Climate Change Considerations for Trail Managers

Section #1 – Introduction

Figure 1: Trail head at Salt Marsh Trail (2024)

In Nova Scotia, climate change impacts are affecting many aspects of our lives including recreational activities and infrastructure such as provincial trail systems. Extreme weather events, warming temperatures and rising sea levels have resulted in extensive damage to transportation networks, disruptions to power distribution systems, degradation of shoreline property, and even the loss of life. Governments at all levels are exploring mitigation options and adaptive strategies for addressing these impacts in an attempt to make vital public infrastructure more resilient and sustainable going forward, and to protect public health, safety and property. Recreational trails are among the valued public assets that are under threat, and trail managers must incorporate climate change considerations in all aspects of trail development, from initial planning and design stages, to trail construction and maintenance programs.

The purpose of this document is threefold:

1. to provide information on climate change impacts and how those impacts may affect recreational trails and trail infrastructure,
2. to identify those site factors which can contribute to the vulnerability of trails to the damaging effects of climate change impacts, and
3. to provide adaptive strategies and actions that trail managers can incorporate into their trail development and maintenance programs to help improve the resilience and sustainability of their trail(s) and trail infrastructure in anticipation of climate change impacts.

The objective in developing this document is to provide a climate change "lens" through which trail managers can better assess the vulnerabilities of their trail systems as it relates to climate change impacts, and to identify some measures that can be taken to improve the long-term viability of their trail(s) and infrastructure. The adaptive strategies are not intended to trump or diminish the importance of all other accepted best practices and standards that are considered in planning and decision-making processes. Rather they are intended to supplement the "toolbox" of best practices that trail managers can draw from to build and maintain high-quality, safe and sustainable trails. Climate change will continue to test the quality and integrity of trail systems going forward. Those that have been compromised by poor planning, sub-standard construction methods or insufficient maintenance programs will be more prone to damage. In effect, climate change has "raised the bar" so that best practices must become the norm. Trail managers cannot afford to regard the occurrence of extreme weather events as a 1 in 100 or 1 in 50 "risk", but must anticipate them and utilize available resources to implement best practices and adaptive strategies that improve the resilience of their trails when they do occur.

The term "trails" embraces travel routes developed for a wide variety of user groups, and constructed to differing standards depending on the intended use(s). They range from narrow (0.5 meters) single track pedestrian trails created with minimal ground disturbance, to motorized vehicle trails that have crowned 2-metre-wide dirt or gravel surfaces that were built with small excavators, to "water trails" incorporating portage routes first used by the Mi'kmaq. They are found in a wide range of natural landscapes from shorelines to mountain plateaus, and often utilize old, abandoned travel corridors that were originally used for purposes such as rail lines, logging roads, public highways or access routes to old settlements. Some are in excellent condition having been built and maintained to the highest standards, while others are in very poor condition due to neglect or a lack of necessary resources. This document seeks to touch on most common trail types, providing general adaptive strategies that apply to many different types, and more specific recommendations for some having unique features (e.g. abandoned rail lines) or are found in very specific settings (e.g. coastal trails).

Recreational trails represent a significant financial investment oftentimes coupled with equally significant "in kind" contributions in the form of volunteer sweat equity, donated materials, landowner permissions, and so on. Recent storm events involving extreme winds and widespread flooding are reminders that the cost of repairing trail infrastructure is also very high. It is therefore incumbent upon all parties involved in building and maintaining trails that this investment be protected by adhering to best practices, and taking appropriate adaptive measures to make trails more resilient when facing the challenges posed by climate change impacts.

Trail interests within government and user groups, Mi'kmaq and non-native communities, and the broader private sector have recognized the need for a coordinated and collaborative approach in developing recreational trail systems in Nova Scotia. This common interest has resulted in the publication of the Shared Strategy for Trails in Nova Scotia - Government of Nova Scotia, Canada (2019) which identifies four major goals with priority actions given for each. One of the first actions undertaken was to create the Trails Strategy Coordinating Group (TSCG) to support and coordinate the implementation of the strategy. **Ultimately**, these goals and associated priority actions will help contribute to achieving the stated vision:

Nova Scotians and visitors have access to a variety of high quality, safe and appealing trail opportunities, and are using them regularly. As a result, we enjoy many health, social, cultural, environmental and economic benefits.

Figure 2: Gull Cove Trail showing rest area pre and post Hurricane Fiona (2022).

Section #2 - Climate Change Impacts

Our changing climate must be considered at all stages in the planning, development, maintenance and funding of recreational trails in Nova Scotia. It is inevitable that climate change impacts will require the allocation of additional resources in terms of time, labour, materials and funds. There will be additional unscheduled inspections and repairs required, temporary trail closures may have to be implemented and monitored, and environmental concerns will have to be addressed. Climate change will test even the best construction and maintenance standards and practices, and will reveal where the weaknesses and shortcomings exist. The following sections provide information on specific climate change impacts being

experienced in Nova Scotia and how are they are affecting trail systems, associated infrastructure and trail users.

- **Warmer temperatures:** Warmer average seasonal temperatures will result in the following impacts to trail systems and usage.
    - Milder winter temperatures will result in a general decrease in the amount, distribution and duration of snow cover in many areas of the province thereby limiting opportunities for winter trail uses such as snowmobiling, cross-country skiing, and snowshoeing. This effect will be most apparent at lower elevations and in coastal areas, and will challenge the viability of winter-use-only trails in these areas.
    - Mild winters will generally result in less ice formation, reduced levels of frost in the ground, and a higher percentage of precipitation falling as rain rather than snow. The combination of short daylight periods, cooler air temperatures and lower evaporation rates during the winter season means that soils are generally wetter than during the late spring to early fall period. When trail beds are wet or saturated, they are less able to withstand the physical impacts and loads associated with trail use. In the absence of frost and/or snow cover, wet trails can be soft and much more vulnerable to erosion and rutting of the trail surface.
    - Snowmobile-only trails that have relied on ice formation and deep snows to "bridge" wet areas and small drainages may require significant upgrades through improved ditching and installation of culverts, puncheons and small bridges. Reduced snow cover will require that trail surfaces be grubbed (removal of stumps and organic material) and properly shaped – especially where trail groomers will be utilized.
    - Temperature changes may alter habitat characteristics and ecological processes, the composition and distribution of plant and animal communities, and individual species distributions. The long-term viability of species which are currently at the fringes of their normal distribution ranges, and those with very specific habitat requirements will be most at risk. These climate change impacts will compound ongoing concerns related to both "species at risk" and invasive species, and put greater emphasis on minimizing the potential impacts that human activity, including trail development and use, might have on vulnerable species and ecosystems.
    - Warmer and dryer conditions elevate the risk of both wildfires as well as heat-related illness associated with trail users. More frequent woods closures and restrictions on certain activities such as open fires will impact the use of some trails and associated facilities such as campsites and picnic areas. Appropriate signage will become more critical in providing key information and raising awareness.

- **Sea level rise:** As global air temperatures rise, year-round ice packs located at or near the poles and at high elevations are shrinking. The melting ice is contributing to a rise in sea levels and the following direct impacts.
    - Rising sea levels will lead to coastal flooding of trails and trail infrastructure in low-lying areas near the coast. This will necessitate modification to, relocation of, or abandonment of impacted trails, infrastructure and related facilities.
    - The progressive flooding of coastal areas will result in the alteration, loss or "migration" of important coastal habitats such as salt marshes, barachois ponds and beaches. As

with temperature change, coastal flooding and the related impacts to critical habitats may result in restrictions to some types of human use and development in these areas in an effort to reduce further stress on the affected ecosystems and species of concern. Recreational pursuits such as trail development and use may be limited in efforts to minimize those impacts, especially on public lands. The physical and ecological changes driven by sea level rise is something of an "evolutionary" process as natural systems are forced to adjust to the changing environmental conditions. Coastal trail systems will also have to adjust to those changes to remain viable.

Figure 3: Gull Cove Trail showing coastal trail sections being undercut by coastal erosion (2023)

- **<u>Increased frequency of extreme weather events:</u>** Perhaps the most obvious consequence of climate change is an increase in the frequency and severity of extreme weather events being experienced in Nova Scotia. These storms have had devastating impacts on trails, trail infrastructure and the lands and environment where they are located. The following is a brief outline of the more damaging impacts that have been observed.
    - High winds can damage trail infrastructure directly or by toppling trees or whole forest stands adjacent to the trails. Uprooted or broken trees can block the trail or damage the trail surface when root systems are pulled from the ground. Leaning or damaged trees close to the trail represent an ongoing safety hazard for trail users, and a future requirement for trail maintenance efforts and resources.

- Forest stands severely damaged or killed by high winds can pose a significant risk of wildfires. This is of particular concern when the forest is composed of coniferous tree species such as fir and spruce whose twigs and needles provide ideal fuels for fire ignition and rapid fire spread. Since most wildfires in Nova Scotia are started as a consequence of some sort of human activity, trail use can be a potential source, especially where motor vehicles are involved. Campfires and stoves, discarded cigarettes, hot engine exhaust and engine sparks are all potential heat sources sufficient to start wildfires.
- Very heavy rains can result in overland flooding, particularly if combined with melting snows and previously saturated soils. Floodwaters washing up against or over trails can erode the trail surface, cause washouts, saturate trail beds causing them to weaken and slump, or damage trail infrastructure.
- Heavy precipitation falling on and immediately uphill of trails can wash sediment and organic material into trail ditches and cross drains. If cross culverts become plugged, runoff could build up in the ditch leading to washouts or erosion of the sides of the trail farther down slope.
- During heavy rain events, watercourses can overflow their banks resulting in flood damage to nearby trails and infrastructure. Trails built along or across natural floodplains are especially at risk.
- Undersized or poorly designed stream crossings that function adequately under normal circumstances can act as bottlenecks during heavy rain storms, raising water levels on the upstream side which can lead to washouts, damage to bridges and culverts, surface erosion and weakening of the trail bed. Even adequately sized stream crossings can be compromised when rain-swollen watercourses push debris into or against the bridge or culvert restricting water flow through the structure and creating a buildup of floodwaters that subsequently cause damage.
- Large storms approaching the coastline can generate very high waves that impact shores with tremendous force. The results can include the erosion and undermining of shorelines and damage or destruction of trails and any associated structures and facilities found there. The level of damage inflicted will be even higher when the wave action is accompanied by rising sea levels, storm-generated ocean surge, and/or high tides.
- Storm events pose a health and safety risk to trail users, both during the storm and prior to damaged sections being repaired. These conditions require more frequent trail inspections, posting and maintenance of appropriate signage, and trail closures where concerns related to public health and safety warrant such action.

Section #3 - Site Factors Affecting Trail Vulnerability to Climate Change Impacts

One broad objective for supporting a wide range of recreational trail opportunities is to provide public access to the amazing diversity of landscapes in Nova Scotia. This mosaic of natural areas includes everything from pristine coastline to intact forested hills and valleys to scenic highland plateaus. Natural landscapes are defined largely by their unique combinations of geology, soil characteristics, topography and associated communities of plants and animals. In addition to this natural diversity, Nova Scotia has a

long history of human use and development which has left its footprint across much of the province. One consequence of this rich diversity of landscapes and human use is that trail builders and managers will have to contend with a range of challenges when developing and maintaining their trails in the face of a changing climate. The following sections will review trail characteristics and site-related factors that determine the sustainability or resilience of trails to climate change and its associated impacts.

Figure 4: "Rails-to Trails" feature stable trail beds and robust infrastructure.

- **<u>Historic use of the trail alignment:</u>** Many trails in Nova Scotia utilize travel corridors that were originally designed and constructed for other purposes including rail lines, natural resource extraction roads and abandoned public highways (i.e. "k-class" public access roads). These existing travel routes are often selected as recreational trails because trail developers are more likely to acquire landowner permission to utilize them as opposed to constructing all new trails, and the initial financial investment required to make the route "usable" for the intended purpose is often comparatively low. Unfortunately, the current condition, suitability and long-term viability of these routes may be compromised for various reasons including:
    - The existing alignment, although suitable for the original purpose, may be less than desirable as a recreational trail corridor, and options to relocate trail segments to avoid problematic areas or take advantage of nearby opportunities may be limited by adjacent land use or ownership.
    - The initial construction methods used in building many old roads are often deficient by today's standards, especially as it pertains to environmental protection and long-term

sustainability. Costs associated with bringing these routes up to present-day trail standards may be comparable to, or even exceed, the cost of building new trails.

- Required trail infrastructure (bridges, culverts, trestles, ditching, etc.) may be wanting, or if present, will likely have to be refurbished or replaced over time at significant, if not prohibitive cost.
- Some older access roads were built by scraping the stumps and upper soil layer off to expose the more durable mineral soil. These "grubbing" were simply pushed to the side creating berms or windrows of material, or pushed up into bigger piles often referred to as "push-offs". The exposed mineral soil became the travel surface of the road, and water was directed off and away from the travel surface with shallow trenches or take-off ditches. This simple construction method left the travel surface of old road beds lower than the grade of adjacent, undisturbed lands to either side. Once the take-off ditching filled in with debris and vegetation, surface water accumulated in low-lying road sections creating wet and muddy conditions. Where the original ditching is now lacking or has filled in, the whole road can act as a channel for surface water runoff. This has led to severe erosion of the sloped sections of many old roads.
- More recent but unmanaged use of these routes, particularly by off-highway vehicles (OHV's), has resulted in accelerated deterioration and rutting of old road beds. Maintenance of these routes in recent years is minimal in nature, often just sufficient to keep the route open to OHV use.
- Many of the original stream crossing structures have disappeared from these roads or are no longer safe to use. Despite this, continued vehicle use on these roads has involved machines crossing through watercourses leaving rutted and eroded approaches to the former crossing. This activity represents an ongoing source of sedimentation, particularly during heavy rain events. The eroded approaches to the old stream crossing are often wider than the natural watercourse channel and lower than the undisturbed stream banks. This makes constructing a new stream crossing in the same location more difficult, and potentially more costly.
- All-terrain vehicles (ATV's) are capable of negotiating very steep, wet and rough terrain. As a result, the alignments of many informal ATV trails go through these areas rather than around, with little apparent attention given environmental impacts or long-term sustainability. The condition of some of these unmanaged trails is very poor with sections characterized by deep ruts and standing water, steep eroded slopes, damaged wetlands and degraded stream crossings with poor or no structures in place. When problems become apparent on these trails, the tendency can be just to go around it rather than fix it. This has led to the development of "braided" trails having multiple parallel trail segments.
- Climate change with its more frequent severe weather events will expose the inherited shortcomings of existing "repurposed" travel corridors and accelerate required repairs and upgrades to these trails.

- **Elevation:** Trails at higher elevations in Nova Scotia, such as the Cape Breton Highlands and the Cobequid Hills, are generally subjected to lower average temperatures and higher levels of precipitation than the rest of the province. Not surprisingly, these areas are popular destinations

for snowmobilers and other wintertime trail users. As warming temperatures lead to a general decline in the amount of snowfall and/or the duration of persistent snow cover, elevated regions of the province will be relied upon more and more to provide those recreational opportunities. Winter-use trails in areas with declining or unreliable levels of snow cover may have to be repurposed for other trail-related uses or abandoned in favour of sites with more reliable snow conditions.

- **Proximity to the Coastline:** Nova Scotia is famous for its scenic coastline and the recreational opportunities it affords. Some of the more popular recreational trails are located along its shores. Rising ocean levels combined with more frequent storms have resulted in flooding of low-lying coastal areas, erosion of exposed coastline and severe wind damage to trail infrastructure and forests. Ecologically important coastal habitats such as salt marshes, estuaries, sand dunes and coastal headlands are being negatively impacted. Some will be lost over time while others may "migrate" inland or develop in newly submerged areas as the coastline recedes. Trails and trail infrastructure in coastal areas exposed to climate change impacts may have to be moved/realigned to more sustainable locations. In cases where relocation is not an option, trails may have to be reinforced (armour stone, etc.) or their travel surfaces built up to avoid rising water levels. Such measures can be very costly, and in worse case scenarios, some trails may have to be abandoned.

Figure 5: Musquodoboit "wilderness" trails and Pugwash Estuary Trail demonstrating very different topographic and soil characteristics.

- **Soils and bedrock:** Soils and their underlying bedrock are important considerations in trail planning, development and maintenance activities. Soil characteristics vary widely across Nova Scotia, posing differing challenges to trail developers. On one end of the spectrum are landscapes dominated by rock outcrops or coarse rock deposits covered with varying thicknesses of vegetation and organic materials, but with very little mineral soil. While it may be possible to navigate such terrain on foot, it is much more difficult to build a trail surface that can be used by wheeled vehicles. At the other end are deep soils and glacial deposits that provide abundant material for building trails of all types. Soil characteristics will influence trail building strategies, and in the context of climate change and its associated impacts, their importance in building resilient trails becomes even more critical. Those characteristics include:
    - Soil texture: - Good soils for building robust trails will contain a mix of fine (clay) to coarse (sand) soil particles combined with gravel and smaller stone. The smaller particles facilitate compaction of the trail surface while the gravel and stone improve its load bearing capacity, durability and resistance to erosion. Ideally, trail surfaces should not incorporate organic material as it tends to absorb and retain moisture while reducing the load-bearing capabilities of the trail. Very fine-textured soils comprised largely or exclusively of clay are generally more susceptible to surface erosion. Wet clay-based trails can take a long time to dry out, but once dry, are capable of carrying loads associated with off-highway vehicles if properly shaped to shed precipitation. An additional covering of gravel or other coarse material is often needed on clay-based trails to provide sufficient resistance to erosion as well as adequate traction during wet periods. Coarse-textured soils may provide excellent drainage but trails constructed of only coarse material may remain uncompacted and “loose” underfoot – similar to walking on beach sand or driving on washed gravel.
    - Soil organic content: - As previously noted, trails that incorporate significant amounts of organic material are not ideal for building trails due to their tendency to absorb and hold moisture. Many soil profiles exhibit an upper soil layer characterized by the presence of roots from trees and other vegetation. These root systems contribute organic material to this upper soil layer making it less suitable for trail building, particularly trails that will be subject to heavier loads and high traffic volumes. Below the upper rooting zone, most soils will also have “mineral soil” layers that tend to have little organic content, are generally coarser in texture with more stone content, and are much more suitable for trail construction.
    - Soil depth: - Deeper soils generally provide more readily available material for building up and shaping trail beds, filling in depressions to level the travel surface, covering culverts and building approaches to bridges. An adequate supply of suitable building material on site is particularly important for motorized vehicle trails. The mineral soils present are normally covered by living vegetation, decomposing organic materials and a layer of organic rich soil – all of which have to be removed to expose the better trail building material. Deeper soils are generally more conducive to tree rooting and therefore forest stands growing on deeper soils are less vulnerable to windthrow than are similar forests on shallow soils. Where mineral soils are lacking and the bedrock near the surface, suitable material required to build trails may have to be transported from nearby sources at additional cost.

- Soil drainage: - Wet soil conditions are common in depressions and flats. These soils tend to be soft and unable to support the weight and physical impacts associated with most pedestrian or vehicle uses. Trails constructed across these areas must be built up higher than the adjacent land to allow the trail bed opportunity to drain. In some cases, suitable material must be imported to infill across poorly drained sites.
- Coastal geology: - It could be argued that coastal areas will face the greatest impacts associated with climate change. Nova Scotia's shores have endured countless storm events in the past but the increasing frequency and severity of storms associated with a changing climate coupled with rising sea levels will expose more and more coastline to pounding wave action, floodwaters and violent winds. Coastline comprised of unfractured hard bedrock like granites will be better able to sustain the onslaught than those characterized by fractured/loose rock, glacial tills, soft stone bedrock like shales and slates, or sand/cobble.

Figure 6: North River Falls Trail showing surface erosion and debris piles in a floodplain zone.

- **Topography:** The varying topography of Nova Scotia has contributed to the recognition of some 80 distinct natural landscapes with their unique combination of landforms, soils and repeating pattern of ecosystem types. The variability is quite amazing given the relatively small size of the province, and includes diverse landscapes such as coastal lowlands and plains, inland rolling hills

and valleys, highland plateaus and taiga, drumlins (rounded hills of glacial deposits), coastal islands, and ridged plains. Each landscape type poses a unique combination of site factors that may influence the vulnerability of trails in the context of changing climate. Important factors related to topography include:

- Slope: - Trail construction in many landscapes requires negotiating slopes of varying steepness. This may involve going straight up or down inclines where slight to moderate slopes permit. Where negotiating moderate to steep slopes is required, it is best to follow a less aggressive "sidehill" alignment that cuts across the slope at a more reasonable incline. Two important considerations related to any sloping trail segment are the steepness of the slope (% slope) and the length of the sloped trail section, both of which contribute to the speed at which surface water will flow down the trail. As the % slope and the unbroken length of the sloped section increase, so does the risk of erosion. Long steeper inclines also require more effort to climb, and traction may be compromised when wet or slippery. Sidehill alignments require a bench to be cut into the side of the incline. Off-highway vehicle trails require a wider bench than does pedestrian or mountain bike trails. It is critical that precipitation and any water that flows onto trails from adjacent uphill areas be diverted off the trail surface as quickly as possible to control erosion.
- Aspect: - Aspect refers to the compass direction that a slope is facing. South facing slopes generally receive more direct sunlight during the day than do north facing slopes. Consequently, those trails on south facing slopes experience higher temperatures and evaporation rates than do trails on north facing slopes. Trails on north facing slopes retain snow cover for a longer period. The degree of "shading" that hills cast on north facing slopes/trails is determined by the steepness and height of the hill, and the position of the trail on the hillside. Trails at the base of a high steep hills may receive significantly reduced direct sunlight even in the summer season.
- Exposure: - Depending on its location, a trail or trail segment may be more or less exposed to the damaging effects of extreme weather events. For example, a trail and its associated infrastructure located at the coast or on top of a hill during high winds would be more exposed to potential damage than a similar trail situated in an inland valley bottom. Higher elevations are generally more exposed to heavier snow loads on structures, more prone to freezing rain and associated ice accumulation, low cloud/fog, and so on. The damage caused as a result of these exposures may be direct such as snow load collapsing a bridge, or indirectly such as ice buildups breaking off tree limbs along the trail.
- Floodplains: - People enjoy being able to access water courses as they travel along trails, whether that is the ocean, inland lakes and ponds or streams and rivers. The attraction to water bodies is also manifest in the near universal preference for rest areas, campsites and picnic areas being located near water whenever possible. While these sites offer a unique appreciation of nature's beauty, heavy rain events and quickly melting snows can transform rivers and streams into dangerous torrents whose waters are capable of exerting tremendous forces and causing immense damage. During such events, many water courses will overflow their banks onto adjacent lands at specific locations along their course. These areas that are periodically, sometimes predictably,

flooded during heavy rains and spring runoff are referred to as floodplains. Floodplains often have a "swept" appearance in the spring after late fall and spring high water has washed away most of the loose leaves and branches. Some of this debris is caught in shrubs and small trees, and can provide some insight into how high the water levels can reach. The periodic flooding adds additional nutrients to these areas making them particularly rich growing areas which often support unique plant communities which may include rarer species. For these reasons, floodplains are not appropriate sites for building trails and related infrastructure.

- Seasonal drainages: - One feature of many hillsides is the presence of small natural drainage channels which carry water downhill from springs and wetlands higher up the slope. Many are seasonal but some contain water year-round. Others may carry water only during spring runoff or heavy rain events, and the volume and the velocity of that flow can be significant. In any event, they represent a water source that may have an impact on any trail that crosses them unless that flow is properly controlled.

- **Forest type and vegetative cover:** Many trail systems pass through forested or partially forested habitats. Forests and trees provide many benefits to trail users including that all-important connection to nature that most trail users are seeking. The trail "experience" is sometimes defined largely by the forest conditions, whether it is the quiet and majesty of old growth forests or the amazing beauty of the fall colours in a hardwood forest. They are also habitat for plants and animals and the nature viewing opportunities they afford. Forest cover gives shelter from cold winds, shading during hot periods, and much, much more. In addition to the benefits associated with trails passing through forested habitats, there are forest characteristics that have a direct bearing on the ability of trails to remain resilient in the face of climate change including:
  - Wind firmness: - Tree species differ in terms of their rooting systems, the strength of their wood, and how long they live. Species like sugar maple, red oak, yellow birch, beech, white ash, white pine and eastern hemlock have comparatively deep and extensive root systems, large and strong boles and limbs, and are relatively long-lived. Forests comprised of these species tend to be more wind firm over a longer period of time. Other tree species like aspen, white birch, balsam fir and white spruce tend to have shallower rooting systems, weaker wood, and are relatively short-lived. Consequently, forests dominated by these species will suffer comparatively higher levels of windthrow and breakage of stems and crowns during storms.
  - Natural Disturbance: - An interesting feature of forests comprised of long-lived tree species like those noted above is that they usually contain trees of varying ages, and as scattered old trees die, they leave gaps in the forest canopy which are soon filled by younger trees. The effect is that these forests seem to change little over time. On the other hand, forests that are dominated by short lived species are often even-aged or same-aged so that virtually whole stands die in a relatively short period of time. The visual effect for repeat trail users can be very pronounced as forests can change from mature healthy trees to stands containing many dead and dying trees to a dense growth of new forest in just a matter of 10 to 15 years or less. The transition from mature forest to regenerating forest can be accelerated even more by extreme wind events which can bring down the aging forest.

- Soil stability: - Trees, shrubs and ground vegetation help to stabilize and hold soils in place with their root systems, and slow the flow of water across the surface of the ground. These functions are helpful when trying to prevent erosion on the sides of trails and ditches. Retaining vegetation along the banks of nearby streams and smaller drainages will help keep the water channels from expanding, and will contribute to minimizing erosion of the trail should those water courses jump their banks.
- Fire hazard: - Deciduous forests are generally less susceptible to wildfires than are coniferous forests. Young coniferous forests and those that have been killed or severely damaged by winds or insects contain large amounts of potential fuel for wildfire ignition and spread, especially if the dead trees still have their needles and fine twigs intact. Particular care must be taken when brushing out trail corridors through forested areas to avoid creating additional fire hazards by concentrating cut brush in piles adjacent to the trail.

- **Stream crossings and adjacent water courses:** Most trail developments of any substantial length will encounter streams that must be crossed using various structures such as bridges, culverts and puncheons depending on the width of the span and the trail type (pedestrian, OHV, etc.). Stream crossings can be costly, and they require ongoing monitoring and maintenance. In the context of climate change impacts, they also represent particularly vulnerable points on the trail and must be managed as such. In best case scenarios, trail developers have the flexibility to select where to install the crossing to take advantage of high stream banks, a straight stream alignment, the absence of a natural flood plain and other factors which help minimize the risk of flood damage. In other cases, the location of the stream crossing has been predetermined and trail managers must make the best of a less-than-ideal situation. The size and design of stream crossings has largely been based on requirements to accommodate the "100-year storm event". Climate change requires that trail managers abandon the view of a future massive rain event as a one-in-a-hundred "risk" and anticipate that these storms will happen sooner rather than later and that appropriate planning and adaptive measures must be taken now to make their trails and their stream crossings as resilient as possible when the time does come.

Figure 7: Pedestrian bridge and puncheon spanning watercourses on Little Falls Trail.

Section #4 - Adaptation Strategies to Improve Trail Resilience to Climate Change

There is a lot of information available on best practices for building and maintaining recreational trails. It is important to note that climate change impacts will test both the quality of trail construction methods and maintenance programs. It is critical therefore that trail managers employ the highest standards in their trail development projects. This section looks at measures that can be taken to improve the long-term sustainability of existing and new trails. Many best practices and adaptive strategies are common to all or most trails and so will be included under the first category of "General adaptive strategies" while others which have a more limited application will be discussed under specific trail types.

Figure 8: Motorized trails contrasting a graded and crowned travel surface (right) with a rutted and moderately eroded surface (left).

- **<u>General adaptive strategies:</u>** The following best practices and adaptive strategies apply generally to recreational trails of all kinds. They are intended to improve the long-term sustainability and resilience of trails and trail infrastructure in view of our changing climate and its associated impacts.
    - *Inventory, inspection and maintenance:* Regularly scheduled inspection and maintenance of trails and trail infrastructure will be key to maintaining the resiliency of trail systems. To assist in this, trail managers should maintain an updated inventory of all structures and facilities associated with their trail system, from culverts and bridges to

signage, benches, privies, and any other feature which may require upkeep. In addition, troublesome sections of trail that require special attention or "touch-ups" (e.g. excessive slope, soft ground conditions, etc.) can be mapped and their condition updated on an ongoing basis. There are several digital mapping systems in use by various government agencies and trail organizations that allow for real-time recording of the locations of trail features, their description, condition, and recommended actions to be taken. Government and trail groups are presently looking into ways to integrate these mapping systems and make them more broadly available.

- *Shaping the trail surface:* It is critical that trail surfaces be shaped so as to shed precipitation off to the side(s) of the trail, and not allow it to accumulate and run down the trail resulting in erosion. Wider travel surfaces such as those required for ATV use can be "crowned" so that it is higher in the center and slopes down to either side. Trails having narrower travel surfaces such as back-country pedestrian trails can simply be sloped (5 %) towards the "downhill" side of the trail or the side facing the ditch (if present). Trail usage and the associated wear will change the shape of the trail surface over time, and so grading of the trail to restore the desired shape should be a key component of maintenance programs. This is particularly true of trails where wheeled vehicles are permitted. Tire traffic will result in rutting of the trail surface, especially during wetter periods. Ruts can retain water on the trail leading to the weakening of the trail surface, and they can channel runoff down sloped portions of the trail, bypassing the ditches and culverts that are in place and causing erosion of the trail surface. Grading trails with tractor blades or more specialized equipment can push material into the ditches and the ends of culverts. Over time this material can restrict water flow if not removed regularly. Grading can also leave a small windrow or berm of material at the edge of the travel surface which can impede precipitation from draining off the trail surface. This may delay drying of the trail surface or erosion of sloping trail sections and so should be removed. When possible, efforts should be made to pull materials back in towards the center of the trail.
- *Ditching:* Trails that feature wider and more robust travel surfaces, such as ATV trails and abandoned rail line corridors, often utilize ditching along one or both sides of the trail to collect precipitation and surface runoff and divert it away from the trail bed. Cross-culverts are installed in the trail bed to channel water in the ditches on the uphill side of the trail to the downhill side. Where trails are sloped, cross-culverts must be placed at intervals along the trail to ensure that the volume and speed of the water in ditches does not build up so as to erode the sides of the trail. The steeper the slope, the shorter the interval between cross-culverts. In some situations, additional "take-off" ditches are dug more or less perpendicular to the trail to carry runoff to lower ground at some distance from the trail bed. Where ditching along the sides of the trail is limited or precluded due to ground conditions such as rock outcrops or bedrock, trails may utilize water bars or shallow surface drains (grade dips) built into and across the trail surface to collect and divert runoff coming down the trail to lower ground to the side of the trail. These water bars and surface drains can also be combined with side ditches to provide additional protection on steeper trail sections where even minor wheel rutting can quickly lead to surface erosion during heavier rain events. Whatever ditching techniques

are employed, ditches and culverts must have the capacity to hold the volumes of runoff associated with extreme weather events. Regular monitoring and maintenance of all ditches are required to assess potential problem areas in a timely manner and remove sediment, debris and vegetation before the capacity of the ditching is compromised. The transition from the trail surface should not exceed a 2:1 slope to maintain stability and minimize erosion along the trail's edge. Similarly, the back sides of the ditches should also have a slope of no steeper than 2:1 to prevent debris from the surrounding area from washing into the ditches and causing them to fill in. Most new trails are built during dryer periods of the year, and trail managers may or may not be sure that the ditching used is able to cope with the runoff from heavy rain events. In those cases, trail managers should conduct more frequent monitoring of the trail to catch potential shortcomings before a big rain or snow melt overwhelms the ditching causing severe erosion and/or washouts. Inadequate or compromised ditching is a major contributor to the damaging effects of major storm events.

- *Minimizing the trail "footprint":* The trail "footprint" refers to the area that is disturbed or altered as a consequence of building the trail. Undisturbed soils are stabilized and protected by ground vegetation, tree root systems and other organic materials that cover them. Trail construction can involve removing vegetation and natural ground cover, digging/excavation work, infilling of undisturbed areas, damage to tree root systems, and so on. All these activities remove the natural protections and expose underlying soils to erosion from precipitation and surface water runoff. Erosion of those soils can lead to siltation of nearby watercourses, ditches and culverts. The deposition of soil on previously undisturbed areas will impact the vegetation growing there and increase the overall footprint even more. Cutting trees and damaging the root systems of living trees can leave the remaining trees more vulnerable to disease and windthrow. The first step in minimizing the trail footprint is to select a trail alignment that can be built with the least amount of disturbance. Do not over-build a trail but ensure that the design and dimensions of the trail and the trail right-of-way are adequate for the intended trail usage. Where manual labour is not a viable construction option, utilize the smallest equipment available that is capable of doing the work. Take advantage of the added flexibility that smaller excavators have over bulldozers in building trails with minimal ground disturbance. Vegetation and organic material removed during excavation work can be set aside and redistributed over disturbed areas once the excavation is complete. This provides some temporary cover for exposed soils while encouraging revegetation of disturbed areas with native plant species. Where possible, covering the roots of living trees rather than removing them will help minimize injury to the trees and lessen the risk of tree mortality.
- *Use of round corrugated culverts:* Round metal or plastic corrugated pipes or culverts are often employed to direct surface water from the ditch on one side of the trail to lower ground on the opposite side. These pipes are often referred to as cross-culverts. Culverts are also installed in small stream crossings and in smaller seasonal drainage channels that the trail must cross. There are a number of common issues with culverts that can negatively impact their effectiveness including: 1) they can get plugged by debris such as leaves, branches and sediment, 2) improper installation can cause them

to twist, bow or even collapse, and 3) frost can push or "heave" them up if not covered by sufficient depth of material. Proper armoring with heavy stone (rip rap) around the ends of culverts helps to prevent erosion. The smaller the culvert, the easier it is for debris to become lodged in the culvert. Smaller culverts are also more difficult to clean out. Functional cross-culverts are key to preventing washouts during heavy rain events or rapid snow melts, so it is recommended that the minimum size of cross-culverts be 400mm or 16 inches. Continuous monitoring and maintenance of cross-culverts is essential, and regularly scheduled assessments in the early winter/late fall period (i.e. after the leaves have fallen) plus the spring should be part of the trail maintenance program. Although culverts can be installed in small streams and seasonal drainages that have defined channels, it is not the preferred option. A better method, particularly in view of more frequent flooding events, is to install a puncheon or small bridge that spans the natural channel without any alteration to the bed or sides/banks of the watercourse. Sill plates or small abutments placed on either side of the channel will raise the decking of the puncheon or bridge above the channel providing some extra clearance during high water periods and more room for debris to be flushed out through the channel. Sills and abutments should be set back from the edge of the channel in case some widening of the channel occurs. During maintenance visits, loose woody debris observed in the channel on the upstream side of the crossing can be removed to prevent it being carried down into the puncheon/bridge.

- *Managing slopes:* With the notable exception of the "rails to trails", most trail systems in Nova Scotia cross some hilly terrain somewhere along their length. Those trail sections that do cross flat ground usually have to be built up so that the travel surface is above the grade of the surrounding land. This ensures that precipitation can be directed off the trail surface to either side, and it allows the portion of the trail bed that is above the surrounding grade to drain and remain firm. If properly built and maintained, trail sections on slight to moderate slopes of 1 to 5 percent can deal quite well with significant rain events and rapidly melting snows. Problems can arise even on slight to moderate slopes when the drainage system is inadequate or compromised in some way, or when surface water is allowed to accumulate on the trail and run down the trail for extended distances. Moderate to more steeply sloped trail sections of 5 to 12 percent are at more risk. In view of an increasing number and severity of rain events, it is incumbent upon trail developers to limit both the steepness and length of sloped trail sections whenever possible. For example, if long sidehills must be climbed, the alignment should include periodic short sections that are more or less horizontal – sort of a "stepped" approach which avoids long unbroken slopes. These intermittent flatter spots will slow the speed of water coming down the trail surface and/or ditches and provide opportunities to redirect the flow away from the trail. For pedestrian trails, these level sections can provide some relief from the strain of making extended climbs. Switchbacks can be an effective way to climb longer hills while limiting the slope of the trail, and the turns provide opportunities to break the flow of any water coming down the trail surface and redirect it onto the hillside below the trail. Limiting slopes may require taking a longer distance to climb a hill, but reducing the slope where possible will improve the resilience of the trail over time, while also reducing maintenance costs.

ATV's, mountain bikes, some hikers and other trail users might easily negotiate much steeper slopes than 12 percent, however, steep trail sections generally degrade more quickly, and the potential rate of surface erosion increases dramatically with increasing slope. In some situations, there may be no alternative to having some trail sections that exceed 12 percent slope, but they will have to be built and maintained to the highest standards to avoid serious damage during extreme weather events. Trail managers will need to monitor these sites closely.

- *Trails located in floodplain areas:* Flooding from nearby watercourses is a major source of damage to trail systems of all kinds, but especially to the larger motorized trails and abandoned rail beds. Streams and rivers can overflow their banks during heavy rain events and/or rapid snow melts. In some cases, this flooding is a regular occurrence, and the area that is impacted can be identified through observation of the event or the telltale signs of water washing over the ground leaving it with a "swept" appearance. Debris can often be seen left in piles or berms along the high-water mark or deposited in clumps on low branches and at the base of trees. The width of a floodplain can vary but is generally widest where the banks of the watercourse are low and the adjacent land is flat. Some floodplains contain what looks like dry or partially dry stream channels, but during flood periods, these channels can fill with the overflow from the adjacent watercourse. Ideally, trails should not be built on floodplains as the forces that are exerted by floodwaters can be difficult, if not impossible to control. Where trails encroach upon floodplains, trail managers should consider realigning those sections to higher ground if possible. In cases where avoidance is not an option, trail surfaces can be built up higher than anticipated flood levels, and the sides of the trail can be strengthened by maintaining vegetation and tree cover or by placing armour stone or other reinforcements. When a built-up trail bed crosses a watercourse and its floodplain, the trail bed can act like a dam restricting the spread of floodwaters and raising the level of the watercourse even higher. To relieve the pressure that floodwaters will exert on the structure that spans the watercourse, culverts can be installed in the bottom of the trail bed to either side of the watercourse to allow floodwaters to flow more freely through the trail bed to areas downstream of the trail.

Figure 9: Barachois River near Red Island Trail rose approximately six feet above normal levels after only a 2-inch rainfall. Extensive flooding visible along the opposite shoreline area.

- *Watercourse crossings:* Stream crossings are particularly vulnerable to the damaging effects of extreme weather events that include heavy rains and/or rapid snowmelt. Bridges and culverts washed out by flood waters are not only expensive to replace, but these occurrences also contribute to sedimentation and habitat alteration in the watercourse. Some of the inherent risk associated with building trails across a watercourse can be relieved by selecting the best available site. A good location to install a crossing would feature a well-defined stream channel with high banks and no defined floodplain. High banks make it easier to elevate the crossing above potential flood levels while allowing more room for debris to pass through. Avoid having to cross a stream at a bend in its channel where flood waters will be striking one embankment more directly and with greater force. When selecting the kind of structure to install, opt for a design which will not alter the bottom and sides of the natural stream channel or restrict the flow. Maximize the size of the opening that the channel must pass through, remembering that even properly-sized structures (i.e. by current standards) can be compromised by things like debris being washed into them, the collapse of upstream embankments, or through the natural transportation of rock and soil along the channel bottom. If sills or abutments are utilized in the structure design, place them back from the edge of the channel sides to avoid adding weight or downward forces where the channel is weakest. For existing structures, reinforce channel banks and bridge abutments with armour stone where needed. Remove any debris in or near the entrance to the structure. When carrying out any right-of-way clearing, do not place any woody material on the upstream side of the trail where floodwaters could potentially carry it into the stream crossing structure. Windfalls and dead trees that fall into or across the watercourse upstream of the crossing should be removed if they pose any threat of being washed into the stream crossing structure. Ongoing monitoring and maintenance of watercourse crossings of all sizes is essential.
- *Species at risk and invasive species:* One of the consequences of climate change is a change in the composition of plant and animal communities. Warming temperatures will have the greatest impact on species which have very specific habitat requirements or are currently at the fringe of their population distribution. While some native species may disappear from Nova Scotia, others which are more adapted to warming temperatures may expand their home range into the province. Trail development and use can add additional stress to species that are already at risk for other reasons including climate change impacts. Although required on some public lands such as in designated wilderness areas, botanical surveys are recommended for all proposed trail alignments prior to construction to document the occurrence of any species listed under the Endangered Species Act as “species at risk”. These species are afforded some level of protection under the legislation, and when found, should be brought to the attention of the land owner. Trail users and managers can play a role in protecting rare species by noting their location and providing that information to the Department of Natural

Resources and Renewables. Those species which are not native to the province are referred to as invasive species. These plants and animals can quickly become established to the detriment of native species. Trail users can also contribute to slowing the spread of these species by washing their boots and clothing between visits to different trail systems, and by regularly washing vehicles and tires to avoid transporting dirt, seeds and small organisms from place to place.

- *Brush clearing and management:* Trail development and maintenance in forested areas will often require the cutting and removal of trees, branches, woody shrubs, windfalls, and other woody debris. This cut material or "brush" does represent a heightened risk for wildfires, particularly if composed primarily of coniferous tree species, and when concentrated in larger piles or windrows. Proper disposal of brush will help alleviate concerns around fire ignition and spread during warm and dry periods. Brush should be spread across the forest floor to either side of the trail rather than in piles. Where possible, larger tree tops can be cut up so that more of the branches are in touch with the ground. This will increase the moisture content of the woody material and hasten decomposition. Chipping the brush before spreading it over the ground near the trail is an excellent way to reduce the risk of wildfires. Brush should not be discarded in trail side ditches or near watercourses as it can be carried by runoff or flood waters into culverts and stream crossings resulting in blockages and reduced flows through those structures.

- **"Rails to trails":** Some of the more popular trails in Nova Scotia have been developed on abandoned rail line corridors. These routes with their modest slopes, solid construction and excellent drainage provide ideal opportunities for a wide variety of trail uses by people having a broad range of interests and abilities. These trails connect communities, take visitors through differing but scenic landscapes, incorporate local history and culture, and provide excellent recreational experiences, whether for a couple of hours or multiple days. They are characterized by long straight stretches, sweeping turns and very robust infrastructure. Though built to support heavy loads, a lack of upkeep and maintenance post abandonment has seen the condition of some structures deteriorate. This raises concerns regarding adequate maintenance programs and future replacement requirements. These trails are being actively managed and maintained by a variety of municipal, community and user groups with assistance from various provincial and federal agencies and programs. The following are some recommended "best practices" and strategies for maintaining these trails and improving their resilience in the face of ongoing climate change impacts.
    - One of the keys in minimizing surface erosion of these trails is to "crown" the trail surface. Crowning involves shaping the trail surface so that it is higher in the center and slopes gradually to both sides. This ensures that surface water on the trail flows quickly off to either side rather than down the trail for significant distances. The crown should be maintained whenever the trail is graded or resurfaced.
    - Grading the trail surface helps maintain an adequate crown on the trail while also filling in potholes and ruts where water can accumulate and soak into the trail bed. When grading, it is important to avoid leaving a berm of loose material or live vegetation at the

very edge of the trail surface which will hinder water running off the trail and into the ditches.

- Due to the need to maintain minimal slopes while also avoiding tight turns, railbed construction often involved a combination of building up the bed (infilling) in low areas, carving a "bench" into the sides of larger hills, and cutting directly through smaller hills and ridges. Cutting through or along the sides of a hill required the installation of ditches to capture and divert water approaching the railbed from adjacent slopes. Over time, these ditches fill it with sediment, plant debris and vegetation reducing their capacity to hold water and carry it away trail bed. Water lying in shallow ditches along the trail will infiltrate the bed of the trail reducing its weight bearing capacity. Maintaining adequate ditches by periodically excavating the debris and vegetation from them is critical to managing surface water runoff and minimizing the risk of surface erosion or slumping of the sides of the trail during heavy rain events. Additional information on proper ditching can be found at trails cover (refer to Section 3.5).
- Suitable material for surfacing these trails will vary depending on the intended use(s). a popular surfacing material in use on multi-purpose trails is crusher dust, a byproduct of crushing stone into gravel and other stone products. This material is not as coarse as gravel and once compacted, provides an ideal surface for foot and wheeled traffic. A key to using crusher dust is to acquire material that has sufficient amounts of finer particles to assist in the compaction process. If missing the finer particles, crusher dust can remain loose underfoot. Once compacted however, the surface provides excellent traction. Crusher dust has limited ability to resist surface erosion, but given the modest sloping of railbeds, this is not a significant shortcoming. "Class A" gravel might provide a more robust and erosion-resistant surface when compacted but may be less appealing for some wheeled traffic such as bicycles and strollers.
- Maintaining vegetation on the sides of railbeds will help stabilize them and reduce surface erosion.
- All stream crossings and culverts should be assessed for their structural integrity and maintenance requirements. Larger bridges and trestles should be referred to qualified engineers for assessment.
- Floodwaters from nearby watercourses, rising sea levels and ocean wave action pose threats to railbed integrity. Assess trail sections in these areas and reinforce the sides of railbeds with armour stone as required (insert image).

- **Trails that utilize abandoned road beds:** Many trail systems in Nova Scotia incorporate sections of abandoned roads in their trail corridors. These roadways were originally built for various purposes including access to natural resources (forest products, mining, etc.), public transportation, and access to privately-owned lands. The origins of some go back many decades to the times of the original settlers. One popular category of old roads is abandoned public highways that are still under the administration of Nova Scotia Public Works (NSPW) but are no longer being maintained for the use of highway vehicles. These listed but abandoned roads are referred to as "k-class" roads and are still available for public use. Organizations wishing to utilize these roadways as recreational trails should contact NSPW for permission to carry out any proposed modifications or improvement work. The bulk of the roadways being used as trails are

forest access roads on Crown and private properties. The condition of abandoned road beds varies widely depending such factors as the construction methods used, topography and composition of the road bed, use and maintenance, regrowth of vegetation, and the presence and condition of ditches, culverts and stream crossings. More recent forestry roads are often well built with adequate ditches and culverts and stream crossing structures. In such cases, a minimum amount of maintenance or upgrading work may be sufficient to reopen the road for the intended trail use. Older roads and those that were built at minimal cost and for short-term uses can be in very poor condition, especially if a combination of ongoing OHV use with minimal trail maintenance have left the road surface rutted and eroded. Abandoned old roads often require significant reconstruction work to restore a properly shaped travel surface, a functional drainage system and properly built stream crossings. A proven technique for rebuilding these old roads is to use a small excavator to dig suitable material from one or both sides of the road bed and use that material to build up the trail surface. The excavations along the side(s) of the road will function as drainage ditches. When building wider trails using this method, the excavated ditches can be much deeper than necessary due to the volume of material required to build up the trail surface. In such cases, grubbing, topsoil and other debris removed during the excavation work can be placed back in the ditches rather than spread along the side(s) of the trail. This will help minimize the overall trail footprint.

- **Accessible Trails:** For those recreational enthusiasts with varying levels of mobility, accessible trails are key in providing opportunities to enjoy the many benefits of outdoor spaces. Accessible trails is not a term that applies only to the travel surface of the trail but encompasses all of the associated trail facilities from the parking area and trail head, to posted signage along the trail, and to all structures and buildings. The construction standards for the travel surface of these trails are more demanding than most other trail types, requiring that it be hard and relatively even with slight to moderate slopes. Commonly employed surfaces include boardwalks, hard-packed finer gravels and crusher dust, asphalt and concrete. For dirt surfaces, it is very important that the travel surface be shaped so that precipitation runs off the trail to either side. Water left pooling on the trail will weaken the surface resulting in soft spots and surface erosion. Ideally, the trail bed is built up above the surrounding grade to improve drainage and provide a more even travel surface. Asphalt and concrete provide a more robust and wear resistant travel surface but the use of those materials may be inconsistent with an overall objective of enjoying nature and “natural” settings. Boardwalks built with rot-resistant wood provide a stable, level and elevated travel surface. Wet lumber can be slippery so traction on sloped sections can be improved by surfacing the deck with a coarse material such as roofing shingles. Boardwalks may be the option of choice where soft (e.g. sand beaches) or saturated ground conditions must be crossed. Abandoned rail beds may be one of the best opportunities to create accessible multi-use trails where ability and mobility are nonissues. Accessible trails, because of their more demanding construction standards, may be more difficult to relocate or realign in response to climate change impacts. Therefore, site selection for new trails or identifying existing trails that could be upgraded to accessible trail standards must incorporate climate change impacts in the evaluation process. Ongoing maintenance of accessible trails is also very important as comparatively minor erosion damage caused by runoff from a heavy rain could be a serious obstacle for those with very limited mobility.

Figure 10: Baille Ard Nature Trail and Old Mill Road Trail provide more accessible trail opportunities.

- **Coastal Trails:** Recreational trails located at the coast are most at risk from the damaging effects of climate change. They are often exposed to the full brunt of storms approaching the province from offshore, and those in low-lying areas along the shoreline are also subjected to flooding and erosion from rising sea levels, pounding surf and ocean surge. The Province of Nova Scotia has made available the Coastal Hazard Map (https://nsgi.novascotia.ca/chm) which is an interactive mapping tool that highlights those coastal areas in danger of flooding due a combination of sea level rise ("worst case" scenario by 2100) and storm surge at highest tide. This tool helps trail managers to identify trail segments that are at highest risk from these climate change impacts, and investigate options for reinforcing those existing trail sections over time or relocating them inland to more secure areas. Another important consideration for coastal trails is coastline erosion and flooding from storm-generated wave action. The rate of coastal erosion is dependent on a number of factors including the composition of the coastline (erodibility), the exposure to onshore winds and wave action, and the length and steepness of the beach. For example, a coastline comprised by high granite bedrock is much more resistant to erosion than is one characterized by glacial deposits or fractured shales and sandstones. Coastline facing the open Atlantic Ocean to the northeast or southeast would generally receive heavier wave action than shoreline along the Bay of Fundy or the Northumberland Strait. Waves that approach beaches that are long and sloped gradually out to sea tend to dissipate their energy over a longer distance before reaching the coastline, while waves that approach over short beaches that slope steeply out to sea will retain more of their energy as they impact the

coastline. Trail managers should have coastal erosion assessments carried out on trail sections at the coast to determine their vulnerability. Comparing current aerial photos and satellite imagery to past years will give some idea of the changes that have occurred over that time period. Actively eroding coastline can be easily identified in the field and is often characterized by newly exposed soils and rock, slumped piles of ground vegetation or fallen trees along the embankment, exposed root systems, and so on. There are limited options for managing coastal trails and associated infrastructure that are being impacted by flooding and/or coastal erosion. For those on less exposed coastline, building the trail surface up and reinforcing the exposed sides of the trail with something like armour stone may improve its resilience going forward, however, these improvements are expensive and may have to be completed over a number of years and as funding is available. Trails on exposed coastlines that are actively being eroded will likely have to be abandoned or realigned to higher ground inland. The forces exerted by ocean waves driven by high winds are enormous, and the cost to protect trail infrastructure on vulnerable coastline would likely be prohibitive. One of the major challenges of realigning coastal trails inland is to maintain the scenic coastal views and user interactions with the coastal environment that contribute to the overall trail "experience". This is particularly true where views might be limited by forest cover. As part of the realignment process, consideration should be given to retaining resilient portions of the original alignment, and accessing additional stable sites, whether by routing the main trail to them or utilizing short spur trails out to look-offs or other interesting features along the coastline. One advantage of using short side-trails for this purpose is that unforeseen erosion at those locations will be less likely to cut off the main trail and restrict access to trail sections beyond that point. Coastal trail infrastructure such as signage, benches/tables, kiosks and privies should be built to withstand severe wind events, and located well above the anticipated maximum wave heights. Structures should be robust in construction and secured using concrete pads, sturdy posts, anchor pins or anchor straps. Although locating infrastructure in or near treed areas may provide some shelter from winds, the exact positioning of structures must also take into account the potential damage that might result from windfalls or broken limbs.

Figure 11: Celtic Shores Coastal Trail showing high water mark (debris line) encroaching on trail surface.

- **Motocross and Extreme Mountain Bike Trails:** A segment of the motocross and mountain bike communities enjoy the thrill and competition associated with the more extreme forms of their sports. Motocross and mountain bike "parks" have been developed for that purpose, but some practitioners enjoy trails that are more extensive. Due to the aggressive driving and the wear and tear these bikes have on these trails, the travel surface is usually well worn into the ground, and displaced material is often pushed up to the sides of the trail. As a result, the trail is deeply concave in cross-section and has the appearance of a ditch more than a trail. This may be intentional to some degree as the berms along the sides assist the bikes to negotiate the twists and turns at higher speeds. Trails that are used for racing contain braided sections used for passing. Obstacles like jumps, rock outcrops and wet holes are part of the trail, offering additional challenges for trail users. These trails have the potential to generate large amounts of sediment, so it is recommended that they avoid crossing streams or areas that are wet and/or poorly drained. One way to limit the degree of erosion during heavy rain events or snow melt is to align the trail so that it does not contain longer unbroken slopes where surface erosion would likely be worse. Alternatively, the alignment should be more undulating in nature with the length of up and down sections being kept comparatively short where possible. The effect on surface runoff is to limit the length it runs downhill before being caught in the depression where the slope changes from a downhill run to a flat or uphill section. Surface water that is caught in the depressions will eventually evaporate or drain off the trail. Regular maintenance can hasten that process. Water bars, grade dips and rock-filled drainage channels installed at intervals on longer slopes will also help direct surface water off the trail. Trail braids that allow for passing during competitions seem to be opportunistic rather than planned in terms of where they occur. If streams must be crossed, trail managers should select a location that does not have long

downhill approaches on either or both sides of the stream. Siltation can be difficult to control on downhill approaches, especially if they are perpendicular to the stream channel. For additional information on mountain bike trails, please refer to Mountain Bike Trail Development Guidelines | IMBA .

- **Water Trails and Portage Routes:** Nova Scotia offers some excellent opportunities for paddlers, whether canoeing on inland river and lake systems or kayaking along undeveloped and scenic coastline. Some of today's more popular water routes were originally used by the Mi'kmaq prior to European settlement. Like land-based trails, water routes can provide day-long or multi-day excursions complete with marked or mapped put-ins and take-outs, camping sites, and portage routes. They are also subject to impacts of climate change. The following are some strategies that can be employed to help improve the sustainability of water trails and portages:
    - Most sea kayakers are careful to check weather forecasts and anticipated marine conditions before venturing out on a trip along the coast. Another part of preplanning is to identify places along the travel route where they can come ashore if the wind picks up, or for a rest, lunch or to camp overnight. Preferably, these landing spots will be on public land to avoid the need to get permission from private landowners for activities that might occur above the mean high-water mark. Unfortunately, coastal kayak routes and options for landing/camping spots in the area are currently not well mapped in Nova Scotia. A project to identify and map the best coastal kayaking opportunities would be a tremendous boost to that sector of the paddling community. Part of that project could be to identify suitable locations on public land for the development of coastal camping sites and facilities (benches, tables, privies, etc.). Prior to investing in the development of any particular site, consideration would have to be given to the likely impacts that rising sea levels and coastal erosion will have on that location to insure its long-term sustainability. There is a rich cultural history associated with canoeing inland waters in Nova Scotia, especially in the central and western regions. There is an ongoing interest in keeping those traditional routes open, and to explore new paddling opportunities. Climate change will continue to impact canoe routes and portages. For example, Hurricane Fiona in 2023 resulted in extensive wind damage to forests in the Liscomb River area, with downed trees blocking sections of portage routes and leaving many trees lying in and over the river. Clearing portage routes will take some time to complete, and the debris in the river will create sweeps and log jams which will pose hazards for paddlers for years to come. Adaptative strategies that might limit the extent of the impacts to these water routes are limited. Where possible, portage routes could be relocated to take advantage of more windfirm forest types nearby, or realigned away from low areas and floodplains near watercourses to higher ground. When identifying new campsites, avoid low-lying areas that might be subject to flooding. Updates on the condition of the water route, portages and other facilities that are posted online or on information signage posted at popular access points to the water route would be helpful. Although information on canoe routes and portages is more readily available in the form of old paper maps and more recent digital mapping than are coastal water routes, more could be done to develop an interactive online mapping

application that would allow new or updated information to be submitted by the paddling community.