Appendix B

Stressors that Affect Goals & Strategies for Vermont Surface Waters and Groundwaters

Acidity

What is acidity and why is it a nonpoint source problem?

Waterbodies exhibit a range of acidity, primarily reflected by the acidity level (or pH) of the water. Natural factors affecting a waterbody's pH include its landscape position, landscape slope, watershed size, bedrock and soil composition. Human activities can alter the acidity of a waterbody through long distant transport and deposition of atmospheric pollutants (commonly referred to as acid rain) and/or through mining activities. More detailed information concerning acidity can be found in Appendix B.

Long distant transport of atmospheric pollutants:

Acid rain occurs when sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are emitted into the atmosphere from burning fossil fuels. These pollutants are known as acid-forming precursors which combine with water and ozone to become sulfuric and nitric acid. Even though Vermont emits the lowest amount of acid-forming precursors of any state in the nation, emissions from upwind mid-west and western states and Canadian provinces blow eastward affecting the chemistry and biology of Vermont's lakes, streams, and forests.

The most obvious environmental effect of acid rain has been the loss of fish in acid sensitive lakes and streams. Acid sensitive lakes or streams have little or no buffering capacity, and because of the type of bedrock underlying these waterbodies, they cannot neutralize the acids. These lakes and streams are found in watersheds with granite bedrock which lack the buffering ions (like calcium) to neutralize the affects of acid rain. Many lakes in the Adirondack area of upper New York State are underlain with anorthsite (a type of granitic rock) and have suffered severe aquatic life loss because of acid rain; these lakes have been called "dead lakes." In reality, the lakes are not completely dead, but their biological communities have been so compromised that only the most tolerant fish, plants and insects can survive. In Vermont, we have also described some acid lakes as "dead" specifically in reference to their fish-less status. In poorly-buffered watersheds like these, scientists have documented significant incremental losses of what buffering ions once existed. In these areas, full recovery of surface waters may be difficult to achieve.

Fortunately, many lakes in Vermont have watersheds with calcium-rich bedrock (such as limestone), that protect surface waters by buffering the acid rain. Vermont surface waters that are most sensitive to acid rain are often smaller, at high elevation, and located in areas with low buffering bedrock. These acid-sensitive waters are mostly found in remote and undeveloped regions of the southern Green Mountains and in areas of the Northeast Kingdom.

Mining:

Vermont had three major copper mines operating from 1800 to about 1958: Elizabeth, Ely and Pike Hill. All three mines are now closed, but the tailing piles left behind at each have caused acidification and the release of heavy metals in downstream waterbodies. Historically, sulfuric acid was used to extract copper from the ore, resulting in the release of acids and heavy metals from tailing piles. The leaching of acid mine drainage continues in some instances to the present day, even if the mines are no longer in operation. Four streams have been listed as acid impaired due to the drainage from the former copper mines. The USEPA has designated Elizabeth and Ely Mines as Superfund sites.

How important is acidity?

Based on an evaluation by DEC's Watershed Management Division, acidity is a moderately ranked stressor, the effects of which are regional in scale, in that certain watersheds exhibit acid sensitivity. In other areas of the northeast, the effects of acidification are more pervasive. A 2010 NESCAUM project demonstrates the extensiveness and severity of acid-forming precursor deposition to northeastern States, concluding that about 30% of Vermont's forests receive excessive loads of acid-forming precursors. In these areas, acidity may be an intense stressor to surface waters with moderate to severe biological impacts. Based on a recent statistically-based survey, up to 16% of Vermont lakes may be stressed by acidity, while 3% of lakes are acid-impaired. The most recent statewide water quality assessment indicates that 38 ponds have been listed as acid impaired due to atmospheric pollutants, and about 160 miles of assessed streams are either stressed or impaired due to acidity.

Long-term results from the volunteer Vermont Acid Precipitation Monitoring Program show trends of decreased acidity or improved pH as a result of the federal air pollution control regulations. With the passage of the 1990 Clean Air Act, sulfate levels in surface waters have been reduced, but there have been no significant trends observed for NO_x, which means it may be too early to detect decreased acidity levels in Vermont surface waters. However, these favorable trends may be too late for the most acidified lakes in Vermont. The reservoir of calcium and magnesium ions in watershed soils not only buffered the acidity of surface waters, but also provided for necessary essential minerals required by aquatic organisms. A decrease in calcium concentrations can be detrimental to the shell development of crustaceans and mollusks as well as to the ability of fish to respond to changes in water temperature and alkalinity. For lakes like Branch Pond in Sunderland, the significant reduction in these beneficial minerals may prevent the full biological recovery once expected with the improving acidic conditions.

Stream channel erosion

What is channel erosion and why is it a nonpoint source problem?

Channel erosion is a natural process that benefits stream and riparian ecosystems. Erosion in naturally stable streams (i.e., streams that are in equilibrium condition[1]) is evenly distributed and therefore minimized along the stream channel. Erosion is also a dynamic process, where the movement, sorting, and distribution of sediment and organic material create a diversity of habitats. When streams are in disequilibrium, excessive erosion occurs in some channel locations, while excessive deposition occur at other locations up and down the stream profile. Some habitats become scoured of beneficial woody debris and sediment, while others may become smothered. Where stream disequilibrium is prevalent in a watershed, nutrients (e.g. phosphorus) that are attached to eroded sediments are released in unnaturally large amounts. DEC has identified four specific anthropogenic causes of channel erosion in Vermont's watersheds along with a suite of nonpoint source sources.

Alteration of hydrologic regimes

The hydrologic regime may be defined as the timing, volume, frequency, and duration of flow events throughout the year and over time. Hydrologic regimes may be influenced by climate, soils, geology, groundwater, land cover, connectivity of the stream, riparian, and floodplain network, and valley and stream morphology. When the hydrologic regime has been significantly changed, stream channels will respond by undergoing a series of channel adjustments. Where hydrologic modifications are persistent, the impacted stream will adjust morphologically (e.g., enlarging when stormwater flows are consistently higher) and often result in significant changes in sediment loading and channel adjustments in downstream reaches. When land is drained more quickly and flood peaks are consistently higher, the depth, slope, and power to erode are higher. Activities that may be a source of hydrologic regime alteration when conducted without stormwater or runoff BMPs include:

a. Urban or Developed Lands (increased runoff)
    i. Stormwater runoff when farm and forest lands are developed
    ii. Transportation infrastructure
b. Agricultural Lands
    i. Wetland Loss (dredge and fill)
    ii. Pastureland (incr. runoff & pollutants)
    iii. Cropland (incr. runoff & pollutants)
c. Forest Land Management
d. Climate Change

[1] Stream equilibrium condition occurs when water flow, sediment and woody debris are transported in a watershed in such a manner that the stream maintains its dimension, pattern and profile without unnaturally aggrading or degrading at the river reach or valley segment scales. Benefits of managing streams towards equilibrium conditions include reduction of flood damages, naturalizing of hydrologic and sediment regimes, improved water quality through reduced sediment and nutrient loading and restoration of the structure and function of aquatic and riparian habitat.

Alteration of sediment regimes

The sediment regime may be defined as the quantity, size, transport, sorting, and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and valley, floodplain and stream morphology. There is an important distinction between "wash load" and "bed load" sediments. During high flows, when sediment transport typically takes place, small sediments become suspended in the water column. These are wash load materials which are easily transported and typically deposit under the lowest velocity conditions, e.g., on floodplains and the inside of meander bendways at the recession of a flood. When these features are missing or disconnected from the active channel, wash load materials may stay in transport until the low velocity conditions are encountered, such as in a downstream lake. These alterations are significant to water quality and habitat, as the unequal distribution of fine sediment has a profound effect on aquatic plant and animal life. Fine-grained wash load materials typically have the highest concentrations of organic material and nutrients.

Bed load is comprised of larger sediments, which move and roll along the bed of the stream during floods. Coarser-grained materials stay resting on a streambed until flows of sufficient depth, slope, and velocity produce the power necessary to pick them up and move them. Bed load materials will continue to move (bounce) down the channel until they encounter conditions of lower stream power. The fact that it takes greater energy or stream power to move different sized sediment particles results in the differential sorting and transport of bed materials. This creates a beneficial sequence of bed features (e.g., pools and riffles). When these patterns are disrupted, there are direct impacts to aquatic habitat. The lack of sorting and equal distribution may result in vertical instability, channel evolution processes, and a host of undesirable erosion hazard and water quality impacts. Activities that may be a nonpoint source of sediment regime alteration include:

a. Instream structures that impede sediment supply
    i. Dams and diversions
    ii. Bridges and culverts
b. Channel incision that leads to increases in sediment supply
    i. Erosion of legacy sediments
    ii. Mass wasting and landslides

Alteration of channel and floodplain morphology

Direct alteration of channels and floodplains can change stream hydraulic geometry, and thereby change the way sediments are transported, sorted, and distributed. Vermont ANR Phase 1 and Phase 2 stream geomorphic assessments and the River Corridor Planning Guide (2010) are used to examine alteration stressors, their effect on sediment regimes, and subsequent channel adjustment processes. The table on the following page sorts alteration stressor causes and sources into categories; those that affect stream power and those that affect resistance to stream power, as afforded by the channel boundary conditions. These categories are further subdivided into components of the hydraulic geometry, i.e., stream power into modifiers of slope and depth; and boundary resistance into those stressors affecting the streambed and stream banks. Finally, stressors are sorted as to whether they increase or decrease stream power and/or increase or decrease boundary conditions. By categorizing alteration activities, it becomes easier to see how they may lead to channel adjustment and the excessive erosion associated with disequilibrium. Activities that may alter channel and floodplain morphology include:

a. Floodplain and river corridor encroachment

b. Channel straightening, constriction, dredging, damming, or berming

		Sediment transport increases	**Sediment transport decreases**
	Stream power as a function of:	**Activities that lead to an increase in power**	**Activities that lead to a decrease in power**
Stream Power	**Slope**	• Channel straightening, • River corridor encroachments, • Localized reduction of sediment supply below grade controls or channel constrictions	• Upstream of dams, weirs, • Upstream of channel/floodplain constrictions, such as bridges & culverts
Stream Power	**Depth**	• Dredging and Berming, • Localized flow increases below stormwater and other outfalls	• Gravel mining, bar scalping, • Localized increases of sediment supply occurring at confluences and backwater areas
Boundary Conditions	**Resistance to power by the:**	**Activities that lead to a decrease in resistance**	**Activities that lead to an increase in resistance**
Boundary Conditions	**Channel Bed**	Snagging, dredging, and windrowing	Grade controls and bed armoring
Boundary Conditions	**Stream Bank and Riparian**	Removal of bank and riparian vegetation (influences sediment supply more directly than transport processes)	Bank armoring (influences sediment supply more directly than transport processes)

Alterations that increase streambank erodibility

The resistance of the channel boundary materials to the shear stress and stream power exerted determines, in large part, whether streambanks will erode. Boundary resistance is a function of the type and density of riparian vegetation and the size and cohesion of inorganic bank materials (e.g., clay, sand, gravels, and cobbles). The root networks of woody vegetation bind stream bank soils and sediment adding to the bank's resistance to erosion. Herbaceous plants in lower gradient, meadow streams serve the same function. The table above categorizes those activities that increase or decrease the resistance of bed and bank materials. Decreasing resistance may lead directly to excessive erosion. Artificially increasing resistance works for a period of time (i.e., when other components of the system are in equilibrium), but will either fail or transfer stream power to the downstream reach. Activities that may increase streambank erodibility include:

a. Livestock trampling

b. Removal of riparian vegetation

How important is stream channel erosion?

The effects of channel erosion are pervasive and consequential throughout Vermont. Where it occurs, unmitigated channel erosion causes long-term impacts (greater than 25 year recovery time) that are very to extremely costly to repair. Seventeen Vermont streams exhibit impaired biological communities due, in large part, to the erosion and subsequent habitat impacts caused by urbanization and altered hydrology. Stream geomorphic data show that two-thirds of assessed stream miles are in major vertical adjustment and experiencing excessive channel erosion due to disequilibrium. Cross-channel structures such as dams and culverts that contribute significantly to stream disequilibrium also impact habitat by obstructing aquatic organism passage. In Vermont there are 1,200 dams and likely tens of thousands of undersized culverts. Based on an evaluation by DEC's Watershed Management Division, channel erosion is considered a highly-ranked stressor.

Flow alteration

What is flow alteration and why is it a nonpoint source problem?

Flow alteration is any change in the natural flow regime of a river or stream or water level of a lake or reservoir induced by human activities. The five components of the natural flow regime now recognized as requiring protection to maintain healthy river and lake ecosystems are:

- Magnitude – the amount of water flowing in the stream at any given time;
- Frequency – how often a given flow occurs over time;
- Duration – the length of time that a given flow occurs;
- Timing – how predictable or regular a given flow can be expected to occur;
- Rate of change – how quickly flows rise or fall.

A natural flow regime refers to a range that each of these five components can be expected to fall within due to the variability of precipitation and other natural hydrologic processes. Significant flow alteration can push these components of flow outside the expected range, leading to environmental degradation. Climate change is another potential driver of shifting flow regimes and must also be considered in a well-informed approach to addressing flow alteration. These same five components influence lake water level and changes from the natural condition in one or more of these components affect the health of lake ecosystems.

In rivers and streams, the flow regime is considered a 'master variable' that determines the stream form, habitat suitability and ecological function. The flow regime significantly affects the type and amount of habitat and the diversity and abundance of species that can utilize that habitat. This stressor is focused on the habitat and water quality impacts associated with instream structures and practices that alter the natural flows or water levels (i.e., activities that obstruct, dewater, or artificially flood aquatic and riparian habitats). Altering flows can also have a negative impact on temperature and water chemistry (e.g., pH, dissolved oxygen, and toxicity), which may significantly lower habitat suitability for certain aquatic organisms. Flow regime alterations from increased runoff, such as stormwater, are addressed in the discussion on channel erosion, as are those dams that alter channel morphology and sediment regimes and create an obstruction to aquatic organism passage, but do not alter instream flows or create significant impoundments.

While rivers are much more dynamic than lakes, these systems also have annual cycles to which the plants and animals that inhabit them have adapted. Lake levels naturally fluctuate over the course of the year with higher levels in the spring and often gradually lowering water levels as the summer progresses. In lakes with natural outlets, rapid changes in water level are typically limited to small lakes during severe storms. In these cases, a rapid rise is usually followed by a more gradual decline back to a seasonally normal level. Rapid or frequent lowering of water levels is not normally found in natural systems. Some reservoirs are operated with substantial dewatered zones at various times of the year, depending on uses such as hydroelectric power or flood control.

Many Vermont lakes have a dam on the outlet which has raised the water level of a natural lake between 3 and 10 feet. In some cases the water level may be drawn down, for varying reasons, in the fall and possibly through the winter. This creates an area of littoral zone exposed to freezing and results in change to the habitat and biota in that area. The consequences of unnatural water level fluctuations in lakes and reservoirs on the ecosystem can be significant. Most immediate is the exposure and stress or death of animals that lack the mobility to move down with the water: mussels, macro-invertebrates, small fish and fish eggs. Any species that have already hibernated may be unable to move. Aquatic plant communities in the dewatered zone can also be degraded, as can wetlands associated with the lake. When native plant communities are killed by drawdowns, often the first species to recolonize those areas are invasive ones. The end result can be a zone bordering the lake that lacks healthy littoral (shallow water), riparian and wetland communities. The extent of this zone depends on the magnitude of the drawdown and the relative slope of the lakeshore and littoral zone. These same dewatered littoral areas have been identified as zones in which atmospherically-deposited mercury may readily be converted to the more toxic methyl-mercury that is created in dewatered littoral zones and flushed into waters when water levels rebound, subsequently accumulating in fish tissue. This phenomenon has been documented by scientists in numerous research areas and helps explain why fish mercury contamination is more severe in managed reservoirs than in natural lakes.

How important is flow alteration?

Based on the evaluation by DEC"s Watershed Management Division, flow alteration (including impoundment and dewatering) is a moderately ranked stressor. The effects are usually localized in scale (such as individual stream reaches, lakes, impoundments, dewatered wetland areas) but in some cases the effects may be evident for miles downstream. Further, flow alteration effects may be numerous on the landscape, so the cumulative impacts can be significant at a watershed level.

Where present, flow alteration is an intensive stressor that moderately to severely degrades aquatic habitat and aquatic biota. The most recent statewide water quality assessment indicates that biological condition does not meet water quality standards in over 6,000 lake acres (11% of total inland lake acres) due to flow alteration, while an additional 4,400 acres (about 8% of inland lake acres) exhibit stress. While the number of lakes that are drawn down is relatively small, the practice tends to occur on larger lakes which increases the area impacted. In addition, drawdowns affect a significant amount of the ecologically important littoral zone in the state. This is because many of the largest impounded lakes may also have large stretches of intact riparian vegetation and habitat, but exhibit degraded littoral habitat due to drawdowns. For streams, the biological condition fails to meet water quality standards in over 206 miles (4% of biologically assessed streams) due to flow alteration, while a further 70 miles exhibit stress.

Encroachment

What is encroachment and why is it a nonpoint source problem?

Encroachment is a term used to describe the advancement of structures, roads, railroads, improved paths, utilities, and other development, the placement of fill, the removal of vegetation, or an alteration of topography into such natural areas as floodplains, river corridors, wetlands, lakes and ponds, and the buffers around these areas. These encroachments cause NPS impacts to the functions and values of those natural areas, such as a decline in water quality, loss in habitat (both aquatic and terrestrial), disruption of equilibrium (or naturally stable) conditions, loss of flood attenuation, or reduction of ecological processes.

Constructed encroachments within river corridors and floodplains are vulnerable to flood damages. Placing structures in flood prone areas results in a loss of flood storage in flood plains and wetlands and heightens risks to public safety. Moreover, protection of these encroachments often result in the use of river channelization practices (such as bank armoring, berming, dredging, floodwalls, and channel straightening) to protect these investments. The removal of vegetation to improve viewscapes or access and the removal of woody debris from rivers to facilitate human use can increase resource degradation and the property's susceptibility to flood damages, causing higher risks to public safety. Such practices or activities result in greater channel instability, excessive erosion, and nutrient loading by concentrating flows and increasing stream velocities and power.

Encroachment also increases impervious cover adjacent to lakes, rivers and wetlands, thereby increasing the rate and volume of runoff, loading of sediment and other pollutants, and temperature of the receiving water. The cumulative loss of wetlands that provide water quality protection to adjacent surface waters can result in ongoing reduction in water quality. The extent of encroachment, the cumulative effects of impervious cover, and the degree to which natural infiltration has been compromised can also contribute to the instability of the stream channel.

Encroachment in lake shorelands usually is comprised of residential development and associated vegetation removal. It can also include roads, parks and beaches and urban areas. Recent development patterns on lakeshores have seen replacement of small "camps" with larger houses suitable for year-round use. This new development generally is accompanied by substantial lot clearing, lakeshore bank armoring (seawalls and or rip-rap), and increase in lawn coverage and impervious surface. Research in Vermont and other states has shown this development results in degraded shallow water habitat and increased phosphorus and sediment runoff. Encroachments into the lake itself include docks, retaining walls, bridges, fill and dredging. The following table outlines NPS related impacts to surface water resources from encroachment.

Impacts from Encroachment	
*****Rivers, Streams & Floodplains*****	
Changes in Hydrology	Changes in Geomorphology
*increase in magnitude & frequency of severe floods	*stream disequilibrium: channel widening, downcutting
*increased frequency of erosive bankfull floods	*increased streambank erosion
*increase in annual volume of surface runoff	*elimination of pool\riffle structure
*more rapid stream velocities	*stream channelization
*decrease in dry weather baseflow on stream	*stream crossings form fish barriers
Changes in Water Quality	Changes in Aquatic & Terrestrial Habitat
*massive pulse of uncontrolled sediment during construction stage	*shift from external to internal stream energy production
*increased wash off of pollutants	*reduction in diversity of aquatic insects
*nutrient enrichment leads to benthic algal growth	*reduction in diversity of aquatic & terrestrial species
*bacterial contamination during dry & wet weather	*destruction of wetlands, buffers, springs
*increased organic carbon loads	
*higher toxic levels, trace metals, hydrocarbons	
*increased water temperatures	
*****Lakes & Ponds*****	
Changes to In-Lake Habitat	Changes in Terrestrial Habitat
*decreased submersed woody habitat	*decrease in natural woody vegetation along shore
*decreased rocky habitat/increased embeddedness	*decrease in habitat for species dependent on riparian areas
*decreased leafy debris	* loss of connectivity between aquatic & terrestrial habitat
*decreased shading/ insect fall	
*increased fine sediment (muck & sand)	
Changes in Water Quality	Changes in Physical Function
*increase in local nutrient availability	* increased adjacent erosion when one shoreline is armored or altered
*increase in attached algae growth	* increased risk of mass failure
*increase in temperature	

*increase in phosphorus loading to the lake	
*decrease in water clarity	
*****Wetlands*****	
Loss of Functions & Values that wetlands provide:	
*Water storage for flood water and storm runoff	*Habitat for Rare, Threatened, Endangered species
*Surface & ground water protection	*Education & research in natural sciences
*Fish habitat	*Recreational value & economic benefits
*Wildlife habitat	*Open space & aesthetics
*Exemplary wetland natural communities	*Erosion control through binding & stabilizing the soil

Table modified from: *Metropolitan Washington Council of Governments. Watershed Restoration Sourcebook. Washington D.C.: Anacostia Restoration Team, 1992.*

How important is managing encroachment?

Based on the evaluation by DEC's Watershed Management Division, encroachment is a highly ranked stressor. Empirical data from the State's Stream Geomorphic Assessment program indicate that 30% of assessed stream miles have encroachment within their river corridor (active portion of the floodplain that allows for the re-establishment and maintenance of "equilibrium" or naturally stable slope and stream channel dimensions). Of those streams that have encroachments, roads and development (structures, parking lots, fill) contribute 65% and 26%, respectively, to the overall extent of encroachment.

Perhaps of greatest concern along rivers are the traditional channelization practices that have been and are used to protect existing encroachments. They can be expensive to maintain, do not address the underlying causes of channel instability, increase erosion hazards to adjacent properties, and cause impacts to aquatic and riparian habitat. More importantly, channelization practices are counter-productive in trying to restore and maintain a stream's access to its floodplain and its ability to achieve stream equilibrium over time. The State Hazard Mitigation Plan reports that "channelization, in combination with widespread flood plain encroachment, has contributed significantly to the disconnection of as much as 75% of Vermont's streams from their floodplains."

Global climate change models predict an increase in temperature of 4°F in Vermont by the year 2100 and an increase in precipitation by as much as 30% during the winter months. Therefore, the degree of encroachment, the river channelization/lakeshore stabilization practices used to protect those encroachments, and subsequent loss of floodplain function in both rivers and lakes could make Vermont particularly vulnerable to climate change-related increases in flood frequency and magnitude along with associated increases in sediment, nutrients and other NPS pollutants.

Invasive species

What are invasive species and why are they a nonpoint problem?

Aquatic invasive species are non-indigenous plants, animals, algae, fungi or pathogens (disease causing organisms like viruses and bacteria) that threaten the diversity and survival of native species or the ecological stability of infested ecosystems, or commercial, agricultural or recreational activities dependent on these natural resources. They are a form of nonpoint source biological pollution.

Why do invasive species do so well and become a nonpoint source problem? They are opportunists not historically known to Vermont or to the northeastern region of the country. Most come without the natural checks and balances – predators, pests, parasites and pathogens – that keep species' reproduction and survival well balanced in their native regions. Many have the advantage of thriving in a wide variety of conditions. Native species find it hard to compete with such invaders.

At least 49 aquatic non-native species are known to be within Vermont. While many of these species have not become invasive, a significant number have, including Eurasian watermilfoil, zebra mussels, water chestnut, and purple loosestrife. Many of the state's waters, especially lakes, have a history of impacts related to these invasions. Preventing new aquatic invasive species from being introduced and established in Vermont is critical, not only to limit the future cost of managing invasive species but also to protect the integrity of Vermont's ecosystems. Programs aimed at preventing the spread or introduction of invasive species into Vermont are the best and least costly means of protection available.

How important is invasive species management?

Based on an evaluation by DEC's Watershed Management Division, invasive species of aquatic, wetland, and riparian habitats is a highly-ranked stressor, the effects of which are pervasive throughout the state and severe in many waters where infestations occur. Where infestations of invasive species achieve moderate or high densities and are left unmanaged, severe long-term (>25 year) impacts to recreation and ecosystem function can be expected. Up to 23% of Vermont lakes over 20 acres in size are affected by invasive species, although not all lakes support high density populations. No systematic surveys have been carried out of riparian invasive species at this time. However, field observations suggest that species such as purple loosestrife and common reed (which preferentially invade wetlands), and Japanese knotweed (which colonizes streambanks with alarming efficiency) are increasingly dominating many of Vermont's riparian zones, wetlands and watersheds. Lotic invasive species (e.g. whirling disease, New Zealand mud snail and "rock snot") have caused sufficient concern to prompt the State of Vermont to prohibit the use of felt-soled waders as of April 1, 2011.

Land erosion

What is land erosion and why is it a nonpoint source problem?

Land erosion is the process by which material on the surface of land is dislodged and moved. Land erosion becomes a water quality stressor when the transported materials reach surface waters. When this occurs, the sediment itself is a pollutant.. Land erosion is a natural process caused by both wind and precipitation; however, precipitation-driven erosion is also the primary water-quality stressor in Vermont. Various human activities can significnatly increase the natural rate of land erosion.

In the precipitation-driven erosion process, soil or other materials are first dislodged from the ground by either the impact of rain hitting the ground, or by being "swept up" by the flow of "sheet runoff water" across the ground surface. Land erosion increases rapidly when vegetation and the intact "duff" or organic outer layer of soil are removed. Erosion rates vary significantly depending on a site's slope, the inherent erodibility or prior compaction of the soil, as well as the extent and condition of vegetation and antecedent moisture conditions. The pollutant load associated with land erosion is dependent on the amount of pollutants that exist on or in the eroding material. The extent to which eroded material is delivered to a receiving water depends on proximity and the existence of constructed or natural conveyances such as swales, channels and ditches, pipes, or culverts. Barriers to sheet-flow based erosion, such as riparian buffers, filter strips, stone-lined roadside ditches, and other green infrastructure practices can significantly reduce or even preclude the impacts of land erosion.

The causes and sources of land erosion generally include activities that either eliminate the vegetation protecting soil from erosion, or result in increased runoff volume and velocity. The causes and sources of land erosion include runoff from developed lands, construction activities, agriculture and forest management. Each of these NPS pollution type categories is described below.

<u>Land erosion from developed lands</u> - Developed land generates more runoff than undeveloped land. Impervious surfaces, including roads (both paved and gravel), parking areas, and buildings prevent precipitation from infiltrating into the ground and, instead, produce runoff of sufficient velocity to erode soil and other materials in the flow path. Additionally, developed land often includes a stormwater collection system, or storm sewer system, that effectively routes large areas of impervious system to single points, thus exacerbating the potential for erosion. Erosion is most pronounced where runoff is collected or concentrated such as in road ditches, or at outfalls of storm sewer systems. Land erosion due to stormwater runoff from developed land can be mitigated using Low Impact Development (LID) and Green Infrastructure (GI) practices such as infiltration trenches, cisterns, rain gardens, porous pavements, and sustainable site design/redesign. These practices attempt to mimic natural hydrology by infiltrating, evapo-transpiring, treating, and storing stormwater as close to the source as possible. Providing appropriate riparian buffers from surface waters can also mitigate NPS impacts of land erosion from developed land sources.

<u>Land erosion from construction activities</u> - Because construction activities typically result in the loss of vegetative cover as well as have disturbed soils, construction sites can produce extremely high rates of soil loss. In addition, altering a site's topography can result in a concentration of runoff. Land erosion due to NPS runoff from construction activities can be mitigated through one or more of the following: practices that reduce the amount of cleared land at a given time (construction phasing) as well as reduce the period during which soil is exposed or left without permanent cover or vegetation; practices that protect the soil during construction (such as mulching); and practices that slow runoff and filter or otherwise reduce the pollutants from the runoff. Providing

appropriate riparian buffers from surface waters can also mitigate NPS impacts of land erosion from construction sources.

Land erosion from agricultural activities – There are a variety of agricultural activities that contribute to land erosion through alteration or removal of vegetation. These include: runoff from impervious surfaces in agricultural production areas (such as barn roofs and concrete barn yards); land disturbance associated with the planting and harvesting of annual crops (such as corn and soy); and unmanaged or poorly managed pasturing allowing livestock direct access to surface water and wetlands and/or overgrazing and denuded vegetation. Any one of these activities leaves soils exposed and alters natural drainage patterns, concentrating flows through ditching or tiling. Similar to NPS runoff from developed lands, land erosion rates from agriculture tend to be highest where runoff is concentrated into a ditch or similar conveyance. Land erosion due to agricultural activities can be mitigated by using a range of practices to reduce the potential for erosion. These practices include: expanding "clean water management" to include hydrologic considerations; planting only perennial crops in sensitive areas such as along rivers, ditches, lakeshores and steep slopes; using conservation or reduced tillage; planting cover crops; installing water and sediment control basins (WASCOB); excluding animals from surface waters; implementing rotational grazing systems. Installing and maintaining appropriate vegetated field borders and riparian buffers from surface waters also mitigates NPS impacts of land erosion from agricultural sources.

Land erosion from logging activities - The construction of logging roads, skidder trails, log landings, inadequate protection of stream and wetland crossings, and log transport activities that expose the soil to precipitation, as well as a lack of site maintenance and close-out, can result in NPS land erosion similar to that of construction activities and runoff from developed lands. On a statewide basis, logging activities result in less land erosion than results from runoff from developed lands and construction activities, however, when erosion from logging operations is allowed unchecked, intense localized impacts occur. Land erosion due to logging activities can be mitigated by using and maintaining practices that properly locate and construct logging roads, skidder trails, stream crossings, and log landings, as well as restrict the use of mechanized equipment to times of the year when there are sufficiently dry or frozen conditions. Providing appropriate buffers from surface waters will also mitigate NPS impacts of land erosion from logging sources.

How important is land erosion?

Available data indicate the effects of NPS land erosion are widespread throughout the state. The delivery of sediments and associated nutrients has multiple effects on receiving waters with the intensity of impact dependent on the type of sediment involved, the nutrient content of the sediments, and the capacity of the receiving water.

Empirical data are not available to describe the quantity of NPS sediments and nutrients delivered from land erosion separately from those delivered by channel erosion. However, the 2010 305b statewide water quality assessment suggests that for rivers and streams, 211 miles are impaired due to sediment with an additional 800 miles being stressed. For nutrients, there are 136 river miles impaired and 498 miles as stressed. Among Vermont's lakes, 100 acres are impaired due to sediment and an additional 8,900 acres are stressed (about 5,400 of which are Lake Champlain). As for nutrients, there are 139,800 acres impaired (132,000 acres of which are in Lake Champlain) and about 3,900 acres stressed. These indications make land erosion a highly ranked stressor.

Nutrient loading

What is nutrient loading and why is it a nonpoint source problem?

The vast majority of the nutrient load delivered to Vermont's surface waters arise from one of three NPS stressors. Channel erosion and land erosion have been described previously. The third is non-erosion nutrient and organics loading. Non-erosion based nutrient and organics loading results from direct application of nutrients to land surfaces (such as fertilizer application on farm fields or gardens) that may be subsequently washed into surface waters without any attendant land erosion, leaching of nutrients embedded in soil or organic matter or from direct or indirect discharges (e.g., wastewater treatment facilities). Phosphorus and nitrogen are the two major nutrients of concern for Vermont's surface waters.

Eutrophication is a natural process of nutrient accumulation in surface waters over long time periods (hundreds to thousands of years). When human activities enhance this process of phosphorus and nitrogen loading to surface waters, accelerated "cultural" eutrophication typically results. Signs of accelerated cultural eutrophication include an increased incidence of algae blooms (and sometimes the nuisance growth of invasive and native aquatic plants) and reduced water clarity, which can affect biological communities in surface waters and also significantly impact recreational uses.

Nutrients that are directly delivered to surface waters from non-erosional sources are typically in a chemical form that is more biologically available and therefore readily assimilated by algae. These nutrients are not bound to sediment particles at the time of discharge or application. Phosphates and ammonium are examples of bioavailable phosphorus and nitrogen. Non-erosional nutrient loading tends to have more immediate and localized NPS impacts when excess quantities of nutrients are discharged. For these reasons, direct discharges of phosphorus are regulated to low levels in most wastewater treatment plants and permitted indirect discharges. Limits are also imposed on nitrogen from permitted discharges to comply with current water quality criteria for nitrogen.

The five principal causes of non-erosion nutrient and organic loading are outlined below.

Domestic and industrial wastewater

Direct discharges from industrial facilities and municipal wastewater treatment facilities (point sources) are operated under NPDES and State permits, which are crafted to limit the release of pollutants, including nutrients and organics, based on the ability of receiving waters' to assimilate pollutants. From a NPS standpoint, non-erosion nutrients can be released due to absence of or poor maintenance of septic systems and underperforming indirect discharges.

Poorly managed animal wastes and silage leachate

Inadequate or poorly managed farm production areas (including undersized manure storage or barnyard and feed storage area) can result in direct runoff of manure or leachate to surface waters. Ongoing operation and maintenance of infrastructure to address these NPS nutrient sources is critical to NPS control success.

Over-application of fertilizer on residential lawns and croplands, and improper spreading practices

Over-fertilization can lead to excess levels of soil phosphorus and elevated levels of nitrogen in groundwater. The potential for over-fertilization of Vermont lawns is high as studies indicate that the soils already contain sufficient phosphorus for turf growth. Over-fertilization does not promote better turf growth, but rather results in excess phosphorus runoff into surface water drainages and, ultimately, into streams and lakes.

Over-application of nutrients on agricultural croplands can also be a potential source of non-erosion phosphorus and nitrogen to surface waters. Infiltrating rainwater can carry leached nutrients to subsurface perforated pipes that are installed to drain fields. The NPS discharge from tile drains is often directed towards streams or other waterbodies. While the practice can reduce overland flow and therefore the erosion of soil, it can also lead to increased discharge of soluble phosphorus and nitrogen.

Legacy phosphorus loading from sediments

Internal phosphorus loading in lakes results from historic or ongoing accumulation in deep lake sediments. Once sufficient quantities of phosphorus are stored in lake sediments, they may re-suspend to overlying waters resulting in algae blooms. This phenomenon is one factor that explains the excessive phosphorus levels found in St. Albans Bay and Missisquoi Bay of Lake Champlain and one small lake in Ryegate, Vermont.

Leaching of nutrients from organic material (leaves and yard/garden waste) from urbanized areas and soil

Phosphorus is part of the matrix of molecules that make up organic material and is released to waterways through the decomposition process. In a natural system, the nutrients would be adsorbed to soil particles or taken up by plants. In cases where leaves collect at the edge of roadways, stormwater can carry nutrients to storm drains. Research from the Midwestern United States indicates that as much as 25% of phosphorus in stormwater runoff is attributable to leaf debris and other yard wastes (Lehman, et al. 2009). Where rain water saturates soils, nutrients can also be leached out as water percolates downslope through soils and eventually carried to storm drains.

Organic pollution and biochemical oxygen demand (BOD)

The presence of discharged organic materials, coupled with the organic matter from algae that proliferate as a result of nutrient discharges, contribute to accelerated bacterial growth in surface waters. These bacteria effectively decompose organic materials while consuming dissolved oxygen (DO), thus reducing available DO needed by fish and other aquatic organisms. Biochemical Oxygen Demand (BOD) is a measure of the oxygen needed by microorganisms to decompose discharged organic matter and nutrients. The more organic waste present, the more bacteria are needed to decompose this waste. BOD is regulated in all Vermont direct waste point source discharges through effluent limits.

How important is nutrient loading?

Since passage of the federal Clean Water Act, considerable effort has been accomplished to control nutrient discharges from wastewater treatment facilities and to impose regulations upon septic discharges. Villages that once discharged collected untreated sewage directly to streams now treat this waste in well-functioning wastewater treatment facilities, the majority of which are subject to advanced phosphorus removal systems. Through the use of the Surface Water Revolving Fund and Vermont's implementation of National Pollution Discharge Elimination System and Indirect Discharge permits, the loads of nutrients to streams and lakes from these sources has been vastly reduced. Since passage of the Clean Water Act, $730M has been spent to construct, upgrade, and improve wastewater treatment infrastructure in Vermont, including $91M during the 2009-2011 funding cycle.

Owing to the major success of point source controls in Vermont, non-erosion nutrient loading (particularly phosphorus) is considered to be a lower-ranked stressor to Vermont waters. However, no Vermont-specific empirical studies are available to assess the extensiveness of other non-erosion nutrient sources such as over-application of fertilizers or agricultural leachate. There are only a few streams reaches, and no lakes, where impairments exist as a result of nitrogen loading.

Pathogens

What are pathogens and why are they a nonpoint source problem?

Waterborne human pathogens are disease-causing bacteria, viruses and protozoa. The pathogens that are of concern in Vermont surface and ground waters are those that come from fecal matter of humans and other warm-blooded animals. These pathogens may cause gastrointestinal problems and pose a more serious health risk to people who have weakened immune systems. Untreated surface or ground waters containing fecal matter may pose a risk to human health when ingested through drinking water or, specific to surface waters, inadvertently through contact recreation.

The primary indicator of fecal material in water is the enteric bacterium *Escherichia coli*. *E. coli* is a common component of the bacterial flora of humans and other warm-blooded animals. When detected in surface water or drinking water, *E. coli* may indicate fecal material has made its way into the water. *E. coli* is therefore used as an indicator of potential fecal contamination of the water. *E. coli* are pathogenic in and of themselves, but the presence of *E. coli* is used in monitoring programs to indicate that other more common fecal pathogens may also be present, including pathogenic viruses, protozoa, or bacteria.

The four major causes attributable to NPS pathogens are briefly described below.

Untreated/unmanaged runoff from developed lands

Overland flow - Urban stormwater runoff occurs when precipitation collects and then runs off impervious surfaces, often directly into streams, rather than infiltrating into the soil. Stormwater in urban areas carries a significant load of pollutants to receiving water bodies. Concentrated activity in urban areas loads stormwater with fertilizers, road salt, animal feces, pesticides, oils, heavy metals, and decaying organic matter.

The bigger issue may be the changes in hydrology that occur in developed areas. Much of urban development involves the construction of buildings, roadways and parking – all of which create impervious surface, that both reduce infiltration and can speed the delivery of stormwater runoff to local receiving waters. These increases in stormwater runoff volume and rate (referred to collectively as "excess hydrology") can, in turn, increase rates of export of pollutants such as pathogens and sediment and sediment-bound phosphorus. In developed residential areas adjacent to surface waters, pet wastes can be a considerable source of *E. coli* bacteria and potential pathogens.

The end result of unmanaged stormwater can include the erosion of valuable property, degraded or destroyed aquatic life and wildlife habitats, algal blooms and pathogen contaminated beaches and water supplies.

Combined sewer overflows - In several of Vermont's larger communities served by centralized wastewater treatment facilities, combined sewer overflows (CSO) represent an on-going NPS pollution problem. The standard used by Vermont for remediation of CSOs is to separate stormwater volumes from wastewater and to provide an acceptable level of treatment. Stormwater procedures encourage the use of overland flow and the attenuation of peak discharges and velocities. Within areas having CSO remediation needs, there is growing interest to capture some volume of stormwater flows through green stormwater infrastructure techniques.

Agricultural activities

Agriculture has been identified as a major contributor to surface water pollution in Vermont. While significant strides have been made to reduce agricultural NPS pollution through the voluntary implementation of soil, water and waste (manure) management practices, agriculture remains one of the most significant sources of NPS pollution. Inadequate and improper animal waste and soil management results in pathogen loading to surface waters.

Untreated or improperly treated on-site wastewater

Certain older or inadequate on-site septic systems can be a source of pathogens to surface and ground waters. There are a number of historic villages in Vermont found adjacent to rivers that do not have treatment facilities but rely on individual on-site septic systems to dispose of and treat wastewater volumes. In these village areas, older or poorly functioning on-site individual septic systems are likely the source of elevated levels of indicator pathogenic bacteria such as *E. coli*. If a system(s) is not working correctly and effluent is directly or indirectly entering surface water, swimmers or other water users may be exposed to high bacteria levels and potentially disease-causing organisms. This can happen under several conditions including when the soil below the leachfield is too shallow or too porous and leachate quickly joins the groundwater. Along a lakeshore groundwater is usually flowing toward the lake and entering lake water through the lakebed. Inadequately treated pathogen-containing effluent can also create problems when groundwater used for drinking water becomes contaminated.

DEC provides direct funding and technical assistance to small communities without sewers to help evaluate and plan for their wastewater needs. It is anticipated there will be a steady demand by several small communities for wastewater planning in the coming years. Many of these communities have not been identified in the past as being sources of NPS pollution but residents are now realizing there may be problems with small lots and older sewage disposal systems. Another factor is the economic viability of small communities which may be restricted in commercial or residential growth due to limiting soil conditions for septic system leachfields.

How important is managing pathogens?

The extensiveness of NPS pathogenic impacts varies depending on geographic location and also on precipitation. For example, *E. coli* may be widely detectable in surface waters following a significant rain event, particularly in agriculturally-dominated watersheds. Conversely, in forested watersheds during low flow conditions with no precipitation, low concentrations of *E. coli* are noted. Importantly, events in the absence of both land use and climatological influences can cause exceedences in *E. coli*, such as improper or inadequate wastewater treatment from septic systems.

Generally, the more sediment runoff, the more potential for transport of *E. coli* bacteria. Controlling NPS sediment runoff can certainly go a long way towards decreasing concentrations of many pollutants, including pathogens. There could be some legacy amounts of pathogens stored in streambank or streambed sediments that can be cycled back into the water column, but these sources are difficult to detect and quantify in conventional pathogen monitoring efforts.

Based on the evaluation by DEC's Watershed Management Division, pathogenic bacteria is considered a lower-ranked stressor (in relation to the other 10 priority stressors), in that known affected areas are discrete and effects are typically localized. When addressed, NPS impacts to surface waters can be rapidly mitigated. However, where pathogens are regularly monitored and found to be chronic in frequency and excessive in numbers, drinking, swimming and other contact recreation uses can be affected.

Thermal stress

What is thermal stress and why is it a nonpoint source problem?

Aquatic organisms have evolved to function most efficiently within an optimal range of water temperature. Certain invertebrates (e.g., stoneflies, caddisflies) and cold-water adapted fish species (brook trout, Atlantic salmon, slimy sculpin) require cold water to support all life stages. Thermal stress is a term to describe a temperature change that is severe enough to cause unfavorable and even lethal conditions to aquatic organisms, their populations, community structure, or ecosystem. Water temperature in rivers and streams does vary by season, over the course of a day, and along the length of a river. However, certain land uses, human activities and NPS discharges, and the physical condition of the aquatic ecosystem can influence water temperatures beyond natural variation to cause thermal stress. Moreover, one of the anticipated impacts of climate change is an increase in ambient air temperatures that could influence water temperature to a point of exceeding incipient lethal limits for some cold-water dependent species. It is therefore extremely important to manage NPS activities on the landscape and control their discharges to reduce their contribution to increased temperature stress.

The impacts of temperature on aquatic habitat are far-reaching, making changes in temperature one of the most influential stressors to aquatic habitat. Increased water temperature can be a physical, biological, or chemical stressor. Physically, higher water temperatures reduce levels of dissolved oxygen, potentially creating a condition of hypoxia. Low oxygen levels can kill or affect species' life cycle functions and can reduce species diversity and population sizes.

Biologically, higher water temperatures directly affect the metabolic rates of aquatic biota, disrupt their life cycle thermal cues, and have an impact on their capacity to resist disease. Certain cold water aquatic macro-invertebrate species will be displaced. Higher water temperatures, coupled with sunlight and nutrients, create more favorable conditions for plant and algae growth and can also result in blooms of microbial populations such as cyanobacteria, which can be toxic to humans and animals. Higher temperatures can also cause E. coli populations to increase and remain viable for longer periods within a stream, causing an increased risk to recreational users. In extreme situations, extensive aquatic plant growth in lakes and ponds can result in critically low oxygen levels at night when photosynthesis stops, and respiration rates increase the biological demand for oxygen (BOD) that further depletes oxygen levels in water.

Chemically, higher water temperatures can alter concentrations of substances which can have an impact on the ability of fish to withstand chemical exposure. Such impacts can also affect recreational uses and public enjoyment of surface waters. Climate change is resulting in shorter ice coverage seasons on many lakes and increased summer water temperatures. The full effects of changes in climate are not completely understood.

How important is managing thermal stress?

Based on the evaluation by DEC's Watershed Management Division, thermal stress is an important stressor. While excessively high temperatures impair a relatively small number of Vermont stream miles, the impacts in those locations are significant. The potential for thermal stress in waterbodies across the state is high, since over 60% of Vermont's streams are small, cold water habitats. In many instances, thermal stress occurs in concert with other stresses to compound the effects on aquatic organisms, particularly those intolerant of elevated temperatures even if for only a brief period of time.

Toxic substances

What are toxic substances and why are they a nonpoint source problem?

Toxic substances can be defined as broad group of chemicals capable of causing harm to plants and animals including humans. There are several classes of toxic substances that have the potential to affect surface or ground waters within Vermont. While many Vermonters are aware that toxic mercury contaminates fish and fish-eating wildlife, there are many other types of toxic compounds that merit attention. For the purposes DEC's Vermont Surface Water Management Strategy, toxic compounds have been grouped into five categories: atmospherically-deposited compounds; organic and inorganic contaminants resulting from industrial, manufacturing or other facilities; pesticides/herbicides; contaminants of emerging concern (CECs); and biological contaminants. These groupings reflect the commonality of management options that are applied to address each contaminant group.

Mercury is the most well-known atmospherically-deposited contaminant. Mercury, a heavy metal, is emitted to the atmosphere by a wide variety of emissions sources and is readily bio-accumulated to hazardous levels in fish and fish-eating wildlife. Mercury contamination has been widely studied in Vermont and New England as well as other regions of the country. The Vermont Department of Health has issued a fish consumption advisory due to elevated mercury in fish tissue (see Appendix ##). Other heavy metals (such as cadmium or vanadium) and certain "organic" contaminants (such as pesticides or dioxins) can also be atmospherically-deposited, although very few instances of this type of contamination have been documented in Vermont.

Organic and inorganic contaminants from municipal and industrial discharges, hazardous waste sites, landfills or stormwater runoff comprise a wide variety of toxic constituents. Historically, compounds such as PCBs, or furans and dioxins were used in a variety of manufacturing applications. Since these compounds are now banned from use their presence/abundance only exist as "legacy" contaminants. Metals have also regularly been used in manufacturing and historically were commonly released to the environment. Facilities that store, distribute, or sell fuels may be sources of polycyclic aromatic hydrocarbons, which can contaminate groundwater and sediment. Mining is another source of metals that has localized effects in Vermont. Federal and State legislation and associated programs have or are addressing these sources in Vermont to a large degree, although legacy contamination persists in localized areas. Road maintenance can result in discharges of toxic pollutants such as chloride and hydrocarbons to surface and ground waters.

Pesticides are regularly used in Vermont, subject to regulation jointly by the Vermont Agency of Agriculture, Food and Markets and DEC with assistance from Department of Health. The largest regulated usage of pesticides is in the agricultural sector with lesser degrees of usage in conjunction with industrial cooling towers and in smaller land uses, such as golf courses, urban grounds maintenance, railroad and utility corridors, roadside guardrail maintenance, aquatic nuisance control, and forestry. The largest category of un-regulated pesticide use is among private applicators and homeowners who apply herbicides, insecticides, and fungicides to lawns, gardens and home. There is minimal to no reporting or tracking for private applicators and homeowner use and sales, even though it is believed this constitutes a significant portion of pesticides used in Vermont.

The use of traditional herbicides such as Atrazine has declined somewhat in recent years, in favor of newer or other compounds having much lower recommended application rates, more targeted toxicity, and faster environmental degradation times. This means that these alternative compounds are not as readily released to waters, are thought to have lesser impacts, and may degrade faster. Limited assessment and research is available on the effects of these new pesticides on aquatic life.

Contaminants of Emerging Concern (CEC) are a group of mostly un-monitored and un-regulated chemicals whose potential to impact the beneficial uses of surface and ground water resources is largely unknown. CECs, which include pharmaceuticals and personal care products (PPCP), polybrominated diphenyl ethers (PBDEs), veterinary drugs, and industrial and household compounds have been found at trace levels in wastewater discharges, ambient receiving waters, and drinking water supplies. They are pollutants not currently included in routine monitoring programs. PPCPs comprise a diverse group of chemicals including prescription and over-the-counter human drugs, fragrances, sunscreens, and anti-microbials. CECs from pharmaceuticals, anti-bacterial agents, detergents and cleaning products, personal care products such as soaps, shampoo, sunscreen, cosmetics, insect repellants and others, have been documented in Lake Champlain's tributaries, wastewater, and combined sewer overflows. Makers and users of this family of chemicals are the sources of and solutions to this issue.

How important is managing toxic substances?

Based on the evaluation by DEC's Watershed Management Division, toxic substances comprise a moderately ranked stressor. The extensiveness of toxic substances impacts varies depending on the group of compound. For example, mercury contamination is widespread in Vermont. A statistical survey indicates that 25% of lakes in Vermont may exhibit mercury levels in standard-sized yellow perch in excess of EPA guidelines. The most recent statewide water quality assessment indicates that 8,165 lake acres and 67 stream miles are identified as impaired due to mercury. Known areas of PCB contamination of fish or sediment are limited to certain areas within Lake Champlain and a short list of contaminated sites. Metals create known impairments in about 100 miles of stream and create stress on an additional 137 miles. Metals have not been documented to impact lakes. Only a few studies have been carried out in Vermont to investigate CECs, most notably in the Lake Champlain Basin. However, a national study by USGS of 139 streams from across the country found one or more of the 95 chemicals for which they sampled in 80 percent of the streams. Of the 95 chemicals, only 14 have drinking water standards or other human health or ecological health criteria. No specific research has been done to investigate the potential biological response to emerging contaminants in Vermont. The occurrence of cyanobacteria and associated cyanotoxins is well documented in areas of Lake Champlain and to a lesser degree in Lake Memphremagog. A few other Vermont inland lakes (Lakes Carmi, Elmore, Iroquois) are also known to exhibit a few instances of recurring cyanobacteria blooms.

The intensity of impact also varies by contaminant and whether the toxic substance bio-accumulates or not. Exposure of biota to toxic compounds may be termed acute (where the toxicity impact is immediate and severe) or chronic (where low-level continual exposure elicits a milder and longer-term response). New science also suggests that although low levels of some contaminants may not have detectable toxic responses to biota, the synergistic effects of exposure to multiple low-level compounds simultaneously may have profound impacts.

The duration of effect also varies by contaminant. For some toxic contaminants, such as active metals releases or gasoline spills, the duration of toxic effects may be relatively short because the effects are reduced or eliminated when a fuel spill is addressed or a release of metals is eliminated. In contrast, certain organic contaminants like dioxins or PCBs will immediately contaminate sediments and create long-term toxicity to species that live in sediments or that rely on sediment-dwelling species for their food source. Mercury is intermediate in the duration of effects. In areas where meaningful controls have been implemented, mercury levels in fish and wildlife of nearby ponds has declined in a few years. The complete control of mercury, however, is a long-term proposition owing to the global distribution of mercury.

Management strategies are in place within Vermont to address many of the toxic contaminants and, therefore, the urgency of threat posed by most toxic contaminants is lower than some of the other stressors affecting Vermont waters. On the other hand, emerging contaminants, due to the prevalence of sources and many unknowns associated with distribution, toxicity, and synergistic effects have a high urgency relative to other toxic substances.