STUDY GUIDE 2026

Non-point Source (NPS) Pollution

Forests Canada

ONTARIO ENVIROTHON 2026

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MAPLE LEAVES
FOREVER

2026 Key Ideas and Learning Objectives

KEY IDEAS

1. What is non-point source (NPS) pollution

2. Impacts of NPS pollution on ecological processes, systems and wildlife

3. What is Low Impact Development (LID)

4. Detection and management strategies for NPS

LEARNING OBJECTIVES

After reading this guide, student should be able to …

1. Define non-point source (NPS) pollution and differentiate it from point source pollution using real-world examples.

2. Define terminology such as non-point source pollution, stormwater, watershed, riparian zone, microplastics, eutrophication, and nutrient cycling.

3. Identify major sources and pathways of NPS pollution in surface water systems (stormwater runoff, hard infrastructure/impervious surfaces, agricultural fields, microplastics, etc.).

4. Explain changes in watershed ecology that influence NPS pollution, including the water cycle, carbon cycle, and nutrient cycles.

5. Describe the impact of NPS on water quality, and how bioindicators can be used as a means of monitoring aquatic ecosystem health.

6. Describe the importance of riparian zones, their impact mitigating NPS, and how they can be maintained.

7. Identify common products that can contribute to NPS pollution including fertilizer, car washing, and pet waste, etc.

8. Explain how population growth, urban expansion, and agricultural intensification contribute to increased NPS pollution locally and globally.

9. Evaluate land use and physical features (slope, impervious cover, vegetative layers, etc.) that can influence runoff and pollutant transport.

10. Identify common best management practices and low-impact development strategies to address NPS pollution (rain barrels, green rooves, rain gardens, and cover crops, etc.).

1.0 Non-point Source Pollution (NPS)

Non-point source (NPS) pollution is water pollution that accumulates over a widespread area and enters into water bodies, such as polluted runoff from agricultural areas entering a stream. **Stormwater** runoff from rainfall or other precipitation picks up and carries natural and human-made pollutants, finally depositing them into streams, rivers, reservoirs and other bodies of water. Pollutants can come from all land uses (e.g. residential, agricultural, commercial, recreational, and industrial, etc.).

Figure 1. Stormwater runoff can carry NPS pollution into waterways.
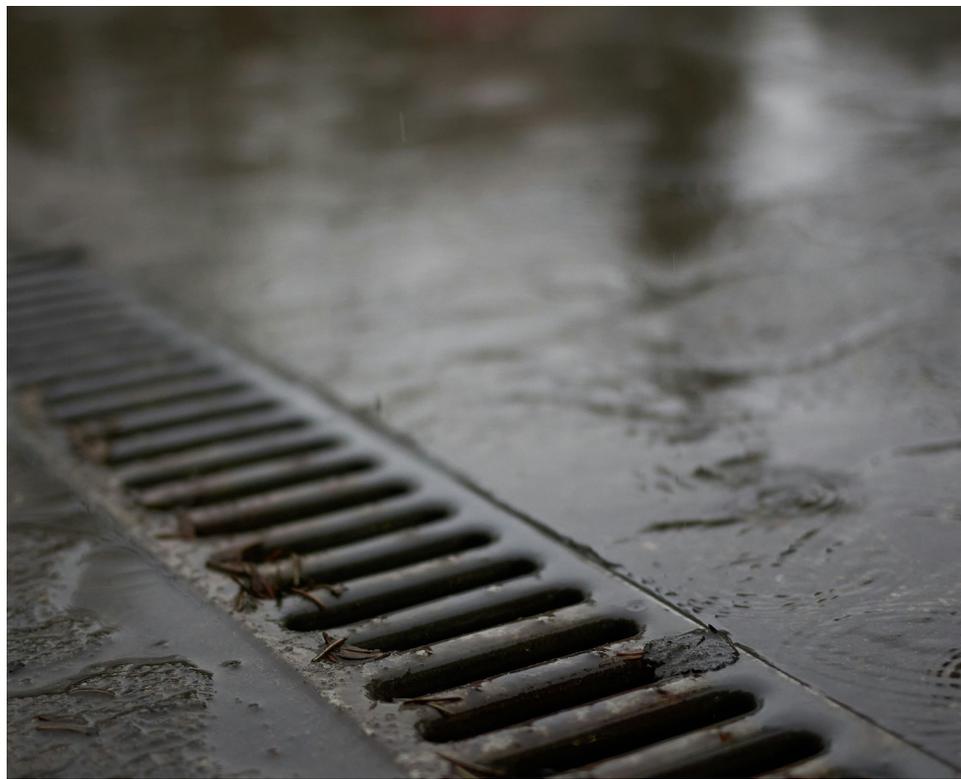
Examples of NPS pollution above differ from **point source pollution**, which can be traced to single, identifiable locations such as industrial factories or sewage treatment plants. Examples of non-point source pollutants include:

- Excess fertilizers, herbicides and insecticides from residential, agricultural and industrial areas.
- Oil, grease and toxic chemicals from urban runoff and energy production.
- Sediment from eroding stream banks and improperly managed construction sites, crops and forest lands.
- Salt and acid from irrigation and mining.
- Bacteria and nutrients from livestock, pet and wildlife wastes, and sewage overflow.
- Microplastics
- Litter

NPS pollution negatively affects drinking water, fish and wildlife, habitats, and can have serious environmental and human health impacts. Stormwater runoff is currently responsible for an estimated 60% of all water pollution, and millions of dollars are spent annually to restore and protect areas that are damaged by NPS pollutants.

1.1 The Water Cycle and Watersheds

1.1.1 The Water Cycle

To better understand the problems with NPS pollution in stormwater, it is important to understand the water cycle, also known as the hydrologic cycle. In basic terms, the water cycle is the constant cycling of water from the sky to the ground and back again. The main components of the water cycle are precipitation, infiltration, evapotranspiration, surface and channel storage, and groundwater storage. As part of this cycle, wherever rainwater falls to the ground, or where snow or hail on the ground melts, that water may do one of several things: it may enter the ground directly, run across the surface and be gradually absorbed into the ground, or travel far enough to directly enter streams and water ways.

While the inner workings of the water cycle vary with precipitation patterns, soil types and other factors, the underlying principles remain the same. In a typical undeveloped area with natural ground cover such as forests or meadows, a large fraction of the water from precipitation infiltrates the soil. Some of this water may remain in the soil near the surface (where it reappears in lakes and streams) while some of it may infiltrate deeper into the soil to replenish groundwater reserves. A significant amount of water returns to the atmosphere through evapotranspiration. Only a small amount of water typically remains on the surface of land to run off into streams and other water bodies. Urbanization can dramatically alter this water cycle by increasing runoff and reducing infiltration, sometimes close to almost 0%. These changes can have profound impacts on water bodies.

1.1.2 Watersheds

A watershed is the area of land that catches rain and snow and drains or seeps it into streams, rivers, lakes, wetlands or groundwater. They encompass all the water within an area, whether flowing or standing; the processes, factors and natural cycles that affect it; and all the organisms that live in and rely on the water for survival.

Some watersheds cross provincial, federal, and even international borders such as the Great Lakes Basin. Watersheds come in all shapes and sizes. Some are millions of square miles, while others are just a few acres. Just as creeks drain into rivers, watersheds are nearly always part of a larger watershed or basin. Every stream, tributary or river has an associated watershed.

Three different scales of a water ecosystem include:

- The bioregion, which is an area of particular physical characteristics that supports certain types of organisms. Ontario has three terrestrial bioregions: Mixed Wood Plains, the Boreal Shield and the Hudson Plains.

- The watershed, for example the Great Lakes watershed

- The watershed sub–basin or sub-watershed (land area drained by a single tributary), for example the Ottawa River (Crins et al, 2009)

Figure 2. The three primary watersheds in Ontario are the Great Lakes, Hudson Bay, and the Nelson River (Ontario Ministry of Natural Resources, 2009).

There are three primary watersheds in the province of Ontario:

- The Great Lakes draining to the Great Lake system into the St. Lawrence.

- Hudson Bay draining north to Hudson Bay.

- The Nelson River draining west to Manitoba.

Watersheds are comprised of several different land types, such as **uplands**, riparian areas, wetlands, streams and lakes. The most common of these land types found across all watersheds are the uplands, which in many areas can cover 99% of the total watershed area. All the precipitation that falls on a watershed area that is not evaporated is stored in the soil, and over time, moves down the slopes through a network of drainage pathways, both underground and on the surface.

In healthy watersheds, vegetation and wetland areas intercept and slow the flow of water, removing sediment and filtering water as it enters the soil and percolates into the groundwater. This water eventually makes its way into water bodies at the base of watersheds. In unhealthy systems, water cannot soak into the ground and quickly travels over the surface – entering water bodies directly without being filtered – which can cause erosion to stream banks.

Human activities and development can negatively impact watersheds and their processes. Improperly managed timber harvesting can cause **erosion** and dump sediment into streams. Agricultural activities can impact water quality through excess use of chemicals like pesticides and fertilizers from crops, and through harmful bacteria from animal wastes. Rural development and human recreational activities can result in the degradation of riparian areas, which destabilizes stream banks and affects animal habitats. Though each person may have minimal impacts on a watershed, the cumulative effects can have severe and profound effects on the overall system. As humans place higher demands on watersheds, more effort will be needed to help reduce these harmful impacts to preserve watershed function for all.

1.2 Impacts of Urban Sprawl on NPS Pollution

There are many different ways that human development and land use can have adverse effects on local waterways contributing to NPS pollution. Some of these impacts are increased flooding, reduced water quality, increased habitat loss, and economic impact.

FLOODING

Increasing the amount of impervious surface area allows for larger amounts of stormwater to travel at higher speeds along the ground's surface. This can cause erosion along the entire distance the water travels, especially where it enters into water bodies. Flooding damages ecosystems like wetlands that normally act as water buffers that control water levels and filter **sediments** and contaminants in the water.

WATER QUALITY DECLINE

Stormwater runoff carries pollutants like pathogens, nutrients, sediments, toxins, and debris into waterways. The amount of these pollutants in runoff is directly related to the percentage of impervious cover in a watershed. In severe cases, this can lead to streams that are completely sterile, incapable of supporting life.

HABITAT LOSS AND ECONOMIC IMPACT

Drought, flooding, erosion and water quality decline can all degrade riparian and aquatic habitats. Without these habitats, the plants and organisms that live in them might not be able to survive, or potentially survive at suboptimal levels.

In losing these ecosystems and their ecological goods and services, humans face economic impacts through loss of recreation, tourism, business opportunities and increased water treatment costs.

1.3 Activity: Where Does Water Go After School?

Adapted from Project WILD

The goal of this activity is to help students understand precipitation and how runoff from rainfall behaves in a number of environments, urban and rural. Understanding this cycle is key to understanding how urban landscapes with and without low impact development respond to situations where runoff and nonpoint source pollution, particularly sedimentation from erosion, can be an environmental issue.

Students will be asked if they know where the water goes when it rains in their community. For the purposes of this exercise, the geographic focus is the school grounds.

RECOMMENDED MATERIALS

Length of rope marked in 1 m increments, trundle wheel, computer with internet access, topographic map of area.

METHODS

Sedimentation from runoff is an important part of NSP pollution, and understanding runoff (how water travels from one place to another on the surface) is important in understanding the possible effects sedimentation can have on a local ecosystem. This sedimentation can carry toxins or an overload of nutrients, or increase the sediment load in our rivers and lakes.

One major aspect of urbanization is the increase of paved surfaces. This means that there are fewer natural areas for water to infiltrate the earth, and there is a greater likelihood of runoff contaminated with effluents and sediment. In more rural areas, areas with few to no paved surfaces, runoff after a precipitation event is less extreme, and there is a greater frequency of water **percolation** and infiltrating the soil. One must keep in mind that some methods of farming do drastically increase the instances of runoff, and can be comparable to runoff in urban environments.

Infiltrated water recharges our water tables (where some of us source our drinking water) and hydrates our forests. Some runoff is normal, and it is important for restoring water levels to aquatic habitats. For example, this runoff water will replace lake water lost due to surface evaporation, and outflow.

PROCEDURE

1. The first step is for students to measure the surface area of their school grounds. The surface areas of the buildings are to be included in this calculation. This can be done with a length of rope, with increments of 1 metre demarcated.

    Area = Length x W

    If a trundle wheel is available, this is recommended. Students can also take the measurement from a mapping website, though measuring skills will be missed and accuracy may be lost.

2. The next step is to determine the amount of precipitation that this area receives. This can be achieved through 3 different means:

    *   Using a weather resource website, such as Environment Canada.
    *   Using a rain gauge.
    *   Calculating the amount of rain that falls in a given storm.

    After this method has been chosen, the students are then asked to measure the amount of water that falls on the school grounds in a specific period of time. This gives a value for the depth of rainfall on the surface.

3. With the depth of rainfall measured and the area of the school grounds measured the next step is to calculate the volume of rainfall.

    Ex. area of school grounds =
    $5000m^2$ annual rainfall = 15 cm (0.15m)
    Volume = area x depth
    = $5000m^2$ x 0.15m
    = $750 \ m^3$ of rain

4. Once the volume of the rain has been calculated, the weight of the rain is next. Water weighs 1000kg per m3.

    Ex. weight = volume x 1000kg
    = $750 \ m^3$ x 1000kg
    = 750 000 kg of rain (750 tones)

5. The next step is to have students understand that there are large volumes of water that need to infiltrate the surface. On average, the infiltration rate for naturally vegetated ecosystems with uncompacted soils ranges from 377 to 634 mm hr, and on compacted soils it averages 160 to 188 mm hr. Urban areas consist of compacted soils and paved surfaces. On paved surfaces there is no infiltration, only surface runoff. This runoff carries with it chemicals and sediments in its path. The students must then ask themselves a few questions:

    *   Where does the water go, when it leaves the school grounds?
    *   How much of this percolates through the surface?
    *   What possible kinds of pollutants does this rainfall come into contact with?
    *   Where is the nearest wildlife habitat to the school?

- How do people use the water between the time it leaves the school grounds and arrives in the wildlife habitat?

- What are some of the positive and negative effects that the water may have on the environment at various points on its journey?

6. The next step is to find a topographic map of the area, and track the route that the runoff water may take, and to find the location of the stormwater sewers in the paving surrounding the school

Figure 3. The difference between rural and urban water cycles.
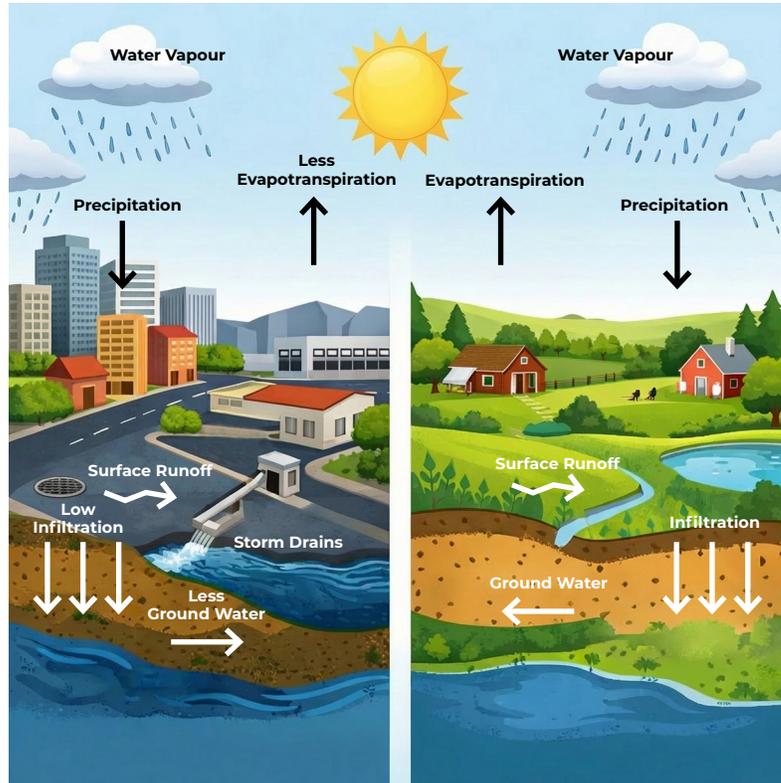
ACTIVITY QUESTIONS

1. What happens to water collected in stormwater sewers? Will this water become drinking water in the future?

2. How will this water affect wildlife and aquatic ecosystems?

1.4 Review Questions

1. Define NPS pollution.

2. Explain the impacts of land use on watersheds and how these contribute to NPS pollution?

Figure 4. Managing NPS pollution through the use of bioswales (Richards, 2009)

2.0 Impacts of Non-point Source Pollution

2.1 Impacts to Aquatic Ecosystems

Covering over 70% of the Earth's surface, water is the world's most precious natural resource. Canada is one of the most water-rich nations. On its own, Ontario holds a quarter of a million lakes, rivers and streams. These lakes are globally significant ecosystems that support numerous coastal wetland habitats, some with internationally rare animals and vegetation communities. The five Great Lakes, four of which have borders with Ontario, hold one-fifth of the world's fresh surface water and are the world's largest continuous body of fresh water. Ontario also holds about 6% of the world wetlands and from one-quarter to one-third of Canada's overall wetlands.

Figure 5. The Great Lakes Basin. Four of the five Great Lakes are found in Ontario (Great Lakes St Lawrence River Water Resources Regional Body, 2024).
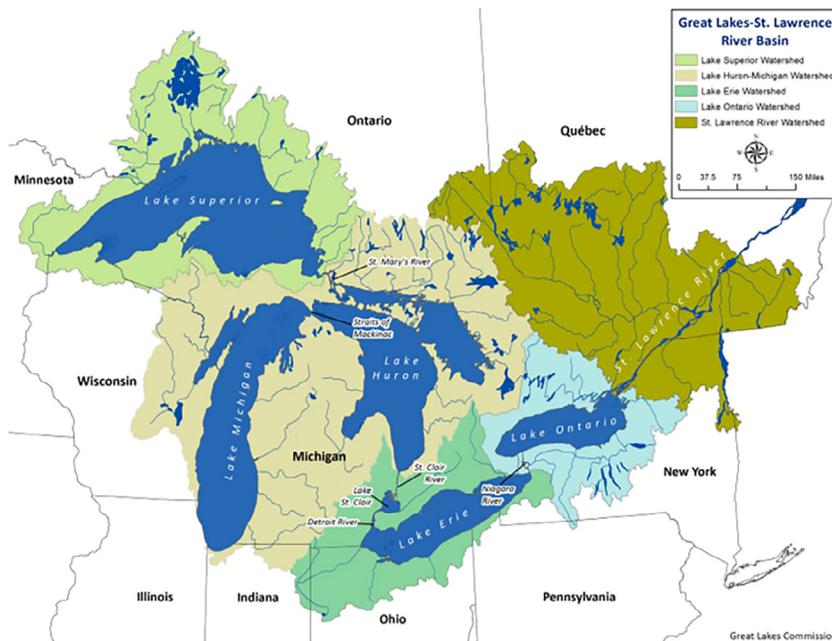
Scientists working in aquatics are concerned about pollution that ends up in aquatic ecosystems. Aquatic pollution can occur when an **aquatic ecosystem** is harmfully affected by the addition of large amounts of material into the system. Examples of this include phosphorus loading, sediment loading, and road runoff such as oil, salt and garbage. One mechanism through which this pollution can happen is NPS pollution.

Aquatic NPS pollution occurs when rainfall or snowmelt water travels over the ground collecting any natural or man-made pollutants in its path and deposits them into streams, rivers, lakes, wetlands, and coastal waters. Some of the primary causes of NPS pollution are crop farming, livestock farming, timber harvesting, new developments, and roads and building construction.

NPS pollution can affect aquatic ecosystems in many ways – the most common ways are through the addition of pathogens, oxygen depleting substances, nutrients, sediments and toxins such as chemicals. These five main categories will be further discussed below.

There are numerous problems connected with nonpoint source pollution, the most common being damage to aquatic ecosystems and animals living there, reduced aesthetics of lakes and rivers, economic losses to commercial and recreational fishing, cost of restoration of affected aquatic ecosystems, and lastly, degraded drinking water and potential human health risks.

Some other effects that are not as prominent include reduced water-based recreational activities, tourism opportunities, and real estate values for waterfront properties.

Figure 6. Relationship between impervious cover and surface runoff. As little as 10% impervious cover in a watershed can result in stream degradation (World Meteorological Organization, 2008).
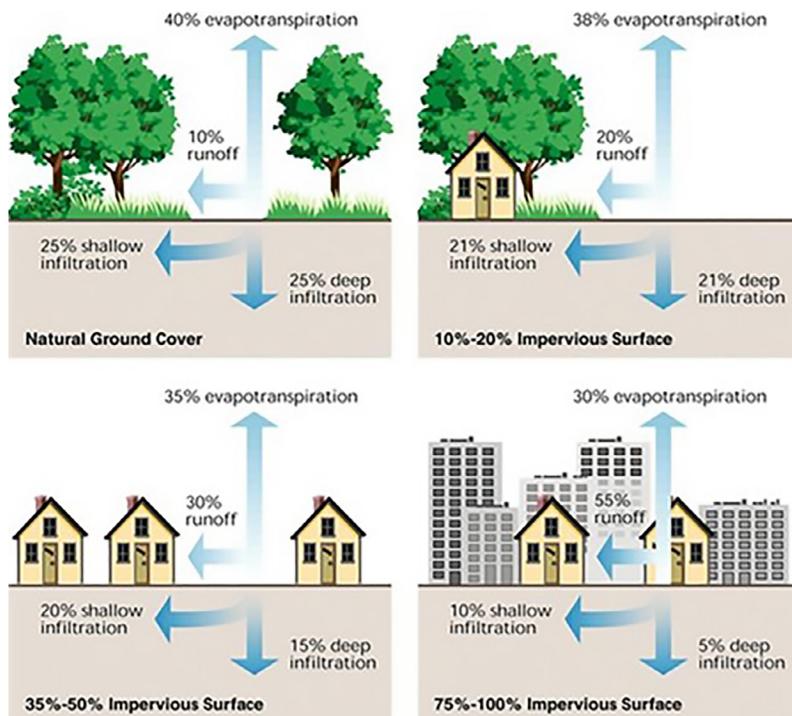
2.2 Types of NPS Pollution in Aquatic Ecosystems

2.2.1 Pathogens

Pathogens are **microorganisms** (bacteria, viruses and protozoa) that cause waterborne illnesses. Pathogens most commonly come from human sewage, such as leaking or ageing municipal sewage systems, residential sewage systems, and overflows from sewage treatment plants.

Another source of pathogens is manure from farm livestock and wild animal scat. One of the most famous examples of a waterborne pathogen contamination in Ontario is the 2000 E. coli outbreak in Walkerton which resulted in 7 deaths and over 2,300 reported cases of illness. In 2006, Health Canada estimated that unsafe drinking water resulted in 90,000 illness and 90 deaths annually.

2.2.2 Oxygen Depleting Substances and Nutrients

Carbon, nitrogen and phosphorous are some of the most important elements which determine the level of productivity in an aquatic system. All of these elements can find their way into aquatic ecosystems naturally, or via non-point source pollution.

In aquatic systems nitrogen and especially phosphorous are limiting factors. In natural ecosystems, these two elements are usually in short supply and therefore limit the growth of aquatic plants. If nitrogen or phosphorous are added to an aquatic system, aquatic plant growth will be stimulated, causing the **eutrophication** of the water body. Eutrophication can be a natural or anthropogenic process where the release of nutrients stimulates aquatic plant growth and eventually increases animal populations. While not always a bad thing, eutrophication can be a concern when too much nitrogen or phosphorus is introduced to a system, often through anthropogenic means.

Increased nitrogen or phosphorus inputs from agricultural fertilizers or wastes and domestic sewage can dramatically change the aquatic community. Both of these elements can stimulate the growth of algae, which can cover the surface of the water and prevent sunlight from penetrating. Algal growth and the presence of suspended particles from pollution sources increases water turbidity, decreasing the amount of sunlight available for aquatic plants, which thus decreases the amount of dissolved oxygen within the aquatic system. Plants found underneath the surface cannot add oxygen to the water since they become light starved and die. In addition, algae from the surface eventually die and sediment to the bottom where they decompose. Bacterial growth and decomposition on the bottom of the water body would occur at a high rate due to the abundance of organic matter, either from dead plant tissues or domestic wastes. This process of bacterial decomposition uses up dissolved oxygen, which has an effect of creating anoxic conditions within the aquatic habitat, ultimately depleting the amount of oxygen available to fish and other organisms in the water.

Table 1. Comparison of P and N loading to Canadian surface and ground waters from various sources (Ritter et al, 2002).

Nutrient Source	Nitrogen (10^3 t/yr)	Phosphorus (10^3 t/yr)
Municipal wastewater treatment plants	80.3	5.6
Municipal Sewers	11.8	2.3
Septic systems	15.4	1.9
Industry	1.8	2.0
Agriculture (residual in the field after crop harvest)	293	55
Aquaculture	2.3	0.5
Atmospheric deposition to water	182 (NO_3 and NH_4^+ only)	N/A

2.2.3 Sediments

Sediments are soil particles that are suspended in water, which make water appear muddy and cloudy. This allows for less light to penetrate the surface of the water - light that is needed to allow plants to perform **photosynthesis**. It also injures or kills fish by damaging their gills, covering spawning areas, and smothering fish eggs. The growth of certain species of fish is also negatively affected by sediment loading over longer periods of time, because fish cannot detect food as quickly as in a clearer, non-cloudy water.

Growth might also be inhibited because fish are stressed and have a higher **metabolic** demand. As fish become more stressed due to the sudden habitat change, their resistance to diseases falls and they become more vulnerable. Other organisms that are affected by sediment loading are **periphyton** - without enough light to perform photosynthesis, their populations drop. This drop in periphyton populations will then cause a drop in the populations of the **macroinvertebrates** that feed on them.

2.2.4 Toxins

Toxic chemicals can enter into aquatic ecosystems from a number of sources, including industrial runoff, agricultural runoff, and even from homes. Chemicals can cause problems with the taste, odour, and colour of water. Animals such as fish and macroinvertebrates are subject to reduced fertility, deformities, immune system damage, tumours, and even death. Many of these chemicals can also be harmful to humans in small amounts. Toxins such as ammonia, nitrate, metals, polychlorinated phenols (PCPs), Polychlorinated biphenyls (PCBs), and pesticides are examples of toxins that can adversely affect aquatic ecosystems.

Figure 7. Toxic substances in the aquatic environment (Environment Canada, 2010).
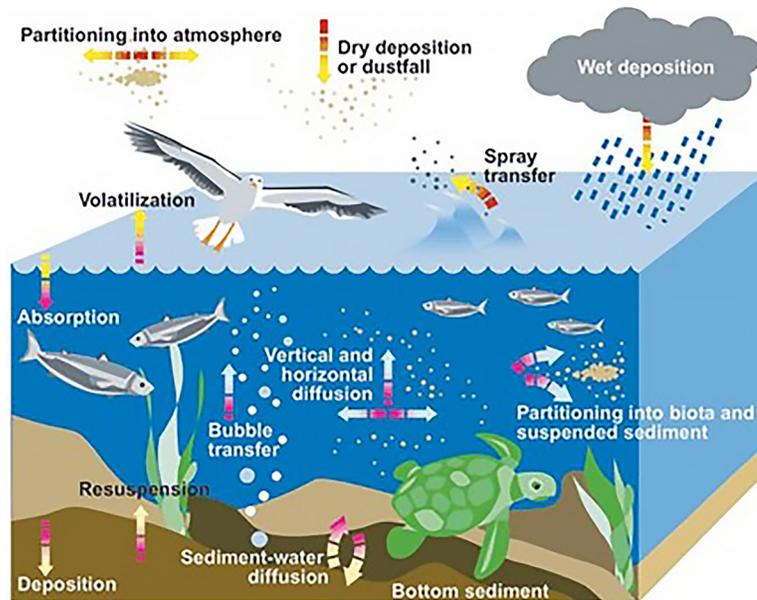
Table 2. Sources of Polluted Runoff (Müller et al., 2020).

	Farmland	**Managed Green Space (e.g. golf courses, parks)**	**Commercial & Industrial**	**Residential**
Nutrients	Fertilizers	Fertilizers	Acid rain, automotive exhaust	Fertilizers, septic system effluent
Pathogens	Domestic & wild animal waste	Pet & wild animal waste	Malfunctioning/ overloaded septic systems and lagoons	Malfunctioning septic systems, pet waste
Sediments	Erosion from fields, stream bank erosion	Erosion from unprotected exposed areas	Construction sites, roadside erosion, road salts and sand	Construction sites, road salts and sand, erosion from lawns and gardens
Toxic Contaminants	Pesticides	Pesticides	Industrial pollutions, automotive emissions and fluids	Household products, pesticides
Debris	Litter, illegal dumping	Litter, illegal dumping	Litter, illegal dumping	Litter, illegal dumping
Thermal	Removal of streamside vegetation	Shallow water impoundments, removal of streamside vegetation	Heated runoff, removal of streamside vegetation, impoundments	Heated runoff, removal of streamside vegetation, impoundments

2.3 Impacts to Soil

2.3.1 Soil Erosion

Soil is affected through erosion via activities like poor farming practices. Small soil particles are transported by excess water after a precipitation event (rain or snowmelt), or after the irrigation of a field, and are carried off to nearby water ways. This **sedimentation** then reduces light and oxygen levels in the water ways, impacting the survival of aquatic species. Excess nutrients in the form of fertilizers applied to farm fields or animal manure may also get transported with the **sediments** - these directly impact ecosystems by increasing the **nutrient load** in the water, potentially causing an increase in the growth of algae and the subsequent possible suffocation of aquatic organisms that require oxygen.

2.3.2 Chemical Seepage

Pesticides and fertilizers can percolate through the soil on farmland. This happens when pesticides and fertilizers that are applied by the farmer are carried through the soil profile and ultimately through to the water table, essentially contaminating it. This is a particular issue with nitrogen-rich fertilizers, which can cause nitrate loading in ground--source drinking water. Phosphorus (another element found in fertilizer) is also a concern as it has a tendency to adhere to clay particles, which then can enter waterways through sedimentation.

2.4 NPS Pollution and Forests

Forest activities can cause significant water quality issues if not properly managed. Sources of nonpoint source pollution associated with forestry include removal of streamside vegetation, road construction and use, timber harvesting and mechanical preparation for tree planting.

The removal of vegetation in **riparian zones** can lead to soil erosion, which impacts local waterways. It also reduces stream bank shading, which regulates water temperature. These changes can have negative impacts for aquatic and terrestrial species by limiting sources of food, shade and shelter.

Road construction and use are the primary source of NPS pollution on forested lands, accounting for up to 90% of the total sediment from forestry operations. Sediment is the most common pollutant from forest harvests. Activities from harvesting timber loosen soil, which is then carried to streams and lakes. Sediment decreases water quality for fish and other aquatic animals and plants. Even if water appears clear, some sediment remains in the water. Timber harvesting and mechanical preparations for planting leave large open spaces and bare ground exposed, also leading to soil erosion that pollutes streams and watercourses.

2.4.1 Riparian Ecosystems and their Importance

Riparian zones link aquatic ecosystems with the surrounding landscape. They cover ravine slopes, banks, shores and wetlands. They are generally more fragile than most upland woodlands, often with sloping lands, on shallow or erodible soils, and are directly adjacent to surface waters. Riparian flora and fauna are often distinctly different than those found in adjacent communities because of the water--rich soils found in riparian zones. Healthy riparian zones provide a number of ecosystem services and are often important habitats for wildlife.

Figure 8. Industrial activities can cause soil erosion and degrade riparian ecosystems.

Figure 9. Algonquin Park Ontario.

Riparian zones provide the same benefits of wetlands in that they protect soil and water quality and provide habitat and woodland products. Riparian woodlands perform these functions more effectively than other woodland types assuming they are extensive in size, continuous in shape, and are relatively undisturbed.

Aside from forestry and logging, riparian zones are also threatened by other factors such as overgrazing, agriculture, building dams and human development.

Riparian zones provide a number of different functions and services:

Stream bank and streambed protection

- Tree roots hold soil, reducing erosion and sedimentation without interfering with natural channel process (meandering and bank shaping).
- Trees and branches in streams form riffles, pools and meanders that improve aquatic habitat.

Water quality

- Trees and understory vegetation filter sediment and other contaminants from runoff.
- Root growth and organic matter addition increase **infiltration rates**.
- Woodland plants absorb nutrients before they reach surface waters.
- Diverse soil and plant life can trap, absorb or convert heavy metals preventing them from entering waterways.

Fish and wildlife habitat

- Surface waters shaded by riparian forests provide cool and cold fish habitats.
- Leaves and other organic debris feed aquatic insects as part of the food chain in aquatic environments.
- Fallen trees and branches provide cover for fish and other aquatic animals.
- Riparian woodlands provide habitat needs – space, cover, food and water – for most mammals, birds, reptiles, amphibians and insects that live in Ontario.

Other environmental functions

- Riparian woodlands are excellent for conserving soil, with buffers, **berms** and **strip-cropping**.
- able to reduce runoff and control erosion.
- Trees and shrubs are efficient for fixing carbon (CO_2) from the atmosphere to form wood and organic soil matter, and prevent dissolved nitrate (NO_3) from turning into nitrous oxide (N_2O), a harmful greenhouse gas.

2.4.2 Characteristics of Healthy and Unhealthy Riparian Ecosystems

Characteristics of healthy riparian areas differ according to the landscape they are found in. Grassy vegetation holds together stream banks formed from sediments, while trees and shrubs dominate on the steep, rocky banks of more rapidly moving and narrower headwaters. In all cases water-tolerant or water-loving plants are more effective at holding soil than plants that are more adapted to upland conditions, because they have deeper and stronger root systems.

Figure 10. Healthy
riparian system.

Healthy riparian areas generally exhibit certain similarities:

- Thick growth of vegetation that covers stream banks and provides shade over the stream.
- Surrounding land remains wet most of the year, except where streams cut through rocky terrain.
- Stream banks are more vertical than flattened out.
- Stream levels vary moderately throughout the year.
- Stream water is relatively clear but contains leaves, twigs or logs that create pools and other habitat for fish and other aquatic organisms.
- A diversity of fish, aquatic life, mammals, birds and other wildlife.

Degraded riparian areas have some or all of the following characteristics:

- Patchy of scrubby plant growth with bare ground.
- Vegetation dominated by upland plants or weeds.
- Soil that is compacted - shows **rills** or **gullies**.
- Stream banks that are eroded, severely undercut or sloughing.
- Streams that flood in spring and become dry in summer.
- Stream water that is muddy or murky and may contain toxic levels or nutrients or contaminants.
- Few mammal or birds alive or feeding.
- Limited numbers and diversity of fish and other species.

2.5 General Impacts of NPS Pollution on Wildlife

Figure 11. NPS pollution can come from many different sources.
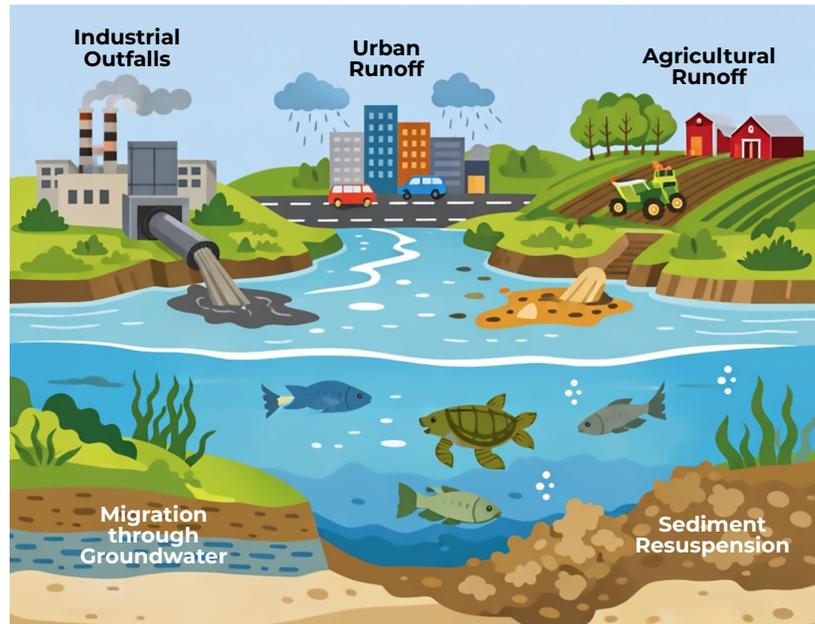
By understanding the effects of NPS pollution on wildlife, we can trace the probable contributors of these pollutants based on what we see happening in local wildlife. By analyzing factors such as presence and absence of species, and population abundance and diversity both within and among species, can show overall trends that allow us to better understand how to manage wildlife. Although the definition of NPS pollution is pollution of unknown origin, by understanding direct effects that specific pollutants have on wildlife it is possible to make conclusions about how NPS pollution works its way through populations. Many commonplace human activities contribute to NPS pollution, these include:

- Dredging of rivers and streams causes sediment re-suspension and can lead to a release of mercury and PCB

- Atmospheric deposition of PCB's and phosphates impacts aquatic and terrestrial habitats

- Hydroelectric dams may cause erosion through increased water velocity

- Livestock and wildlife grazing can lead to an increase in nitrogen, phosphates and ammonia through an excess of manure or erosion or both

- Metal smelters (e.g. zinc, ore, etc.) can lead to waterborne heavy metals

- Agricultural runoff, farm effluents, and other chemical use may lead to an increase of nitrogen and phosphates

- Urban, sewage and **grey water** runoff can also contribute to nitrogen and phosphates increases

- Mining and drill exploration and processing can introduce lead, heavy metals or PCB runoff

These contributors of NPS pollution are just a few among many, and they affect the condition of lakes, rivers, streams and other aquatic systems. This is water that wildlife depends on. Some wildlife are affected more than others, and the degree to which they are affected depends on the connection a particular species has to the pollutants. Will the effects be more direct or indirect?

2.6 Bioaccumulation and Biomagnification

Toxins in contaminated water will affect different wildlife species differently. For example, in a river containing **low-tolerant** and **high-tolerant** aquatic invertebrates, alteration of the chemical quality of water allows only the high-tolerant species to survive or maintain natural cycles. These surviving species will also pick up toxins and pollutants, which are eventually transferred to their predators. Factors such as the decreased biodiversity of that river and the increasing influence of high-tolerant species will affect higher trophic levels. Predacious fish species, amphibians, birds (marsh and songbirds) and mammals rely on the presence of contaminate-free aquatic invertebrates, as well as one another, for prey. Scientific evidence shows that even trace amounts of toxins consumed by wildlife can cause subtle effects on reproduction and development. In the short term these effects are unnoticeable, but in the long term these pollutants can have serious and damaging consequences. These can include irreversible damage on the immune system and nervous systems, impacted pre-natal and post-natal development, infertility, and the development of some cancers.

Biomagnification refers to an increase in the concentration of substances as you progress along a food chain. The concentration of the pollutant is often greater across the top of food webs and among the individuals at higher trophic levels. Both bioaccumulation and biomagnification refer to very similar, converse concepts regarding the build-up of pollutants within a system or individual. A top predator will bioaccumulate large amounts of pollutants in its lifetime as a result of the biomagnification of pollutants within their diet. This can have acute or chronic affects depending on the substance.

2.7 Vertical Transmission

Another issue with wildlife and NPS pollution is the vertical transfer of toxins, wherein toxins are passed down through generations. For example, female eagles can pass on pollutants to their offspring as they develop through their unlaid eggs. If the female adult eagle has directly come into contact with contaminated fish prior to egg-laying, contaminants will directly affect unhatched chicks, which will then be subject to birth defects. The **cascade** effects of pollution have direct connections to wildlife's relationship with fresh water.

2.8 Specific Effects of NPS Pollution on Wildlife

Each pollutant can have different effects on wildlife and ecosystems. Examples of these effects include the following:

- Acid rain resulting from atmospheric pollution destroys fish life in aquatic systems.

- Nutrient pollution such as phosphates and nitrogen causes intensified growth of aquatic vegetation and toxic algae; this excess growth chokes the life from the aquatic system by decreasing oxygen and increasing outbreaks of disease.

- Chemical contamination such as oil can negatively influence development of aquatic organisms; stress and weaken immune systems allowing susceptibility to disease; cause damage to a number of body systems like the reproductive and nervous systems; and cause gastrointestinal irritation and liver and kidney damage.

- PCB contaminants such as mercury can negatively impact behaviour, growth and development, alter or destroy reproduction, and cause death.

- Fertilizers and pesticides can cause abnormal fish habits, physical characteristics and death.

- High amounts of salt can also be lethal.

Figure 12. Wildlife taking advantage of low impact development, a Killdeer on green roof (Kelly Luckett, 2010).

2.9 Microplastics

Plastics are among the most universally used materials in modern society, and improper management of plastic waste has led to a great deal of plastic pollution. Canadians generated 4.4 million tonnes of plastic waste in 2019, and only 9% of that waste was recycled (Health Canada, 2024). Plastic pollution has been found on shoreline, sediment, groundwater, soil, indoor and outdoor air, food, and drinking water. Many plastics degrade slowly over time and remain persistent in the environment, which means that plastic pollution will only increase over time. In Canada, it is estimated that 1% of plastic waste enters the environment. (Environment and Climate Change Canada, Health Canada, 2020).

Single use plastics such as plastic bottles, plastic bags, and plastic straws are some of the most common pieces of plastic litter found on Canadian shorelines, but they are not the be-all, end-all of plastic litter. Plastic pellets, called nurdles, can be found along shorelines, in soils, and beyond, mingling with organic materials. A greater abundance of plastic has been found in areas with high human activity, such as the Great Lakes (ECC, 2020).

Plastics are categorized by size in an environmental context, where anything 5 mm or smaller is classified as a **microplastic**. Microplastics can come from various sources, such as microfibres released from washing clothing (one of the most common sources) or microbeads released through wastewater (Health Canada, 2024). These are called primary microplastics. In Canada, microbeads have been banned in products such as toothpaste, skin cleansers, and other cosmetics or toiletries as of July 1, 2018 (Health Canada, 2023).

Figure 13.
Microplastics are smaller than 5 mm.

Microplastics can also be formed through the breakdown of larger plastic items in the environment, also known as macroplastics. Microplastics formed in this way are called secondary microplastics. There are ultimately a wide variety of sources of microplastics – litter, mismanaged waste, agricultural activities, or lost fishing gear can all be sources of plastic in terrestrial or aquatic environments. (Environment and Climate Change Canada, 2020).

Microplastics can be found in sediment and soil through various pathways, and can act as a major sink for plastic particles, which can remain in soil for a long period of time due to vertical transport through the soil. The only major evidence for this has been the finding of microplastics in groundwater, where they may be travelling to via soil (ECC, 2020).

Biosolids are produced at wastewater treatment plants by settling and stabilising the solids found in municipal wastewater. This sewage sludge can be added to landscapes and used as a conditioner and fertilizer in agriculture or landscaping (Environment and Climate Change Canada, Health Canada, 2020). They are carefully regulated in Canada for heavy metals, nutrients, and pathogens, but microplastics do not currently have any specific regulations. Wastewater treatment plants are efficient at removing microplastics from water, but leave them behind in these biosolids that can then enter terrestrial ecosystems through agricultural application. (Sivarajah and Vermaire, 2025).

Figure 14.
Microplastics in municipal biosolids (Sivarajah and Vermaire, 2025).
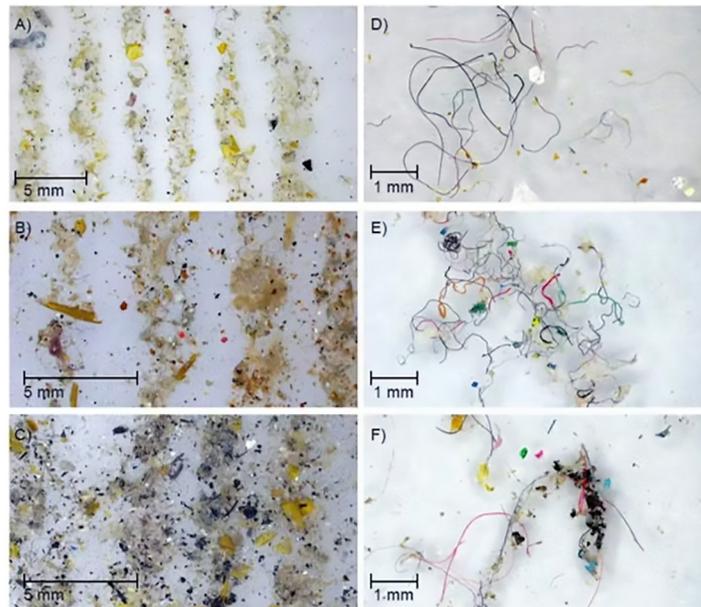
2.9.1 Microplastics and Health

Plastics are a broad category of materials and can potentially contain harmful chemicals. If ingested, these chemicals can leak from the plastic to an animal. Additionally, microplastics can harbour harmful microorganisms on their surface, which could increase health risks associated with them (DFO, 2021).

In aquatic environments, microplastics have been found in all sorts of aquatic animals, and can be consumed via filter feeding, breathing through gills or at the surface of the water, directly eating plastic found in the water, or by consuming prey that has ingested microplastics in one of those ways. While the effects of microplastics are still being researched, ingestion can cause both physical and toxicological impacts. These particles can accumulate in the digestive systems of animals, and may lead to issues feeding, growing, moving, reproducing, and ultimately may cause changes to life expectancies (DFO, 2021).

The Government of Canada has put money towards researching the effects of microplastics on human health through the Environmental Health Research Contribution Program, as there are still many unknowns in the impact of microplastics on human health (Health Canada, 2024).

2.10 Activity: What Does "Parts Per Million" Mean?

Adapted from Project WILD

The goal of this activity is to have students understand that even small amounts of contaminants can have a detrimental effect on aquatic ecosystems. Sometimes pollutants are in a quantity that is so small that detection is next to impossible without extensive testing. You may not be able to see or smell contaminants, but that does not mean that they are not there.

METHODS

Students are asked to research what types of chemical pollutants may be contained in the runoff water in the area where they live, and the impact these may have on the environment.

BACKGROUND INFORMATION

Depending on the area where you live, different pollutants may be more common than others. The types of pollutants found in a given area are determined by the activities that take place in that area. These can include things like heavy metals (arsenic, lead, mercury, cadmium), toxic chemicals (barium, antimony), and others (Health Canada, 2025)

Sometimes just a small amount can harm human health or the health of an ecosystem. Aquatic ecosystems are particularly vulnerable. But what exactly do parts per million (ppm), or parts per billion (ppb) really mean?

RECOMMENDED MATERIALS (PER GROUP)

One stir stick, two containers of tap water (one for rinsing, one for diluting), food colouring, one eyedropper, 10 clear containers, and white paper.

PROCEDURE

1. Line up 10 clear containers in a row and place a piece of white paper underneath each, labelled "1" through "10".

2. Place 10 drops of food colouring into the first container.

3. Take one drop of food colouring from "Container 1" and transfer it to "Container 2". Rinse the eyedropper well.

4. Add nine drops of water to "Container 2" and stir.

5. Transfer one drop of the solution from "Container 2" into "Container 3". Rinse the eyedropper well. Add nine drops of water to "Container 3" and stir.

6. Transfer one drop of the solution from "Container 3" into "Container 4". Rinse the eyedropper. Add nine drops of water to "Container 4" and stir.

7. Continue in the same method until all the containers are filled with solution.

ACTIVITY QUESTIONS

1. If the solution in "Container 1" is one part food colouring to 10 parts water, what is the concentration of each successive container?

2. Which container is the first one holding colourless liquid, and what is the concentration of that liquid?

3. What would remain in each container if the water were removed?

Explain the importance of being aware of trace chemicals and the importance of using equipment to measure them.

2.11 Review Questions

1. Define aquatic NPS pollution.

2. List and describe different types of NPS pollution.

3. What forestry practices can negatively impact water quality? How can these impacts be mitigated?

4. What is a riparian zone?

5. Why are riparian zones important? Describe ecosystem services riparian zones provide.

6. List five major threats to riparian zones.

7. How does NPS pollution affect wildlife? Give specific examples.

8. What is bioaccumulation, biomagnification and vertical transmission? How do these processes impact species and food webs?

Figure 15. Water pollution.

3.0 Detecting NPS Pollution and Best Management Practices

We have now looked at the impacts of non-point source pollution, but not what can be done about it. As there are many sources for NPS, and such a wide range of impacts and entry points into terrestrial or aquatic environments, it is important to note that there is no single method that can be used to perfectly detect the presence and severity of pollution, nor is there a one-size-fits-all approach to reducing the spread and/or impact of NPS pollution across all potentially impacted environments.

In this section, we will explore how bioindicators are used to detect NPS pollution in aquatic environments, examples of how to reduce NPS pollution and its impact in the context of forest management and general land use with use of best management practices (BMPs), and then a series of activities that will let you explore both how NPS pollution can spread and how it can be managed.

3.1 Measuring Aquatic NPS Pollution

Biological indicator species are an excellent way to determine the conditions of the stream, lake, river or wetland that they were found in. They are a species or group of species whose function, population or health can be used to determine the ecosystem's integrity. Examples of biological indicators are fish, macroinvertebrates, periphyton and macrophytes. Such species are good indicators because of the way in which they respond to pollution, such as with population increase or decrease, given their tolerance or sensitivity to specific changes in environmental conditions such as nutrient loading, decreased light, and presence of toxins, metals, herbicides and salt contaminants.

3.1.1 Fish

For many years fish have been used to determine whether a body of water is clean or polluted, or to determine whether the water quality is improving or getting worse. Simply assessing individual fish is not enough; to use fish as a measurement of ecosystem health, it is important to know the species that should be found in the body of water, the population size of each species, and the relative health of the that population. Fish can be excellent indicators of water pollution because they:

- Differ in their tolerance to amount and types of pollution
- Are easy to collect with the right equipment
- Live for several years
- Are easy to identify in the field

3.1.2 Benthic Macroinvertebrates

Benthic macroinvertbrates, or BMIs, are large, bottom-dwelling invertebrates such as worms, crustaceans, insect larvae, or mature adult insects found in rivers, lakes and streams that can be used to indicate the health of a body of water. BMIs are widely used in determining the health of aquatic ecosystems because they:

- Live in the water for all or most of their life
- Stay in areas suitable for their survival
- Are easy to collect
- Are easy to identify in a laboratory
- Have known tolerances to water pollution and/or conditions (i.e. temperature, level of dissolved oxygen)
- Often live for more than one year
- Have limited mobility

This allows us to look at the presence and abundance of BMIs in a given aquatic ecosystem, and then determine the quality of the water by using various models. In Ontario, the Ontario Ministry of the Environment and Environment Canada came together to create the Ontario Benthos Biomonitoring Network (OBBN). This network allows for aquatic ecosystems to be evaluated using shallow water BMIs and the reference condition approach. The reference condition approach gathers samples from minimally impacted rivers, lakes and streams to determine the normal range of variation for a range of indices that summarize the different BMIs found in the site.

3.1.3 Periphyton

Periphyton are **benthic** algae that grow attached to rocks, bedrock, or larger plants. Periphyton are considered primary producers and are very sensitive to environmental changes in waterways, including physical and chemical disturbances.

Other reasons that make periphyton good indicators are:

- A naturally high number of species
- A rapid response time to both exposure and recovery
- Identification to a species level by experienced biologists
- Ease of sampling, requiring few people
- Tolerance or sensitivity to specific changes in environmental conditions are known for many species

Figure 16. Periphyton are important for water absorption and nitrogen fixation. (Ontario Ministry of the Environment, 2011)

3.1.4 Macrophytes

Macrophytes are aquatic plants that grow in or near water. They can be floating such as the White Pond Lily or Water Shield, submergent (underwater) like Milfoil or Common Bladderwort, or emergent (growing out of the water) such as Water Arum and Arrow Head. Aquatic plants are essential to aquatic ecosystems because they provide food and cover for fish and habitat for macroinvertebrates, but most importantly they provide oxygen for water. A lack of macrophytes in an aquatic system could result in a reduced population of fish and waterfowl. It could also indicate water quality problems such as excessive turbidity, herbicides, or **salinization**. An excess of macrophytes can indicate high nutrient levels and can interfere with lake processes and recreational activities, as well as detract from the overall aesthetics of the water body.

Macrophytes are excellent indicator species because they:

- Respond to nutrients, light, toxic contaminants, metals, herbicides, turbidity, water level change, and salt.

- Are easily sampled through transects or aerial photography.

- Do not require laboratory analysis.

- Are easily used for calculating simple abundance metrics.

- Are integrators of environmental condition.

Figure 17. Common Bladderwort.

3.2 Managing for NPS Pollution in Forestry Activities

To limit water quality impacts caused by forestry, forest managers can develop and use different pre-harvest management plans. These plans clearly identify the area to be harvested; locate special areas of protection, such as wetlands and riparian areas; plan for the proper timing of forestry activities; describe management measures for road layout, design, construction and maintenance; and discuss harvesting methods and **forest regeneration**. Identifying the area to be harvested and conducting site surveys can help identify areas that need special consideration during forestry operations. Sensitive landscapes include areas that have steep slopes, greater potential for landslides, sensitive rock formations, high precipitation levels, snowpack, or special ecological functions such as those provided by streamside vegetation. Activities in these areas have a high chance of affecting water quality. Planning for proper timing of forest operations can have a significant impact on water quality. Rainy seasons, fish migration and spawning sites and other events should be avoided.

Figure 18. Treed buffer design. Zone widths according to U.S.D.A. guidelines (Virginia Outdoors Foundation, 2007).
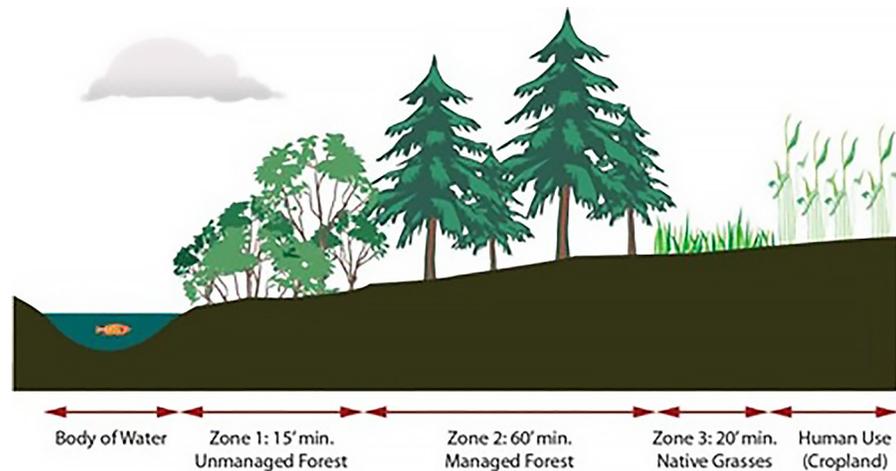
Not all riparian forests need management; in many cases the best strategy is to leave these areas alone. At the very least, establishing no-harvest zones adjacent to watercourses can lead to ecosystem protection. When active management is needed, best management practices (BMPs) are available to help people establish buffered zones to protect and enhance riparian areas. In a treed buffer design, three different zones are established to buffer the distance between aquatic ecosystems and upland development. Zone 1 provides vegetation that shades the water and stabilizes the banks. Zone 2 provides distance between streams and upland development, while soils and vegetation help to filter sediments and promote infiltration and sediment storage. Zone 3 filters runoff from development areas such as cropland and urban areas and prevents encroachment. When planning and managing riparian zones, a variety of factors must be considered. For example, different vegetation types are better suited for different desired functions (Table 3). It is also important to match species appropriately to the surrounding landscape, taking into account factors such as soil composition and pH, moisture regime, temperature and cover type (e.g., trees species in different woodland cover types.

Table 3. Relative Effectiveness of Riparian Types by Function. (Lane 2008).

Function	Vegetation Type		
	Grasses and Forbs	**Shrubs**	**Trees**
Bank/Shore Stability	Low/Medium	Medium/High	High
Filtration of Sediment	High	Low/Medium	High
Filtration of Soil-bound Nutrients, Bacteria and Pesticides	High	Low/Medium	High
Retention of Soluble Nutrients, Bacteria and Pesticides	Low	Low	Medium
Water Storage	Low	Medium	High
Flood Protection	Low	Medium	High
Fish Habitat	Low	Medium	High
Wildlife Habitat	Medium	Medium	Medium
Forest Habitat	Low	Medium	High
Greenhouse Gas Reduction/ Carbon Sequestration	Low	Medium	High
Nitrate Uptake	Low	Low	Medium/High
Phosphorus	High	Low/Medium	High
Economic Products	Medium	Low	High
Visual Diversity	Low	Medium	High

## 3.3 Case Study: Sediment Barriers and NPS Pollution.

Sediment barriers are temporary fences or structures that are installed across or at the bottom of slopes. The purpose of the barriers is to stop any amount of sediment from collecting in runoff and contaminating aquatic ecosystems. There are many different types of sediment barriers; some of these include sandbags, hay or straw bales, brush from clearings, and slit fences. The main source of sediment runoff is construction sites because of the soil that is disturbed in the process of construction.

This case study looks at a sediment barrier that was tested by the University of Guelph and the Toronto Region Conservation Authority. In a 2009 study titled "Effectiveness of Compost Biofilters in Removal of Sediments from Construction Site Runoff", the authors of the study wanted to determine the effectiveness of a compost biofilter. They evaluated the through-flow capacity of the biofilter for hydraulic design of the system, biofilter effectiveness in removing suspended sediments from stormwater runoff near construction sites, and overall biofilter longevity. The compost biofilters were made up of yard wastes such as leaf, twigs, bark and wood chips, which were then stuffed into 'socks' composed of mesh tubes with different diameters ranging from 20 to 61 cm. After the biofilter's life expectancy is over, the filter is sent to a composting facility for recycling and the contaminated sediments are removed, sieved and sent to a landfill to be properly disposed of.

Through a literature review, this study found that if left unchecked construction sites can have four times higher total suspended solids than the median value for varying storm conditions. They also found that there is a 46% removal efficiency of incoming sediment in outflows of sediment barriers. The percentage of sediments removed depends on the site and on proper installation, and the effectiveness of the sediment barrier itself depends on the minimum particle size that it was meant to stop and the size of the sediments in the runoff.

Figure 19.
Sediments in an aquatic ecosystem can cause many problems for wildlife, particularly for fish and amphibians.
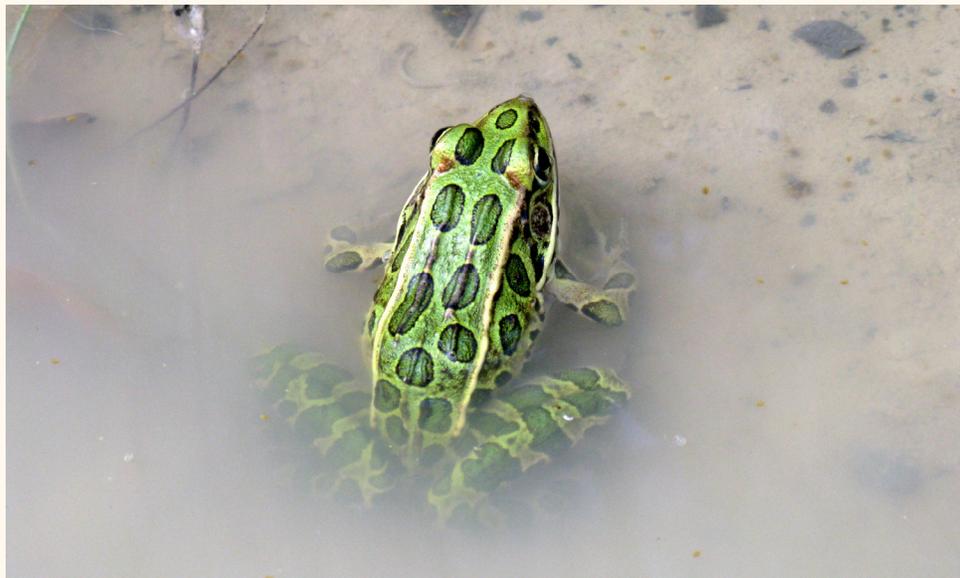
The study used compost from three major compost producers in southern Ontario: the Region of Peel, the Region of Waterloo and Alltreat Farms. They then made biofilter socks from each compost producer, making three different biofilters using the same size compost. They also made two different sized socks: one 20 cm and the other 45 cm. They then preformed a number of tests on the biofilters to determine their effectiveness. The physical test that they preformed were to determine the size of the compost that would go into the sock. This test determined that there is a 60 – 70% void space in all three compost samples. The next test that they preformed was the clean water test, which tested for total suspended solids, pH, turbidity, phosphorous, electrical conductivity, total nitrogen, total phosphorus, and total organic carbon. Earlier they had predetermined a target water quality guideline for the protection of aquatic life, in which a maximum of 25 mg/L total suspended solids was given for chronic exposure and 80 mg/L for acute short-term exposure. They determined that after a 10-minute flush of water, the total suspended solids would be under 25 mg/L. Turbidity was the same for all compost types, and after 10 minutes turbidity reached zero. pH for all compost types met with the Provincial Water Quality Objectives set by the Ontario Ministry of Environment and was well within the 6.9 to 7.2 range. Total phosphorous concentrations dropped below the detection limit after about five minutes. Total organic carbon after five minutes ranged from 0 to 7 mg/L.

They also conducted field experiments where they looked at the effect of the number of socks and the performance of the biofilters. They conducted tests with 5, 10 and 15 socks and determined that 15 socks will achieve between 50 and 60% sediment removal efficiency.

In the end, the authors determined that the compost biofilters were as effective if not more effective than other sediment barriers in use. This method of sediment barrier is also more environmentally friendly with the reuse of compostable material and the method of disposing of the biofilters themselves.

Case Study Questions

1. What are sediment barriers? What are they used for?

2. What kind of material was used in the compost biofilters in this study?

3. What did the authors determine to be the acceptable range of sediments in water for aquatic life?

4. Based on this case study, do you think sediment barriers are effective at preventing NPS pollution?

3.4 Review Questions

1. Define Best Management Practices.

2. Give examples of different bioindicators that can be used to evaluate NPS pollution in an aquatic system.

3. Discuss bioindicators as a means of monitoring aquatic ecosystem health.

4.0 Low-Impact Development

One major effort that is used to combat the effects of NPS pollution is the increased use of **low impact development (LID)** practices. LID attempts to manage stormwater runoff at its source by increasing infiltration rates, **evapotranspiration** rates, and reuse of rainwater, thereby reducing how much water travels into streams, lakes and other water bodies. LID practices enhance natural systems and mimic the water cycle through the use of site design and planning techniques. These include things like preserving and recreating natural landscape features, minimizing the use of impervious sources like asphalt, and creating functional and appealing drainage areas like rain gardens that use runoff as a resource rather than a waste product. Through these combined practices, stormwater runoff in both urban and rural areas can be managed to have neutral or even positive effects on the environment.

Specifically LID aims to:

- Preserve open space and minimize land disturbance
- Protect natural systems and processes (drainage ways, vegetation, soils, wetlands)
- Re-examine the use and sizing of traditional infrastructure (lots, streets, curbs, gutters, sidewalks) and customize site design
- Incorporate natural site elements (wetlands, stream corridors, mature forests) as design elements
- Decentralize and micromanage stormwater at its source

There are many practices that have been used to adhere to these principles such as rain gardens, green roofs, rain barrels, bioretention facilities, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. LID practices have been successfully integrated into many municipal development codes and storm water management ordinances throughout Canada and around the world. With the implementation of these principals urban areas and other developments' impact on aquatic ecosystems can be reduced and managed to promote the natural function of the water systems being affected.

Figure 20. Managing NPS pollution in urban (above) and agricultural (below) areas through LID and BMPs (Natural Resources Canada, 2008).
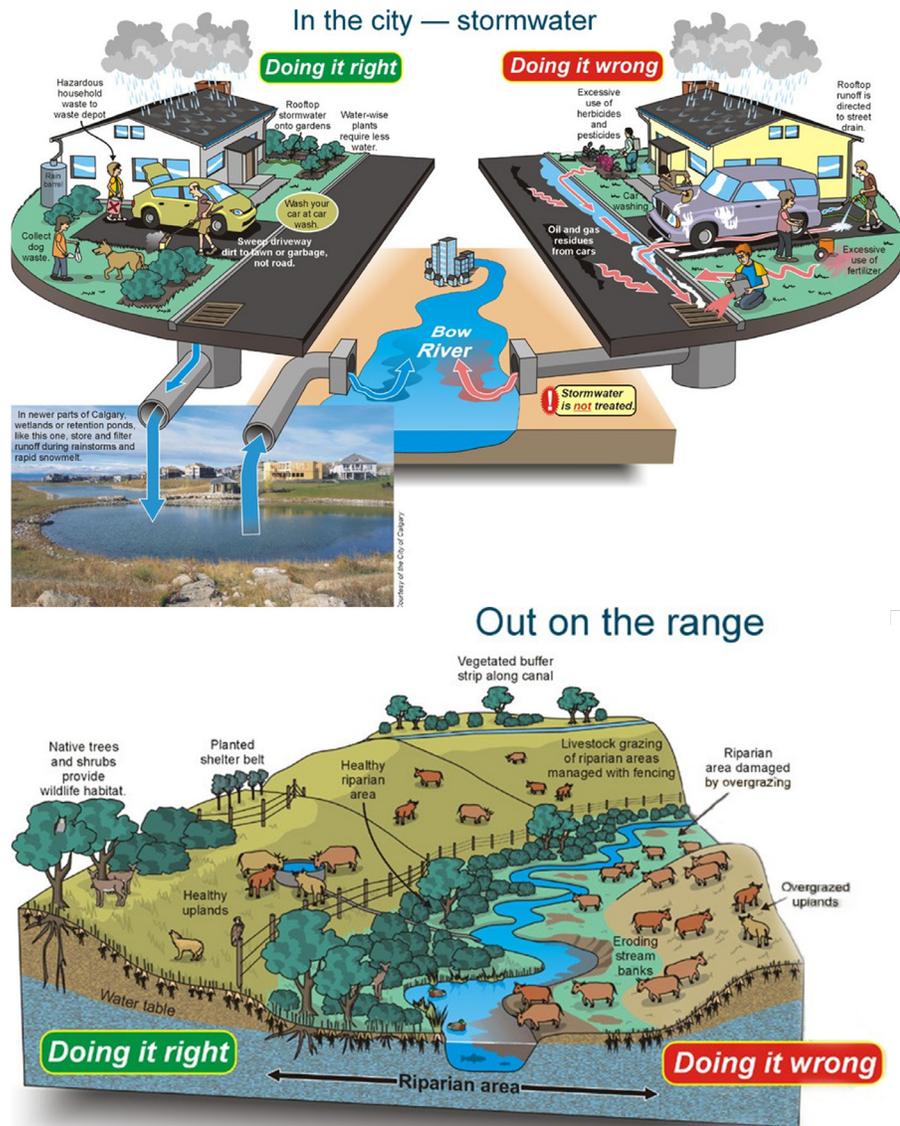
4.1 Costs and Benefits of LID

LID can be applied to new developments, urban retrofits, and redevelopment/revitalization projects at many scales. At a small scale, LID techniques can be used to better handle rainfall for a single family lot through rain barrels and rain gardens. At a larger scale, proper site design in combination with many landscaping and infiltration techniques distributed throughout a subdivision or development will cumulatively improve water quality and reduce runoff.

Specific benefits of LID in urban areas include:

- Improved aesthetics

- Expanded recreational opportunities

- Increased property values due to the desirability of the lots and their proximity to open space

- Increased total number of units developed

- Increased marketing potential and faster sales

- Reduced runoff volumes and pollutant loadings to downstream waters

- Reduced incidences of combined sewer overflows

- Improved habitat

- Aesthetic amenities

- Improved quality of life

Conventional development practices and approaches to stormwater management typically involve hard infrastructure such as curbs, gutters and piping. These practices often clear all trees and valuable topsoil from a site and regrade it so that all water ends up in one area. The resulting problems include loss of recharge, increased water temperature, decreased water quality and higher runoff volumes.

LIDs based designs, in contrast, are designed to use natural drainage features or engineered swales and vegetated contours for runoff conveyance and treatment. The LID approach protects the natural ability of the site to capture precipitation, keep it clean and allow it to recharge the local water table.

In terms of costs, LID techniques can reduce the amount of materials needed for paving roads and driveways and for installing curbs and gutters. Other LID techniques can eliminate or reduce the need for curbs and gutters outright, thereby reducing infrastructure costs. Also, by infiltrating or evaporating runoff, LID techniques can reduce the size and cost of floods control structures. In some circumstances, however, LID techniques might result in higher costs due to more expensive plant material, site preparation, soil amendments, installation of under drains and connections to municipal stormwater systems and increased project management costs. Other considerations include land required to implement a management practice and differences in maintenance requirements. Finally, in some circumstances LID practices can offset the costs associated with regulatory requirements for stormwater control.

4.2 Types of LID Practices

There are a number of different types of LID practices. Some examples that will be discussed in depth here are green roofs, rain barrels and cisterns, and permeable pavements.

4.2.1 Green Roofs

Green roofs are extremely beneficial for urban settings in runoff control. Roof runoff can contain deposited atmospheric pollutants, particles of roofing materials, and nutrients and bacteria from bird droppings. The concentration of these pollutants is reduced on a green roof as stormwater is absorbed by vegetation and soil used to make up the roof. Green roofs provide stormwater management benefits by making use of biological, physical, and chemical processes found in plant and soil complexes to prevent airborne pollutants from entering water systems through runoff.

Green roofs are built with a lightweight soil media, a drainage layer, and then a high-quality impermeable membrane that is designed to protect the building structure. Plants that are picked to grow on green roofs are those that can handle arid, warm conditions and full sun on top of buildings. The plants also have to be able to withstand high winds during storms.

Figure 21. Deconstruction of a green roof (Low Impact Development Center, Inc., 2007).
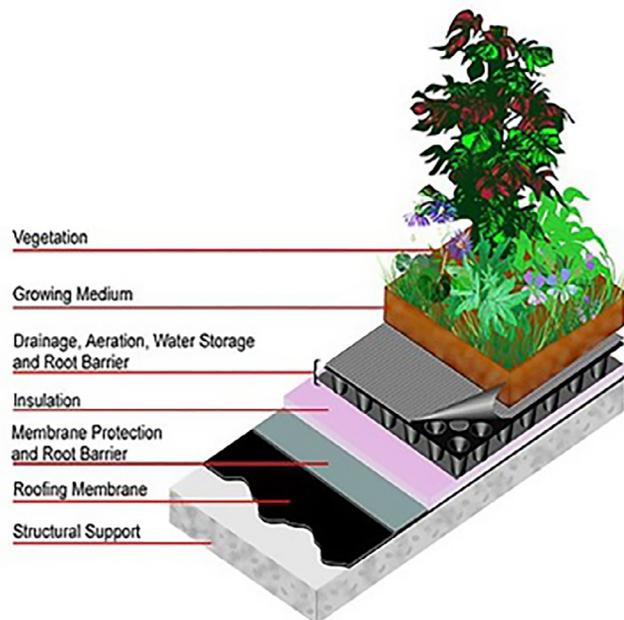
There are two major types of green roofs: intensive/active, and extensive/passive.

Intensive green roofs have deep growing mediums, which allows for a wide range of landscape design options and more room for plants to grow. These types of green roofs can even support trees, and often incorporate recreational use with features like benches, shallow pools and fountains.

Extensive green roofs have shallow growing mediums, often just 1½ to 6" thick; are more self-sustaining; and require less maintenance than intensive green roofs. Because they are lighter, they require less structural support and are less expensive than intensive systems. They are typically seeded with grasses, which are able to spring back between long periods without rain.

From 2010 to 2025 City of Toronto's Green Roof Bylaw required all new commercial, institutional, and residential developments with a minimum floor area of 2,000 m^2 to include a green roof. This resulted in the creation of approximately 1,200 green roofs in the city. A good example of a green roof in Toronto is the York University green roof, which was installed in 2001 and is approximately 20,175 ft^2. It is located on the Computer Science and Engineering building.

Ottawa has one of the largest green roofs in North America that is 10, 684m^2. This green roof sits on top of the Canadian War Museum and is covered in a natural tall grass species that is found along the Ottawa River. The roof is a self-sustaining ecosystem that needs little maintenance in fact the plants on the green roof clean in the environment around the building by reducing the amount of smog in the air and by reducing the amount of runoff.

Figure 22. Green roof on Computer Science and Engineering building at York University (City of Toronto, 2011).

Figure 23. Green roof on the Canadian War Museum (Canadian Museum of Civilization Corporation, 2009).

4.2.2 Rain Barrels and Cisterns

Rain barrels are a very effective way for houses and commercial sites like green houses, to manage rain runoff from roofs and reduce non-point source pollution. Rain barrels are low in cost and are easy to maintain.

There are three basic parts to a rain barrel system: (1) a catchment area, like the roof of a house or building; (2) a conveyance system, such as gutters on a house; and (3) the storage area, which would be the barrel itself. Rain that collects on roofs of buildings or that sits in rain barrels is said to collect microbiological contaminations as well as increases in pH, turbidity, metal and organic levels. However, a study using cisterns and rain large rain barrels for water uses other than drinking found that there were minimal levels of microbiological contaminations and trace metals found in rain barrels. The study's authors concluded that there is minimal risk associated for non--drinking purposes such as watering gardens, laundry and toilet flushing. The use of rain barrels provides an excellent way to reduce the amount of municipal water used for watering gardens and lawns. In this way the collection of rainwater can be used productively and efficiently instead of collecting sediments and pollutants before entering into aquatic ecosystems.

Cisterns are very similar to rain barrels except that they are much larger and hold more water, and they can be adapted for more uses. By adapting cisterns to pump water for laundry and toilet use, this will let homeowners reduce their municipal water bills.

4.2.3 Permeable Pavement

Most of the urban world is covered by pavement and concrete in the form of roads and parking lots. This pavement is considered impermeable and does not allow water to flow through it. Leaving water to flow to its lowest point usually results in it ending up in drains that in turn end up in waterways.

Figure 24. Permeable pavement (BuildingGreen, 2007).

Use of permeable materials, however, can allow water to drain into the ground at the source. It can also eliminate problems with standing water, provide groundwater recharge, control erosion of streambeds and riverbanks, as well as facilitate pollutant removal.

There are a variety of different types of permeable surfaces, most of which are grouped into three main types: modular interlocking concrete block pavement; porous asphalt and concrete; and plastic grid systems. Modular interlocking concrete blocks consist of concrete blocks that interlock with each other and let water permeate into a reservoir through inter-block or intra-lock voids. These voids can be filled with gravel, soil or grass. Porous asphalt or concrete is standard asphalt or concrete with the finer aggregates removed, allowing water to flow through the pavement. Plastic grid systems are plastic interlocking bricks with spaces in the middle that allow them be filled with gravel or planted with grass.

The implementation of permeable surfaces has beneficial impacts on the environment by reducing runoff volume and thus lowering erosion by stormwater and lowering sediment loading. They also help to reduce the amount of pollution that would normally be picked up by stormwater runoff from roads or other sources such as salts, total suspended solids, total phosphorus, and total nitrogen.

4.2.4 LEED© Certification and LID

LEED© stands for Leadership in Energy and Environmental Design, and is an internationally accepted, third-party certification program that recognizes green building practices. This certification verifies that buildings are designed and built using LID strategies to promote environmentally sustainable practices. Performance is measured with respect to five different categories: sustainable development, water efficiency, energy efficiency, materials selection and indoor environmental quality. An additional category not recognized under these five encompasses innovation, building expertise, exemplary performance and other measures.

Figure 25. LEED© Gold Certification (Canada Green Building Council, 2026)

The LEED rating system was originally begun in 1998 by the U.S. Green Building Council, and has since expanded to encompass more than 30 member countries. The Canadian rating system is adapted from the U.S. system and is tailored to Canadian climates, construction practices and regulations. Certification is based on a total point score using established criteria focused on six areas of human and environmental health, and is divided into four levels: certified, silver, gold and platinum.

LEED certification helps both the public and private sector to promote:

- Promote awareness of environmental stewardship issues
- Use innovation to improve efficiency and reduce costs
- Validate and recognize achievement
- Be recognized as committed to environmental and human health issues

Figure 26. The George and Kathy Dembroski Centre for Horticulture at the Toronto Botanical Garden is LEED silver certified (TBG, 2026).

4.3 Case Study: Real life Applications of LID

Urbanization, and all the features that come hand in hand with it (e.g. impervious pavements, storm sewers, etc), have a huge impact on the environment and increase the incidence of NPS pollution. LID provides an alternative solution to these issues. The first time that LID was officially recognized as an alternative means to dealing with stormwater and preserving the original hydrology of an area was in 1999 in Prince George's County, Maryland, U.S.A. Here, they used manmade landscaping features to deal with the effects of precipitation events in the form of porous pavements, stormwater ponds and rain gardens. This was the first large-scale application of LID in a modern North American urban community.

The effectiveness of LID against traditional development methods was tested in Connecticut, when two subdivisions were built side-by-side. One was built using LID principles, while the other was a regularly built subdivision. The LID-built subdivision responded more effectively to precipitation events and measured less runoff on site. In the LID site they tried to mimic the pre-existing hydrological conditions before the site was developed, and they did this by using grassed swales and bioretention gardens. It was found that the conventional site experienced 47% more runoff, and that there was more nutrient loading in the surrounding watershed originating from the conventional site.

Case Study Questions

1. What are some of the contaminants that can be diminished by the use of LID practices in an urban residential development?

2. Can you think of an example of LID in your area? Describe it and explain how it works.

3. Do you think that LID is more or less expensive than conventional building practices? Why are why not?

4.4 Activity: Planning for Healthy People, Wildlife and Communities

Adapted from Project WILD

The goal of this activity is to help students understand the importance of land use planning in an urban setting, and to recognize the negative influences that pollution has on wildlife and the urban ecosystem. The activity will explore how to improve wildlife impacts by designing an environmental and socially sustainable community though proper land use planning.

METHODS

Students are asked to visualize and research the community where they live, and what it was like before development took place. Four types of pollutants are introduced, and once their characteristics are understood, students will design planned sustainable communities that deal with the effects of these pollutants.

BACKGROUND

Generally cities develop over time with little thought of community functions and future issues. They form from this way to satisfy a communities notion of basic needs and dependencies, which include: food, shelter, transportation, trade, and a sense of solidarity amongst citizens. Although communities and cities do meet these needs, they also contribute to high population densities and an interruption of ecosystem integral functions.

Figure 27. Water drains into a local waterway.

Unfortunately, for these reasons urban areas contribute to the presence, increase and transportation of pollutants. These are pollutants that fall into the following four categories:

Chemical Pollution: The introduction of toxic substances into an ecosystem.

Thermal Pollution: Rapid changes in water temperature (above or below the normal condition) caused by human influence which can disrupt the cycles of aquatic organisms or change physical properties of water (i.e. reducing rate of dissolved oxygen). For example, power plants using water to cool machinery or urban run off can cause thermal pollution.

Organic Pollution: Pollutants generated by, or derived from plants and animals (i.e. sewage, agricultural run-off). While organic pollution can occur naturally it can still negativity impact ecosystems. Organic pollutants can increase nutrient load in aquatic ecosystems or introduce bacteria to human drinking water.

Ecological Pollution: Pollutants which can be created by natural processes or cycles but stress ecosystems when produced in excessive quantities (i.e. carbon dioxide). This can include adding a naturally occurring substance that is not normally present in a particular ecosystem (i.e. extreme tides can introduce saltwater into habitats ordinarily protected from seawater).

It is this pollution that infiltrates the basic cycles of ecosystems, entering and disrupting waterways, degrading the state of and interconnectedness of water. Every day water continues to be polluted, which sometimes stresses ecosystems and wildlife habitats to the point where they cannot support life.

Other impacts of unplanned urban development can include: an increase in crime and unemployment, poor housing, smog, contamination of water supplies by industrial and sewage waste disposal, and increased energy consumption and transportation costs. Urban sprawl is among major issues facing Ontario's cities and towns. We need to make some the ethical decisions and ask questions when developing land-use plans. This must be done whether redeveloping old cities or building new communities. Students are asked to take into consideration the benefits of LID and naturalized vegetated land, and how both can provide essential services that can reduce pollution and minimize ecological and human heath issues, while maintaining an environmental and socially sustainable community.

RECOMMENDED MATERIALS

For the Models (recommendations)

- Heavy cardboard or masonite, salt clay for model building (salt, flower and water to make salt clay, glue, toothpicks, natural materials (dried grass, twigs, etc.), construction paper, tempera paint and brushes, etc.

For the Visual Drawing (recommendations)

- Large--scale paper or bristle board, pencils and erasers (rough sketching), straight--edge rulers, drafting triangles, colouring materials (pencil crayons, markers, paint, etc.)

PROCEDURE

1. Students are asked to visualize a large community or city they live in or near, and what it looks like. Then get them to imagine what the natural area would have looked prior the urban development. This includes the type of vegetation, terrain geography, wildlife, and water systems (creeks, rivers or lakes).

2. The next step is to research these details. As a group, the students are to report back with visual and verbal descriptions, and share their research (vegetation types, wildlife, food and water sources that wildlife depend on). The goal is that everyone involved in this activity will get a realistic perspective of the natural ecosystem that once existed in their area.

3. (Research sources can include provincial, regional, city or county historical societies, libraries, etc. City, regional and provincial land--use planning offices may also have such information)

4. What are the four major categories of pollution? Discuss each and how these pollutants can affect the health of wildlife, humans, and ecosystems.

5. Divide into smaller groups of 2–4 students. Each group is to develop a community in the naturalized area, which reflects the referenced research compiled by the whole group. When planning a design for the community the students should aim to develop a community in where people live and work with the least possible negative impact on the existing vegetation, air quality, water, soil and wildlife. At the same time these communities should strive to meet the social needs of the people in the community. Be mindful of the four pollutants, and their sources and effects. A number of considerations must be met:

    - Water sources, including the transportation and treatment of water
    - Economic base: e.g., industry, small business
    - Kinds of housing, school, shopping areas, jobs sites
    - Ecological and recreational features: e.g., open space, green belts, parks
    - Sewage and water and trash disposal
    - Aesthetics
    - Environmental safe guards (buffers, river riparian zones, green roofs)
    - Renewable energy
    - Other criteria as brainstormed by students

6. Once each group has come up with a community design plan, discuss their plan with them.

7. After the design plans have been approved, supply the groups with necessary materials to visually draw/draft or construct a scale model. (See recommended materials)

8. After community design models are completed, allow group to explain the design features of their community. Discuss the positives and negatives of the design models in detail. Include such questions as "What actions have you taken to reduce the spread of pollution contamination caused by waste produced by this particular community?" and "If there is a severe winter or drought, would it be necessary to take special measures to assist the wildlife?"

9. After a week or so has passed, ask the groups if they had to live in the communities they designed, would they go about changing any of its aspects of it.

10. Ask a local architect, city planner, wildlife biologist or other resource manager to visit the whole group, in order to review and discuss the various model communities with the groups who designed them.

ACTIVITY QUESTIONS

1. What do you think are the most important considerations in urban planning when considering wildlife?

2. Does your community have any LID or green practices in place to reduce NPS pollution or create habitat for wildlife?

5.0 Conclusion

Non-point source pollution can affect aquatics, forests, soils and wildlife in a very negative way. Some examples of the consequences of NPS pollution include having polluted stormwater enter rivers and contaminating the water for fish and other wildlife, or having soils being eroded from river banks and from tree roots, killing trees. These processes can be minimized or even eliminated through the employment of LID best management practices. Many of these strategies are urban-based, such as green roofs and permeable pavements, but others can be rural such as rain barrels that collect water for gardening and other lawn maintenance. With the use of these strategies and through public education and awareness programs about what NPS pollution and LID are, the amount of this kind of pollution can be greatly reduced.

Conventional forms of development can have adverse effects on the environment; however, local decisionmakers and community members have the power to choose how they develop and can take measures to offset these impacts through the use of LID practices. Through the use of natural resource planning and site design in new development, stormwater can not only be managed to have neutral effects on waterways but can actually used to enhance natural features.

6.0 Glossary

B **Benthic** - Relating to or characteristic of the bottom of a lake, or deep river, or the animals and plants that live there.

Berms - A natural ridge or flat platform.

Bioaccumulation - The accumulation of harmful substances such as radioactive elements or heavy metal in an organism, as a consequence of their source(s) of food.

Biosolids - nutrient-rich, organic materials resulting from the treatment of sewage in a wastewater treatment facility (i.e. treated sewage sludge)

C **Cascade** - A succession of things such as chemical reactions or components in an electrical circuit, each of which activates, affects, or determines the next.

E **Ecological integrity** - Relating to the environment and the way that plants, animals, and humans live together and affect each other in a state of being sound or undamaged.

Erosion - Erosion refers to the wearing away of the surface of the earth by running water, wind, or ice. ex. acid rain, contamination of water supplies by pesticides, etc.

Eutrophication - The process by which a body of water becomes rich in dissolved nutrients from fertilizers or sewage, thereby encouraging the growth and decomposition of oxygen-depleting plant life and resulting in harm to other organisms.

Evapotranspiration - Evaporation and transpiration; the process by which plants release water they have absorbed into the atmosphere.

F **Forest regeneration** - To redevelop a forest, or to bring back to its original state.

G **Grey Water** - Waste water that can be reused for some purposes without purification, e.g. bath water, which can be used to water plants.

Gully (Gullies) - Channel(s) or small valley, especially one carved out by persistent heavy rainfall.

H **High Tolerant** - Able to physically put up with harsh conditions or treatment in relation to water quality.

I **Infiltration Rates** - The time and speed it takes to pass through a substance by filtration or make a liquid or gas pass through a substance by filtration.

L   **Low Impact Development (LID)** - Describes those practices that minimize the effects of nonpoint source pollution through site design and planning.

Low Tolerant - Unable to physically put up with harsh conditions or treatment in relation to water quality.

M   **Macroinvertebrates** - Macroinvertebrates or benthos are large, bottom-dwelling organisms such as worms, crustaceans, caddis fly larva, may fly larva, etc.

Microorganism - A tiny organism such as a virus, protozoan, or bacterium that can only be seen under a microscope.

Microplastics - plastic particles smaller than 5 mm. They can be found in air, water, soil, and living tissue. They have many potential origins, and can be harmful to life.

N   **Non-point Source Pollution** - Pollution that collects from diffuse sources and runs into water bodies after rain and snowmelt

Nutrient Load - Nutrient load refers to any dissolved nutrients in a body of water. They are usually nitrogen compounds.

P   **Percolation** - The downward movement of water through soil; specifically, the downward flow of water in saturated or nearly saturated soil.

Periphyton - Sessile organisms, such as algae and small crustaceans, which live attached to surfaces projecting from the bottom of a freshwater aquatic environment.

Photosynthesis - A process by which green plants and other organisms turn carbon dioxide and water into carbohydrates and oxygen, using light.

R   **Rills** - small channels in a ploughed field formed as a result of the runoff of rainwater.

Riparian Zone(s) - the interface between land and a river or stream.

S   **Salinization** - The process through which systems accumulate soluble salts.

Sedimentation - Sedimentation occurs when soil becomes suspended in moving water but fall out of suspension when the water stops moving or are trapped out of suspension by a barrier (such as tree roots or other plant material).

Sediments - Sediments are soil particles that are suspended in water.

Strip cropping - The growing of different crops on alternate strips of ground that usually follow the contour of the land, recourse to minimize erosion.

U   **Uplands** - Higher elevation, typically above floodplain, with dry or well drained soils.

7.0 References

BuildingGreen. (2007). *Permeable Pavement*. Retrieved March 11, 2011 from Building Green TV: http://www.buildinggreentv.com

Canada Green Building Council 2026. *LEED*. Retrieved February 24, 2026 from Canadian Green Building Council: https://www.cagbc.org/our-work/certification/leed/

Canadian Museum of Civilization Corporation. (2009). *The Canadian War Museum's Sustainable Design*. Retrieved April 4, 2011, from The Canadian War Museum: http://www.warmuseum.ca/cwm/about--the-- museum/building--features

City of Toronto. (2011). *What is a green roof*? Retrieved March 16, 2011 from City of Toronto: What is a green roof: http://www.toronto.ca/greenroofs/what.htm

City of Toronto. (2025). *City of Toronto Green Roof Bylaw*. Retrieved September 15, 2025, from City of Toronto: https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/green-roofs/green-roof-bylaw/

Crins, W.J, Gray, P. A., Uhlig, P. W. C., Wester, M. C. (2009) The Ecosystems of Ontario, Part 1: Ecozones and Ecoregions. Retrieved November 14, 2025, from https://www.ontario.ca/page/ecosystems-ontario-part-1-ecozones-and-ecoregions

Department of Fisheries and Oceans Canada (2021). Microplastics. Retrieved February 26, 2026 from https://www.dfo-mpo.gc.ca/science/environmental-environnement/microplastics-microplastiques/index-eng.html

Environment Canada. (2010). *Clean Water - Life Depends on It!* Retrieved March 2, 2011 from Water: http://www.ec.gc.ca/eau--water/default.asp?lang=en&n=06F1403C--1

Environment and Climate Change Canada, Health Canada. (2020). Science assessment of plastic pollution. Retrieved February 26, 2026 from https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/science-assessment-plastic-pollution.html

Great Lakes St. Lawrence River Water Resources Regional Body. (2025). *The Great Lakes Basin.* Retrieved February 26, 2026 from About the Great Lakes St. Lawrence River Basin: https://www.glslregionalbody.org/about/about-the-great-lakes-st-lawrence-basin/

Luckett, Kelly. (2010). *St. Louis Community College Wildwoods Campus.* Retrieved February 24, 2026 from Green Roofs: https://www.greenroofs.com/projects/st-louis-community-college-wildwood-campus/

Health Canada (2024). Government of Canada funding research on health risks of microplastics. Retrieved February 26, 2026 from https://www.canada.ca/en/health-canada/news/2024/01/government-of-canada-funding-research-on-the-health-risks-of-microplastics.html

Health Canada. (2023). Microbeads. Retrieved February 26, 2026 from https://www.canada.ca/en/health-canada/services/chemical-substances/other-chemical-substances-interest/microbeads.html

Health Canada (2025). Drinking water and health: Awareness resources. Retrieved January 2, 2026, from https://www.canada.ca/en/health-canada/services/environment/drinking-water/contaminants.html

Lane A. (ED.). (2008). *Establishing Tree Cover*. Best Management Practices: Agroforestry Series Volume 2. Ontario Ministry of Agriculture, Food and Rural Affairs. 127 p.

Low Impact Development Center, Inc. (2007). *Green Roofs*. Retrieved March 19, 2011 from Urban Design Tools: http://www.lid--stormwater.net/greenroofs_home.htm

Müller, A., Österlund, H., Marsalek, J., & Viklander, M. (2020). The Pollution conveyed by urban runoff. A review of sources. Science of the *Total Environment*. Volume 709, 136125

Natural Resources Canada. (2008). *Bow River Basin Waterscape - Keeping the River Clean*. Retrieved March 16, 2011 from Geoscape Canada: http://geoscape.nrcan.gc.ca/h2o/bow/clean_e.php

Ontario Ministry of the Environment, Toronto and Region Conservation Authority (2011). An Algal Bioassessment Protocol for use in Ontario Rivers. Retrieved Jan 7, 2026 from https://www.ontario.ca/page/algal-bioassessment-protocol-use-ontario-rivers

Ontario Ministry of Natural Resources. (2009). *Watersheds*. Retrieved March 4, 2011 from The Nature of Water Resources: http://www.mnr.gov.on.ca/en/Business/Water/2ColumnSubPage/STEL02_163599.html

Richards, L. (2009). *PCJ Article 284: Managing Stormwater Runoff*. Retrieved February 26, 2026 from PlannersWeb: https://plannersweb.com/wp-content/uploads/2012/07/284.pdf

Ritter, T., Solomon, K., Sibley, P., Hall, K., Keen, P., Gevan, M. & Linton, B. (2002) Sources, Pathways, and Relative Risks of Contaiminants in Surface Water and Ground Water: A Perspective Prepared for the Walkerton Inquiry. *Journal of Toxicology and Environmental Health*. Part A, 65:1-142.

Sivarajah, B., & Vermaire, J. (2025). How microplastics ar making their way into our farmland. Retrieved February 26, 2026 from https://carleton.ca/news/story/microplastics-pollution-farmland/

TBG. (2026). Toronto Botanic Garden History – Overview. Retrieved Jan 6, 2026, from Toronto Botanical Garden: https://torontobotanicalgarden.ca/about/overview-history/

Virginia Outdoors Foundation. (2007). *Riparian Buffers: An Introduction*. Retrieved March 5, 2011 from Virginia Outdoors Foundation: Information About Riparian Buffers: http://www.virginiaoutdoorsfoundation.org/VOF_resource--ripbuffer.php

World Metrological Organization. (2008). Urban Flood Risk Management: *A Tool for Integrated Flood Management*. Retrieved February 26, 2026 from https://www.floodmanagement.info/publications/tools/Tool_06_Urban_Flood_Risk_Management.pdf