal Government Act* contains a Statement of Provincial Interest which specifically discourages development on floodplains as part of the Canada-Nova Scotia Flood Damage Reduction Program. This program uses the 100-year flood plain in participating communities, of which there are five in Nova Scotia (see Section 3.6.2.5. Service Nova Scotia & Municipal Relations, 2011).

Under this program, the 100-year flood plain is delineated and “a two zone approach has been used where future development is prohibited in the floodway, defined by the 20-year flood, but is permitted in the flood fringe if adequate flood proofing is carried out.” (Environment Canada, 2010). Newfoundland uses a similar approach (in Newfoundland’s floodplain policy, the 100-year floodplain is equivalent to 15 m). Mapping efforts could be prioritized by population or development density.

> ***Pros:*** Allows governments to focus management and financial resources on the more dynamic high hazard areas of its watercourses. This is a “common sense” approach that is easily understood by land owners. If mapping is done accurately, this approach will be scientifically rigorous and fit the local context.
> ***Cons:*** Requires intensive mapping to delineate floodplain for areas of interest or the entire province

4.1.9. Delineation method

There are two general ways to delineate setbacks or buffers: delineation from a fixed point or from a "floating" point. See *Appendix D* for a detailed exploration of delineation methods in coastal zones.

Fixed: Fixed setback lines are usually delineated in the field by a stationary reference point, such as a concrete monument or a roadway. Development waterward of the setback line is either prohibited or regulated. This approach is very rare due to the recurring need to relocate monuments as shorelines erode.

> ***Pros:*** Certainty of locating the setback in the field; ease in delineating the setback line on a map; and checking permit compliance.
> ***Cons:*** Unresponsiveness to shoreline dynamics. A storm, beach nourishment project, or a new erosion control structure may quickly render the line obsolete unless the setback is periodically revised.

Floating: Floating setbacks use natural features as the baseline. Baselines include the landward toe or crest of the primary dune, the receding bluff edge, the vegetation line, and the mean high water line.

> ***Pros:*** Natural features respond to changing erosion and accretion rates and are in a sense "self-updating" and for this reason are often regarded as superior to setbacks delineated from static features.
> ***Cons:*** Financial and administrative burden of managing and monitoring this "dynamic" line; vulnerability of natural features to storms; mean high water mark or other water level-related measurements are difficult to identify in the field, for landowners or enforcement officers, a surveyor would be required. There is some debate in the mapping community about the accuracy of sea level measurement systems in particular (T. Webster, personal communication, November 4, 2011).

4.1.10. Permitted activities

The Province must determine whether a vegetated buffer will be a "no- touch" zone or whether certain activities and structures will be permitted. A "no-touch" approach cannot be applied to setbacks as this would make them, in essence, vegetated buffers (assuming that in a "no-touch" zone that vegetation would be able to re-generate). In general, more activities tend to be permitted in setbacks than in vegetated buffers. Permitted and prohibited activities should be clearly defined.

In a setback, where the separation distance is the key feature (rather than vegetation as with vegetated buffers), constraints on structures and materials stored in the setback may be considered. For example, oil storage tanks could be prohibited in these areas but small, non residential structures such as sheds could be permitted. The size and location of such structures should be clearly defined.

Water-dependent structures are permitted in most jurisdictions. Water-dependent structures may include bridges, boat ramps, boat houses, docks, and boat building facilities, structures related to water treatment and distribution, and fishery related uses. Conditions may be placed on the design and location of these structures. Given the central role of coastal and marine industries to Nova Scotia's economy, particularly in rural regions, it is illogical to apply setback or buffer policies which will hamper access for these industries. It may not be a significant issue; for example, no new federally-managed wharves or private boat building facilities are planned or anticipated (P. MacDonald, Small Craft Harbours- DFO, personal communication, August 2011; Tim Edwards, NS Boast Builders Association, personal communication, August 2011).

Recreational or “passive uses” are often permitted in both setbacks and vegetated buffers. Passive uses are usually uses that have little impact on ecosystem functioning, or are not significantly damaged by flooding. For example, walking trails are often permitted in vegetated buffers with conditions on trail width, proximity to water and trail surface type. In some jurisdictions, sports fields or playgrounds may be permitted on floodplains where more permanent development is prohibited.

If vegetated buffers have been identified as the most appropriate management tool, then the thinning of vegetation is a potential activity that should be clarified. Tree thinning is often associated with residential development and forestry operations; however, other industries would also benefit from clarification around this practice. Different thinning practices may be permitted in order to accommodate the needs of different sectors, or a single thinning practice may be chosen in order to create an easily understood and enforceable approach.

The following from Neary *et al*. (2011) provides an excellent summary of the literature around thinning. “Lee *et al.* (2004) found that about 80% of the jurisdictions surveyed in their study allowed for the option of tree cutting within the [Special Management Zone (SMZ)] buffers. The types of cutting allowed included single tree and group selection, and zoned harvest. Although there were differences in SMZ harvesting prescriptions, the restrictions imposed by most guidelines for buffer zone harvesting were similar. They included:

- Retaining >50% of the tree volume, cover, or basal area
- Minimizing or eliminating machinery operations
- Protecting understory species and overstory regeneration
- Preventing harvesting-related streambank or shoreline erosion
- Spatially distributing cutting via single tree or group selections
- Preventing removal of all large or “old-growth” stems

The objectives of harvesting within SMZs stated in various guidelines include economic benefits from tree harvesting, maintaining tree-replacing disturbances, keeping riparian woody vegetation in a vigorous, rapid growth mode, and removing trees susceptible to wind-throw. Palik *et al.*’s (2000) treatise on riparian silviculture and experiments by Lakel *et al.* (2010) concluded that partial harvest inside SMZs has relatively little impact on water quality characteristics such as temperature and sediment. Long-term effects on woody debris inputs to streams still need to be evaluated. Lee *et al.* (2004) noted that some jurisdictions in the USA and Canada are using multiple management zones with increasing intensities of harvest grading from stream channels upslope [i.e., a “feathered” approach as discussed above].” Without explicit direction regarding vegetation retention, it is likely that vegetation will be removed by landowners. In a 1992 study, Castelle *et al*. found that 95% of implemented vegetated buffers showed signs of human alteration, and in all cases where the vegetated buffer abutted a residential lot, the natural vegetation was converted to lawn. In a study on riparian deforestation in the Sackville River watershed, Sterling and Rideout (2012) discovered that in residential areas in particular, riparian vegetation was fully intact in some areas, moderately or extensively thinned in other areas, or completely removed in other areas. This range of practices on residential properties demonstrates that for residential land use, property owners are likely to remove some or all vegetation unless expressly prohibited from doing so (Sterling & Rideout, 2012).

Since much of the value of residential waterfront properties is derived from the scenic views of the watercourse, thinning of vegetation is permitted in some jurisdictions to allow landowners to create a viewscape of the water. Three types of thinning on residential properties are possible, “vertical”, “even” and “window” thinning. “Vertical” thinning is when the lower branches of trees, for example within 3 m of the ground, are removed providing a view plane at eye level while maintaining root and canopy structure. “Even” thinning involves removing one or two trees at regular intervals along the length of the riparian buffer providing slightly improved, but not excellent views while again retaining root and canopy structure. “Window” thinning involves removing all the trees in a short section of the buffer, for example, the middle 10 m of a 30 m long buffer, or one third of the total length, creating a window through the trees. Window thinning is not ideal as it damages root and canopy structure and may allow surface runoff to enter watercourses in concentrated flows without the benefit of being filtered and slowed by riparian vegetation.

In the forestry sector in Nova Scotia, thinning is permitted in order to increase the harvest merchantable timber under the *Wildlife Habitat and Watercourse Protection Regulations*; the regulations state that the basal area of living trees may not be reduced to less than 20 m^2 per hectare (Nova Scotia Natural Resources, 2002). This criterion allows operators to increase their harvest of merchantable timber while maintaining some degree of riparian functioning.

It should also be noted that wind-throw becomes more prevalent in vegetated buffers that have been thinned. McCurdy and Stewart (2008) found that within 20 m wide vegetated buffers adjacent for timber harvests in central Nova Scotia, "thinning to 20 m^2 basal area almost doubled the amount of trees that blew down compared to the unthinned [vegetated buffers] (92 trees/ha thinned; 49 trees/ha unthinned)."

Providing clarity around permitted thinning practices will facilitate the preservation of vegetation while enhancing flexibility around landowner-activities.

> ***Pros:*** Permitting more activities rather than fewer allows more flexibility for land owners to modify their property. Permitting fewer activities will allow vegetation to continue to provide important functions, or will allow vegetation to regenerate.
> ***Cons:*** Permitting fewer activities may make any new policy less popular. Permitting more activities may limit the functionality of riparian or coastal vegetation and reduce the number and quality of services provided by vegetation.

4.1.11. Regulatory approach

The literature review and surveys identified several regulatory avenues through which the above mentioned vegetated buffer and setback designs can be implemented. Regulatory approaches can be used in isolation, but are more commonly used in combination.

Legislation: An Act or regulation is the most legally stringent of methods as failure to comply with the law results in legal action which in turn acts as a strong deterrent for would-be law breakers. For example, any new regulations could be enacted via the *Environment Act* so that they would be broadly applicable. Alternately, the *Environmental Assessment Regulations* could be amended to include a trigger for any new development within a certain distance from watercourses for example, 20 m, 50 m, or 100 m. Legislation can act as a strong disincentive to site new developments near water.

> ***Pros:*** Legally defensible. Government is seen to be "doing something about the issue". Sends a clear message to residents and industry about the values and expectations of government.
> ***Cons:*** Can be costly and time-consuming to develop. Difficult to enforce. May result in legal challenges and court cases. "Command and control" approach can be seen as too heavy handed by some.

Permit: This method requires that property owners apply for a permit to develop within a setback zone. A permitting system allows the responsible department to screen proposed activities and prohibit those likely to cause significant environmental damage while allowing well designed developments to proceed. This method attempts to mitigate damage caused by development without trying to prevent it completely

> ***Pros:*** Could allow for many types of developments with conditions. Could be seen as "development friendly". Could promote the use of intelligent coastal designs.

Cons: May fail to adequately reduce damages to ecosystems and prevent risks to property owners. Potentially large administrative burden on government, moderate administrative burden on developers.

Incentives & market-based approaches: This method uses financial mechanisms to influence where and how coastal and riparian activity occurs. In many cases, a signal from government can influence market activity without the need for legislation. Some examples of financial incentives or disincentives include direct payments, tax relief, restrictions on government subsidies and conditions on disaster relief payments.

- **Direct payments:** One way to incent certain land use practices is to pay landowners to comply. Funding can be a one-time direct payment, or a cost-sharing arrangement. This form of incentive can be used to encourage landowners to leave vegetated buffers along watercourses. For example, a government could pay $X for every Y riparian acre that was allowed to re-vegetate, or X% of the costs of replanting vegetation or installing cattle fencing or off-stream livestock watering equipment. Nova Scotia Agriculture used to share up to 75% of the cost of implementing 15.2 m vegetated riparian buffers on farm land under the Soil and Water Management Program when land was cleared for the first time; however this program was discontinued in the 1990s due to the decrease in new land clearing (L. Cochrane, Nova Scotia Agriculture, personal communication, October 28, 2011).
    - *Manitoba*: The Government of Manitoba partnered with Manitoba Water Stewardship, Ducks Unlimited Canada, and the Manitoba Habitat Heritage Corporation to provide a Wetland Restoration Incentive Program which pays land owners $200 per acre to restore 40 acres of wetlands drained before 2006.
    - *PEI*: The Government of PEI provides an Alternative Land Use Services (ALUS) program which financially compensates farmers if they remove additional land from agricultural production beyond the 15 m required by law. Activities eligible for compensation include taking land out of production to establish soil conservation structures, planting native trees in the 15 m vegetated buffer, planting grassed headlands, expanding the vegetated buffer, retiring high-sloped land and erecting fencing to exclude livestock. Compensation rages from $100 - $250/hectare per year or $0.30/metre per year.

- **Tax credits:** This form of incentive is also used to encourage landowners to leave vegetated buffers along watercourses. In order to gain the highest level of buy-in in the absence of regulations, incentives should be equal to the value of the land that is “lost” to a vegetated buffer. Small incentives may only be taken up by landowners who would be inclined to protect these zones without an incentive. Larger incentives may be necessary to convince reluctant landowners to comply. The ability to use tax credits to incent the regeneration of riparian vegetation on agricultural land in Nova Scotia is limited as farmers do not pay property taxes (H. Vissers, Nova Scotia Federation of Agriculture, personal communication, August 3, 2011; L. Cochrane, Nova Scotia Agriculture, personal communication, October 28, 2011).
    - *Manitoba*: Manitoba’s Riparian Tax Credit program allows farmers who make a 5 year commitment (between 2011 and 2015) to claim $20-$28 per year per acre for farmers if they restore a 30 m vegetated riparian buffer and exclude cattle from watercourses.

- **Disaster relief:** In some cases, governments will reduce or eliminate disaster relief payments for properties located in a prescribed setback, or place conditions on how property can be repaired or replaced after being damaged. Conditions can be created which limit eligibility for disaster relief payments or limit the funds available for claims. Examples of conditions include permanent structures built in the 100-year floodplain being ineligible for disaster relief, properties only being eligible for a single disaster relief claim, property owners only being allowed to claim disaster relief funds if they relocate structures to comply with setback requirements or adopt flood-proofing measures.

  - *Maine*: Maine's Coastal Sand Dune Rules stipulate that the reconstruction of buildings severely damaged by wave action must meet setback requirements, and that buildings located within the most hazard-prone areas cannot be reconstructed more than once.
  - *Newfoundland*: Newfoundland's Policy for Flood Plain Management states that in the event that compensation by government is awarded to flood victims, it will be the policy of this Department to encourage victims to apply the compensation towards relocating rather than replacing or repairing damaged property in situ. If it is deemed acceptable by the Department to repair or replace damaged property in flood risk areas, then it will be required that the compensation be used firstly for appropriate flood proofing measures.

- **Subsidy restrictions:** The Province could reduce or eliminate government funding to projects located in hazard prone areas. By eliminating what is often a significant source of funding, many developments would reconsider siting a project adjacent to a watercourse. This of course depends on the type of development proposed. For example, a water-dependent development project may be exempt from subsidy restrictions.

    Pros: Market-based approaches mean that government is seen to be less intrusive than under legally binding approaches. Allows landowners to decide how they will develop land. Direct payments can provide compensation to landowners for the land that cannot longer be used for agriculture, forestry or for development.
    Cons: Depending on the type of incentive, costs to government, either from direct payments or from lost tax revenues may be costly. Tax incentives may be irrelevant for certain sectors such as agriculture. Incentives may not be large enough to compensate landowners for the lost use of their property.

Provide guidance to municipalities: Rather than requiring a specific setback or vegetated buffer width, many state and provincial governments choose to leave or delegate coastal and/or riparian management to municipal governments. Some states and provinces provide stringent guidance for municipalities while others provide only general encouragement to engage in coastal and/or riparian zone planning. The Province could clarify its interest in the use and development of coastal and riparian zones to both municipal governments and itself by creating a Statement of Provincial Interest under the *Municipal Government Act*.

Pros: Allows for flexibility to create setback design that accommodates local economic, geologic and geographic conditions, shifts financial and human resources burden to local governments.
Cons: Would not apply to crown lands or resources under provincial jurisdiction. Local governments may have limited capacity to implement such a complex zoning policy.

Best Management Practices: The provision of Best Management Practices (BMPs) to municipalities, landowners and industry is a common approach for provincial and state level governments. This method involves government giving clear direction about the preferred methods and materials used in coastal development. BMPs are often paired with supporting documents that help municipalities, residents and industry implement them.

Pros: Allows for flexibility. Does not require enforcement. Seen to be "development friendly" and less intrusive by avoiding onerous, legally binding directions to industry, municipalities and residents.
Cons: Not legally binding. May only be taken up by select individuals, firms or organizations or in certain areas – may not be universally applied due to financial and capacity challenges. May leave room for interpretation resulting in a range of development practices. May result in uneven protection of coastal and riparian zones.

Education Campaign: An education campaign can help Nova Scotians understand that setbacks and vegetated buffers can produce a myriad of socio-economic benefits, both private and public, in addition to ecological benefits over the short and long term. An education campaign could be implemented in combination with one or more other regulatory tools, and would be an important element of a government setback or vegetated buffer strategy. Some research, however, suggests that education campaigns alone will not result in behavioural change (Mackenzie-Mohr, 2000).

> ***Pros:*** Can create buy-in by helping Nova Scotians understand how these land use planning practices benefit landowners and the public good.
> ***Cons:*** Challenge of reaching a large, multi-sectoral audience. Unlikely to be effective if it is the sole tool chosen.

Enhance and enforce existing regulations, programs and policies: The Province has a number of regulations, programs and policies which could be promoted, enforced and enhanced to achieve some of the outcomes of riparian and coastal zone protection. For example:

- The *Subdivision Regulations* under the *Municipal Government Act* could require vegetated buffers;
- The *On-site Sewage Disposal Systems Regulations* could require a greater setback distance from watercourses;
- A Statement of Provincial Interest regarding vegetated buffers or setbacks could be created, or the existing floodplain SPI could be clarified to include a specific setback distance;
- Watercourse alteration permits under the *Activities Designation Regulations* could be required for a greater number of activities including vegetation removal and construction;
- The *Wildlife Habitat and Watercourse Protection Regulations* could be expanded or more vigorously enforced;
- The creation of conservation easements could be promoted;
- Educational and incentive programs could be created; and
- Environmental Home Assessment Program and the Environmental Farm Plan programs could be extended and expanded.

> ***Pros:*** Requires less financial investment and data. Avoids the need for new legislation.
> ***Cons:*** Requires high degree of coordination amongst departments, programs and industries. May require additional human resources. May fail to produce desired changes in riparian and coastal management. May be seen by the public as an ineffective or "weak" approach.

In summary, all of these regulatory pathways are frequently used across different jurisdictions. Although incentives and market-based approaches are slightly less common in Canada, they are used frequently in the U.S.

4.1.12. Timing of selected regulatory approach

Legislation or permitting, as opposed to voluntary approaches, can be implemented immediately or can be phased in.

Incremental: For example, during the first 2-5 years, the Province could implement a set of BMPs around the use of vegetated buffers and setbacks and work with all relevant sectors to provide educational tools and technical support. After this initial period, regulations could be implemented to require these same vegetated buffer and setback standards. Another example is that legislation could first apply to crown land only, and then on private land.

> ***Pros:*** Allows industries and stakeholder groups to shift practices over time which can reduce any negative impacts of requiring immediate compliance.

Cons: Knowing that regulations are coming in the future might result in a "rush to build" in some sectors.

All at once: New vegetated buffer or setback legislation or permits can be implemented all at once to reduce the likelihood of a "rush to build". According to one interviewee, the market exerts a stronger influence over peoples' decision to buy or develop land than upcoming regulations. A rush to build can be prevented by implementing a moratorium or by issuing approvals with fixed expiry dates. Neither New Brunswick nor PEI experienced such a rush when their policies were implemented.

Pros: Can prevent a "rush to build".
Cons: Does not allow enough time for industry to adjust resulting in lost revenue or increased costs.

4.2. *Challenges implementing vegetated buffers and setbacks*

In the literature review and interviews, the following challenges to implementing a vegetated buffer or setback were identified.

Determine an appropriate setback or buffer design: Despite the information provided in this report, it will be challenging to determine exactly how a vegetated buffer or setback should be designed and implemented. There are many factors which must be taken into consideration including width, vertical elevation, approach, allowable thinning, permitted and prohibited activities etc.

Identify levels and areas of risk: If the Province chooses to adopt a hazard or floodplain mapping approach, a great deal of mapping, human, technological and financial resources may be required.

Enforce current and proposed policies: Municipal and provincial planning departments often lack the resources to enforce regulations. Ensuring compliance with requirements, such as tree retention and prescriptions for slope, can be particularly difficult both because of limited human resources and the difficulty of measuring compliance in the field.

Identify and manage legal liability: The Province must assess the extent of its legal liability when instructing citizens to site development at a certain distance from watercourses. For example, if a setback is too small to protect property from erosion in high risk areas, can the Province be held accountable? Another example is whether, by regulating or otherwise limiting activities in a vegetated buffer or setback, the Province can be sued for the lost use of land? Advisers have indicated that Canadian law allows owners to use their property for various activities, but it does not specifically entitle them to build on their land (R. Capozi, personal communication, November 25, 2011).

Clarify how vegetated buffers and setbacks are used with coastal armouring: If armouring is permitted, there is a question of how vegetated buffers and setbacks should be applied if erosion has been significantly limited by armouring. For example, New Brunswick's' Coastal Areas Protection Policy prohibits the use of groins, but permits the use of "acceptable erosion control structures."

Determine appropriate jurisdiction for policy: The Province has a mandate to protect the environment (via the Environment Act) and regulate certain land uses (e.g. forestry, agriculture) while municipalities have the power to regulate development. The Province must determine if a provincial vegetated buffer or setback is appropriate or if municipalities should be tasked with the management of these zones.

Balance private property rights and public interest: Municipal policies and by-laws regulate land use on private land to reduce the risk of land use conflicts and to protect the public interest. In the interest of fairness, municipalities will often permit development on lots that existed prior to the implementation of new regulations even if the proposed development does not meet minimum vegetated buffer or setback requirements.

Balance competing interests: Waterfronts serve a wide variety of uses that are frequently incompatible. Residential and industrial development, tourism operations, agriculture, forestry, aquaculture and other land uses can lead to pressures and changes that can directly affect ecosystems and other uses. Such impacts can extend beyond the direct footprint of the development and can be lead to pollution, sedimentation and changes in coastal dynamics.

Balance simplicity and complexity in regulatory approach: It will be challenging to identify a regulatory approach that captures the complexity of the issues discussed in this report and is easy for land owners, developers and industry to understand. For example, a 20 m vegetated buffer for all land uses and watercourse types is easy to understand, however, its simplicity may result in a limited ability to protect diverse landscapes for diverse land uses. Conversely, a regulation that requires different widths, conditions for slope, permitted activities and application to different land uses will be difficult for land owners, developers and industry to navigate.

4.3. *Supporting recommendations*

During the course of this research, several related gaps were identified that limit the ability of the Province to manage riparian and coastal zones effectively. Below are listed several recommendations which would support the development of tools and general efforts to manage these zones.

Create a policy on coastal armouring to ensure consistency and best practice: According to several government staff and stakeholders, coastal armouring is being inappropriately installed. There is no guidance for property owners regarding when or where armouring should be used. The scientific literature suggests that armouring should be used only as a last resort to save properties that are certain to fall into the ocean without intervention. Unfortunately, armouring often shifts erosion to other, unprotected sites and no recourse is available to these owners other than armouring their properties as well. Emphasis should be placed on siting development as far back from the coast as possible to render armouring unnecessary and to allow the coast to naturally change over time while protecting ecosystems. Clarity should be provided about when armouring should occur, information about the consequences of armouring (even when it is done well), as well as a list of qualified professionals. Clarity should also be provided about whether or not setbacks are required if armouring is installed.

Obtain LIDAR for entire coast: Several interviewees suggested that the Province should engage in funding partnerships with municipalities, academia, industry and NGOs to obtain LIDAR data for priority (and eventually all) coastal regions. Possessing this data would allow government to perform more detailed analysis of coastal hazards (including sea level rise, storm surge and erosion rates), and also use the data to inform other areas of provincial interest. If the data collected were to be made available to the public, non-government groups and academics would be able to perform a wide range of analysis and share their results with the Province allowing government to benefit from the research of professionals at no (or low) additional cost. According to Tim Webster of the Applied Geomatics Research Group, many sections of the coast have already been flown and flying the remaining areas could be prioritized based on risk or population density. The Government of New Brunswick recently engaged in funding partnerships to obtain LIDAR for the entire coast, and Prince Edward Island has already flown the entire province. The GeoNova secretariat will be releasing a report from its LIDAR working group regarding recommendations for the strategic direction of LIDAR for the province in the near future; this report may help to inform any decision regarding the possibility of obtaining LIDAR data of Nova Scotia’s coasts.

Map the area of Nova Scotia affected by vegetated buffers or setbacks: It may be of interest to the Province to determine how much land would be included in a vegetated buffer or a setback policy. Using GIS, the Province could see how much land would be captured by a 15 m, 30 m, 50 m etc. vegetated buffer or setback.

Undertake a risk assessment for coastal infrastructure: The same roads repeatedly wash-out, and are repaired at great expense by government. As part of the ACAS program, the Department of Transportation and Infrastructure Renewal (TIR) will start an inventory of "hotspots" in Summer 2012 and TIR has already developed a draft strategy to implement appropriate adaptation actions in coastal areas and near vulnerable streams (Pett, 2012; Webster & Pett, 2012; see ACAS website http://atlanticadaptation.ca/ACAS-Conference). Municipalities and the Nova Scotia Climate Change Directorate are also beginning these assessments, however an auditing system should be developed to document success, costs, benefits and best adaptive management practices.

Investigate appropriate metrics for establishing a vertical setback for coastal zones: There is little literature on establishing an appropriate vertical setback and how it should be calculated. Interviews suggest that the maximum recorded storm surge should be combined with the maximum predicted sea level rise to establish a vertical setback that will protect property from storm events and climate change; however this is more of a common sense approach than a scientifically rigorous one. More research is recommended to determine a rigorous method of determining an appropriate vertical setback.

Seek legal advice about government liability: The Province should inform itself of its legal liability related to the content and wording of buffer and setback policies distances designed to protect people and property from harm. Likewise, the wording of vegetated buffer and setback policies should be examined by legal professionals to ensure that regulations can be defended in court if necessary. When PEI updated its riparian buffer policy in 2008, they removed many conditions such as allowable thinning and slope because they were not legally defensible due to the way the legislation was worded. When providing guidance to the public about erosion rates and appropriate setback or vegetated buffer widths, government should clearly state the potential for error and with whom the risk ultimately lies (i.e., the land owner).

Clarify policy application along Nova Scotia-New Brunswick border: The Nova Scotia-New Brunswick border shares a minimum of two rivers along which different policies may exist on each side of the river. Extra effort should be made to inform residents in these areas of any new policy developments and how they differ from New Brunswick's policies.

Develop new construction standards for homes in the coastal zone: Innovative building designs appropriate for coastal environments could be encouraged or required. While placing houses on stilts, as is done in the mid and South Atlantic coast, is not appropriate for the North Atlantic climate, new, locally appropriate designs could be investigated. See the Designed … for safer living® program by the Institute for Catastrophic Loss Reduction.

Conduct water quality monitoring to measure policy effectiveness: Coastal and inland water quality monitoring should be undertaken before and after vegetated buffers are implemented to measure the effectiveness of any new policies.

5. Conclusion

This report has provided a summary of key background information regarding the ecological, economic, and societal functions provided by riparian and coastal zones as well as vegetated buffers and setbacks. Scientific literature was examined and summarized in order to present a picture of the vegetated buffer or setback widths necessary to preserve a range of ecological functions. Policies from Canadian, American and some international jurisdictions were examined in order to gain an understanding of common policy approaches to riparian and coastal zone management and the use of vegetated buffers and setbacks in these zones. Guidelines were prepared to help the Province determine how vegetated buffers and/or setbacks can best be designed and implemented to achieve the desired objectives. Supporting recommendations have also been provided that may complement the development of policies regarding vegetated buffers and setbacks in Nova Scotia.

It is apparent that vegetated buffers and setbacks in riparian and coastal zones can provide many valuable services to Nova Scotians that may outweigh the costs of implementing a buffer/setback policy as discussed in Section 3.4. Vegetated buffers have been shown to filter pollution in overland runoff, promote of bank stability and reduce erosion, deliver and cycle nutrients, provide terrestrial & aquatic habitat, support riffle-pool stream morphology, enhance habitat connectivity and biodiversity, and moderate peak flow during storms. Setbacks can protect property from flooding and erosion. In short the use of one or both of these management tools can protect people, property, water quality, and wildlife habitat.

This review indicates that:

1. There is no provincial-level vegetated buffer or setback policy in Nova Scotia for all land uses for either riparian or coastal zones;
2. Different vegetated buffer and setback widths are required to protect different ecosystem services, and wider buffer is needed to provide terrestrial habitat services. The literature review did not reveal the minimum setback distance needed to protect property or ecosystems in riparian or coastal zones;
3. Ecological, hydrological and geological processes occur differently in coastal zones than riparian zones, therefore separate policies should be developed for each zone;
4. In order to determine an appropriate setback or vegetated buffer width in coastal zones, LIDAR data and tidal flood modeling are recommended to create coastal hazard maps, or alternatively, site specific assessments could be used; and
5. There are ten key management decisions required to establish a vegetated buffer or setback policy in riparian or coastal zones.

The scientific literature provides some guidance regarding the vegetated riparian buffer widths required to provide various ecosystem services; different vegetated buffer and setback widths are required to protect different ecosystem services. Although vegetated riparian buffers used around the world have a wide range of widths due to individual site conditions, the scientific studies indicate that a 20-30 m wide vegetated buffer captures most of the bank stability, nutrient filtering, and stream temperature control services, and that wider buffers (e.g., ≥50 m) are required to protect terrestrial habitat. Setbacks and armouring provide almost no ecological services beyond immediate property protection. One thing is clear: coastal water quality can best be protected by protecting inland water quality through the use of vegetated riparian buffers.

The literature is less clear about the setback or vegetated buffer distances required to protect coastal property from erosion, flooding and sea level rise, to filter pollutants, and to protect coastal ecosystems from development. This scarcity of information can likely be attributed to the fact that it is harder to generalize ecosystem types and erosion patterns in coastal zones than it is in riparian zones; therefore it is much harder to define vegetated buffer or setback widths that will provide a particular ecosystem service.

Because of the unique geology, ecology and hydrology of coastal zones, the use of LIDAR to create coastal hazard maps, or site specific assessments are needed to tailor the recommendations to specific coastal areas. Not only must setbacks or vegetated buffers in coastal zones take local geology, tide and wave action, and storm history into account, they should also include a vertical component that will account for sea level rise, storm surge, and the Higher High Water Large Tide. In short, a single setback or vegetated buffer width in coastal zones for the province is not scientifically defensible, and due to the ecological, hydrological and geological differences between coastal and riparian zones, separate policies are advisable.

Coastal setbacks and the use of financial incentives are common in U.S. states. Vegetated riparian buffers are common requirements for forestry operations in Canada and the U.S. Some Canadian provinces (e.g., New Brunswick, PEI, Newfoundland) have regulations and/or policies that require province-wide vegetated buffers or setbacks in coastal and riparian zones. Nova Scotia lags behind Newfoundland, New Brunswick, PEI, Manitoba, BC, and many U.S. states when it comes to province-wide legislated vegetated buffers or setbacks – legislated vegetated buffers are only required for forestry operations, and setbacks are only required for on-site septic systems. What currently exists in Nova Scotia is a complex system of provincial permits and municipal land use by-laws which require setbacks for certain types of development. Other provinces are taking unified and proactive approaches to land use planning in order to protect people, property, and ecosystem functions from harm while saving millions of dollars on storm damage and disaster relief payments.

In closing, a few key points must be emphasized:

- Policy objectives will determine whether vegetated buffers or setbacks are applied in coastal and/or riparian zones, and how they are designed.
- Because of the impact of individual site characteristics, vegetated buffers and setbacks based on provincial mapping or site-specific data should be more successful at achieving the desired policy outcomes. Arbitrary or single-width setbacks and vegetated buffers will be less effective.
- Water-dependent infrastructure including wharves, docks, boat ramps, pump stations and supporting pipes for the purposes of accessing water should be exempt from (but encouraged to comply with where possible) setback or vegetated buffer requirements.
- Liability for storm-related damage to private property should be clearly communicated under all potential policy scenarios. Clarity around liability and funding for damages caused by storm-related erosion and flooding can help to discourage inappropriate waterfront development.
- Incentives will help encourage land owners to retain or restore vegetation in the absence of a policy explicitly requiring it.

As the information outlined in Table 3.1 and Table 3.2 suggests, the benefits to the public good, to provincial and municipal governments, and to individual property owners are significant. By enacting the *Environmental Goals and Sustainable Prosperity Act*, the Province has already recognized the importance of protecting important ecological functions that benefit the provincial economy and well-being. The Province should continue to balance environmental, social and economic impacts and benefits by requiring vegetated buffers or setbacks in riparian and coastal zones across the province. It will be challenging to create a policy approach that is both easy to understand and to enforce, and complex and flexible enough to address the geographical and ecological variation across the province. Nevertheless, vegetated buffers and setbacks are two management tools that are relatively simple, cost effective, and can provide numerous benefits to both the provincial government and the people of Nova Scotia.

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7. Appendices

Appendix A - Evaluation of scenarios presented in the decision-making flow chart

Table A. 1. Pros, cons, information needs and availability of this information at Provincial level of all possible elements of the decision-making framework illustrated in Figure 4.1 and Figure 4.2.

Element of Decision-making Framework	**Pros**	**Cons**	**Information Needs**	**Information Available?**
Application to land use				
Apply to all land uses ("Universal" approach)	Simple for government to implement, and for the public to understand. Could be perceived as fair in the sense that a "universal" policy would apply to everyone and not target or exclude specific sectors.	May place restrictive requirements on certain industries which would result in the loss of revenue. Not able to focus restrictions on land uses responsible for the most impact. Could be seen as unfair because it may unnecessarily restrict sectors that have little or no impact.	None	N/A
Vary by land use ("Sectoral" approach)	Allows government to focus restrictions on land uses that cause the most impact, to protect the most vulnerable sectors from erosion and flooding, or to exempt certain sectors from restrictive setback or vegetated buffer requirements that may hamper their economic viability.	Can result in uneven protection of watercourses. May be perceived as unfairly targeting or exempting certain sectors.	Effects of each industry on water quality, ecological functioning, and the vulnerability of each industry to sea level rise, flooding and erosion.	Information available but not likely assembled and analyzed
Framework for prioritizing sites				
Apply to new properties only (a "Protective" approach)	This approach is proactive and will slow or stop the advance of riparian and coastal deforestation and/or the damage caused to development, particularly residential development, by storms.	Fails to address the lack of vegetation and proximity of structures to the water of existing riparian or coastal developments, only protects ecosystem functions, and people and property in a portion of the province; will not necessarily produce healthy ecosystems.	None	N/A
Apply to new and existing properties (a "Restorative" approach)	Addresses deforestation and siting issues on existing properties, works to restore ecological functioning across the entire province. Can act as an educational tool for property owners who would not otherwise learn about new programs under a protective approach (e.g., by purchasing new property).	Difficult to implement. Legislative appropriation of lands can result in legal challenges and political unpopularity. May be difficult to enforce.	None	N/A
Application to stream or coastal type				
Apply to all coastal ecosystems	Provides uniform protection along entre coast (depending on which land uses are covered). Recognizes that all coastal ecosystems provide important functions. Protects property on all coastal types.	May require setbacks or vegetated buffers on coastal ecosystems which are not at risk of erosion or flooding.	None	N/A

Ecological features of value	Allows government to focus effort and resources on vulnerable ecosystems or ecosystems that provide key services such as storm surge absorption, or recreation and tourism activities.	Fails to address damage occurring outside of selected ecosystems which may still have ecological impacts and/or may impact the selected ecosystem type indirectly.	Maps of wetlands, marshes, sand dunes etc.	Yes (wetlands), unknown
Hazard Classification	Allows governments to focus management and financial resources on the more dynamic high hazard areas of its coastline.	Requires extensive aerial photography and mapping to determine extent of hazards. There is some debate about the accuracy of erosion-rate mapping using aerial photographs: the margin of error can be as much as the annual erosion rate.	Surficial and bedrock geology maps, digital elevation, storm history	Yes
Erosion Rates	A simple number that captures regional variation. If the annual erosion rate is known, it is an easy distance for landowners to calculate.	Difficult to calculate (requires aerial photography and mapping), margin of error may be equivalent to annual erosion rate. Annual erosion rate will not capture major episodic erosion events caused by storms or naturally-occurring bank collapse.	Erosion rates	Not province-wide, can be difficult to estimate
Climate Change Projections	Taking a long-term view of coastal planning can reduce waste and costs when developments are damaged by coastal hazards or need to be destroyed or relocated as sea level rises. This approach can minimize the initial costs of considering sea level rise; adaptation costs are distributed over time.	Climate change projection mapping is costly and time consuming, and the margin of error can be significant due to the uncertainty in global and local sea-level rise projections.	Mapping of predicted sea level rise for some or the province's entire coastline.	Only in some ACAS communities. Unknown
Apply to all streams	Provides uniform protection along all streams (depending on which land uses are covered). Recognizes that all riparian zones provide important functions. Protects property on all stream types.	Vegetated buffers or setbacks on small streams (<1 m) may be un-popular.	None	N/A
Apply to fish bearing streams	Focuses effort and funds on specific ecological values. By protecting fish habitat, other ecological functions can also be protected (bank stability, filtration and infiltration, protection of property from flooding and erosion, provision of terrestrial habitat)	Focusing protection on specific ecological features of streams may ignore other ecological features of importance or non-ecological threats to property. Will only protect a portion of the province unless species of importance exist in all streams.	Identify streams bearing species of interest	Unknown.
Vary by stream size	Achieves policy objective of protecting property from flooding. Wider vegetated buffers will provide many ecological services (filtration, infiltration, terrestrial habitat etc.).	Difficult to apply the largest buffers in areas that tend to have existing development (e.g., estuaries)	None	N/A
Apply to flood prone areas	Will protect property from seasonal damage. A common sense approach that would likely be supported by the public.	Setbacks or vegetated buffers widths based on seasonal flooding may not be large enough to protect property from major storm events which can produce higher flood levels than occur seasonally. Mapping of flood prone areas may be difficult at the provincial level (expensive and time consuming) – may be better administered by municipalities. Will not protect ecological functioning in non-flood prone areas or the province.	Flood risk mapping	Unknown

Lot or structure size	Allows smaller lots to have accordingly small setbacks, doesn't penalize small property owners over large property owners. Matches setback to lifespan of structure	A small setback may be ineffective at protecting property from flooding or from erosion depending on the local relief and geological composition. For example in Maui, lots smaller than 30 m in depth are only required to have a 7.6 m setback, a distance that is unlikely to avoid the damages caused by storm surge during a significant storm event. Incorrectly calculated lifespans may result in flooding or land eroding away under a structure before the end of its functional life.	Average lifespan of various types of structures (i.e., residential, institutional, commercial) in Nova Scotia	Unknown
Site specific assessments	Site-specific, scientifically rigorous. Easily defensible in court. Province-wide data collection and database-building increases knowledge base. Effort and risk can be outsourced.	Would likely require a great deal of time, effort and resources by the private and public sectors to create such a system. There is a cost to the homeowner to hire an assessor.	None	N/A
Application of slope	Applying conditions for slope (i.e., requiring wider vegetated buffers on sloped land) can improve water quality by promoting the filtration of sediment and other pollutants. Can facilitate the application of appropriate vegetated buffer widths to local conditions.	Can be difficult to delineate and enforce.	Field measurement methods	N/A
Dimensions				
Single zone	This approach is the simplest for government as it requires less mapping, assessments or creation of complex policies. Simple for the public to understand.	Does not take into account local conditions; setbacks or buffers may be too small for some areas with rapid erosion rates and low elevations, and too large for others with slow erosion rates and high elevations. In coastal zones, land owners may feel that large setbacks are unfair if they live on a rocky coast with a high elevation. If the chosen setback or vegetated buffer distance is too small to capture the highest risk level, land owners may sue the government for requiring an "unsafe" setback or vegetated buffer width, unless the Province specifically divests itself of the legal responsibility for damages resulting from inappropriately sized setback or buffer widths.	Stream network, coastal boundary (e.g., high water mark)	Yes, but flawed
Feathered zones	Allows landowners more flexibility to modify their property. The overall setback distance ensures that structures are well back from watercourses providing excellent flood protection. The intermediate zone provides some riparian functions (e.g., such as nonpoint source pollution absorption and habitat provision) despite thinning and small structures. The vegetated buffer along the bank provides erosion prevention.	Can place a burden on landowners and enforcement staff when delineating the different zones. Can be challenging for enforcement staff to assess the degree of thinning that has occurred, an issue that could make legal challenges difficult. Reduced loss of trees due to wind-throw.	None	N/A

Coastal floodplains	Technically rigorous, easily defensible in court. Allows governments, industry and the public to site coastal development appropriately. Takes into account elevation. Does not subject landowners unfairly with blanket requirements which are unjustified by local relief and geology. Provides excellent visual materials for the public.	Does not take erosion risk into account. Financially and labour intensive. Maps would not be detailed enough to provide property-level information.	Floodplain mapping, flood frequency estimation, LIDAR or surveying	Not province-wide; needs geoscientist or engineer to map flood risk
Riparian floodplains	Allows governments to focus management and financial resources on the more dynamic high hazard areas of its watercourses. This is a "common sense" approach that is easily understood by land owners. If mapping is done accurately, this approach will be scientifically rigorous and fit the local context.	Requires intensive mapping to delineate floodplain for areas of interest or the entire province	Floodplain mapping, flood frequency estimation, LIDAR or surveying	Not province-wide; needs geoscientist or engineer to map flood risk
Delineation methods				
Fixed	Certainty of locating the setback in the field; ease in delineating the setback line on a map; and checking permit compliance.	Unresponsiveness to shoreline dynamics. A storm, beach nourishment project, or a new erosion control structure may quickly render the line obsolete unless the setback is periodically revised.	Monuments or other stationary boundary	No
Floating	Natural features respond to changing erosion and accretion rates and are in a sense "self-updating" and for this reason are often regarded as superior to setbacks delineated from static features.	Financial and administrative burden of managing and monitoring this "dynamic" line; vulnerability of natural features to storms; mean high water mark or other water level-related measurements are difficult to identify in the field, for landowners or enforcement officers, a surveyor would be required. There is some debate in the mapping community about the accuracy of sea level measurement systems in particular.	If chosen, the HHWLT or mean high water mark. The line of permanent vegetation does not require mapping	Unknown, N/A
Permitted activities	Permitting more activities rather than fewer allows more flexibility for land owners to modify their property. Permitting fewer activities will allow vegetation to continue to provide important functions, or will allow vegetation to regenerate.	Permitting fewer activities may make any new policy less popular. Permitting more activities may limit the functionality of riparian or coastal vegetation and reduce the number and quality of services provided by vegetation.	None	N/A
Regulatory approaches				
Legislation or regulation	Legally defensible. Government is seen to be "doing something about the issue". Sends a clear message to residents and industry about the values and expectations of government.	Can be costly and time-consuming to develop. Difficult to enforce. May result in legal challenges and court cases. "Command and control" approach can be seen as too heavy handed by some.		
Permit	Could allow for many types of developments with conditions. Could be seen as "development friendly". Could promote the use of intelligent coastal designs.	May fail to adequately reduce damages to ecosystems and prevent risks to property owners. Potentially large administrative burden on government, moderate administrative burden on developers.		

Incentives & market-based approaches	Government is seen to be less intrusive than under legally binding approaches. Allows landowners to decide how they will develop land. Provides compensation to landowners for the land that cannot longer be used for agriculture, forestry or for development.	Depending on the type of incentive, costs to government, either from direct payments or from lost tax revenues may be costly. Tax incentives may be irrelevant for certain sectors such as agriculture. Incentives may not be large enough to compensate landowners for the lost use of their property.		
Provide guidance to municipalities	Allows for flexibility to create setback design that accommodates local economic, geologic and geographic conditions, shifts financial and human resources burden to local governments.	Would not apply to crown lands or resources under provincial jurisdiction. Local governments may have limited capacity to implement such a complex zoning policy.		
Best Management Practices	Allows for flexibility. Does not require enforcement. Seen to be “development friendly”. Avoids “stepping on peoples’ toes” by not prescribing onerous, legally binding directions to industry, municipalities and residents.	Not legally binding. May only be taken up by select individuals, firms or organizations or in certain areas – may not be universally applied due to financial and capacity challenges. May leave room for interpretation resulting in a range of development practices. Results in uneven protection of coastal and riparian zones.		
Education Campaign	Can create buy-in by helping Nova Scotians understand how these land use planning practices benefit landowners and the public good.	Challenge of reaching a large, multi-sectoral audience. Unlikely to be effective if it is the sole tool chosen.		
Enhance and enforce existing programs and policies	Requires less financial investment and data. Avoids the need for new legislation.	Requires less financial investment and data. Avoids the need for new legislation.		
Armouring	Immediate protection from erosion	Can damage habitat, provides few ecosystem services, exacerbates erosion in other areas	Energy of water	Needs engineer or standardized assessment

Appendix B - Summary of ecosystem services provided by different vegetated buffer & setback widths

Table A. 2. Summary of research on ecosystem services provided by different vegetated buffer and setback widths (see references from Tables A.3-A.14). Studies indicate a 20 m buffer can capture 60% of the nutrients for most site types. Further, for most sites studied, a 20-50 m vegetated buffer captures most of the aquatic habitat services; a wider buffer is needed to provide terrestrial habitat services. Setbacks provide almost no ecological services beyond protecting property. The same is true with armouring.

	0-5 m	**5-10 m**	**10-20 m**	**20-50 m**	**50-100 m**	**> 100 m**	**Armouring**	**0-10 m**	**10-20 m**	**20-50 m**	**50-100 m**	**60 x erosion rate**	**< 100 yr storm**	**> 100 yr storm**	**2 m**	**4 m**
Services Provided	**Vegetated Buffer**							**Horizontal Setbacks**					**Vertical Setbacks**			
Riparian Zones																
Riparian bank stabilization (reduced erosion)	🟥	🟨	🟩	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Filtration of nitrogen species and phosphate (50% removal)[1]	🟥	🟨	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Sediment filtration (50% removal)[1]	🟥	🟨	🟨	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Fish habitat	🟥	🟥	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Invertebrate habitat	🟥	🟥	🟥	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Plant habitat	🟥	🟥	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Bird habitat	🟥	🟥	🟥	🟨	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Mammal habitat	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Reptile and amphibian habitat	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Peak flow management	🟥	🟥	🟥	🟥	🟨	🟩	🟥	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Coastal Zones																
Dune stabilization (reduced erosion)	🟥	🟨	🟩	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Reduced erosion of low rocky beaches	🟥	🟥	🟥	🟥	🟥	🟥	🟨	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
Cliff stabilization (reduced erosion)	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	⬜	⬜	⬜	⬜
Reduced hazard of loss of property on slowly eroding cliffs	🟥	🟥	🟨	🟩	🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟨	🟩	🟥	🟥
Reduced hazard of loss of property on rapidly eroding cliffs	🟥	🟥	🟨	🟨	🟨	🟩	🟨	🟥	🟥	⬜	🟩	🟨	🟨	🟩	🟥	🟥
Coastal flood protection (storm surge & sea level rise over next 50 years)	🟥	🟥	🟨	🟩	🟩	🟩	🟨	🟥	🟨	🟩	🟩	🟨	🟨	🟩	🟨	🟩

1. filtration efficiency is greater for shallower slopes and depends upon vegetation type

🟩	Able to provide the service	🟨	Uncertain ability to provide the service
🟥	Not able to provide the service	⬜	Not relevant

Appendix C - Riparian zone science

Riparian zones provide five main ecosystem services: bank stability and erosion prevention, pollutant filtration, flow moderation, provision of habitat and wildlife corridors, and channel morphology control.

1. Bank stability & erosion prevention

Studies have shown that sediment from stream banks can account for over 50% sediment yield in a given watershed (Lawler *et al.,* 1995). Riparian vegetation helps to hold soils in place, preventing bank erosion, a process that contributes sediment to water bodies which reduces water quality, and channel widening which can bring banks closer to dwellings. Preventing bank erosion can maintain property size, appearance and value (Michael *et al.*, 1996; McMahon, 1994; Arbour Day Foundation, n.d). It should be noted that while vegetation can slow erosion, it is unclear whether it can withstand the effects of extreme storm events or episodic erosion events, particularly in coastal zones.

The root systems of riparian vegetation “moderate soil moisture conditions in stream banks and roots provide tensile strength to the soil matrix, enhancing bank stability” (Fisher & Fischenich, 2000). By increasing bank stability, riparian vegetation can reduce the number of active channels (braided streams), reduce horizontal migration rates, and create narrower and deeper channels and increased channel relief, effects which increase with vegetation density (Gran & Paola, 2001).

The ability of riparian soil to retain moisture also affects freeze-thaw cycles in these zones which can weaken soils and increase vulnerability to erosion (Wynn & Mostaghimi, 2006). According to Van de Wiel and Darby (2007), riparian vegetation provides the most bank stabilization utility when located on low, shallow, banks comprised of weakly cohesive sediments.” There are seven mechanisms through which vegetation can reduce streambank erosion (Gray, 1977; Bailey & Copeland, 1961; Allen & Leach, 1997; Klingeman & Bradley, 1976; Stuart & Edwards, 2006):

1. Increase soil resistance to erosion
    2. Increase soil strength through increasing root networks;
3. Reduce erosive power of water
    4. Intercept water, reducing rain splash erosion;
    5. Increase water infiltration, reducing overland flow;
    6. Reduce soil water by increased loss through transpiration; and
    7. Roots and LWD can induce sediment deposition by causing zones of slow velocity near the bank, allowing coarse sediments to deposit.

There has not been a great deal of research about the specific buffer width necessary to prevent bank erosion, however several studies have visually or empirically observed that riparian vegetation provides localized bank protection (Dillaha *et al*., 1988; Abernethy & Rutherfurd, 2000; Zaimes *et al*., 2004 & 2008). Allen & Leach (1997) suggest that riparian buffers need to be 10-20 m wide to adequately prevent erosion, and Wenger (1999) suggests that buffers should be 9 m at an absolute minimum. Wenger (1999) suggests that “as a general rule, buffer widths sufficient for other purposes should also be sufficient to prevent bank erosion and allow reasonable stream migration.”

2. Filtration of pollutants

Riparian vegetation can filter sediment, nutrients, bacteria, pharmaceuticals, salt and toxins that can reduce water quality and make it unsuitable for uses such as drinking water, agriculture, industry, recreation, and for aquatic habitat (Poletika *et al*., 2009; Lowrance & Sheridan, 2005; Robbins *et al*., 2001; Carpenter *et al*., 1998; Swackhamer *et al.*, 2004). By increasing surface roughness, riparian vegetation can slow the flow of contaminated water into watercourses (Borin *et al.*, 2005) and can absorb some of the water-borne pollutants during the retention time in the buffer (Livingston & McCarron, 2008; Blanche *et al.*, 2003).

Land-based sources of nutrients, such as nitrogen and phosphorous, enter watercourses and encourage excessive growth of algal blooms in inland and coastal waters (Carpenter *et al.*, 1998; Swackhamer *et al.*, 2004). These blooms increase the Biological Oxygen Demand (BOD) in water, which can cause oxygen levels to drop resulting in die-offs of other aquatic organisms (Boesch *et al.*, 2001, Rabalais *et al.*, 2001). The unwanted growth of algae (i.e., eutrophication) is an important water quality issue because it limits economic, tourism and recreational opportunities and can affect drinking water quality (USEPA, 2009a). An excess of nitrates in drinking water sources can pose a human health risk (e.g., methemoglobinemia or "blue baby syndrome" (USEPA, 2009a)).

An important concept in stormwater management is the concept of the "first flush" wherein "the early stages of runoff the land surfaces, especially the impervious surfaces like streets and parking areas, are flushed clean by the stormwater. This creates a shock loading of pollutants. Studies in Florida have determined that the first one inch of runoff generally carries 90% of the pollution from a storm" (Livingston & McCarron, 2008).

There is little consensus in the scientific literature about the overall effectiveness of riparian buffers at removing pollutants or about the vegetated buffer widths that will effectively remove them, although a great deal of research has been conducted on the subject (Walter *et al*., 2009; Mayer *et al.*, 2005; Mayer *et al.*, 2007; Schulz, 2004; Krutz *et al.*, 2005). Despite the lack of consensus, multiple studies have attempted to quantify the ability of riparian buffers to remove pollutants suspended in overland runoff.

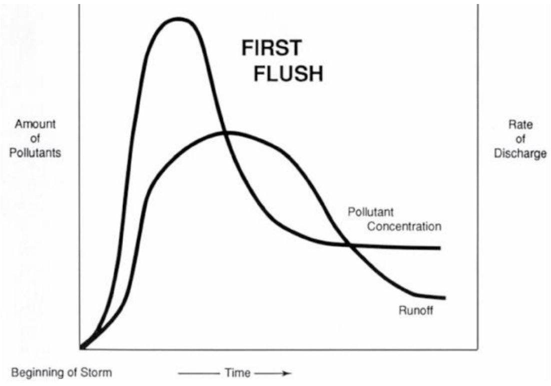

Figure A.1. Illustration of "first flush" concept (Livingston & McCarron, 2008).

Numerous studies have reviewed literature pertaining to phosphorous and nitrogen absorption by vegetated buffers (Walter *et al*., 2009; Mayer *et al.*, 2005; Mayer *et al.*, 2007; Schulz, 2004; Krutz *et al.*, 2005; Liu *et al.*, 2008; Dorioz *et al.*, 2006; Hoffmann *et al.*, 2009; Stevens & Quinton, 2009), however, according to Walter *et al*. (2009), "the data are particularly imprecise with regards to vegetated buffer sizes required for effective reduction in soluble nonpoint source pollutants such as nutrients, pesticides and pathogens." Walter *et al*. (2009) suggest that nitrogen is the best understood nutrient, and phosphorus the worst, when it comes to riparian processes.

Polluted runoff can move horizontally into surface waters, or vertically into groundwater (Desbonnet *et al.*, 1994). Nutrients and chemical pollutants can enter watercourses in their dissolved form or when they bind to sediments (Munoz-Carpena & Parsons, 2004). Metals, pesticides, phosphorus and some forms of nitrogen have a greater tendency to bind to sediments, whereas nitrates have a lower tendency to bind to sediments and are often found in a dissolved phase (Desbonnet *et al*., 1994).

Phosphorus is often attached to sediment or organic matter and vegetated buffers designed to trap sediment will be effective at removing phosphorus (Wenger, 1999). Wenger (1999) also argues that vegetated riparian buffers are only effective as phosphorus sinks in the short-term, and that on-site management of phosphorus sources is the most effective way to control phosphorous deposits in the long-term.

Vegetated buffers can provide very good control of nitrogen, including nitrates (Wenger, 1999; Mayer *et al.*, 2007). There are two ways in which a vegetated riparian buffer can remove nitrogen: uptake by vegetation and denitrification (Wenger, 1999). In a review of 45 studies, Mayer *et al.* (2007) found that wider vegetated buffers (e.g., >50 m) remove nitrogen more effectively than narrower vegetated buffers (e.g., 0-25 m), and that nitrogen removal occurred more efficient at the subsurface level than at the surface. Deep-rooted vegetation is more effective at removing subsurface nitrogen than shallow rooted vegetation (Desbonnet *et al*., 1994; Cooper, 1990). However, as with phosphorous, vegetated buffers that are designed to trap sediments will also trap sediment-bound nitrogen (Mayer *et al.*, 2007).

The widths necessary for reducing pollutant concentrations vary based on area ratio of buffer to source field, slope, vegetation type, permeability of soils, pollutant load concentration and distribution (e.g., concentrated or sheet flow) (Fischer & Fischenich, 2000; Liu *et al*., 2008). Sloped land can reduce the effectiveness of vegetated buffers as they reduce the retention time of runoff water which is an important factor in pollution absorption (Peterjohn & Correll, 1984; Dillaha *et al.*, 1989; Magette *et al.*, 1989; Phillips, 1989; Desbonnet *et al*., 1994). A slope of 15% or less allows for adequate retention time and pollution absorption and slopes greater than 15% may be less effective (Desbonnet *et al*., 1994). Similarly, Franti (1997) showed that slopes ranging from 3-12% vegetated buffers can remove 56-97% of sediment, depending on the width of the vegetated buffer and the area draining in to the vegetated buffer (Franti, 1997). "Dillaha *et al.* (1988, 1989) found that as buffer slope increased from 11% to 16%, sediment removal efficiency declined by 7-38%" (Wenger, 1999).

Connectivity of reaches with intact riparian vegetation is important for filtration processes (Naiman *et al.,* 2005; Rabeni & Smale, 1995). Pollutants, sediment or nutrients from adjacent land can easily enter the stream through gaps in riparian areas (Freeman *et al*., 2003, Gergel *et al*., 2002; Liu *et al*., 2008). Poletika *et al*., (2009) found that pesticides were removed most effectively by grassed buffers when runoff flow was uniform (across the whole length of the buffer), and less effective when volume was high or when concentrated (buffer only 10% of plot width). In New Zealand Storey and Cowley (1997) found that after crossing pastoral regions, streams needed to pass through at least 300 m of remnant forested patches for dissolved oxygen and temperature to return to control levels and at least 600 m to restore macro invertebrate communities and nutrient concentrations to those of controls. Similarly, (Frimpong *et al*., 2005) identified 600 m at a width of 30 m as the optimal length of riparian area for fish communities in an agricultural area of Indiana.

Vegetation type (i.e., grasses, shrubs, and trees) is often a factor when measuring pollutant removal since different foliage and root types affect pollutant deposition and absorption (Knight *et al*., 2010; Desbonnet *et al*., 1994; Fisher & Fischenich, 2000). Grassy buffers are reported to be very effective at filtering out sediment and nutrients that are bound to sediment or organic matter, particularly stiff or tall varieties due to their flow-retarding structure (Dosskey, 2001; Mayer *et al*., 2007; Liu *et al*., 2008), but are less effective than other vegetation types on lands that are frequently flooded. Grassy buffers also have low wildlife habitat value (Desbonnet *et al*., 1994). Woody plants with deep root systems are reported to be better at removing nitrates and phosphorus from groundwater (Søvik & Syversen, 2008); hardwood species are reported to be better than conifers at performing this function (Desbonnet *et al*., 1994). While trees might effectively remove nitrates and phosphorus, trees alone are less effective than herbaceous species at sediment retention (Daniels & Gilliam, 1996). Shrubs or other plants with shallow roots are reported to be less effective at removing non-sediment-bound nitrogen and phosphorous (Desbonnet *et al*., 1994; Schmitt *et al.*, 1999; Uusi-Kamppa *et al*., 2000).

There appears to be some consensus that wider buffers remove more pollutants (Mayer *et al*., 2007; Zhang *et al*., 2010; Liu *et al*., 2008). For example, Vaidya *et al.* (2008) tested a 20 m no cut vegetated buffer, a 20 m select cut, a 30 m select cut, and a control in Nova Scotia and found that the 30 m select cut buffer protected water quality more effectively than the 20 m no cut buffer, indicating that width is more important that tree density.

Regarding the efficacy of riparian vegetation in removing phosphorous, nitrogen and nitrates, Wenger (1999) concludes that "In most cases 30 m (100 ft) buffers should provide good control, and 15 m (50 ft) buffers should be sufficient under many conditions." According to several studies, relatively thin (e.g., <20 m) vegetated buffers can be effective at removing sediment (e.g., Broadmeadow & Nisbet, 2004; Hawes & Smith, 2005). Liu *et al.* (2008) show that beyond 10 m in width, sediment trapping efficacy does not improve significantly. Wong and McCuen (1982) found that the relationship between buffer width and percent sediment removal was not linear and that disproportionally bigger buffers are required to achieve incremental increases in sediment removal. Table A.3 and Table A.4 list vegetated buffer widths required to filter sediments and pollutants with varying levels of efficacy. According to Desbonnet *et al.* (1994), optimal efficiency is achieved at 80% removal.

Table A.3. Recommended widths of buffer zones and corridors for water quality considerations (Adapted from Fisher & Fischenich, 2000).

Author & Vegetation Type	Width (m)	Reported Reductions
		Forest
Lowrance (1992)	7	Nitrate (groundwater) 100%
Shisler *et al.* (1987)	19	Nitrogen 89%, phosphorus 80%
Lynch *et al.* (1985)	30	Sediment 75–80%
		Grass
Horner & Mar (1982)	61	Sediment 80%
Schwer & Clausen (1989)	26	Sediment 45%, phosphorus 78%, total Kedall N 76%, ammonia 2%
Young *et al.* (1980)	25	Sediment 92%
Chaubey *et al.* (1994)	24	Nitrate 96%, phosphorus 88%, sediment 80%, bacteria 0%
Schellinger & Clausen (1992)	23	Fecal coliform 30%
Arora *et al.* (1996)	20	Herbicides 8–100%, sediment 40–100%
Nichols *et al.* (1998)	18	Estrogen 98%
Daniels & Gilliam (1996)	6–18	Sediment 30–60%, total Kedall N 35–50%, ammonia 20–50%, nitrate 50–90%, phosphorus 60%, orthophosphorus 50%
Ghaffarzadeh *et al.* (1992)	9	Sediment 85%
Magette *et al.* (1989)	5–9	Nutrients <50%
Dillaha *et al.* (1989)	4–9	Sediment 84%, phosphorus 79%, nitrogen 73%
Madison *et al.* (1992)	5	Nitrate and orthophosphorus 90%
Lee *et al.* (1989)	3–6	Sediment 66–77%, total-N 28–42%, nitrate 25–42%, total-P 37–52%, orthophosphorus 34–43%
		Mixed
Lee *et al.* (2000)	7–16	Sediment 70–90%, total-N 50–80%, nitrate 41–92%, total-P 46–93%, orthophosphorus 28–85%

Table A.4. Effectiveness of various vegetated buffers widths at removing sediment, nitrogen and phosphorous. Desbonnet *et al.* (1994) argue that in general, a 5 m wide vegetated buffer will remove greater than 50% of pollutants (Desbonnet *et al.*, 1994).

	Vegetated Buffer Width (m)		
% Removal	**Sediment**	**Nitrogen**	**Phosphorous**
50	0.5	3.5	5
60	2	9	12
70	7	23	35
80	25	60	85
90	90	150	250
99	300	360	550

3. Flow moderation

Vegetation adjacent to watercourses helps to control infiltration rates. "When water seeps into the ground it is either absorbed by the plants and soil or passes through the soil to become part of the ground water supply" (Livingston & McCarron, 2008). Riparian vegetation (and all natural vegetation) helps to slow the flow of stormwater over land when stalks, stems, branches, and foliage increase the resistance to flow and reduce the local flow velocities, allowing water to infiltrate more slowly (Figure A.2) (Gray, 1977; Bailey & Copeland, 1961; Allen, 1978; Klingeman & Bradley, 1976; Rose, 2004). Riparian vegetation intercepts approximately 20% of total annual precipitation which helps slow the flow of water over land into streams (MacDonald *et al.*, 2012). A high infiltration capacity enables overland flow form rain events to be absorbed by the riparian zone before reaching the watercourse, resulting in moderated peak flows and a reduced likelihood of flooding (Walsh *et al*., 2005).

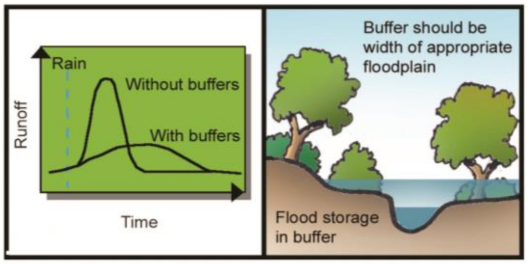

Figure A.2. Effect of vegetated riparian buffer on flow moderation in floodplains (U.S. Department of Agriculture – National Agroforestry Centre).

In highly impervious watersheds, water is unable to infiltrate the soil and water flows quickly over the land increasing rates of water delivery to streams which can affect in-stream peak flows, potentially causing flooding if water enters too quickly (Figure A.3) (Rose, 2004; Scheuler, 1994). Conditions that encourage a high filtration rate include well vegetated land, avoidance of soil compaction and a topsoil layer that has been made porous by insect and animal burrowing (Fetter, 1994). One study showed that forest vegetation and litter lowered stream elevation from 9.9 m to 5.3 m for a 100-year flood (Bertulli, 1981).

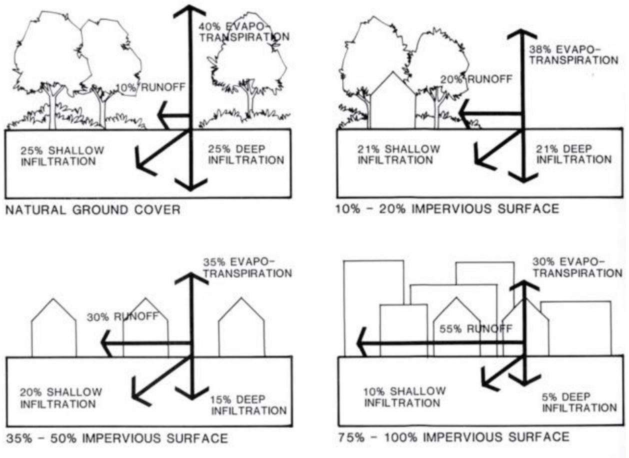

Figure A.3. Changes in runoff flows resulting from paved surfaces (Livingston & McCarron, 2008)

Because riparian zones constitute such a relatively small portion of catchments areas that they have a limited effect on stormwater processes (Walsh *et al.*, 2005).

4. Ecosystem Values

Riparian vegetation provides important habitat and food sources for fish, reptiles and amphibians, invertebrates, birds, mammals and plants. They can act as movement corridors for wildlife and are sites of high biological diversity.

Riparian ecosystems are unique due to their proximity to water and their function as a transitional zone, or ecotone, between aquatic and upland ecosystems (Castelle *et al*., 1994). The microclimate of riparian zones is different from upland areas: there is generally more shade, higher humidity, and increased air movement. These zones form highly productive corridors with a high degree of biodiversity (Decamps *et al*., 2004). A study by Stauffer *et al.* (2000) demonstrated that streams with wooded riparian zones "had higher index of biological integrity (IBI) scores, species richness, diversity, and percentages of benthic insectivores and herbivores than streams with open riparian zones." They provide year round habitat for many aquatic and riparian-obligate species and serve as migration corridors or feeding grounds for others (USEPA, 2009; Environment Canada, 2005; Stoffyn-Egli & Willison, 2011).

Riparian vegetation provides habitat for wildlife, both directly through the provision of shelter for terrestrial species and indirectly through the provision of microclimate moderation for aquatic species (MacMillan *et al*., 2008; Macdonald *et al*., 2003; Jackson *et al.*, 2001; Poole & Berman, 2001). The increased humidity is important to plant and lichen growth and tends to make the environment more favourable for many amphibians and some small mammals (Bancroft & Crossland, 2009).

Table A.5. Effectiveness of various vegetated buffers widths for providing terrestrial wildlife habitat (Adapted from Desbonnet *et al.*, 1994).

Vegetated Buffer Width (m)	Wildlife Habitat Value
5	Poor wildlife habitat; good for temporary wildlife activities
10	Minimally protects stream wildlife habitat; poor wildlife habitat value; good for temporary wildlife activities
15	Minimal general wildlife and avian habitat
20	Minimal general wildlife habitat; some value as avian habitat
30	May have use as a wildlife travel corridor and avian habitat
50	Minimal general wildlife and avian habitat value
75	Fair to good general wildlife and avian habitat value
100	Good wildlife habitat value; may protect significant wildlife habitat
200	Excellent wildlife habitat value; may support a diverse community
600	Excellent wildlife habitat value; supports a diverse community; protection of significant wildlife habitat

4.1. Fish habitat

Sediment water temperature and organic inputs, including leaf litter and large woody debris (LWD) are important determinants of aquatic habitat quality which are provided by riparian vegetation (Wenger, 1999; May *et al.*, 1997). Excess sediments introduced into streams via overland runoff or through bank erosion can suffocate salmon eggs which require gravel stream beds (USEPA 2009b; Davies & Nelson, 1994; Jones *et al*., 1999). Riparian trees shade the stream, cool shallow groundwater and maintain cool temperatures ideal for fish populations, including salmonids, and other aquatic species (MacMillan *et al.*, 2008; Macdonald *et al*., 2003; Jackson *et al.*, 2001; Poole & Berman, 2001). Stream temperature is important because many aquatic organisms can only survive within a relative narrow temperature range, trout being a good example of such a species (Allan, 1995; MacMillan *et al*., 2008). According to Karr and Schlosser (1978), increased water temperatures reduce oxygen solubility which can harm some aquatics species and reduce the ability of water to assimilate organic material. Shading has the greatest impact on small and headwater streams (Wenger, 1999; Collier *et al*., 1995; Freeman *et al*., 2007).

Riparian vegetation contributes LWD which creates a riffle-pool stream structure that provides still pools for fish spawning (Mossop & Bradford, 2004; Fisher & Fischenich, 2000; Naiman & Bilby, 1998). Organic matter in the form of leaf litter provides food for fish and macroinvertebrates (Johnson & Covich, 1997; Fisher & Fischenich, 2000; Bilby & Bisson, 1992, 1998; Gregory *et al.*, 1991; Murphy & Meehan, 1991). A study by Sawyer *et al*. (2004) showed that "water chemistry showed the greatest relationship to macroinvertebrate and fish community structure followed by instream habitat and land use….Analysis of land-use data showed that agricultural practices and urbanization occurring within 30 m of the stream had higher correlations to macroinvertebrate and fish community structure than catchment area land use."

Table A 6. List of buffer widths required to maintain fish habitat from multiple studies.

Authors	Width (m)	Ecosystem Impacts
Davies & Nelson (1994)	10	Stream temperatures were significantly enhanced (by 1.2°C km^{-1}) only when buffer widths fell below 10 m, presumably because of the almost complete removal of shading from riparian vegetation
Barton *et al.* (1985)	10	For fish to be present, 80% of banks within 2.5 km upstream had to have forests of at least 10 m wide, or sufficient to shade the stream
Wenger (1999)	15	A 15 m buffer appears necessary to provide woody debris inputs to the stream.
Broderson (1973)	15.2	Buffers 15.2 m wide provided adequate shade for small streams
Brazier & Brown (1973)	24	Found that forested buffers 24 m wide was often sufficient to shade streams adjacent to logging
Wenger (1999)	30	Overall, recommend a 30 m buffer to mitigate the effects of logging such as increased riffle sediment, length of open stream, periphytic algal cover, water temperature and snag volume.
Moring (1982)	≥30	Increased sedimentation from logged, unbuffered streambanks clogged gravel streambeds and interfered with salmonid egg development. Buffer strips at least 30m wide allowed eggs to develop normally
Wenger (1999)	12-15	No tree harvesting should occur within 12 m of the stream (15 m is preferable), and harvesting in the remainder of the buffer should leave some mature and senescent trees.
Osborne & Kovacic (1993)	10 -30	Buffer widths of 10-30 m can effectively maintain stream temperatures
Murphy *et al.* (1986)	15-30	Stream reaches that were protected by 15-30 m wide riparian buffers were found to be similar in habitat quality to old growth reaches
Brosofske *et al.* (1997)	≥45	Buffers at least 45m wide on each side of the stream are needed to maintain an unaltered microclimatic gradient near streams (air temperature, soil temperature, surface air temperature, and relative humidity)
Collier *et al* (1995)	one tree height	Recommend a buffer width of at least one tree height to maintain inputs of LWD, although for stability purposes (e.g., to prevent wind-throw) they suggest that a width equal to three tree heights may be necessary.

4.2. Reptile & amphibian habitat

Reptiles and amphibians vary in their dependence upon riparian areas (Wenger, 1999). Many amphibian species spend their entire lives within the stream and riparian zone, while other species use it for breeding or as part of a larger range (Brode & Bury, 1984). As with birds, reptiles and amphibians require buffers on the larger end of the range commonly prescribed in the literature, requiring buffers 75 -150 m wide.

Table A.7. List of buffer widths required to maintain reptile and/or amphibian habitat from multiple studies.

Authors	Width (m)	Ecosystem Impacts
Culp & Davies (1994)	≤l0	Stream temperature increased by a factor of 10% in streams with buffers of ≤l0 m adjacent to logging.
Culp & Davies (1994)	≤30	Brown trout abundance decreased by around 50% in streams with buffers of <30 m width adjacent to logging.
Rudolph & Dickson (1990)	≥30	The authors recommend retaining streamside zones of mature trees at least 30 m wide and preferably wider when forest stands are harvested. Zones this wide will benefit amphibians, reptiles, and other vertebrates.
Gomez & Anthony (1996)	75-100	In Western Oregon reptiles and amphibians that are dependent upon riparian areas may require buffers of 75-100 m
Burbrink, Phillips & Heske (1998)	100	100 m naturally vegetated riparian zones supported reptile and amphibian diversities that were as high as 1 km wide naturally vegetated riparian zones.
Buhlmann (1998)	≥135	Aquatic turtles may spend a greater proportion of a year in terrestrial habitat (e.g., buffer strips adjacent to wetlands) than in the wetland where they would have been predicted to occur
Semlitsch (1998)	≥165	To maintain viable populations and communities of ambystomatid salamanders, attention must be directed to the terrestrial areas peripheral to all wetlands; maintaining the connection between wetlands and terrestrial habitats will be necessary to preserve the remaining biodiversity of our remaining wetlands.
Burke & Gibbons (1995)	275	A 275 m upland buffer was found to be required to protect all nest and hibernation sites for certain freshwater turtles.

4.3. Invertebrate habitat

Aquatic and terrestrial invertebrates are a valuable food source for birds, fish, reptiles and amphibians. Aquatic invertebrates feed on leaf litter from riparian vegetation, and most emerge from the stream as adults and use the riparian zone for reproduction (Wenger, 1999; Erman, 1984). Aquatic invertebrates are sensitive to changes in stream temperature, periphytic growth, sedimentation and snag volume and are therefore excellent indicators of stream health (Davies & Nelson, 1994; Bunn *et al.*, 1999). In western Newfoundland, "insects were 1.2-2.0 times more abundant along riparian buffer strips than along undisturbed shorelines in balsam fir forest" (Whitaker, 2000 in Staicer, 2005). There appears to be some consensus regarding vegetated buffer widths required to sustain invertebrate habitat (e.g., ≥30 m).

Table A.8. List of buffer widths required to maintain aquatic invertebrate habitat from multiple studies.

Authors	Width (m)	Ecosystem Impacts
Culp and Davies (1994)	≤30	Macroinvertebrates decreased in abundance with buffer strip width, with leptophlebiid mayflies and stoneflies being most affected at widths <30 m
Erman, Newbold, & Roby (1977)	≥30	Maintained background levels of benthic invertebrates in streams adjacent to logging activity
Davies & Nelson (1994)	≥30	In streams adjacent to logging activity, macro-invertebrates decreased in abundance with buffer strip width, with leptophlebiid mayflies and stoneflies being most affected at widths <30 m. The degree of impact was therefore dependent on buffer width, with the intensity and number of variables responding being greatest when riparian vegetation was severely damaged or effectively removed (0-10 m buffer width).

4.4. Bird habitat

There has been a great deal of research conducted in recent decades regarding the use of riparian zones by birds. Research suggests that forested riparian zones provide higher quality habitat than upland sites due to the presence of open water and thus large insect populations (Larue *et al*., 1995; Kinley & Newhouse, 1997; Bub *et al*., 2004; Whitaker *et al*., 2000; Warkentin *et al*., 2003). The Barred Owl, Pileated Woodpecker, Eastern Wood Pewee, and Veery are species found in Nova Scotia and show a preference for riparian forests in the northeastern U.S. (DeGraaf & Yamasaki, 2000). In Pennsylvania, Miller *et al.* (1997) found that more species that are dependent on undisturbed forest such as neotropical migrants were found in headwater streams, whereas more generalist and edge effect and disturbance-tolerant species were found in lower reaches of streams. Dickson *et al*. (1995) found that edge species or early-successional species were common in narrow buffers, whereas mature forest species such as the Pileated Woodpecker, Downy Woodpecker, and Red-eyed Vireo, were common in wide buffers in pine plantations in eastern Texas.

Riparian zones often act as movement corridors for birds in fragmented landscapes, and for migrating birds (Doherty & Grubb, 2002; Desrochers & Hannon, 1997). Some forest interior species such as the Downy Woodpecker, Red-eyed Vireo, Red-breasted Nuthatch, Veery, Ovenbird, Canada Warbler, and Pine Siskin, do not cross or reside in gaps left after logging so riparian forest provides a refuge (Desrochers & Hannon, 1997; Robichaud *et al*., 2002). According to Schmeigelow *et al.* (1997), boreal bird species showed no ill effects of fragmentation when 100 m wide forested buffers connected two habitat fragments. Riparian zones can provide refuge for birds when they occur next to disturbed, usually cleared, land (Jobin *et al*., 2004) and the presence of even a narrow forested riparian buffer dramatically enhances an area’s ability to support songbirds compared to a stream or running through a cleared area (Keller *et al.*, 1993). Researchers have also noted a temporary crowding of bird species in riparian zones after land clearing and a decline in species abundance three years after a harvest (Darveau *et al*., 1995; Hagan *et al*., 1996).

Birds tend to require larger vegetated riparian buffers than other types of species or other riparian functions (Spackman & Hughes 1995; Pearson & Manual 2001; Whitaker & Montevecchi, 1999; Keller *et al*., 1993) and as previously mentioned, vegetated riparian buffer policies designed to protect water quality or fish habitat (10-30 m on average) may not be large enough to provide the habitat required by terrestrial wildlife, including birds (Gregory & Ashkenas, 1990; Schaefer & Brown, 1992). Riparian habitat is often used as a refuge after habitat fragmentation and as such may support a limited number of species; however research suggests that narrow buffers will not provide adequate habitat area for riparian-obligate and interior forest species (Schaefer & Brown, 1992). A study by Sinclair *et al.* (2004) showed that nest predation by mammals was higher in narrower buffer and lower in larger buffers and they argue that buffers should be a wide as possible to reduce threats to bird population through nest predation. In boreal forests, Whitaker and Montevecchi (1999) suggest that vegetated riparian buffers widths >20 m may be beneficial to forest generalist species in boreal forests. In a 2008 study, Akerman and Staicer compared bird use of riparian and upland forest and the influence of the width of forested buffers for 27 bird species of conservation concern in Nova Scotia and others known to be sensitive to forest harvesting and riparian buffer width. The authors found that the forested buffers had significantly fewer target individuals and species than the reference forest. They also found that "rather than a linear relationship between buffer width and bird abundance or species richness, results suggested a threshold effect at 40 m, twice the required buffer width" under the *Wildlife Habitat & Watercourse Protection Regulations* (20 m). According to Perry *et al*. (2011), the optimal width of vegetated buffers for bird habitat depends on the species of greatest conservation interest as different species succeeded to varying degrees in a range of buffer widths.

Table A.9. List of buffer widths required to maintain bird habitat from multiple studies.

Authors	Width (m)	Ecosystem Impacts
Whitaker & Montevecchi (1999)	>20	Vegetated riparian buffers widths >20 m may be beneficial to forest generalist species in Boreal forests
Akerman & Staicer (2008)	40	Threshold effect found with 40 m buffers
Hagar (1999)	>40	Although riparian buffers along headwater streams are not expected to support all bird species found in unlogged riparian areas, they are likely to provide the most benefit for forest-associated birds species if they are >40 m wide
Tassone (1981)	≥50	Many neotropical migrants will not inhabit strips narrower than 50 m
Whitaker & Montevecchi (1999)	40-50	40-50-m-wide riparian buffers only supported densities <50% of those observed in interior forest habitats in Newfoundland
Darveau *et al*. (1995)	≥60	There was evidence that 50-m-wide forested buffer strips were required for forest-dwelling birds. Bird populations may decline in strips before re-generation of adjacent clearcuts provide suitable habitat for forest birds
Schmeigelow *et al*. (1997)	100	When fragments were connected by 100 m wide buffers, birds of the boreal forest showed relatively small effects of fragmentation.
Mitchell (1996)	≥100	Need >100m-wide buffers to provide sufficient breeding habitat for area sensitive forest birds and nesting sites for red-shouldered hawks
Triquet, McPeek & McComb (1990)	≥100	Neotropical migrants were more abundant in riparian corridors wider than 100 m; riparian areas <100 m wide were inhabited mainly by resident or short-distance migrants
Keller, Robbins & Hatfield (1993)	≥100	Riparian forests should be at least 100 m wide to provide some nesting habitat for area-sensitive species
Hodges & Krementz (1996)	≥100	Riparian strips >100 m were sufficient to maintain functional assemblages of the six most common species of breeding neotropical migratory birds
Spackman & Hughes (1995)	≥150	Riparian buffer widths of at least 150 m were necessary to include 90% of bird species along mid-order streams
Vander Haegen & deGraaf (1996)	≥150	Managers should leave wide (>150 m) buffer strips along riparian zones to reduce edge-related nest predation, especially in landscapes where buffer strips are important components of the existing mature forest
Kilgo *et al*. (1998)	≥500	Although narrow bottomland hardwood strips can support an abundant and diverse avifauna, buffer zones at least 500m wide are necessary to maintain the complete avian community

4.5. Mammal habitat

While mammals, particularly large ones, may not use riparian zones as core habitat, some mammal species prey on birds and fish or forage in the riparian zone (Dollof, 1993; Ben David *et al*., 1997; Naiman & Decamps, 1997; Naiman & Rogers, 1997). Riparian zones have been noted for their utility as travel corridors for mammals (Van der Haegen & Degraaf, 1996), although some researchers question this theory (Fisher & Fischenich, 2000), and few studies have determined the minimum buffer width required to provide either core habitat or travel corridors for mammals (Wenger, 1999; Spackman & Hughes, 1994). As with other species, mammals use riparian zones as refuge when surrounding landscapes are cleared (Virgos, 2001; Van der Haegen & Degraaf, 1996; Brusnyk & Gilbert, 1983).

A review of the literature reveals no real consensus about the minimum buffer width required for large mammals, likely because few large animals are riparian obligate species. The beaver is often studied due to its riparian dependent nature and role as an ecosystem engineer (e.g., Stoffyn-Egli & Willison, 2011).

There are some studies that provide recommended vegetated riparian buffer widths for different species. Stoffyn-Egli & Willison (2011) recommend that vegetated buffers be a minimum of 50 m in order to protect habitat for riparian obligate species. Riparian zones appear to be of less importance to small mammals; four studies found no significant differences in the track patterns of several small mammal species in riparian and upland areas (Forsey & Baggs, 2001; Darveau *et al*., 2001; Cote & Ferron, 2001; De Groot, 2002). However Dickson (1989) found that a minimum riparian width of 50 m was required to maintain gray squirrel populations. One study found that 85% of the locations of radio-collared furbearers in Maine occurred within 100 m of a watercourse (DiBello, 1984). Red fox and fisher use the vegetation within 100 m of watercourses (Stocek, 1994).

4.6. Plant habitat

Few studies have examined the riparian buffer widths necessary to maintain plant species diversity and abundance as they are most often recognized for their ability to protect water quality and fish habitat and their utility as wildlife corridors (Gregory *et al*., 1991). However, riparian areas can support high plant heterogeneity and play an important role in plant dispersal (Gregory *et al*., 1991). “Many floodplain plants require regular cycles of flooding for seed dispersal and germination” (Wenger, 1999). In a study of forested buffers in un-fragmented forest in Vermont, Spackman and Hughes (1995) found that although no single minimum buffer width was appropriate for all stream corridor systems, 90% of plant species surveyed were represented within 10-30 m of the high water mark and that. On average, an additional 5-10 m was required to increase the included species to 95%.

4.7. Wildlife corridors

Riparian zones can act as movement corridors for terrestrial wildlife in fragmented landscapes caused by land clearance for agriculture, forestry, or urban development (Harper *et al.*, 2005; MacDonald, 2003; Hannon *et al.*, 2002). The effects of habitat fragmentation include “increased external influences (such as invasion or predation), altered microclimate (e.g. associated with evapotranspiration, wind and hydrological cycles), and increased isolation from other areas of similar habitat” (Saunders *et al.*, 1991). The proximity of riparian zones to fresh water provides ideal corridors for terrestrial species (Stoffyn-Egli & Willison, 2011). Wildlife corridors (not necessarily riparian) allow for the movement of individuals as well as genetic material across disturbed landscapes, and provide refuge habitat after land clearing occurs (Darveau *et al.*, 2001; Macdonald, 2003). The ‘quality’ of a wildlife corridor depends on its spatial configuration, landscape context, habitat type, scale, the nature of the connected areas, and the species likely to use the corridor; the quality of the corridors also varies depending on the species concerned (MacDonald, 2003; Anderson & Danielson, 1997). The proximity of riparian zones to fresh water provides ideal corridors for terrestrial species (Stoffyn-Egli & Willison, 2011). One drawback to movement corridors is their high proportion of edge-to-interior area which may be unsuitable for edge-intolerant species (Harper *et al.*, 2005, 2007; Forman & Godron, 1986; Lines & Harris, 1989). Maximizing the width of vegetated buffers has been suggested as a way to reduce edge effects (Bennett, 1999). Other methods of mitigating edge effects include management efforts to reduce the severity of the boundary between corridors and surrounding landscapes, in other words, the use of a ‘feathered approach’ (Start, 1991).

There is debate amongst researchers about the use of riparian buffers as travel corridors for terrestrial wildlife. Some researchers have been strong advocates for the use of corridors because of their ability to aid genetic exchange (Tewksbury *et al.*, 2002; Haddad *et al.*, 2003; Gelling *et al.*, 2007), whereas others argue that funds would be better used to purchase large undisturbed tracts of lands for conservation (Rosenberg *et al.*, 1997; Simberloff *et al.*, 1992). In Tasmania, 100 m wide wildlife habitat strips are prescribed for forestry operations (Tasmania Forest Practices Board, 2000). Wenger (1999) points out a lack of empirical research on the subject and suggests that given the lack of consensus, policy makers should focus on establishing buffer widths based on the habitat requirements of terrestrial species.

5. Channel morphology control

It should be noted that the effect of riparian area removal on riparian health varies with the type of channel morphology. The main types of channel morphologies are straight, meandering, braided and anabranching (Church, 1992). Based on these typologies, the type and degree of impacts from riparian deforestation will vary based on channel morphology. Riparian deforestation will have a less of an impact on river reaches that are confined by bedrock and stream temperature and fish habitat will be less impacted in wide, braided reaches (Montgomery & Buffington, 1997). Meandering streams are particularly sensitive to riparian deforestation because they are in alluvial reaches. Alluvial reaches are characterized by fine soil particles that have already been transported by the river in the past and are easily transported by overland runoff and flooding, and steeper gradients can increase the velocity of overland runoff into streams thereby possibly increasing in-channel erosion rates (Montgomery & Buffington, 1997). Steeply graded streams in bedrock are eroded less easily because the soil particles are more likely to be rocks and gravel rather than sand and small soil particles found in alluvial reaches, and require more energy than the river has available to transport the material (Rose, 2004).

Appendix D - Costal zone science

1. Coastal management philosophies

There are four approaches, or philosophies, towards sea level rise and coastal hazards in general, which underlie the coastal management approach chosen by a jurisdiction. These are: avoid, retreat, accommodate, and protect (retreat and avoid practices are sometimes combined in the literature under the heading "retreat") (NRCan, 2007a; IPCC, 1990; Green Shores, 2010). Retreat measures are generally preferred over protect and accommodate measures because they tend to have less impact on the shoreline environment (Green Shores, 2010).

Avoid: This approach uses measures to avoid impacts from coastal hazards including setbacks, and restricting development in areas that will be inundated by storm-induced flooding and predicted sea level rise. This proactive approach can reduce disaster relief costs, allows the coast to migrate naturally, and avoids aesthetically unpleasant armouring. This approach has the potential to restrict landowners' ability to modify their property and to use it for certain activities, and may result in legal challenges if land is appropriated by a setback (Green Shores, 2010).

Retreat: Often called "managed retreat", the underlying philosophy of this approach is that "if some lands must give way to the rising sea, the economic, environmental, and human consequences could be much less if the abandonment occurs according to a plan rather than unexpectedly" (USEPA, 2011b). According to the U.S. Environmental Protection Agency (2011b), managed retreat often occurs in undeveloped areas and is uncommon along developed ocean beaches and very rare along developed estuarine shores.

There are a few types of retreat, but common features include:

- "Laws or regulations that allow the conditional use of property located in areas susceptible to erosion and flooding,
- Economic incentives and disincentives to control development,
- Restrictions on hard structural protection and a preference for "soft" engineering,
- Protection of critical environmental areas through acquisition and prohibitions of development, and
- Post-storm redevelopment restrictions." (Klarin & Hershman, 1990).

One type of managed retreat is the "rolling easement" in which no effort is made to restrict land use, and shoreline protection is prohibited. The typical characteristics of rolling easements include:

- No shoreline armouring;
- A rolling design boundary (e.g., dune vegetation line), seaward of which the owner's property rights are reduced;
- No new structures seaward of the rolling design boundary;
- Encouragement or requirement to remove pre-existing structures when erosion leaves them seaward of the rolling design boundary;
- Warnings about the policy to prospective buyers of coastal property;
- Provisions for public access; and
- Indication whether beach nourishment and adding sand to dunes are allowed (USEPA, 2011b).

Another type of retreat is the "laissez-faire" approach. This approach makes no effort to prevent either development or shore protection, but instead seeks to eliminate government subsidies for both, in the hope that eventually the forces of nature and economics will convince owners to allow their lands to be submerged. The laissez-faire approach is based on "the assumption that investors are more likely to appropriately manage known risks if they bear all of the burdens of bad decisions and reap all of the rewards of good decisions" (USEPA, 2011b). This tactic is popular in the U.S. where market-based mechanisms and the protection of private property rights are more popular than government regulation.

In short, retreat programs allow development to occur *and* allow the shoreline to migrate landwards while transferring the risk and cost to the property owner. Managed retreat has as lower cost to government and a lower administrative burden than other approaches. It can allow the coast to migrate naturally and avoids aesthetically unpleasant dykes, sea wall or armouring. Allows development to occur and avoids heavy-handed government intervention in coastal development. There are fewer legal risks compared to the traditional setback approach. Rolling easements require less scientific data than some other shoreline management approaches such as setbacks (National Oceanic & Atmospheric Administration, 2010). The challenges associated with this approach include any costs related to relocating homes or abandoning them and finding new homes. This approach is ineffective on coasts that are already heavily developed and cannot be abandoned. In addition, if shoreline protection measures are not banned for the whole jurisdiction then properties with easements will suffer from accelerated erosion rates caused by protection structures downshore (National Oceanic & Atmospheric Administration, 2010).

Accommodate: This strategy involves "the continued use of vulnerable areas and acceptance of the risk to property and beach area" (Fish *et al.*, 2008). This strategy does not try to prevent tidal inundation, erosion, or flooding: instead of moving people out of harm's way, coping strategies, such as adaptive construction designs, are developed that enable continued human habitation in spite of the increased hazards. Accommodation measures include:

- Designing restoration or rehabilitation works for rising sea level (e.g., constructed intertidal marshes);
- entering into appropriate covenants that acknowledge the potential hazard and limit liability of public agencies, and
- raising structures above projected climate change-induced flood levels

Wetlands and beaches will continue to migrate inland, and new construction is still permitted. Beach nourishment also falls in this category. This approach allows coastal development while allowing the coast to migrate naturally. At this time, there are no approved or certified coastal construction standards in place for Nova Scotia. While raising structures above water levels is common practice on the southeastern U.S. coast, this design may not be feasible for residences in Nova Scotia due to the cold winter temperatures.

Protect: This strategy attempts to protect land and buildings from erosion and flooding using "hard" structures such as armouring, dykes, groins seawalls, bulkheads or "soft" protection measures such as storm berms or dunes, beach replenishment and wetland restoration or creation. Shoreline protection is popular because it often (but not always) costs less than what the protected property is worth (USEPA, 2011b) and because it effectively stops erosion in the short term (i.e., for the lifespan of a structure).

> "Soft" engineering is achieved by using vegetation and other materials to soften the land-water interface, thereby improving ecological features without compromising the engineered integrity of the shoreline
> -U.S. Fish & Wildlife Service (2008)

The protect approach can have negative impacts on coastal processes and ecosystems. For example, wetlands and beaches are eventually eliminated as they are squeezed between the rising sea and the shoreline armouring resulting in beach loss (Trenhaile, 2007; Dugan & Hubbard, 2006; Dugan *et al.*, 2008; Griggs, 2005; Hsu *et al.*, 2007), and often require beach nourishment (Defeo *et al.*, 2009). In addition, if armouring tends to displace wave action to neighboring stretches of shoreline, which if un-armoured will experience accelerated erosion (Frihy, 2001; Hsu *et al.*, 2007; Miles *et al.*, 2001; USFEMA, 2011). Hard structures are generally seen as a short term solution and are only recommended in areas where avoid, retreat, and protect approaches will be ineffective, or as a last-ditch effort to protect properties that have a high risk of falling into the sea (USFEMA, 2011).

Three U.S. states (North Carolina, Maine and South Carolina) prohibit the use of shoreline protection structures (Bernd-Cohen & Gordon, 1999). There are currently no guidelines in Nova Scotia about how armouring should be installed; poorly installed armouring may be ineffective or may collapse.

Figure A.4. Extreme example of residential coastal armouring near Melmerby Beach, Nova Scotia (left). Example of shoreline armouring near East Linden, Nova Scotia on Northumberland coast (right) (Nova Scotia Department of Natural Resources, 2011).

2. Erosion

Terrestrial and marine environments are constantly interacting as sediment is exchanged between beach/cliffs and foreshore (Trenhaile, 2007). In the short term, coastlines may be erosional, accretional, or stable depending on the local geology and wave action. Erosion may occur steadily over time or large portion of land may erode during a single event (i.e., “episodic” events). Coastline activity tends to vary a great deal in the short term but may “average out” over the long term (USFEMA, 2011). Zhang (1998) examined long-term erosion rates along the Atlantic coast of the U.S. and found that erosion was the dominant pattern along the coast, with erosion rates averaging 1 m per year. However, coastal processes vary a great deal from one location to the next and in some areas erosion occurred at a rate of more than six metres per year whereas other location experienced accretion; the same trends occur in Nova Scotia (ACAS, 2011; Beaton, 2008).

Erosion can affect all coastal landforms (e.g., cliffs, low rocky shores, sandy or stone beaches) to varying extents. Coastal cliff erosion processes are the result of complex interactions between subaerial slope processes and marine effects such as wave attack (Shaw *et al.*, 1993). Cliff erosion can occur slowly over time from weathering and wave action, but it can also occur suddenly when large sections of the cliff collapse. Cliffs composed of hard rock type such as limestone and volcanic rocks will erode more slowly than unconsolidated cliffs composed of soft rocks such as sandstones and clays (Cambers, 1997). The overall slow rate of erosion on coastal cliffs makes this coastal feature one of the more stable relative to other coastal feature such as sandy beaches or sand dunes (USFEMA, 2011). Unconsolidated cliffs in Nova Scotia can retreat 5-10 m per year when initially exposed to wave action and during extreme storm events, but at slower rates (<0.5-1 m per year) as protective beaches, lag shoals or boulder frames accumulate at the base of the cliffs (NRCan, 2007b; Shaw *et al.*, 1993). To protect properties from sudden cliff collapse, Cambers (1997) recommends a setback of 15 m which will accommodate structures over their average lifespan of 30 years. This lifespan may be an underestimate given that the average lifespan of most residential buildings is 50 years, for commercial structures it is 75 years, and for light and heavy industry the appropriate life-span is 100 years (O’Connor, 2004; State of Pennsylvania, 1980).

Low rocky shores also are generally composed of hard rock types and therefore erode more slowly than sand or stone beaches but more quickly than hard rock cliffs, although the low elevation of any rocky shores makes them susceptible to flooding during storms. Cambers (1997) suggests a setback of 30 m for low rocky shores.

Sand or stone beaches are highly susceptible to naturally occurring erosion (Cambers, 1997; Fish *et al*., 2008). According to Shaw *et al.* (1993), "beach retreat rates are sometimes very high (>8 m/a) in some locations, but low elsewhere, in some cases showing almost no movement over the past 10 years, and neighbouring beaches are sometimes observed to behave in completely different ways." Cambers (1997) recommends that the setback distances for beaches established on a beach by beach basis and that they be delineated from the line of permanent vegetation. Sand or stone beaches are particularly susceptible to erosion when the land behind beaches has been hardened by development.

Hard shoreline protection measures have a significant impact on beach ecosystems, particularly on sandy or gravel beaches. Armouring structures, including rip rap, seawalls, groins, revetments, and offshore breakwaters "alter the natural hydrodynamic system of waves and currents, thereby affecting sand transport rates, which in turn control the erosion-accretion dynamics of beaches" (Defeo *et al*., 2009). Amouring generally causes sand to erode away when beaches become "trapped" between the sea and the shoreline protection structure, a phenomenon called "coastal squeeze" (Sobocinski, 2003; Martin *et al*., 2005; Dugan & Hubbard, 2006; Bertasi *et al*., 2007; Defeo *et al*., 2009; Fish *et al*., 2008; Beaton, 2008). Armouring can affect local currents and sand transportation patterns, causing erosion at points further along the coast (Frihy, 2001), meaning that localized, short-term erosion prevention is often achieved at the expense of longer term, integrated coastal adaptation.

In recent years, beaches have become starved of sands deposits as many rivers have been dammed which trap the sediments that would have naturally nourished beaches (Sanchez-Arcilla, Jimenez & Marchand, 2011; Nordstrom, 2000; Sherman *et al*., 2002). As a result of shoreline armouring and reduced sediment deposits, many coastlines are experiencing accelerating rates of erosion (Sanchez-Arcilla, 2011; Innocenti & Pranzini, 1993; Cooper & McKenna, 2008). The loss of sandy beaches to erosion on armoured shores is often mitigated by beach nourishment, although this process can have negative effects on both the donating and receiving sites (USFEMA, 2011; Defeo *et al.*, 2009).

An alternative to hard shoreline protection measures is the use of "soft engineering" techniques which uses the roots of coastal vegetation to hold soils in place (Speybroeck *et al.*, 2006; Nordstrom & Psuty, 1980). Soft engineering techniques can help to slow gradual erosion but may be powerless to prevent large erosion events caused by storms. Vegetation would likely be the more effective on low lying shores than on cliffs, as vegetation will not be able to prevent the types of erosion that commonly occur on cliffs (i.e., episodic slumps) (G. Demont and R. Naylor, personal communication, September 30, 2011).

Erosion rates are commonly used in U.S. coastal states to determine setback distances. For example, South Carolina's setback distance is 40 times the annual erosion rate, the intention being that structures adhering to this setback will "survive" for 40 years before being threatened by coastal erosion (State of South Carolina, 1988). These rates are typically calculated by comparing current and historical aerial photographs, historical charts, and beach profiles. However, many government staff and non-government stakeholders indicated that these methods are so imprecise as to be useless due to the large margin of error of 1 or more metres in some cases which can produce annual erosion rates that either under, or overestimate the actual erosion rate (Leatherman, 2003; USFEMA, 2011; Anders & Byrnes, 1991; T. Webster, personal communication, November 4, 2011; G. Demont and R. Naylor, personal communication, September 30, 2011). In cases of rapid erosion (e.g., >5 m/year), the margin of error found in aerial mapping and other crude mapping technologies may be less relevant because the overall trend is still visible, however, in region with lower erosion rates (e.g., <2 m/year), the margin of error can obscure the trends (Leatherman, 2003). Another source of error in determining the annual erosion rate is the occurrence of one-time storm related erosion events which obscure the overall trends of gradual erosion (Leatherman, 2003). Pajak and Leatherman (2002) and Zhang (2002) suggest that this error can be reduced by using only summertime data to calculate annual erosion rates. More recently, LIDAR data is being used to determine annual erosion rates, and is much more accurate than aerial photographs with accuracy up to 15 cm (Leatherman, 2003; Renslow, 2005).

Despite the significant improvements in accuracy in LIDAR over aerial photography, neither method is able to predict erosion rates for climate change scenarios that include higher sea levels, a higher incidence of storm events and loss of winter pack ice (IPCC, 2007); this is a significant flaw associated with the use of erosion rates for setback delineation, and additional distances should be added to erosion rate-based setbacks to account for this uncertainty.

Sea level rise will have an impact on coastal erosion (IPCC, 2007), changing the rate at which it occurs. The Intergovernmental Panel on Climate Change (IPCC) reports that 1 cm rise in sea level erodes beaches about 1 m horizontally; a rate that becomes a significant issue for developed beaches within 5 m from the ocean (IPCC, 1997).The Bruun rule, developed by Per Bruun in 1962, has often been used to measure how sea level rise will affect erosion rates on sandy shores (UNFCCC, 2008). The Bruun rule states that "a typical concave-upward beach profile erodes sand from the beach face and deposits it offshore to maintain constant water depth" and is calculated by multiplying the predicted sea level rise in metres by 100 to produce the shoreline recession rate (UNFCCC Secretariat, 2008). For details on the Bruun rule and other coastal erosion formulas see *Appendix E*. Applying the Bruun rule to Nova Scotia with a predicted average sea level rise of 1.07 m by 2100 (Richards & Daigle, 2011) this prediction produces 107 m of erosion by 2100. Cooper and Pilkey (2004) contest the accuracy of the Bruun rule, arguing that despite its popularity as an erosion prediction tool, it lacks scientific credibility (e.g., it is only applicable to local sites because cross-shore transport models become complex over long stretches of coast). In addition, the Bruun rule is only applicable to sandy beaches which comprise only a portion of Nova Scotia's coastal types (CBCL Ltd., 2009).

There are two ways to delineate horizontal setbacks: delineation from a fixed point or from a "floating" point. Fixed setback lines are usually delineated in the field by a stationary reference point, such as a concrete monument or a roadway. This approach is very rare due to the recurring need to relocate monuments as shorelines erode. Floating setbacks use natural features as the baseline and are considered to be "self-updating" as they change over time. There are many coastal features from which floating setback or vegetated buffers can be delineated. Figures A.5 and A.6 describe a wide range of options, and Table A.15 in *Appendix F* examines how each boundary is identified and the challenges associated with using each. Delineation boundaries can be grouped into two broad categories: visually discernible and tidal datum-based (Boak & Turner, 2005). Within the visually discernible category, there are three sub categories: "based on the alignment of man-made structures, e.g., the landward edge of a revetment structure. The second type is based on a morphological feature, e.g., an erosion scarp. The third type of visibly discernible features includes those based on the position of a selected waterline, e.g., previous high-tide high-water level" (Boak & Turner, 2005).

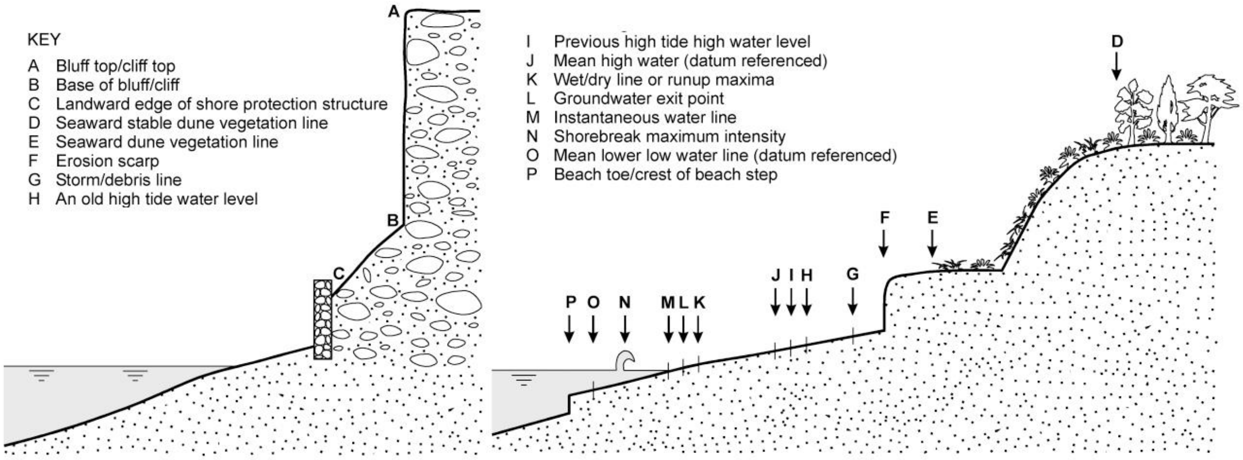

Figure A.5. Sketch of the spatial relationship between many of the commonly used shoreline delineation boundaries (Boak & Turner, 2005).

Figure A.6. An example of a range of visibly discernible shoreline indicator features, Duranbah Beach, New South Wales, Australia. For key, see Figure A.5 (Boak & Turner, 2005).

According to Boak & Turner (2005), the most common coastal feature used in setback delineation if the ‘‘high-water line’’ (HWL), however the interpretation of the HWL from aerial photographs has the potential to be a significant source of error for shoreline mapping (Anders & Byrnes, 1991; Moore, 2000; Pajak & Leatherman, 2002; Stockdon *et al.*, 2002). Because of the variable nature of the mean high-water mark, Florida uses the seasonal mean high-water mark, defined as the mean high-water mark plus 1.5 times the annual mean tidal range for the particular reach of shoreline. One issue with using a water level as a boundary is that a setback would still include some beach area which will likely change over time and may still impact development, particularly if the setback is a narrow one. The line of permanent vegetation may be a better boundary to address this issue. It is also easy for landowners to locate on the ground, and easy to detect in aerial photography, although it cannot be used as a boundary with LIDAR mapping as vegetation is not shown with type of mapping.

3. Flooding

Coastal flooding can be caused by storm surge in the short term and sea level rise in the long term. In the future, these two phenomena will interact and produce higher water levels than have historically occurred and will involve more intense and more frequent coastal flooding (Richards & Daigle, 2011; USFEMA, 2011). Richards & Daigle (2011) define storm surge in the following way:

> “A storm surge can be defined at the coast as the difference between the observed water level and the predicted astronomical tide… Storm surges can be positive or negative and may therefore raise or lower sea level from its predicted value. Storm surges occur everywhere along our coastlines and can occur anywhere in the tidal cycle or may last over several tidal cycles. Large positive storm surges at times of high tide are events that lead to coastal flooding, whereas when they coincide with low tides, flooding problems are averted… The magnitude of storm surges depends on the nature of the meteorological event responsible for the reduced atmospheric pressure and the strength of the winds associated with a particular event. Atlantic Canada has seen extreme cases of coastal flooding, and the frequency of these events seems to have been increasing over the past ten years.”

Wave action can affect coastal development in a number of ways, including wave run-up, breaking waves, wave reflection and deflection, and wave uplift. The most severe damage is caused by breaking waves (Figure A.7). According to U.S. Federal Emergency Management Agency (2011) “the force created by waves breaking against a vertical surface is often 10 or more times higher than the force created by high winds during a storm event.”

Figure A.7. (Left) Storm waves breaking at Peggy’s Cove, Nova Scotia during Hurricane Earl on September 4, 2010 (Andrew Vaughan-The Canadian Press). (Right) Wave runup beneath elevated buildings at Scituate, MA, during the December 1992 nor’easter storm (USFEMA, 2011)

According to CBCL Ltd. (2009), the highest storm surges tend to occur along the province’s Northumberland Shore, along western Cape Breton, and at the head of the Bay of Fundy, however, the data presented by Richards and Daigle (2011) in their recent report on climate change scenarios for Nova Scotia and PEI show that the highest recorded storm surges have occurred along the southern shores of the province (e.g., Lunenburg, Liverpool, Yarmouth, Halifax – Table A.10).

Table A.10. Maximum storm surge to date in 12 regions in Nova Scotia (Adapted from Richards & Daigle, 2011).

Data Collection Site	Maximum Storm Surge to Date (m)
Burncoat Head	1.28
Canso Harbour	1.63
Cheticamp	1.38
Digby	1.49
Halifax	1.63
Hantsport	1.28
Joggins	1.28
Liverpool	1.63
Lunenburg	1.63
Pictou	1.49
Sydney	0.97
Yarmouth	1.49
AVERAGE	**1.43**

“Vertical” setbacks, or elevation distances, are a way to address the risk of storm surge-induced flooding in coastal setback policies. Vertical setbacks are measured vertically from the chosen boundary (e.g., mean high water mark, line of permanent vegetation). Surprisingly few jurisdictions include a vertical setback in addition to, or instead of, a standard horizontal one, in order to protect properties from storm surge and flooding (as opposed to erosion). The author found very little information about methods for calculating an appropriate vertical setback. One intuitive option is to combine predicted sea level rise with the average or highest recorded storm surge run-up. Table A.10 lists the highest recorded storm surge to date for 12 Nova Scotian regions, with a provincial average of 1.43 m. Vertical setbacks combining this data with predicted sea level rise (a province-wide average of 1.07 m by 2100 (Richards & Daigle, 2011)) would result in an average province-wide vertical setback of 2.5 m.

When incorporating storm surge levels into setback or vegetated buffer policies, it is important to consider the impacts of the plausible extreme high water level (i.e., the combination of the upper limits of predicted sea-level rise, subsidence, and the highest storm surge previously recorded) (Richards & Daigle, 2011). This precautionary approach helps ensure that development is sited far enough inland to avoid damage from storm surge during the largest of storms. Estimates of plausible extreme high water levels are presented in Table A.11.

Table A.11. Maximum storm surge to date as well as plausible upper bound water levels for year 2100 in 12 regions in Nova Scotia calculated as the sum of: current Higher High Water Large Tide (HHWLT), predicted sea-level rise plus error bar, and the maximum storm surge recorded to date (Adapted from Richards & Daigle, 2011).

Data Collection Site	HHWLT (m)	Sea-Level Rise (2100) + Error Bar (m)	Maximum Storm Surge to Date (m)	Plausible Upper Bound Water Level (m) by Year 2100
Burncoat Head	16.50	1.53	1.28	19.31
Canso Harbour	1.85	1.58	1.63	5.06
Cheticamp	1.37	1.58	1.38	4.33
Digby	9.13	1.53	1.49	12.15
Halifax	2.16	1.54	1.63	5.33
Hantsport	15.26	1.48	1.28	18.02
Joggins	13.40	1.53	1.28	16.21
Liverpool	2.30	1.54	1.63	5.47
Lunenburg	2.43	1.54	1.63	5.6
Pictou	2.05	1.53	1.49	5.07
Sydney	1.32	1.58	0.97	3.87
Yarmouth	5.16	1.54	1.49	8.19
AVERAGE	**6.08**	**1.54**	**1.43**	**9.05**

There is some question about how to use horizontal and vertical setbacks in combination. For example, is it better to require that structures be setback the larger distance of the two? In some cases, depending on height above sea level, this may result in an unacceptably large distance. Or should one be used instead of both? If this is the case, then property may not be protected from either erosion rates in the case of a vertical setback in highly erosive environments, or flooding in the case of horizontal setbacks in low lying environments. One option might be to require two different horizontal setback distances depending on height above sea level. For example, a setback of X m for structures above Y m above sea level, and a Z m horizontal setback for structures below Y m above sea level.

The USFEMA uses the 100-year floodplain to create its National Flood Insurance Rate Maps (USFEMA, 2012; Harris *et al.*, 2010). A 100-year has a 26% chance of occurring over 30 years, a typical mortgage period (USFEMA, 2012).

4. Sea level rise

Sea level rise is one of the primary outcomes of anthropogenic climate change (IPCC, 2007), and is caused by the thermal expansion of the oceans due to increased global air temperatures, and by the melting of glaciers (Najjar *et al.*, 2000; Richards & Daigle, 2011; Bernier, 2005). Although not related to climate change, crustal subsidence (approximately 3 mm per year or 30 cm per century) also causes sea level to rise relative to previous levels (Najjar *et al.*, 2000; Richards & Daigle, 2011; Bernier, 2005; Shaw *et al.*, 1993). These three phenomena (thermal expansion, glacial melting, and subsidence) combined are called “relative sea level rise” (Richards & Daigle, 2011), however for the purposes of this report will simply be called “sea level rise”.

According to the IPCC Response Strategies Working Group (1990) "the extent to which individual coastlines will be affected by sea-level rise is strongly determined by local physical, biological and socio-economic conditions". In Nova Scotia, sea level is expected rise an average of 1.07 m by 2100 (this number includes coastal subsidence –Table A.12) (Richards & Daigle, 2011).

Table A.12. Estimates of anticipated changes in total sea level for the years 2025, 2055, 2085 and 2100 (Adapted from Richards & Daigle, 2011)

Data Collection Site	Global Sea-Level Rise (2100)	Crustal Subsidence (2100) (Note 1)	Total Change (2025) (Note 2)	Total Change (2055) (Note 3)	Total Change (2085) (Note 4)	Total Change (2100)
Burncoat Head	0.90 ± 0.43	0.15 ± 0.05	0.15 ± 0.03	0.42 ± 0.15	0.82 ± 0.36	1.05 ± 0.48
Canso Harbour	0.90 ± 0.43	0.20 ± 0.05	0.16 ± 0.03	0.45 ± 0.15	0.86 ± 0.36	1.10 ± 0.48
Cheticamp	0.90 ± 0.43	0.20 ± 0.05	0.16 ± 0.03	0.45 ± 0.15	0.86 ± 0.36	1.10 ± 0.48
Digby	0.90 ± 0.43	0.15 ± 0.05	0.15 ± 0.03	0.42 ± 0.15	0.82 ± 0.36	1.05 ± 0.48
Halifax	0.90 ± 0.43	0.16 ± 0.05	0.15 ± 0.03	0.43 ± 0.15	0.83 ± 0.36	1.06 ± 0.48
Hantsport	0.90 ± 0.43	0.20 ± 0.05	0.16 ± 0.03	0.45 ± 0.15	0.86 ± 0.36	1.10 ± 0.48
Joggins	0.90 ± 0.43	0.15 ± 0.05	0.15 ± 0.03	0.42 ± 0.15	0.82 ± 0.36	1.05 ± 0.48
Liverpool	0.90 ± 0.43	0.16 ± 0.05	0.15 ± 0.03	0.43 ± 0.15	0.83 ± 0.36	1.06 ± 0.48
Lunenburg	0.90 ± 0.43	0.16 ± 0.05	0.15 ± 0.03	0.43 ± 0.15	0.83 ± 0.36	1.06 ± 0.48
Pictou	0.90 ± 0.43	0.15 ± 0.05	0.15 ± 0.03	0.42 ± 0.15	0.82 ± 0.36	1.05 ± 0.48
Sydney	0.90 ± 0.43	0.20 ± 0.05	0.16 ± 0.03	0.45 ± 0.15	0.86 ± 0.36	1.10 ± 0.48
Yarmouth	0.90 ± 0.43	0.16 ± 0.05	0.15 ± 0.03	0.43 ± 0.15	0.83 ± 0.36	1.06 ± 0.48
AVERAGE	**0.90 ± 0.43**	**0.17 ± 0.05**	**0.15.5 ± 0.03**	**0.43.3 ± 0.15**	**0.83.6 ± 0.36**	**1.07 ± 0.48**

Note 1. The value of 90 cm is the central value from Rahmstorf (2007) year 2100 estimates and the ±43 cm error bar represents the associated range
Note 2. Total includes linear increase of crustal subsidence (25%) + prorated non-linear (polynomial) increase of 100-year global sea-level rise
Note 3. Total includes linear increase of crustal subsidence (55%) + prorated non-linear (polynomial) increase of 100-year global sea-level rise
Note 4. Total includes linear increase of crustal subsidence (85%) + prorated non-linear (polynomial) increase of 100-year global sea-level rise (Richards & Daigle, 2011).

Beaches are expected to move inland as a result of sea level rise (Davidson-Arnott, 2005). The distance that beaches retreat inland will depend on the land use behind the beach and the extent to which it has been developed (Fish *et al.*, 2008; McLean *et al.*, 2001): areas with dense coastal development will suffer greater impacts due to sea level rise than natural or low density sections of the coast (Airoldi *et al.*, 2005). Fish *et al.* (2008) show that beach loss decreases as setback width increases, and that wider setbacks will better accommodate beach retreat. Sea level rise poses a significant threat to coastal infrastructure as water encroaches on development rendering unusable (Najjar *et al.*, 2000; USFEMA, 2011). Defending coastal development from the rising sea can "often cost more than what the property being protected is worth" (Titus, 2011).

Coastal ecosystems are also threatened when the shoreline is prevented from behaving dynamically. In a study about beach and sea turtle habitat loss under different sea level rise and setback scenarios in Barbados, Fish *et al*. (2008) found that "under a 10 m setback and a 0.5 m [sea level rise]…the percentage of the original nesting area lost ranged from 62% to 100%.With a 30 m setback, the loss ranged from 0.5% to 50% of the original nesting area."

Table A.13. Summary of qualitative impacts of increased sea level rise and storm events on the natural coastal system (CBCL Ltd., 2009).

Element of Natural Coastal System	Impacts of Increased Sea Level Rise and Storm Events
Beaches	Large-scale morphologic adjustments to absorb the wave energy, including: - Overwashing and increased erosion - Potential formation of new beaches downdrift of erosion areas - Landward migration of barrier beaches
Unconsolidated cliffs	Accelerated erosion
Estuaries and tidal rivers	Increase in tidal volume and exchange Further saltwater penetration
Freshwater marshes	Gradually become salt marshes or migrate landward
Salt marshes	More frequent tidal flooding Sedimentation and possible landward migration at a rate commensurate with sea level rise depending on sediment and organic matter supply
Aquifers	Potential saltwater intrusion affecting potable and agricultural groundwater supplies. In some areas this may be mitigated by recharge from increased annual precipitation
Species and ecosystems	*Sea level rise and storm impacts*: Modification of coastal habitat as listed above *Other climate change impacts:* Threatened viability from changes in numerous factors including, but not limited to, water temperature, salinity, sea ice patterns (e.g., seals), runoff, and water quality.
Small islands	Submergence

5. Water Quality

Coastal water quality is negatively impacted by pollutants which include sediment, nutrients, bacteria, pharmaceuticals, salt, acid rain, and toxins which enter marine waters primarily via streams, but also via localized surface runoff (Walters *et al.*, 2011; Airoldi, 2003; Steger & Gardner, 2007; Jartun & Pettersen, 2010). As previously mentioned, an important water quality problem is the unwanted growth of algae. Land-based sources of nutrients, such as nitrogen and phosphorous, enter watercourses and encourage excessive growth of algal blooms in coastal waters (Howarth & Marino, 2006; Diaz & Rosenberg, 2008; Swackhamer *et al.,* 2004). These blooms can cause die-offs of other aquatic organisms (Boesch *et al.*, 2001, Rabalais *et al.*, 2001). Research also shows that the habitat structure of sea grass beds is impacted by coastal water pollution (Livingston, 1984). In Nova Scotia, “monitoring results show that coastal waters off parts of Cumberland, Pictou, Antigonish, Inverness, Colchester, Kings, Annapolis, and Digby counties may be at an increased risk for algal blooms” (CBCL Ltd., 2009).

It appears that very little research has been conducted to assess the ability of different vegetation types to filter nonpoint source pollution for a variety of coastal zones. This is perhaps due to the fact that most pollutants enter coastal waters through streams and groundwater rather than through overland runoff (Koç, 2012; Dorner *et al.*, 2006; Desbonnet *et al.*, 1994). Coastal wetlands, including wetland forests, salt marshes and freshwater marshes, serve as important filtration systems for excess sediment, nutrients, heavy metals, and organic toxic substances such as pesticides (Najjar *et al*., 2000). Coastal vegetation will reduce sedimentation at local scales by stabilizing banks and filtering sediment contained in runoff and root systems will absorb some nutrients from groundwater (McClain *et al.*, 2011, Le Maitre *et al.*, 1999); however the protection of coastal wetlands and riparian vegetation will likely produce more significant pollutant reductions than by protecting vegetated coastal buffers.

As previously mentioned little research has been conducted about pollutant filtration in coastal vegetation. The research that has been conducted seems to apply the logic behind riparian filter pollutant filtration processes to coastal zones; however it is unlikely that hydrogeological processes operate in the same way in both zones, although it is likely that the same factors that modify the effectiveness of vegetated riparian buffers (e.g., slope, vegetation type, soil type, buffer width) are still relevant in coastal zones. Desbonnet *et al*. (1994) apply the same pollutant filtration logic to both riparian and coastal zones. According to the authors, coastal waters are sensitive to nitrogen and therefore coastal vegetated buffers should be designed to remove nitrogen (mix of grass and hardwood species or other deep-rooted species). As shown in Table A.4, Desbonnet *et al*. (1994) report that vegetated buffer widths of 5-85 m will remove 50-80% of pollutants and that beyond 80% efficiency, ever greater buffer widths are required to achieve incremental increases in pollutant removal.

6. Ecosystem values

A great deal of research recognizes the unique and important nature of coastal ecosystems to support wildlife. Climate change threatens coastal ecosystems; when sea levels rise coastal habitats are threatened by inundation, erosion, and saltwater intrusion. Large storm events and changes in air and water temperatures will also disturb coastal habitats (Rogers & McCarty, 2000; Guntenspergen *et al*., 1995; Conner *et al.*, 1989).

Coastal wetlands serve as highly productive wildlife habitats; spawning grounds (Najjar *et al*., 2000). Small pannes, tidal pools, and tidal creeks, all usually less than 1 m deep, attract large densities of shorebirds and wading birds especially during May and August migration periods. Small forage fishes, polychaetes, mollusks, and insect larvae serve as primary prey. Such habitats are particularly important for shorebirds during rising and high tide periods when intertidal flats may become unavailable (Erwin, 1996).

In Nova Scotia, several plant and animal species listed as threatened, endangered, or species of concern can be found in the coastal zone including Long's Bulrush, the piping plover, Redroot, Eastern Lilaeopsis, Golden-crest, Water-Pennywort, Pink Coreopsis, Tubercled Spike-rush and the New Jersey Rush (Nova Scotia Natural Resources, 2011).

As beach width narrows due to “coastal squeeze” along armoured shorelines, so too does beach wildlife habitat, resulting in reductions in diversity and abundance of organisms, particularly in the upper intertidal zone (Sobocinski, 2003; Dugan & Hubbard, 2006; Dugan *et al*., 2008; Nordstrom, 2005). Reduced species diversity and abundance, particularly amongst invertebrates, can impact higher trophic level species such as birds when their food source and habitat area declines. Studies in California have shown that bird diversity and abundance is lower on armoured beaches than on un-armoured ones (Dugan & Hubbard, 2006; Dugan *et al*., 2008).

In addition to impacting the size of beach habitat, armouring can also impact the quality of beach wildlife habitat. Armouring can affect the deposition and quantity of driftwood, macrophyte wrack and other natural debris washed ashore by wave action and which can be important to habitat structure (Sobocinski, 2003; Dugan & Hubbard, 2006). Beach nourishment is a common response to the disappearance of beaches caused by shoreline armouring and can also impact beach and aquatic wildlife habitats (Lindeman & Snyder 1999; Peterson *et al*., 2000).

6.1. Bird habitat

Beaches and dunes are critical habitats for shorebirds (Hosier *et al*., 1981; Hubbard & Dugan, 2003) and are sensitive to disturbances which can alter key behavioural traits that are crucial to their survival and reproduction (Burger, 1994; Lord *et al*., 2001; Verhulst *et al*., 2001).

Intertidal flats are home to vibrant ecosystems. According to Erwin (1996),

> "These shallow (mostly <2.5 m deep) areas include both unvegetated mudflats and in some regions extensive beds of submerged aquatic vegetation (SAV). Large mudflat expanses are especially critical to migrant shorebirds in May and August-October, while SAV beds are important to waterfowl both as summer brood-rearing habitat and winter foraging habitat. …Longer-legged shorebirds use the flat areas (to depths of 10-15 cm) as waters recede during ebb tide, while all shorebird species invade the newly-exposed mudflats"

In Nova Scotia, the piping plover, an endangered species under the federal *Species at Risk Act* and the Nova Scotia *Endangered Species Act*, nests on sandy beaches and have been shown to be highly vulnerable to human disturbance (Flemming *et al.*, 1988), including:

- "changes to foraging behaviour resulting in less feeding time, shifts in feeding times and decreased food intake;
- decreased parental care when disturbed birds spend less time attending the nest, thus increasing exposure and vulnerability of eggs and chicks to predators; and
- decreased nesting densities in disturbed areas and population shifts to less impacted sites." (Defeo *et al*., 2009).

In many areas, the quality of nesting beaches has already been compromised by beachside construction, exposing nests to lights, activity, noise and altered physical characteristics, all of which can affect nesting success (Erwin, 1996).

Table A.14. Recommended buffer distances (in m) to reduce human disturbance at activity sites of selected waterbird and shorebird species (Adapted from Ervin, 1996).

Type of Bird	Distance (m)
Piping Plover	200
Bald Eagle	100 – 200 (when roosting) 400 – 800 (when nesting)
Osprey	100
Wading birds (herons)	100 – 200
Sea Birds	50 – 200
Shorebirds (sandpipers, plovers & relatives)	50 – 100
Cormorants	400 – 600
Canvasbacks	550 – 1000

6.2. Insect habitat

According to Defeo *et al*. (2009), "most beach species are found in no other environment, their unique adaptations for life in these dynamic systems include: mobility, burrowing ability, protective exoskeletons, rhythmic behaviour, orientation mechanisms and behavioural plasticity." Sandy beaches in particular are home to many interstitial organisms (e.g., bacteria, protozoans, microalgae and meiofauna) which favour the space between grains of sand, as well as invertebrate species, including crustaceans, molluscs and polychaete worms, who burrow in the sand or mud (Defeo *et al.*, 2009).

Beach debris, such as macrophyte wrack, supports crustacean and insect populations (Defeo *et al*., 2009). The effect of intertidal swash and sand conditions on invertebrate assemblages is stronger on reflective beaches and weakest on dissipative beaches meaning that dissipative beaches have higher species colonization rates, primarily robust crustaceans, than reflective beaches (McLachlan & Dorvlo, 2005). The range of lower beach fauna can extend in the surf-zone to feed on zooplankton, shrimps and prawns which can be abundant in this zone (Defeo *et al*., 2009).

6.3. Fish habitat

Surf zones are important nursery and foraging areas for fishes (Defeo *et al*., 2009). Nonpoint source pollution can harm coastal fish habitat (Clark, 1996), particularly suspended sediments which can result in a decrease in the number of species intolerant to these conditions (Sawyer *et al*., 2004). Studies have shown that "sedimentation decreases available spawning habitat, increases egg and larvae mortality, and can decrease feeding success of species that rely on visual search strategies (Henley *et al*., 2000; Berkman & Rabeni, 1987)" (Sawyer *et al.*, 2004). The environmental conditions during the larval stages of many fish and shellfish strongly affect natural mortality rates in the species and are correlated with abundance (Najjar *et al*., 2000). No information was found stating specific vegetated buffer or setback widths necessary to protect water quality for fish; however reductions in pollutants carried by streams (e.g., the use of vegetated riparian buffers) will improve coastal water quality and benefit fish populations (Halpern *et al.*, 2008; Howarth *et al.*, 2011).

Appendix E - Coastal erosion formulas

From the IPCC's *Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change - Bruun Rule Description (2011).*

The Bruun Rule

The first and best known model relating shoreline retreat to an increase in local sea level is that proposed by Per Bruun (1962). The IPCC reports that 1 cm rise in sea level erodes beaches about 1 m horizontally. This becomes a large issue for developed beaches that are less than 5 m from the ocean (IPCC, 1998).

The Bruun rule states that a typical concave-upward beach profile erodes sand from the beach face and deposits it offshore to maintain constant water depth. The Bruun rule can be applied to correlate sea-level rise with eroding beaches. The Bruun rule estimates the response of the shoreline profile to sea-level rise. This simple model states that the beach profile is a parabolic function whose parameters are entirely determined by the mean water level and the sand grain size.

The analysis by Bruun assumes that with a rise in sea level, the equilibrium profile of the beach and shallow offshore moves upward and landward. The analysis is two-dimensional and assumes that:

- The upper beach is eroded due to the landward translation of the profile;
- The material eroded from the upper beach is transported immediately into the offshore and deposited, such that the volume eroded is equal to the volume deposited;
- The rise in the nearshore bottom as a result of deposition is equal to the rise in sea level, thus maintaining a constant water depth in the offshore (SCOR, 1991).

The Bruun rule is only applicable for small scale local sites. Over long stretches of coast, the Bruun rule and associated cross-shore transport models become complex. There have been a number of critiques e.g. Cooper and Pilkey (2004).

Key input: An increase in sea level, (S), cross shore distance (L) to the water depth (h) taken by Bruun as the depth to which nearshore sediments exist (depth of closure), and B is the height of the dune. Bruun rule has been applied but caution needs to be exercised where other factors influence sediment budget or control profile.

From Alexandra Scouller's *The Challenges of Coastal Setbacks in New Zealand* (2010).

The following equations can be used to calculate appropriate coastal setback distances based on local context.

B (Buffer zone width) = $[(N \times R) + C] + F$

Where: R = the rate of long-term erosion (m/year)
C = the extent of short-term cyclonic erosion (m)
N = planning period of 50 years
F = a factor of safety of 40m to allow for uncertainties in the various factors involved (Gibb, 1998)

$CEHZ = [(X + R) T + S + D] F$

Where: X =rate of erosion caused by sea level rise (m/year)
R =long-term erosion-accretion rate (m/year)
T =an assessment period
S =maximum short-term erosion-accretion (m)
D =stable slope factor
F =safety factor expressed on a scale from 1.0 (0%) to 2.0 (100%) (Gibb, 1998)

Factor X is determined by the Bruun Rule, IPCC estimates of sea level rise, subtraction of critical local and regional effects and identification of the seaward limit of onshore-offshore beach sediment movement. Factor D is the magnitude in metres of retreat of the top seaward edge of the erosion scarp cut into sand dunes as a result of slumping to attain a stable slope. For the safety factor F which is expressed on a scale from 1.0 to 2.0, it is determined by averaging the sum of errors for the other components, and making sure there is an adequate distance for a nominal foredune or beach ridge and the end of the planning horizon (Gibb, 1998). Further equations have been developed for coastlines with an identified long-term trend of shoreline advance and well as to identify CLHZ.

$CHZ = R + 2F (max) + \Delta y + D$

Where: CHZ = a linear distance measured in land from a reference point
R = long-term shoreline erosion or accretion rate (m/year)
F (max) = the decadal term dune-line fluctuation (m)
Δy = dune line retreat due to sea level rise (m)
D = dune line stability factor (Healy and Dean, *in press* in Auckland Regional Council, 2000)

$Hz=ST+SE+DS+SL+LT$

Where: ST =short-term fluctuations (m/year)
SE =shoreline response to storm erosion (m)
DS =distance from 1.0m above MSL to the active dune/beach
SL =the magnitude of shoreline retreat due to possible accelerated sea level (m)
LT =the long-term rate of horizontal shoreline movement (m/year) (Tonkin and Taylor (2004))

Appendix F - Summary of common shoreline indicators

Table A.15. Summary of some common shoreline indicators (Adapted from Boak & Turner, 2005)

Reported Shoreline Indicator	Identification of Feature	Comments	Reference
Bluff top/ cliff top	Landward edge of the bluff top or cliff top, or break in slope resulting directly from wave erosion or from mass movements triggered by wave erosion	Good erosion indicator, but will not show accretion; morphology specific (hard coasts)	Moore, Beaumof & Griggs 1999; Priest, 1999; Crowell, Douglas & Leatherman, 1997; Guy, 1999
Landslide headwall	Top of the headwall; only used on bluffed shorelines with zones of mass movement, e.g., earth flows, landslides, slumps, or transitional slide blocks	Good erosion indicator, but will not show accretion; morphology specific (hard coasts)	Priest, 1999
Base of bluff/cliff	Base of bluff or cliff; used when bluff/cliff top is rounded, and it is not easy to determine the landward edge	Not clearly defined; base position may be distorted due to rubble, etc; morphology specific (hard coasts)	Moore, Benumof & Griggs, 1999
Landward edge of shore protection structure	Landward edge of shore protection structures and development	Case specific: only where the coastline has been protected. A properly designed structure is designed not to move/fail within its design life, so the indicator is unlikely to relocate.	Moore, Benumof & Griggs, 1999
Seaward stable dune vegetation line	Seaward edge of stable, long-term vegetation	Case specific: only where dune vegetation is present. Good erosion indicator, but may not show accretion or will show it with a significant time lag. What defines stable and long term?	Priest, 1999; Guy 1999
Seaward dune vegetation line	Seaward edge of dune vegetation, distinct edge in image based on tonal differences (brightness) between the vegetated and non-vegetated beach areas	Case specific: only where dune vegetation is present. Good erosion indicator, but may not show accretion or will show it with a significant time lag. What defines stable and long term?	Moore, Benumof &Griggs, 1999; Komar, Diaz-Mendez & Marra, 2001; Hoeke, Zarillo & Synder, 2001
Vegetation line	Distinct edge in image based on tonal differences (brightness) between the vegetated and non-vegetated beach areas	Case specific: only where dune vegetation is present. Good erosion indicator, but may not show accretion or will show it with a significant time lag. What defines stable and long term?	Hoeke, Zarillo & Synder, 2001
Erosion scarp	Appears as a topographic break or scarp between the wind- or wave deposited dunes and the seaward sloping beach, or the upper level of the highest spring tide, a sharp break in slope from the gentle upper beach to the steep dune front, or a dune erosion scarp	Good erosion indicator, but will not show accretion. Not always present, both spatially and temporally.	Stafford & Langfelder, 1971; Battiau-Queney *et al.*, 2003
Storm line/ debris	A line of seaweed and debris	Represents only elevated water conditions during storms.	Gorman, Morang & Larson, 1998

Previous high-tide HWL	Seaward line of two lines of slight discoloration. The more landward line is the storm/debris line, or a change in color or gray tone caused by differences in water content of the sand on either side of the high-water line	May not be clearly visible. Affected by wind/wave/tide conditions at the time.	Honeycutt, Crowell & Douglas, 2001; Zhang, Douglas & Leatherman, 2002; Crowell, Farrell *et al.*, 1999; Zhang *et al.*, 2002
Mean high-water line	Tidal datum–based MHW is superimposed on a digital terrain model of the subaerial beach	Does not account for short-term hydrodynamic variation (waves, runup, etc.).	Fisher & Overton, 1994; Parker, 2001; List & Farris, 1999; Stockdon *et al.*, 2002
Wet/dry line	On a rising tide = maximum runup limit; on a falling tide = part of beach that is still wet, but it may be beyond the instantaneous runup limit, or distinct edge in image based on tonal differences (brightness) between the dry and wet beach areas	Clearly visible on all photos. Variation due to sand drying is not quantified. Affected by wind/ wave/tide conditions at the time. Dolan, Hayden, and Heywood, (1978) infer that the wet/dry line is a stable shoreline indicator and is less sensitive to tidal stage than the instantaneous runup limit.	Dolan, Hayden & Heywood, 1978; Dolan *et al.*, 1979; Hayden, Dolan, And Felder, 1979; Doland *et al.*, 1980; Fenster & Dolan, 1999
Shorebreak maximum intensity	The maximum intensity (brightness) of the time-averaged shorebreak	Not useful in locations with wide swash zones. Affected by wind/ wave conditions at the time.	Plant & Holman, 1996; Plant & Holman, 1997; Arninkhof, 2003
Mean lower low water line	Tidally determined MLLW is superimposed on a three-dimensional model of the sub aerial beach	Actual MLLW	Fisher & Overton, 1994
Beach toe/ crest of beach step	Change in slope at the transition between nearshore and foreshore. Natural feature that marks the seaward edge of the beach. Crest of beach step, marked by a distinct tonal contrast by the change in water depth over the feature.	Not visible at many locations	Coyne, Fletcher & Richmond, 1999; Norcross, Fletcher & Merrifield, 2002