Final Report

of the

Ecosystems Work Group

of the

New York State Department of Environmental Conservation
Comparative Risk Project

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Disclaimer of the Ecosystems Work Group

This report presents the results of an evaluation of the effects of 14 groups of stressors on the ecosystems of New York State. It **DOES NOT** represent all stresses on the environment, some of which may be of equal or greater ecological significance than those considered in this report.

The results of this report are intended to guide pollution prevention strategies only, and not to constrain other programs directed at the conservation of natural resources, ecosystems, or biological diversity.

Executive Summary

During 1997, the Ecosystems Work Group of the Comparative Risk Project evaluated, characterized, and compared the risks associated with the release of 14 groups of chemicals and pollutants, referred to as stressor groups, into the ecosystems of New York.

The Work Group developed four ranking criteria to evaluate the stressor groups: severity of effects, reversibility of effects, ecological significance, and geographic scale. The Work Group also assessed impacts on the following types of ecosystems: oceans and bays; estuaries and tidal wetlands; freshwater wetlands; streams and rivers; lakes and ponds; uplands, including forests; agricultural areas; and urban and suburban areas. The following ecological regions of the state were considered in evaluating effects of the stressor groups: Lake Plains, Appalachian Highlands, Adirondacks and Northern New York, Catskill Mountains, Hudson-Mohawk Valleys, and New York Metropolitan Area and Long Island. In characterizing the effects of the stressor groups, the Work Group asked the following questions:

- What stressors are included in the group?
- What do they do ecologically?
- What are the important sources and pathways of the stressor?
- What systems or species/organisms are particularly sensitive or affected?

Stressor groups were researched and evaluated, and relative rankings ascribed to each group. The Work Group jointly reviewed draft documents and came to agreement on rankings for each stressor group. Results are aggregated as follows, listed alphabetically within categories:

Stressor Groups of High Ecological Concern (Ranked as A)
Atmospheric gases
Non-volatile halogenated organic compounds
Nutrients
Suspended and settleable solids

Stressor Groups of Medium Ecological Concern (Ranked as B)
Metals and cyanide
Pesticides
Petroleum Products
Polynuclear aromatic hydrocarbons
Non-volatile and semi-volatile organic compounds

Stressor Groups of Low Ecological Concern (Ranked as C)
Acidic and alkaline substances
Halogens
Particulates
Radionuclides
Volatile organic compounds

I. Introduction

A. Project Description and Charge to the Work Group

The purpose of the Comparative Risk Project is to evaluate, characterize, and compare the risks associated with releases to the environment of substances that have the potential to harm human health or the environment of New York State, taking into account both scientific data and public values; and to recommend a strategy for reducing those risks through the multimedia pollution prevention program of the New York State Department of Environmental Conservation.

The Ecosystems Work Group was asked to evaluate, characterize, and compare risks to and relevant effects on the ecosystems that exist throughout New York State. The health and preservation of the plants, animals, and aquatic and terrestrial landscapes that make up the ecosystems, as well as ecosystem processes, were to be considered. Use of ecosystems by humans and risk to human health that results from ecosystem damage were not part of the analysis. (See Appendix A.)

II. Methods and Materials

A. General Approach

The composition of the Ecosystems Work Group (hereafter referred to as the Work Group) was established by DEC's Pollution Prevention Unit and was endorsed by the Steering Committee. The Work Group consisted of individuals with an array of backgrounds and, cumulatively, considerable expertise in ecotoxicology and ecosystems (Appendix B). The Work Group did not, however, have in-depth technical expertise in every one of the stressor groups and relied on research findings, group discussion, and professional judgement in the decision making process.

The Work Group met monthly in Albany from December 1996 to October 1997, had conference call meetings in November 1997 and February 1998, and held a concluding meeting in March 1998. At these meetings, the Work Group determined the approach it would take in implementing its charge, developed criteria, assigned and reviewed work products, and reached agreement on conclusions. Work Group Methods for Analysis were provided by the Steering Committee (Appendix C), and the Work Group operated comfortably and efficiently together.

B. Stressor Groups

The list of stressor groups was provided by the Steering Committee to the Work Group and was the limit of consideration for the project. Appendix D contains the final Environmental Problem List as adopted by the Steering Committee. It contains the list of stressors that are released into the environment, grouped into chemical categories. The list of 14 stressor groups includes (listed alphabetically):

- Acidic and Alkaline Substances
- Atmospheric Gases
- Halogens
- Metals and Cyanide
- Non-volatile Halogenated Organic Compounds
- Non-volatile and Semi-volatile Organic Compounds
- Nutrients
- Particulates
- Pesticides
- Petroleum Products
- Polynuclear Aromatic Hydrocarbons
- Radionuclides
- Suspended and Settleable Solids
- Volatile Organic Compounds

The list was developed with input from the Work Group and includes a number of stressor groups specifically requested by the Work Group, such as nutrients and suspended and settleable solids.

C. Ranking Criteria

The Work Group drew upon the expertise of and experiences in other states in developing the criteria by which the 14 stressor groups would be evaluated and ranked. The Work Group reviewed ranking criteria used in other ecological comparative risk projects, identified common issues and refined those criteria for application in New York's Comparative Risk Project. Recommendations from the Western Center for Comparative Risk (1996) and, in particular, California's ranking criteria, were useful in guiding development of criteria for this project.

The Work Group initially drafted four criteria with five rating categories for each criterion. This format was reviewed by the Steering Committee, and although few comments were provided on the content, the Steering Committee asked the Work Group to reduce the rating categories to three (A, B, and C). A subsequent iteration was approved and used in initial assessments of the stressor groups. However, upon application, two clarifications were needed to emphasize that evaluations are based on current releases and assess actual current impacts to the ecosystems in the state. Appendix E presents the ranking criteria as used in final assessment and ranking of the stressor groups. In summary, the four criteria are:

Criterion 1. Severity of Effect
Criterion 2. Reversibility of Effect
Criterion 3. Ecological Significance
Criterion 4. Geographic Scale

D. Ecosystems and Ecozones

Unlike human risk assessment, where effects on individual people might be considered, the evaluation of ecological risks focuses not just on individual plants or animals, but on broader systems of interacting organisms. While some stressors might have acute, lethal effects on an individual animal, they may not affect the whole population or system. Conversely, a stressor might not have acute, lethal effects on any individual organism, but may adversely affect ecosystem processes or the viability of whole populations.

The Work Group invested considerable time discussing the level at which effects would be considered, and what would be meant by "ecosystem." The Work Group agreed that in addition to individual organisms, it was concerned with the processes that drive ecosystems, such as biogeochemical cycling and energy flow. The Work Group also recognized a hierarchy of biological organization, from the individual level, through populations and communities to ecosystem and landscape levels. This distinction was reflected in evaluation criteria and in the presentation of results. For the purposes of this project, the Work Group agreed on the following definition of ecosystem:

"An ecosystem is the combination of abiotic physical and chemical environments, and the biotic assemblage of plants, animals, and microbes, and their interrelationships, structure, functions, and dynamics."

The Work Group also recognized that not all stressor groups will affect all ecosystems in the same way. For example, suspended or settleable solids have direct significant impacts in aquatic communities, but are an issue in terrestrial ecosystems only as risk cascades (Suter 1994) when the particles impose changes in the aquatic productivity as used by terrestrial organisms. In addition, implementing pollution prevention strategies might be very different for problems in coastal estuaries as contrasted with Adirondack forests. For the purposes of characterizing, evaluating and ranking the effects of the stressor groups on the ecosystems of New York, the Work Group identified the following ecosystems:

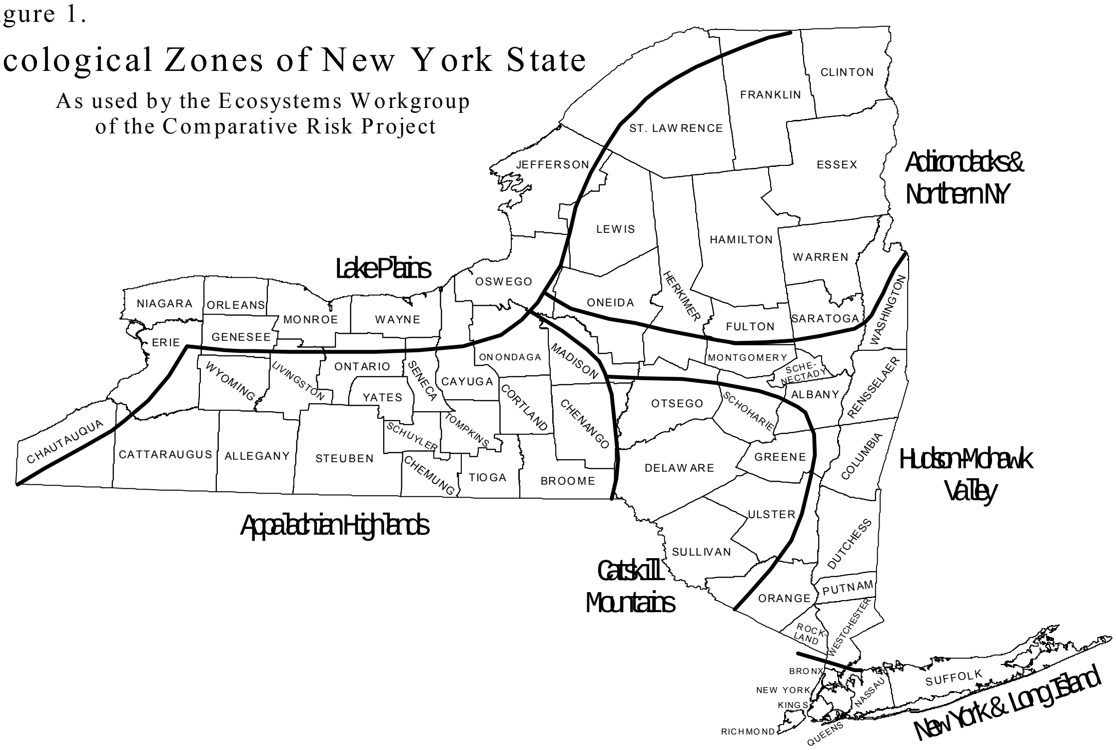
- Oceans and bays
- Estuaries and tidal wetlands
- Freshwater wetlands
- Lotic aquatic communities, such as streams and rivers
- Lentic aquatic communities, such as lakes and ponds
- Uplands, including forests
- Agricultural areas
- Urban and suburban residentially developed areas

New York clearly is a large and diverse state, and its climate, hydrology, geography, topography, geology, and other variables affect how ecosystems manifest themselves across the state. Forests in northern New York are different from those on Long Island, and the stressor groups considered in this project affect those forests differently. In addition, discharges of chemicals in the various stressor groups are not equally distributed, nor are their effects. Therefore the Work Group identified six ecological zones of the state for characterizing, evaluating, and ranking the stressor groups (Figure 1). These zones are a simplification of various ecological zones proposed for the state (O'Connor and Cole 1989).

Figure 1.

Ecological Zones of New York State

As used by the Ecosystems Workgroup of the Comparative Risk Project



Judy Marth Stevens, NYSDEC Bureau of Habitat, Dec '97.

E. Stressor Group Evaluations

The Work Group identified a lead person for each stressor group (Table 1), with up to two people assisting in researching and drafting each of the stressor group reports. In addition, staff from DEC were available for and often provided technical support. The lead person defined and clarified the stressor group and prepared a characterization statement that explains the following four issues:

1. What stressors are included? This section explains what specific chemicals or groups of chemicals are included in the stressor group and elaborates on the nature of the stressor group as it relates to ecosystems. This section provides more detail and depth than is provided with the Problem List supplied to the Work Group by the Steering Committee.

2. What do they do ecologically? This is an important section of the characterization statement because it explains the ecological implications of the stressor group. This section explains the nature and severity of the effects of the stressor groups on ecosystems or populations and is the basis for subsequent rankings and evaluations.

3. What are the important sources and pathways of this stressor? This section focuses primarily on sources and pathways that are relevant for evaluating impacts associated with a stressor group. Not all sources of a stressor are identified, but an effort was made to distinguish those that might serve as means for significant risk reduction.

4. What system or species/organisms are particularly sensitive or affected? This section is used to highlight particular ecological problems associated with a stressor group, such as vulnerable populations being affected.

Table 1. Lead Person for Each Stressor Group

Stressor Group	Group Leader
Acidic and alkaline substances	Edward Horn
Atmospheric gases	Susan Olson
Halogens	Richard Rutkowski
Metals and cyanide	John Hickey
Non-volatile halogenated organic compounds	James Gillett
Non-volatile and semi-volatile organic compounds	James Gillett
Nutrients	Gary Neuderfer
Particulates	Mark Sengenberger
Pesticides	Margaret Novak
Petroleum products	John Hickey
Polynuclear aromatic hydrocarbons (PAHs)	Margaret Novak
Radionuclides	Dennis Dunning
Suspended and settleable solids	Gary Neuderfer
Volatile organic compounds (VOCs)	Sarah Meyland, Timothy Sinnott, Patricia Riexinger

After the characterization statements were completed and discussed, the group leader completed the research on the stressor group, analyzed the findings, and evaluated the stressor group according to the four criteria. It is important to note that the group leaders did not critically evaluate the literature used in the report, but accepted the findings as presented in the literature. All sources of information were used, including professional literature, governmental and academic agency reports and databases, compilations available on the Internet, personal communication with professional colleagues, and personal expertise.

A final ranking was proposed based on the ranking for each of the four criteria, along with overall best professional judgement of the stressor group leader and Work Group. For example, radionuclides received two C's, one A, and one B, and was assigned a final rank of C because even though releases occur in all ecological regions (A rank) and are fairly persistent (B rank), releases are very localized and not pervasive in the environment and, overall, have presented very little demonstrable ecological threat in numerous studies, *especially when compared to the other 13 stressor groups.* The Work Group did not determine final rankings by weighting the ranking of any one criterion. Instead, the Work Group members used judgement, group process, and professional expertise to determine the final rankings, with a view to guiding priorities of future risk reduction efforts. This is consistent with guidance provided by the Western Center for Comparative Risk (1996): In undertaking the final phase of a comparative ecological risk assessment, professional judgement plays a critical role, but the level of precision required is only enough to make a rough relative comparison, rather than absolute estimates of risk. USEPA (1993) also recognizes this reality of ecological risk assessment:

> "A comparative ecological risk assessment applies the principles of risk assessment to available data, supplemented by best professional judgement, to rank the relative risks of significant environmental "problem areas." Problem areas are evaluated and ranked in terms of a set of criteria that reflect environmental values that society is most concerned about and/or best scientific information and professional judgement about ecological integrity."

The stressor group leader then compiled a draft report that included the revised characterization statement along with the proposed rankings and the attendant rationale for those rankings. The Work Group reviewed the report, and the final rankings were determined based on a discussion of the research findings as presented in the report. The group discussed the report, raised issues or concerns, and resolved questions. This dialogue resulted in a clarification of the ecological problems and threats. Final rankings were frequently modified to reflect the elucidation provided by the dialogue.

Part III. Issues and Constraints

A. The Stressors Evaluated

The scope of this project and the results presented in this report are limited solely to the list of stressor groups provided by the Steering Committee to the Work Group. However, this project and report do not address all the stresses on New York's ecosystems. There are many other stresses that may be of equal or greater ecological significance than those considered in this report. In fact, the Western Center for Comparative Risk (1996) lists an array of ecological stressors considered in other states as part of ecological risk assessments. These included: grazing, agriculture, energy production, road construction, fire suppression, mining, timber management, water resource management, channelization, climate change, non-point source pollution, exotic species, earth moving, erosion, and other forms of habitat alteration. U.S. EPA Region II, which includes New York State, undertook a comparative risk assessment and concluded that the two highest ranked problems dealt with the effects of land use on habitats (USEPA 1991). Their assessment was based on a list that also included nonpoint source pollution, dredging, hazardous waste disposal, mobile air pollution sources, and ozone depletion.

Therefore, the Work Group submits this report with caution about its use and the interpretation of the results. These results are intended to guide DEC's pollution prevention strategies *only*, and should not be used as justification for constraining other programs directed at the conservation of natural resources, ecosystems, or biological diversity.

B. The Approach Used

This effort is part of a Comparative Risk Project for the purpose of risk reduction in DEC's Pollution Prevention Unit. The approach used in this project is *not* a formal ecological risk assessment as described by EPA (1996, 1997), nor does it conform to "ecological risk assessment" as discussed in some of the literature. Instead, this project reviewed and evaluated available data on groups of chemicals according to four criteria and six ecological regions of the state. Results were presented according to three generic, non-numeric rankings, by ecological zone, and by ecosystem types in the state. While not formal risk assessment, this project was a very useful exercise in amassing and considering the effects of groups of chemicals on the ecosystems of the state; it is a major step forward from ignoring ecological risk altogether. Furthermore, the exercise emphasizes the importance and the health and ecological benefits of risk reductions and it facilitates identifying commonalities between ecological, human health, and quality of life risks.

C. The Importance of Ecosystems

Daily (1997) identifies a list of ecosystem services "that earthlings take for granted": purification of air and water, mitigation of floods and droughts, detoxification and decomposition of wastes, generation and renewal of soil and soil fertility, pollination of crops and natural vegetation, control of the vast majority of potential agricultural pests, dispersal of seeds and translocation of nutrients, maintenance of biodiversity, protection from the sun's harmful ultraviolet rays, partial stabilization of climate, moderation of temperature extremes and the force of winds and waves, support of diverse human cultures, and providing of aesthetic beauty and intellectual stimulation that lifts the human spirit. "Ecosystem services are generated by a complex of natural cycles, driven by solar energy, that constitute the workings of the biosphere" (Daily 1997). While "pervasive," these processes and services are virtually unnoticed by humans. They also are complex beyond the capacity of human understanding. "Ecologists have only recently begun to investigate the functional role of biodiversity at all levels, from genes to species, communities, ecosystems, and landscapes. Although the field is young, clearly organisms have profound effects on the ecological processes that supply human beings with food, water, energy, clean air, and other services. It is not just the numbers of species, but their identity, locations, and interactions that are key to the workings of the earth's life-support systems" (Baskin 1997).

The Work Group, therefore, submits that protecting ecological structure and function and overall biological diversity is critical to the long-term health of humans.

D. The Timing of the Assessments

The Work Group emphasizes that all assessments and rankings are based on current residual releases into the environment of the state and our understanding of those releases. As releases change over time, the subsequent level of concern also might change, as it has for pesticides in the past. If new release patterns should emerge without abatement, or if our understanding about the magnitude of a release changes, certain stressor groups might be considered a higher risk and would very likely be elevated as a stressor group of concern.

Acknowledgements

The Work Group would like to thank Sharon Rehder, of DEC's Pollution Prevention Unit, for serving as liaison between the Steering Committee and the Work Group. Special thanks also go to Dr. Ben Wodi, of SUNY Cortland, who assisted Dr. Hickey considerably with preparation of the section on Metals and Cyanide and to Timothy Sinnott, of DEC's Bureau of Habitat, Ecotoxicology Section, who provided invaluable assistance in revising and completing the section on Volatile Organic Compounds.

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IV. Risk Assessment

A. Final Comparative Risk Summary Tables

Table 2. Summary of Ecological Risk for Each Stressor Group.

Stressor Groups	**Criterion 1** Severity of Effect	**Criterion 2** Reversibility of Effect	**Criterion 3** Ecological Significance	**Criterion 4** Geographic Scale	**Final Rating**
Acidic and alkaline substances	B	B	C	C	C
Atmospheric gases	A	A	A	B	A
Halogens	C	B	C	A	C
Metals and cyanide	B	A	B	A	B
Non-volatile halogenated organic compounds	A	A	A	A	A
Non-volatile and semi-volatile organic compounds	B	B	C	B	B
Nutrients	A	B	A	A	A
Particulates	C	C	C	A	C
Pesticides	B	B	B	A	B
Petroleum products	B	B	B	A	B
Polynuclear aromatic hydrocarbons (PAHs)	B	B	C	A	B
Radionuclides	C	B	C	A	C
Suspended and settleable solids	A	B	A	A	A
Volatile organic compounds (VOCs)	C	C	C	B	C

Table 3. Summary of New York State Ecoregions Affected by Each Stressor Group.

<table>
<tr><th rowspan="2">Stressor Groups</th><th colspan="6">Ecological Zones</th></tr>
<tr><th>Lake Plains</th><th>Appalachian Highlands</th><th>Adirondack and Northern Forests</th><th>Hudson Mohawk Valley</th><th>Catskill Mountains</th><th>New York and Long Island</th></tr>
<tr><td>Acidic and alkaline substances</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Atmospheric gases</td><td colspan="2">Foliar damage</td><td>Acid deposition causes forest and aquatic ecosystem damage</td><td>Acid deposition affects crops</td><td>Acid deposition causes forest and aquatic ecosystem damage</td><td>Acid deposition and ozone affects crops</td></tr>
<tr><td>Halogens</td><td colspan="6">Total residual chlorine is discharged from wastewater treatment plants to aquatic ecosystems in every ecological zone</td></tr>
<tr><td rowspan="2">Metals and cyanide</td><td colspan="6">Wastewater treatment plant discharges account for 40-60% of all metal pollution. Urban areas account for 10-40%. About 5% of metal pollution is airborne. Larger population centers in NYS produce and concentrate most metal pollution</td></tr>
<tr><td>Metals are higher near industrialized rivers, such as the Buffalo, Niagara, and Genesee. Onondaga Lake has high concentrations of metals. Cash crop farms and orchards also tend to accumulate metals from some pesticides</td><td>Localized metals pollution from hazardous waste sites, wastewater treatment plants, and industrial and urban areas</td><td>Airborne pollutants, especially mercury, are a significant problem</td><td>Metals levels are elevated in this developed, heavily populated transportation corridor. Localized hot spots of metals pollution also exist in this area.</td><td>Localized metals pollution in developed areas</td><td>Heavily populated and industrialized areas such as these concentrate metals pollution. New York Harbor area has elevated metals levels.</td></tr>
<tr><td>Non-volatile halogenated organic compounds</td><td>High impacts on fish-eating animals, raptors, fish</td><td>Few problems noted</td><td>Some impacts on birds of prey</td><td>Bioaccumulation on fish and raptors is most severe</td><td>Few problems are as extensive as suppression of birds of prey</td><td>Another highly impacted area; affects both resident and migratory birds of prey</td></tr>
</table>

Stressor Groups	Ecological Zones					
	Lake Plains	Appalachian Highlands	Adirondack and Northern Forests	Hudson Mohawk Valley	Catskill Mountains	New York and Long Island
Non-volatile and sem-volatile organic compounds	Releases very high in Genesee, Niagara, Oswego, and Seneca Rivers; local problems by some of the heaviest releases in the state	Significantly less releases in Susquehanna River system	Few releases	High releases, somewhat reduced	Few releases	Releases significantly less than in some other ecoregions, reduced from past, and declining problem
	Regional variations not well suited to distinction because of less well defined nature of the problems caused and by the widespread and extensive nature of the end-user inputs of SVOCs. Waste sites (primarily old landfills) with SVOC leakage are located in all regions, as are end-user inputs.					
Nutrients	Aquatic and marine ecosystems are affected by nutrients from point and non-point discharges across all ecoregions					
Particulates	Terrestrial ecosystems are locally affected downwind of particulate sources across all ecoregions. Particulates may also contribute to acid rain, ozone depletion, and global warming, although not well understood.					
Pesticides	Agriculture with runoff during rains and spring snow melt; urban and residential applications	Agriculture with runoff during rains and spring snow melt	Effects probably limited, but pesticides are used in forest situations, eg: aerial spraying for mosquitoes, black flies; herbicides applied to roadways	Intensive agriculture with runoff during rains and spring snow melt; numerous pesticides measured in water column samples in rivers and tributaries	Effects probably limited, but pesticides used in forest situations can contribute; herbicides applied to roadways can contribute	Urban and residential applications

Stressor Groups	Ecological Zones					
	Lake Plains	Appalachian Highlands	Adirondack and Northern Forests	Hudson Mohawk Valley	Catskill Mountains	New York and Long Island
Petroleum products	Pollution from petroleum products is present in all developed areas of the state. Chronic effects exist from point source, non-point source, and accidental discharges (oil spills) of a wide variety of petroleum products.					
	Petroleum related pollution is greater in waterways near urbanized and industrialized areas. Transportation corridors and especially waterborne transportation areas including Buffalo, Rochester, Oswego and St. Lawrence Seaway have the added threat of oil spills	Discharges from oil wells in the Allegheny region result in chronic toxicity to aquatic organisms.	Petroleum pollution and the threat of oil spills is lessened in these areas of lower human population density and development.	The major transportation corridor is oil spill prone. Its urban and other developed areas are associated with increased discharges and chronic effects of petroleum products. This area and NYC account for 60% of the oil spills in the state.	Petroleum pollution and the threat of oil spills is lessened in these areas of lower human population density and development	The high levels of urbanization, industrialization, and waterborne commerce are associated with high levels of petroleum products in the environment. This area and the lower Hudson account for 60% of the oil spills in the state.
Polynuclear aromatic hydrocarbons (PAHs)	Intensive industry in upstate metropolitan areas (Buffalo, Rochester), auto emissions	Industrial and urban sources	Effects probably less than in other ecological zones; however, air emissions and airborne transport can contribute to PAHs in these zones; transportation spills of petroleum products will release PAHs into environment			Intensive industry, engine emissions; petroleum refining (some out of state); PAHs found in invertebrate tissues in NY harbor area
Radionuclides	Problems have not been documented in the state.					
Suspended and settleable solids	Aquatic and marine ecosystems are affected by nutrients from point and non-point discharges across all ecoregions.					
Volatile organic compounds (VOCs)						

Table 4. Summary of Ecosystem Types Affected by Each Stressor Group.

Stressor Groups	Ecosystem Types							
	Marine		Freshwater			Terrestrial		
	Oceans and Bays	Estuaries and Tidal Wetlands	Wetlands	Ponds and Lakes	Streams and Rivers	Uplands, including Forests	Agricultural Areas	Urban and Residential Areas
Acidic and alkaline substances								
Atmospheric gases			Acid deposition affects those with little buffering capacity, alters water chemistry, and causes releases of mercury and aluminum, which are toxic to aquatic and avian species			Acid deposition affects trees; leaches metals, minerals and nutrients from soils; reduces litter decomposition rate	Ozone and acid deposition damages crops	Acid deposition affects trees; leaches metals, minerals and nutrients from soils; reduces litter decomposition rate
Halogens	Potential exists for effects to all freshwater and marine ecosystems from spills, but present regulatory system minimizes impacts from permitted discharges					Potential for localized effects from spills		
Metals and cyanide	Being so widespread throughout the state, metals affect all ecosystem types. As the vast majority of metal pollution enters the environment from wastewater treatment facilities and from urban runoff, aquatic ecosystems are at the most risk							
	Since NYC and Long Island tend to have higher metal levels, the oceans and bays that are at risk from metals concentrations	The Hudson River estuary has elevated metal levels as does the NY Harbor and surrounding areas.	Localized metal pollution from hazardous waste sites and developed areas may contaminate this ecosystem type.	Mercury is elevated in many Adirondack ponds and lakes to the extent that levels in fish resulted in consumption advisories.	Urban and industrialized rivers such as the Buffalo, Niagara, Genesee, and Hudson Rivers have elevated metals levels.	Airborne sources contribute to overall metals contamination in these areas.	Pesticides that contain metals such as arsenic, when used in these areas can result in elevated levels.	Developed areas tend to display higher metals levels than less developed areas.

Stressor Groups	Ecosystem Types							
	Marine		Freshwater			Terrestrial		
	Oceans and Bays	Estuaries and Tidal Wetlands	Wetlands	Ponds and Lakes	Streams and Rivers	Uplands, including Forests	Agricultural Areas	Urban and Residential Areas
Non-volatile halogenated organic compounds	Many severe effects on fish-eating animals, contamination of foodweb via sediment in particular.		Recycling of materials from land and sediment via foodweb presents exposure of entire community and vulnerability to reproductive efforts is shown.			Impacts less severe to habitat but many species affected.	Residual levels continue to be problematic.	Serious problems from earlier urban pest control, industrial uses.
Non-volatile and semi-volatile organic compounds	Probably protected more by dilution than other deliberate efforts.	Probably vulnerable as a collecting point for watersheds.	May be sinks, an important place of biodegradation for natural and anthropogenic compounds in surface runoff.	Vulnerable, especially when small and with low throughput.		May receive some SVOCs from airshed, but many similar natural chemicals are already present and handled successfully.	Inputs associated with pesticides, as "inactive" ingredients, appear to be handled well, but may contribute to runoff to wetlands and lotic systems. Use as enhancing agents in pesticide formulations makes field observations difficult.	Certainly high source areas and potentially impacted locally, many unabated end uses of products, spills and releases, but no particular problems identified.
	Moderate exposure and weakly expressed effects on invertebrates and fish.			Releases by waste treatment facilities (industrial and municipal) still biggest threat, especially with COD, BOD levels.				
Nutrients	Point and non-point sources of nutrients change community structure and cause oxygen depletion in all marine and freshwater ecosystem types.					Effects not well documented.		
Particulates	Effects not well documented.					Effects tend to be localized to plants and wildlife at sites downwind of the particulate sources.		

Stressor Groups	Ecosystem Types							
	Marine		Freshwater			Terrestrial		
	Oceans and Bays	Estuaries and Tidal Wetlands	Wetlands	Ponds and Lakes	Streams and Rivers	Uplands, including Forests	Agricultural Areas	Urban and Residential Areas
Pesticides	Runoff from agricultural and/or urban-residential applications during rain events or spring snow melt, causing direct mortality of exposed sensitive species (plants and animals), and subsequent alteration of community composition as tolerant or unexposed species become dominant in an ecosystem.					Direct mortality on non-target organisms in the application areas (either plants or animals); drift from application areas causing death to or sub-lethal effects on non-target species (either plant or animal); subsequent shifts in community composition of these affected areas.		

Stressor Groups	Ecosystem Types							
	Marine		Freshwater			Terrestrial		
	Oceans and Bays	Estuaries and Tidal Wetlands	Wetlands	Ponds and Lakes	Streams and Rivers	Uplands, including Forests	Agricultural Areas	Urban and Residential Areas
Petroleum products	Petroleum pollution is widespread in all developed areas, but the highest non-spill levels exist in urban and industrial areas. Oil spills present the greatest ecological threat to marine and freshwater harbors and transportation routes.							
	These areas are at moderate risk from spills and moderate risk from chronic non-point sources (nps).	These areas are at high risk from spills and moderate risk from chronic nps.	These areas are at moderate risk from spills and moderate risk from chronic nps.	Inland bodies in remote areas are at low risk from spills and low risk from chronic nps. Inland bodies with developed shorelines are at moderate risk from chronic nps. Lakes Erie and Ontario are at high risk from spills and moderate risk from chronic nps.	These areas are at moderate risk from spills if they are near roads and are at high risk if they are used for shipping and industry.	These areas are at low risk from spills and low risk from chronic nps.	These areas are at low risk from spills and low risk from chronic nps	These areas are at low risk from spills and moderate risk from chronic nps
Polynuclear aromatic hydrocarbons (PAHs)	Majority of PAHs entering these bodies of water remain close to sites of deposition and are concentrated around metropolitan areas.		PAHs entering these bodies of water become bound in sediments and can contribute to body burdens of benthic invertebrates; probably concentrated around urbanized areas.			Effects probably less than in other ecosystems; however, air emissions and airborne transport can contribute to PAHs in these areas; transportation spills of petroleum products will release PAHs into environment.		Industry and auto emissions contribute to releases to the environment.
Radionuclides	Problems have not been documented in the state.							

Stressor Groups	Ecosystem Types							
	Marine		Freshwater			Terrestrial		
	Oceans and Bays	Estuaries and Tidal Wetlands	Wetlands	Ponds and Lakes	Streams and Rivers	Uplands, including Forests	Agricultural Areas	Urban and Residential Areas
Suspended/settleable solids	Suspended/settleable solids from point and non-point discharges alter habitats and marine and freshwater communities					Not applicable		
Volatile organic compounds (VOCs)								

B. Characterization, Problem Analysis, and Risk Analysis for Each Stressor Group

1. Acidic and Alkaline Substances

a. Stressor Characterization

(1) What stressors are included?

This stressor group includes strong acids (e.g., hydrochloric, sulphuric, nitric, and phosphoric acids) and strong bases (e.g., sodium and potassium hydroxide). The strong acids are liquids and are used extensively in industry and commerce for a wide variety of applications. Mines can be a source of strong acids produced by leaching and microbial activity. Hydrochloric acid aerosols are produced by combustion of chlorinated hydrocarbons (e.g., polyvinyl chloride plastics), but acid precipitation is not included in this stressor group (see Atmospheric Gases). Strong bases (caustic substances) can be solids, but are often transported and usually used as concentrated solutions. They, too, are used extensively in a wide variety of industrial and commercial establishments.

(2) What do they do ecologically?

In general, extremes of pH are lethal to most organisms with some being more tolerant than others. In freshwater environments, organisms exhibit varying degrees of sensitivity to extremes of pH. Bell and Nebeker (1969) found that the tolerance to low pH of larvae of 10 species of aquatic insects varied from pH 4.65 for mayflies to 1.50 for caddisflies. These larvae were held for 96 hours in test chambers artificially acidified with hydrochloric acid and the pH at which 50% of the organisms died was reported. Fish are less tolerant of such low pHs.

Heavy metals are more soluble at low pH. Thus, particularly where chronic acidity affects aquatic communities, toxicity can occur from elevated levels of heavy metals (e.g., aluminum and manganese), or the production of fine suspended solids, where neutralization leads to the precipitation of iron or aluminum compounds.

In aquatic environments, spills of strong acids or caustic material may not completely mix with all the water in the waterbody. Areas of unaffected water (refugia) remain (e.g., upstream of a spill or discharge to a river or stream, in pockets around underwater springs), and fish move into these refugia to avoid lethal conditions. Cairns reviewed four case studies and identified the availability of recolonizing organisms as a major factor in the recovery of damaged rivers. Even when the damage has been severe and extensive, recovery is usually within a couple of years or less. (Cairns, et.al. 1971 and Herricks and Cairns 1976). However, prey populations can be affected by more intense predation in these refugia (including increased fishing success by anglers). Once adverse conditions are neutralized, surviving populations of fish may not have enough food to survive in the affected area.

(3) What are the important sources and pathways of this stressor group?

The primary sources and pathways of these stressors include:

(a) acid mine drainage,
(b) industrial discharges, and
(c) transportation (truck, barge, or rail) spills.

In New York State, acid mine drainage and industrial discharges of acidic compounds are affecting few ecosystems. Acid mine drainage from coal mines in Pennsylvania has affected water quality in the Tioga River (about 8 miles of water from the Pennsylvania line to its junction with the Canisteo River). Although macroinvertebrate populations (mostly insect larvae) appear to be in good condition, fish populations in the Tioga River "are not what they should be" (NYSDEC 1996; Bode et al. 1993). Fish populations in the 4-mile segment of Turnpike Creek upstream of its confluence with the Oswegatchie River may also be affected by mine drainage (NYSDEC 1996). Industrial discharges of acidic compounds are controlled by water quality permits from state or local governments. In New York, no ecosystems are known to be impaired by acidic or caustic industrial discharges.

In New York, spills of hazardous materials must be reported to New York State Department of Environmental Conservation or to the New York City Department of Environmental Protection. Since 1992, the New York State Department of Health has compiled data on non-petroleum spills in New York reported to these programs. In five years (1992-1996), 1,897 spills of non-petroleum hazardous substances were reported. Thus, New York is averaging about 380 non-petroleum chemical spills each year. Of the 1,897 spills, 350 (18%) were spills of acid or caustic substances with hydrochloric acid, sulphuric acid, and caustic soda (sodium hydroxide) dominating the list (303 or 87%). The largest spill over that time frame was a spill of 92,000 pounds (about 8600 gallons) of hydrofluoric and sulfuric acids. However, the median spill was only 20 gallons, and 75% of the spills were less than 100 gallons. Only 5% of the spills exceeded 1,000 gallons. (NYSDOH 1997).

(4) What systems or species/organisms are particularly sensitive or affected?

Strong acids or bases will affect poorly buffered aquatic ecosystems such as upland streams and ponds. Other aquatic ecosystems (rivers, lakes, freshwater wetlands, and even estuaries, tidal wetlands and bays) are generally well-buffered, and would only be affected if the quantities of acids or bases were quite large.

b. Analysis of Problem

(1) Severity: Rank = B

Populations can be eliminated or chronically depressed by acid mine drainage (a continuous discharge), or by frequent releases sufficient to cause mortality. Ecological diversity can be significantly reduced.

(2) Reversibility: Rank = B

Even when entire populations are eliminated, recovery is reasonably rapid, but some members of the community recover more slowly. Although insect larvae and minnow species may recover in a stream within a year or two, molluscs and predator fish species can remain depressed or absent longer.

(3) Ecological Significance: Rank = C

No areas in New York of high or moderate ecological significance are affected by strong acids or bases, recognizing that the effects of acid precipitation (see Atmospheric Gases) are not being considered in this stressor group.

(4) Geographic Scale: Rank = C

At most only a few localized areas are currently affected or threatened by this stressor in New York State.

(5) Final Ranking: Rank = C

Even though acids and bases could produce severe local effects, they are not a significant problem in New York State at this time. Continuous or frequent environmental releases have been successfully controlled or remediated. But because large quantities of these materials are used in and transported through New York, constant vigilance and attention to safety are needed to prevent accidental releases and continue the successful history of control of this environmental stressor.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Acidic and Alkaline Substances		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**B**	Populations can be eliminated or chronically depressed by acid mine drainage (a continuous discharge), or by frequent releases sufficient to cause mortality. Ecological diversity can be significantly reduced.
2. Reversibility	**B**	Even when entire populations are eliminated, recovery is reasonably rapid, but some members of the community recover more slowly. Although insect larvae and minnow species may recover in a stream within a year or two, molluscs and predator fish species can remain depressed or absent longer.
3. Eco-significance	**C**	No areas in New York of high or moderate ecological significance are affected by strong acids or bases.
4. Geo-scale	**C**	At most only a few localized areas are currently affected or threatened by this stressor in New York.
Overall Rank	**C**	Even though acids and bases could produce severe local effects, they are not a significant problem in New York at this time. Continuous or frequent environmental releases have been successfully controlled or remediated. Constant vigilance to safety is needed to prevent accidental releases.

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2. Atmospheric Gases

a. Stressor Characterization

(1) What stressors are included?

The atmospheric gases category includes nitrogen oxides (NOx, which includes NO and NO_2 taken together with NO_3 aerosol), dinitrogen oxide (N_2O), and sulfur dioxide (SO_2). These are precursors to ambient ozone (O_3), which is also included in this category. Acid rain is caused when sulfur dioxide and nitrogen oxides chemically react with other substances in the atmosphere to form acidic compounds. The single most important species in clouds and precipitation is probably the hydrogen ion, whose concentrations can be indicated by specifying the solution acidity or pH value.

Dinitrogen oxide (N_2O) is a greenhouse gas (discussed below) that is non-reactive and long lived in the lower atmosphere. Nitric oxide (NO) is a highly reactive and short-lived gas that plays critical roles in atmospheric chemical reactions, including catalyzing the formation of petrochemical smog. In the presence of sunlight, NO and oxygen react with hydrocarbons to form ozone.

This category also includes carbon monoxide (CO), which is a well-known metabolic poison that interferes with extra-cellular oxygen transportation in the blood. Both carbon monoxide and nitric oxide (NO) have been indicated as intracellular modulators of physiologic function and are toxic to birds and small animals, demonstrating the impact of atmospheric gases on small animals.

The atmospheric gases category includes all greenhouse gases (e.g., gases with absorption bands in the infrared portion of the spectrum) except for Chlorofluorocarbons (CFCs). The principal greenhouse gases in Earth's atmosphere are water vapor (H_2O), carbon dioxide (CO_2), ozone (O_3), methane (CH_4), dinitrogen oxide (N_2O), and two very stable Chlorofluorocarbons, CF_2Cl_2, and $CFCl_3$. Collectively, greenhouse gases are the "absorbing molecules." Since terrestrial radiation has the best chance to escape in the infrared window, any gas that absorbs strongly in that region will have a warming effect. Dinitrogen oxide (N_2O) is a very effective heat-trapping gas in the atmosphere, in part because it absorbs outgoing radiant heat from the earth in infrared wavelengths that are not captured by the other major green house gases, water vapor and carbon dioxide. By absorbing and re-radiating this heat back toward earth, dinitrogen oxide (N_2O) contributes to overall greenhouse warming.

Although not specifically included, ammonia (NH_3) must be included in any discussion of atmospheric gases. Ammonia is a related and resultant product of chemical transformations of nitrogen oxides (NOx) and sulfur dioxide and it becomes an important inorganic nitrogen compound in water droplets and the aerosols formed from them. Large concentrations of ammonium salts are found in aerosol particles. Intensive fertilization of agricultural soils increases the rates at which nitrogen in the form of ammonia is volatized and lost to the air. Ammonia is a primary pollutant for groundwater and surface water. The ability of ammonia to enter cells increases with pH and temperature in zero-salinity water. As levels of ammonia concentrate in cells, they become toxified.

Sulfur dioxide is an acid precursor and the cycling of sulfur through the troposphere plays an important role in atmospheric chemistry, especially in the formation and growth of aerosol particles. Sulfur compounds are short-lived species (the atmospheric lifetime of most sulfur species is a matter of days) that are subject to chemical transformation, washout, and dry deposition and lead to acid precipitation problems. Sulfur dioxide converts to SO_2 and SO_4 when it combines with water. Sulfur dioxide is considered a pollutant because it reacts with water to form sulfuric acid (H_2SO_4). While there are no long-lived species of sulfur and it has no connection to the stratosphere, it remains a pollution problem in the troposphere. Sulfate deposition has been a focus of acid rain research impacts and controls for some fifteen years.

Similarly, methane must also be included in any discussion of atmospheric gases. Ozone can be produced by methane and/or carbon monoxide oxidation cycles, depending on the presence of NO and NO_2. The potential for ozone formation in the troposphere is large and limited only by the availability of NO and NO_2 as catalysts (Graedael and Cruzen). Roughly estimated, if all worldwide hydrocarbon and carbon monoxide emissions resulted in ozone formation, the tropospheric ozone concentrations could be more than 10 times larger than that produced by the principal natural sources for tropospheric ozone. Since ozone is a phototoxic and poisonous gas, if its concentrations were to grow to that level there would be serious environmental consequences.

(2) What do they do ecologically?

The trace gases included in the atmospheric gases category are associated with environmental perturbations, including the greenhouse warming, stratospheric ozone depletion, acid deposition, smog, corrosion, decreased visibility, and decreased self-cleaning of the atmosphere. Many of these gases have multiple impacts and the impacts themselves can have multiple causes. In many cases, the gases may have positive or negative impacts depending on temperature, altitude or other factors.

While all of the different gases included in the atmospheric gases category have common processes for the transfer and uptake, analysis and research focuses on particular groups of pollutants and their effects. Significant research has been done on the effect of deposited nitrogen (NH_3, NH_4^+, and NO_3^-) and sulfur (SO_4^{+2}) on species composition and acidification of ecosystems; the phytotoxic effects of SO_2 and O_3 on plants; the phytotoxic effects of acidic pollutants deposited as droplets on high elevation forests; and the effect of SO_2 and NO_2 on crops (Baker and Tingey 1992).

(a) Aquatic Ecosystems:

Substantial evidence indicates that acid deposition alters water chemistry in sensitive lakes and streams. Sulfur deposition has caused long-term chronic acidification of watersheds, and nitrate deposition has caused acidic episodes during snowmelt and large precipitation events. Many watersheds in areas of high nitrogen deposition appear to be approaching nitrogen saturation, and the increasingly acidified soils have little capacity to buffer acid rain before it enters streams. Most vulnerable are small lakes and streams in watersheds that have little capability to neutralize acid due either to the chemical composition and/or thinness of the soils or to the terrain that is so steep or rocky that rainfall runs over it before it can be neutralized.

High nitrogen loading causes eutrophication in stratified marine waters, where a sharp temperature gradient prevents mixing of warm surface waters with colder bottom waters. The result can be anoxia (no oxygen) or hypoxia (low oxygen) in bottom waters. (Note: this does not occur in freshwater.) Periods of hypoxia have increased in Long Island Sound, resulting in significant losses of fish and shellfish.

Nitric acid (HNO_3) and sulfuric acid (H_2SO_4) predominate among the pollutants that accumulate in the winter snow pack. Much of this nitric acid (HNO_3) is flushed out with the first batch of spring melt-water often washing a sudden, concentrated "acid pulse" into vulnerable lakes. These highly acidic episodes often occur during the time that young trout fry are emerging from the stream gravel. Such episodic effects can be especially damaging to streams.

Fish are sensitive to the acidic levels and to the toxic metals, primarily aluminum and mercury, that are released from the watershed under acid conditions. When waters become more acidic ($pH < 5$), many fish species are eliminated and major changes occur in the lake ecosystem processes. High acidity conditions, toxic concentrations of metals (e.g., aluminum), or some combination of the two, appear to change lake ecosystem processes. Fish respond to aluminum by secreting mucous that can clog their gills, reduce breathing, and lead to their death by suffocation or poisoning.

(b) Crops:

Ozone is a gaseous pollutant that is toxic to plants. Ozone may be responsible for up to 90 percent of atmospheric gas-related damage to crops (Baker and Tingey 1992; Chapman and Kohut 1984; Smith 1990; Irving 1991). Observed effects include both damage to the quality of crops (leaf spotting) and reductions in yield (Baker and Tingey 1992). The role of pollutant mixes may also be significant, since acid deposition seldom occurs with the absence of other pollutants. In some cases, it appears that the presence of sulfur or nitrogen oxides in the atmosphere makes crops more susceptible to ozone damage (Baker and Tingey 1992). Pollutant mixtures are responsible for greater than additive responses in certain crops (Irving 1991). Some plants are more susceptible to insect damage when exposed to SO_2 or O_3 (Irving 1991).

(c) Forest Ecosystems:

Acid deposition has a number of damaging consequences for the health and functioning of ecosystems. Concern over the effects of acid deposition and ozone on forests (Smith 1990) stem from observed productivity declines and tree death in areas with elevated pollution levels (Baker and Tingey 1992). Acid deposition may be a factor either by affecting trees directly (Smith 1990) or by altering the soils on which trees grow. Acid deposition may remove essential nutrients such as calcium and magnesium directly from tree foliage. In some cases, such as very tall red spruce and Norway spruce, forest canopies can capture wind driven fog and cloud droplets directly (Baker and Tingey 1992). There is some uncertainty about which tree species are most susceptible to foliar nutrient loss and the level of acid deposition at which such loss becomes harmful.

Of greatest concern are forest ecosystems with poorly buffered soils. The major soil-mediated risks from acid deposition include: mobilization of metals (e.g., aluminum) that are toxic to plants in sufficient quantities (Smith 1990); and potential stripping of calcium, magnesium, and other nutrients essential for plant growth from the soil (Smith 1990).

There is a hypothesis that heavy metals depress decomposition rates of forest litter, and remobilization of nutrients will be slower or less complete as heavy metal ions bind with colloidal organic matter (Baker and Tingey 1992).

In Northeastern forests the increased leaching of nitrates from the soil and large shifts in the nutrient ratios in tree leaves have been observed in limited areas. These areas can be characterized as high-elevation sites that receive large nitrogen deposits and sites with shallow soils containing few alkaline minerals to buffer acidification.

Some forests have a very high capacity to retain added nitrogen, particularly re-grown forests that have been subjected to intense or repeated harvesting (an activity that usually causes severe nitrogen losses). Overall, the ability of a forest to retain nitrogen depends on its potential for further growth and the extent of its current nitrogen stocks. Thus, the impacts of nitrogen deposition are tightly linked to other rapidly changing human-driven variables such as shifts in land use, climate and atmospheric carbon dioxide and ozone.

Atmospheric gases can affect animals directly or indirectly (Baker and Tingey 1992). Certain species are at risk because they are more physiologically sensitive to atmospheric gases than other species or because they are more ecologically sensitive to atmospheric gas effects.

While it may be contentious, concerns were raised in the Ecosystems Work Group that CO and NO act as neurotransmitters that might affect animals in forest ecosystems. Neurotransmitters are chemicals that have the ability to cross the nerve synapse and bind to the dendrites (cell projections of the receiving cell at the synapse in nerve connections) of the adjacent neuron. CO and NO are thought to be endocrine modulators or disrupters that affect the way in which natural hormones (chemicals that produce a reaction in a particular organ or tissue of the body) function in the body (USEPA 1997). Endocrine modulators can cause chemical perturbations that result in functional abnormalities. The consequences depend on the stage of development that the exposure occurred. Although some of the endocrine modulators are less potent than natural hormones, it is thought that they can undergo bio-magnification in the food web.

Exposure to atmospheric gases can alter succession patterns or species composition in forests (Smith 1990). In addition, shrub and herb strata can be affected (Smith 1990). Nitrate is a fertilizer often added to soils to increase plant or tree growth. Increased levels of nitrogen showered upon an ecosystems can cause a shift in the dominant species and also a reduction in overall species diversity as the plant species adapt to take full advantage of high nitrogen out compete their neighbors. Dramatic reductions in bio-diversity have been created by fertilization of grasslands that were then much less stable in the face of a major drought and even in non-drought years, variation in the productivity was greater than in more diverse plots.

Increased emissions of airborne nitrogen have led to enhanced deposition of nitrogen on land and oceans. Experiments in Europe and America indicate that a large portion of the extra nitrogen retained by forest, wetland, and tundra ecosystems stimulates carbon uptake and storage. On the other hand, this nitrogen can also stimulate microbial decomposition and this releases carbon from soil organic matter. On balance, however, the carbon uptake through new plant growth appears to exceed the carbon losses, especially in forests.

(3) What are the important sources and pathways of this stressor group?

(a) Sources of Atmospheric Gases

(i) Dinitrogen oxide (N_2O) and Nitrogen Oxides (NOx)

While the earth's atmosphere is 78 percent nitrogen gas, most plants and animals cannot use nitrogen gas directly from the air as they do carbon dioxide and oxygen. Instead, most plants and animals must wait for nitrogen to be "fixed", pulled from the air and bonded to hydrogen or oxygen to form inorganic compounds, mainly ammonium (NH_4) and nitrate (NO_3), that they can use. Natural processes represent only a small addition to previously fixed nitrogen that cycles among the living and non-living components of the ecosystem. Most nitrogen is locked up in soil organic matter - partially rotted plant and animal remains - that must be decomposed by soil microbes that release nitrogen as ammonium or nitrate and allow it to be recycled through the food web. Two major natural sources of new nitrogen entering this cycle are nitrogen fixing organisms and lightning.

Human activities have accelerated the rate of nitrogen fixation, effectively doubling the annual transfer of nitrogen from the atmospheric to biologically available forms. Major sources of this supply include industrial processes that produce nitrogen fertilizers, combustion of fossil fuels, and cultivation of crops that host symbiotic nitrogen-fixing bacteria.

Industrial fixation of nitrogen for use as a fertilizer represents is the largest contribution of new nitrogen to the global cycle. Organic nitrogen fertilizers are a transfer of already-fixed nitrogen from one place to another rather than new fixation. While the use of industrially produced fertilizer has stabilized in developed countries, their use in developing countries has increased.

The burning of fossil fuels such as coal and oil releases previously fixed nitrogen from long-term storage in geological formations in the form of nitrogen-based trace gases such as nitric oxide (NO). High temperature combustion also fixes a small amount of atmospheric nitrogen directly.

Annual NOx emissions in the US over the last 80 years have increased dramatically, from less than 1 to about 22 Tg (teragrams or millions of metric tons) (Takle).

On a global basis natural sources of NOx include soils (10 to 20 Tg annually); lightening (2 to 8 Tg annually); and transport from the stratosphere (.5Tg annually). Natural sources are in the range of 13 to 29 Tg annually. Anthropogenic sources (24 to 30 Tg) include fossil fuel combustion (21 Tg); biomass burning (2.5 to 8.5 Tg annually); and tropospheric aircraft (0.6 Tg annually). The magnitude of these sources is not the same as their chemical importance. For instance, atmospheric residence of emissions is longer at higher altitudes and emissions from lightning and aircraft are more important than their magnitude. (See Gradual and Crutzen for estimated source fluxes for atmospheric NOx.)

Dinitrogen oxide (N_2O) is a non-reactive and long lived gas (lifetime of 110 to 168 years) in the lower atmosphere (Takle). Natural sources (8.1 Tg/year) include oceans (1.4 to 2.6 Tg/year) with the remainder from land areas (including tropical soils, wet forests, dry savannas, and extra-tropical forests, together, at about 5.5 to 6.7 Tg/year). The imbalance between the source and the sink for dinitrogen oxide tells us that some 11.7 to 13.2 are emitted from all sources. Anthropogenic sources include cultivated soils (including agricultural use of nitrogen fertilizers), biomass burning and other combustion processes, and acid production processes. Anthropogenic sources are estimated at 3.6 to 5.1 Tg/year. Such an increase is important because of dinitrogen oxide's long atmospheric lifetime. (See Graedel and Crutzen for estimated sources and sinks of dinitrogen oxide.)

Over time, dinitrogen oxide concentrations have been increasing steadily. Ice cores show that over the last 2,000 years dinitrogen oxide concentrations were nearly constant at 280 ppbv (parts per billion by volume) until about the beginning of the Industrial Revolution, at which time there began a fairly dramatic increase which continues today at about 0.2 to 0.3% per year (Takle). Natural removal processes are incapable of stemming this increase because of dinitrogen oxide’s stability. The largest known process for destruction of dinitrogen oxide is stratospheric photolysis (breakdown by solar energy, principally ultraviolet radiation).

(ii) Sulfur dioxide

Sulfur dioxide is generated by the combustion of sulfur-containing fossil fuel (e.g. coal and petroleum) and ore smelting (Smith 1990). Sulfur dioxide is implicated in acidic precipitation and reduced visibility, among other effects. Visibility is a function of total airborne particulate mass concentration.

The most common sulfur species involved in gas to particle conversion in the troposphere are sulfur dioxide (SO_2); dimethlysulfide (DMS or CH_3SCH); and hydrogen sulfide (H_2S). These reactive gases are converted to sulfuric acid that then condenses out onto cloud droplets and aerosol particle surfaces. It was suspected that one or more sulfur containing gases entered the stratosphere that were then converted into particulates after transport to the stratosphere.

However, most of the particles in the stratosphere are sulfuric acid which is unlikely to be transported to that level because air entering the stratosphere (mostly from the tropics) is washed out and particle free. The suspected sulfur species has been identified as carbonyl sulfide (COS) which is chemically stable in the troposphere, has low solubility in water, and is disintegrated by ultraviolet radiation to CO and S in the stratosphere. This freed up sulfur is rapidly converted to SO_2 and H_2SO_4 that can then form a sulfate aerosol. (Graedel and Crutzen)

The major source of anthropogenic sulfur (globally) is the burning of high-sulfur coal that contributes 70 to 89 Tg of sulfur per year, mostly in the form of sulfur dioxide. Biomass burning contributes 0.8 to 2.5 Tg to global total. Natural sources include ocean production of dimethlysulfide, soil and plant production of dimethlysulfide and hydrogen sulfide (H_2S). Volcanoes, which are episodic sources, may contribute 7 to 10 Tg annually (Houghton). Anthropogenic emissions now dominate natural sources in the atmosphere. While in a global context the natural and anthropogenic sulfur emissions are on the same order of magnitude, anthropogenic emissions dominate over the natural emissions in the northeastern US. In fact, data shows that the region between 35 degrees and 50 degrees North is seriously impacted with anthropogenic emissions and only 8 percent of the total sulfur emissions coming from natural sources in this region (Bates).

A recent finding indicates that sulfur dioxide may have a secondary effect in the earth's atmosphere. Although it is not a greenhouse gas, it appears to contribute to the radiation balance of the earth. In the presence of clouds, atmospheric SO_2 becomes dissolved in water droplets and forms weak sulfuric acid (H_2SO_4). Such clouds are brighter than natural clouds and can reduce the amount of solar energy entering the earth/atmosphere/ocean system. This secondary effect may contribute to global cooling.

Studies have shown that dimethlysulfide (DMS) can promote the production of cloud condensation nuclei which are favored particles for cloud droplet growth. An abundance of marine plant life can produce sufficient amounts of dimethylsulfide (DMS) to enhance cloud formation and, possibly lead to increased precipitation. This provides a link between stratospheric ozone and local meteorology in that increased ultraviolet levels over the ocean could suppress ocean biology that could reduce the emission of dimethylsulfide (DMS), which could reduce cloudiness and precipitation in ocean areas.

(iii) Carbon monoxide (CO)

Carbon Monoxide is the most abundant and widely distributed atmospheric gas found in the atmosphere. At least ten times more carbon monoxide enters the atmosphere from natural sources than from anthropogenic sources. Almost eighty percent of carbon monoxide is emitted by the oxidation of decaying organic matter in the topsoil.

(iv) Carbon Dioxide (CO_2)

Carbon Dioxide is a product of fossil fuel combustion, and is of particular concern as a major component of the greenhouse effect.

(v) Ammonia (NH_3) and methane (CH_4)

Ammonia (NH_3) and methane (CH_4) result from decaying natural organic matter, livestock wastes, fertilizers and industrial activities. Ammonia can also result from chemical transformation of nitrogen oxides (NOx) and sulfur dioxide. Manure and urine from animals contain ammonia that evaporates into the atmosphere and combines with nitric acid pollution to form ammonium nitrate particulates. Livestock waste also emits volatile organic compounds and methane, chemicals that contribute to global warming.

Nearly 70 percent of global ammonia emissions are related to human activities, including ammonia volatilized from fertilized fields, ammonia released from domestic animal wastes and forest burning.

Ammonia is used as a fertilizer. Liquid ammonia is released from pressure and is applied to fields directly as an ammonia gas that is readily dissolved in the moisture of slightly acidic soil. In such applications the ammonia is immediately converted into the ammonium ion and enters the natural nitrogen pathway of soil. Deliveries of liquid ammonia product to agricultural areas have led to accidental spills that contribute to ground water and surface water pollution.

Anhydrous ammonia can be used in the production of agricultural chemicals by combining it with nitric acid or sulfuric acid. Even with appropriate application procedures, such fertilizer chemicals can eventually be washed into streams, lakes, ponds or waterways.

As ammonium builds in the soil, it is increasingly converted to nitrate by bacterial action, a process that releases hydrogen ions and helps acidify the soil. The buildup of nitrate enhances emissions of dinitrogen oxide (N_2O) from the soil and also encourages leaching of highly water-soluble nitrate into streams of groundwater. As these negatively charged nitrates seep away, they carry with them positively charged alkaline minerals such as calcium, magnesium, and potassium. The human modifications to the nitrogen cycle decrease soil fertility by greatly accelerating loss of calcium and other nutrients that are vital for plant growth. As calcium is depleted and the soil acidified, aluminum ions are mobilized, eventually reaching toxic concentrations that can damage tree roots or kill fish if the aluminum washes into streams. Trees growing in soils replete with nitrogen but starved of calcium, magnesium, and potassium can develop nutrient imbalances in their roots and leaves. This may reduce their photosynthetic rate and efficiency, stunt their growth, and even increase tree deaths.

Nitric oxide (NO) and ammonia (NH_3) are highly reactive in the lower atmosphere and are short lived. Nitric oxide (NO) plays several critical roles in atmospheric chemistry, including catalyzing the formation of petrochemical or brown smog. In the presence of sunlight, nitric oxide and oxygen react with hydrocarbons emitted by automobile exhausts to form ozone, the most dangerous component of smog. Ground level ozone has serious detrimental effects on human health as well as the health and productivity of crops and forests. In contrast to nitric oxide (NO), ammonia (NH_3) can act as the primary acid-neutralizing agent in the atmosphere, having an opposite influence on the acidity of aerosols, cloud-water, and rainfall.

(b) Deposition Processes and Pathways

(i) Atmospheric Circulation

Atmospheric circulation is a major deposition process for transport and mixing of atmospheric gases. Atmospheric winds move air parcels and emissions across continents in a few days, often called long range transport. Species whose low reactivity or poor solubility allows them to remain in the atmosphere longer are effectively moved regionally and globally across political boundaries. The major processes involved in this dispersion, transport, and removal of atmospheric pollution can be classed into three groups: dispersion, chemical transformation, and deposition.

Long range transport of SO_2 from tall smoke stacks in the Ohio Valley region is the primary contributor to acidic deposition in New York State. As a result of the Clean Air Act Amendments, SO_2 emissions have declined (1995 was the final year that Phase I reductions were required). In addition, sulfate deposition has declined about 25 percent and sulfate concentrations in Adirondack Lakes have declined. Reductions in particulates resulted in decreases in deposition of calcium, magnesium, and sodium which formerly neutralized some of the atmospheric acidity.

Although dinitrogen oxide (N_2O) is non-reactive and long lived in the lower atmosphere, when it rises to the stratosphere it can trigger reactions that deplete and thin the stratospheric ozone layer that shields the earth from damaging ultraviolet radiation. The most important catalysts for the destruction of ozone are the oxides of nitrogen, NO and NO_2, present as a consequence of ground level emissions of dinitrogen oxide (N_2O). Dinitrogen oxide (N_2O) emissions are largely from micro-biological processes in soils, especially from soils that have been heavily fertilized. N_2O is quite non-reactive in the troposphere with a lifetime of 150 to 200 years. In the stratosphere, several processes can break it down. NO can also be directly injected into the stratosphere by aircraft emissions, by nuclear explosions, or by solar proton bombardment. Although NO production by these latter means is much smaller than that in the troposphere by soil microbial activity, fossil fuel and biomass burning, and lightning, the oxidation of NO to soluble HNO_3 strongly limits the likelihood of NO transfer to the stratosphere.

The concentration of dinitrogen oxide (N_2O) is currently increasing at the rate of 2-3 tenths of a percent per year. The sources of the increase remain unresolved although a wide array of human driven sources are indicated (fertilizers, nitrogen enriched groundwater, nitrogen saturated forests, forest burning, land clearing, and the manufacture of nylon, nitric acid, and other industrial products).

(ii) Hydrologic Cycle

The hydrologic cycle is a major deposition process that includes cloud effects and uses vertical redistribution, wet removal, and aqueous chemistry to distribute atmospheric gases.

(iii) Dry Deposition

Dry deposition of pollutants occurs as dust and other particles fall from the atmosphere. These particles then are washed into waterways and carried to soils during precipitation events. They may contribute as much as half of the total acidic deposition to an area.

Forest soils are important sinks for a variety of air contaminants (Smith 1990). Only certain forest soils are at risk to acidification from hydrogen ions in the atmosphere (Smith 1990). Hydrogen ions are presumed not to be directly toxic to tree roots. The most significant influence of increased hydrogen ion input to the soil profile may be the enhancement of the availability of toxic ions such as manganese and aluminum (Smith 1990).

The primary modes of exposure of terrestrial animals are inhalation, adsorption (adhesion of gases or particulates to external surfaces or membranes), and ingestion of the pollutant. Habitat alteration can indirectly affect animals as well.

Pollutants (sulfates and particulates) deposited on the surface water result in physical and bio-geochemical changes created to the water. The primary modes of exposure for aquatic animals are ingestion and adsorption of the resultant chemicals. Habitat alteration can affect aquatic communities as well.

An additional factor in many areas is that nitric acid predominates among the pollutants that accumulate in the winter snow pack. Much of this nitric acid (HNO_3) is flushed out with the first batch of spring melt water often washing a sudden, concentrated “acid pulse” into vulnerable lakes.

Atmospheric gases affect plants. Pollutants can alter leaf areas, stem strength, and root biomass. Pathways into the plant include leaf surface and stomata uptake. Atmospheric gases exert these direct and indirect effects on the plant. Directly they chemically disturb the biochemistry of the plant, resulting in such effects as foliar mottling. Indirectly they can alter the plant's ability to compete for resources (e.g., light), withstand other biotic stresses (e.g., pest and pathogens), or abiotic stresses (e.g., drought); produce other toxic chemicals that in turn provide the stress (e.g., increased levels of soil aluminum or depleted base cation due to acidic deposition). The stress can result in adaptations of the plant stomata closure, leaf abscission and root exploration.

(4) What systems or species/organisms are particularly sensitive or affected?

(a) Forests:

All forest ecosystems are not expected to respond to acid precipitation in the same way. Effects are likely to be site specific and dependent on the relative contributions of external and internal sources of acidity. Soil acidification in a forest ecosystem is an important factor.

Acid precipitation has been considered a contributing factor, along with ozone and other factors, in the forest dieback in Europe and North America affecting spruce, maple, beech, and oak. This habitat change has been observed on mountaintops in Vermont, New Hampshire, and New York. These tree species have an important value to wildlife. A reduction in their abundance could influence the presence and abundance of animal species (Baker and Tingey 1992).

The northern hardwood forest is subject to significant atmospheric gas exposure, and ozone exposure is particularly high during the growing season in numerous locations in this forest (Smith 1990). The pollutant with the greatest stress potential is ozone. The role of long term deposition of strong mineral acids and heavy metal remains uncertain.

Chronically high nitrate concentrations in lakes and streams have been documented in the Catskill Mountains. Such conditions indicate nitrogen saturation (more nitrogen comes in than can be taken up by plants and microorganisms). Under such conditions, a substantial fraction of the incoming nitrogen leaches out of the ecosystem and into ground water and surface water. This large release of nitrogen moves through the watershed, removing base cations and reducing the acid neutralizing capacity of lakes and streams. There is some concern, based on experiments in Maine, that forested watersheds may move rapidly toward nitrogen saturation in response to nitrogen loading (EPA 1998).

(b) Lakes and Ponds:

Not all lakes will respond to acid deposition in the same way (Pfeiffer and Festa 1980). Certain site specific characteristics, such as the amount of snow melt, the flow paths of runoff, the water chemistry of the lake, the size of the lake, and the acidification of the soils can delay a lake’s response to acid deposition.

The reason that the number and species of fish have declined results from multiple and complex causes, including more acidic water conditions, increased concentration of toxic chemicals, the inability of fish to reproduce, and the destruction/change in the aquatic food chain.

Elevated levels of metals such as mercury, cadmium, and lead have been found in lake waters and biota from acidified areas in the Adirondack Region. In regions remote from direct sources of contamination, levels of metals in wildlife tissues are higher in acid-stressed habitats than in unstressed habitats (Baker and Tingey 1992).

Both chronic and episodic acidification can adversely affect aquatic biota. Several chemical changes accompany episodic decreases in acid neutralizing capacity, including a decrease in pH and calcium and an increase in dissolved aluminum. The available evidence suggests that episodic acidification is particularly important in streams (Irving 1991). Young fish seem to be especially vulnerable to these changes in pH. Spring fish kills are associated with spring thaw, when the sudden surge of water melting from snow packs introduces acids into the streams in large volumes. EPA's Episodic Response Project documented occurrence of acidic episodes/ high aluminum concentrations in thirteen streams in the Adirondacks and the Catskills. Streams that had such episodes had significant fish mortality (EPA 1998). In 1993, 1994 and 1996, approximately 50 percent of the highly and moderately sensitive lake classes in the Adirondack Long Term Monitoring Study became acidic during the snowmelt period (EPA 1998).

Results of models based on chemical survey data and geo-chemical assumptions, combined with information on species acid tolerances, indicate substantial losses in biota in certain parts of the United States. Lakes in the Adirondacks, Poconos-Catskills, and southern New England have lost perhaps 50 percent or more of the species in certain taxonomic groups (Baker and Tingey 1992).

The effects of acidification on fishes and other aquatic biota have been widely documented (Baker and Tingey 1992). Brook trout is a common sport fish species in lakes and streams that is susceptible to acidic deposition, and generally can not survive or reproduce at pH levels below 4.8-5.2. In most areas, few fish species persist below pH 4.5. Brook trout are often the only game fish that live in high elevation habitats. The presence of brook trout in high elevation ponds is a way to measure acidification effects in the Adirondacks. Surveys in 1975 and in 1980 (Pfeiffer 1980) have documented a relationship to acidic lake conditions and the absence of brown trout.

Results from liming studies in the Adirondacks indicate that the establishment of tributary spawning populations of brook trout may be possible with future reductions in acid deposition. However, restoration of tributary spawning habitat may not be sufficient to produce self-sustaining populations because of the high rates of predation on young trout as they move downstream into lakes. Woods Lake is being used to evaluate the effectiveness of liming to provide a self-sustaining brook trout population (EPA 1998).

Several warm water species (including small mouth bass and walleye) are particularly intolerant of acidic water conditions and experience reproductive failure. Former bass lakes (Woodhull Lake, Big Moose Lake, and Canada Lake) have lost their small mouth bass population, and other marginal bass waters (Cranberry Lake and Tupper Lake) experienced marked decline in number of bass. In the 1979 extensive water chemistry survey, 23 percent of the waters by number (and 33 percent by acreage) with pH below 5.00 had potential losses of warm water fishes. While initial concern focused on small brook trout, analysis shows that other warm water habitats and food chains are being lost or endangered.

There are some 2800 lakes in the Adirondacks. Small lakes are numerous in the Adirondacks and are more likely to be acidic than the larger lakes. There are about 100 naturally acidic bog waters and a larger number that are influenced by natural organic acids. Based on Adirondack Lakes Survey Corporation data, more than 300 Adirondack lakes are fish-less because of acidification, and an additional 300 waters have been impacted to the point where fish species have been lost.

Studies in the Adirondack Mountains show that for the majority of lakes, the acid-neutralizing capacity has remained fairly constant, but it has continued to decline in the sensitive lakes (acidification has increased) despite relatively large decreases in sulfate concentrations in lake water. As a result, the recovery anticipated in the 1990 Integrated Assessment has not been realized (EPA 1998). In contrast, lakes in New England, especially those considered highly sensitive to acid deposition, have shown statistically significant recoveries in acid neutralizing capacity, based on analyses of long-term monitoring data. The extent to which base cation reserves in the soil have been depleted by acid deposition may be an important factor (EPA 1998). Some studies now show that acid deposition and landscape processes are of approximately equal importance as regulators of surface water acid-base chemistry within watersheds. The need to include land use in future modeling efforts will increase because nitrate leaching from forested watersheds is largely controlled by age dependent forest nitrogen uptake processes as well as atmospheric deposition of nitrogen.

(c) Agricultural Areas:

At this time, no satisfactory estimate of the effects of atmospheric gases on New York State crops is available. Some studies show that the growth and yield of some crops are negatively affected while others show they were positively affected. Net response of a crop to acid precipitation results from the interaction of the positive effects of sulfur and nitrogen fertilization; the negative effect of acidity; and the interactions of these factors with other environmental variables such as soil chemistry and gaseous air pollutants (Chapman and Kohut).

Chamber studies for New York State have given estimates for crop losses due to ozone. The estimated crop yield losses for green beans is 26 percent; for grapes is 16 percent; for tomatoes is 33 percent (McKee).

Economic evaluation of ozone damage has suggested an estimate of $2 million for New York State, reflecting a 5.5 percent yield loss predicted for ozone exposure for wheat and a 2 percent loss for corn (Chapman and Kohut 1985).

Agricultural impact of ozone is documented for oxidant stipple on grapes, although economic significance is not understood (Chapman and Kohut 1984). Ozone may be increasing the costs of production since many growers apply additional nitrogen fertilizer and spray with an antioxidant in attempts to reduce the incidence of foliar ozone injury. This is important because New York State ranks second in the nation for grape production and is the largest grape juice producer and the second largest wine producer in the United States. Agricultural impact of ozone is documented for oxidant stipple on grapes, although economic significance is not understood (Chapman and Kohut 1984). Ozone may be increasing the costs of production since many growers apply additional nitrogen fertilizer and spray with an antioxidant in attempts to reduce the incidence of foliar ozone injury.

b. Analysis of Problem

(1) Severity: Rank = A

Atmospheric gases have seriously affected and severely damaged ecosystem structures and reduced bio-diversity. Numerous ecosystems are affected/damaged. Populations have been significantly affected and some have been lost.

(2) Reversibility: Rank = A

It will take more than twenty years to reverse the damaging effects of atmospheric gases on New York's ecosystem structures. Some damage may not be reversible.

(3) Ecological Significance: Rank = A

Atmospheric gases, especially in the Adirondacks and Catskills are affecting areas of high ecosignificance. Impacts are numerous and affect bio-diversity of unique natural communities in the Adirondacks and Catskills. Spawning grounds and migratory pathways are negatively affected. Impacts are taking place on diverse organisms at several levels of development and functions.

(4) Geographic Scale: Rank = B

The damage to New York State's ecosystem structures is very broad, with all regions affected. These include foliar damage in the Lake Plains and Appalachian Highlands regions; forest and aquatic damage in the Adirondack and Northern Forest and Catskill Mountain regions; crop damage in the Hudson - Mohawk Valley; and acid deposition and ozone damage in the New York and Long Island region.

(5) Final Ranking: Rank = A

The impact on New York State will last for decades and affects many different ecosystems at several different levels of function in all regions.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Atmospheric Gases		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**A**	Numerous species and ecosystems are affected
2. Reversibility	**A**	Impacts will last for decades
3. Eco-significance	**A**	Action is through the food chain and is taking place on diverse organisms at several levels of development and functions
4. Geo-scale	**B**	New York state is impacted in several different regions
Overall Rank	**A**	The impact on New York State will last for decades, affects many different ecosystems in several regions at several different levels

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3. Halogens

a. Stressor Characterization

(1) What stressors are included?

Halogens are a small group of elements consisting of chlorine, fluorine, bromine, iodine, and astatine. This group of chemicals is used in industrial applications as reactants and disinfectants, chlorine being the most commonly used for both purposes. Therefore, this report will focus on chlorine and its related compounds as the ecological stressor.

(2) What do they do ecologically?

Chlorine and its compounds have different levels of toxicity to different species of aquatic life, depending upon duration and levels of exposure. Testing of chlorinated effluents consistently shows damaging effects to *all* test specimens, with concentrations of total residual chlorine as low as 10 μg/l having a detrimental affect on survival and reproduction of aquatic life. Generally, organisms are much more tolerant of intermittent chlorine exposures than they are of continuous exposures. Laboratory toxicity testing of aquatic life has shown the following results:

(a) During acute tests, king salmon fry died within 14 hours of exposure to total chlorine residuals of 0.2 - 0.3 μg/l (USEPA 1975).

(b) Larval stages of marine species appear to be more sensitive to chlorine than either the egg or the adult stages (USEPA 1976).

(c) Chronic toxicity effects of total residual chlorine (TRC) on growth and reproduction occur at lower concentrations than those causing mortality (USEPA 1976).

(3) What are the important sources and pathways of this stressor group?

In routine use situations, chlorine's largest impact to the ecosystems of New York is via the wastewater effluents from municipal wastewater treatment plants. Discharges from the following activities are typically treated at municipal wastewater treatment plants:

(a) Industrial and chemical processes (e.g., solvent production, paper manufacturing, plastic synthesis, and food processing);

(b) Residential use (e.g., cleaning agents and private swimming pools); and

(c) Commercial and municipal activities (e.g., swimming pools and potable water treatment plants).

In rare instances, spills of chlorine during transport, storage, or use could affect ecosystems. In one such occurrence, a chlorine gas release to the atmosphere caused damage to terrestrial plant life immediately downwind of the chlorine release site. In a related scenario, chlorine management problems have occurred in the New York City potable water system, causing storage reservoirs to become toxic to aquatic life. On a smaller scale, discharges from municipal swimming pools that have no sanitary sewer available may affect aquatic ecosystems. These occurrences are infrequent, localized, and site-specific.

(4) What systems or species/organisms are particularly sensitive or affected?

Any water body or wetland that is located downstream of an effluent discharge from a wastewater treatment facility could be affected, with smaller ecosystems being particularly sensitive. Any freshwater or marine species may temporarily be adversely affected by toxicity. Studies on fish (king salmon fry, brook trout, fathead minnows, coho salmon, white sucker, walleye, yellow perch, and largemouth bass) and invertebrates (amphipods, stonefly, caddisfly, crayfish, Daphnia, and pulmonate snail) have been completed.

In general:
(a) Fish are more sensitive to discharges of residual chlorine in wastewater effluents than invertebrates.
(b) Early life stages of fish are very sensitive to chlorine toxicity.
(c) Game fish (e.g., trout, salmon) are generally more sensitive to chlorine than are forage fish (e.g., carp).
(d) Resistance to chlorine is proportional to the size of the scales of the fish (e.g., large scaled carp are less sensitive than small scaled trout and salmon).

More specifically:
(a) Feeding activity of oysters is suppressed in chlorinated waters.
(b) Spawning and egg hatchability is diminished in chlorinated effluents at very high concentrations (i.e., 110 μg/l for fathead minnow). Fathead minnows are deformed during testing for chronic exposures to chlorine.
(c) At high chlorine concentrations, mortality of both amphipods and Daphnia occurs.
(d) Fish eating birds (e.g., herons, eagles) and mammals (e.g. otter, mink) are notably sensitive to long-term effects on reproduction.

b. Analysis of Problem

(1) Severity: Rank = C

The State Pollutant Discharge Elimination System (SPDES), which authorizes permits for the discharge of wastewater and is administered by the New York State Department of Environmental Conservation, incorporates a dilution factor and limits chlorine residual within the discharge for each permitted facility, so that the impacts to aquatic ecosystems are minimized. Additionally, it is assumed that any aquatic life that is motile will be able to avoid the effects of chlorine toxicity by moving to another area of the water body that is not impacted. However, some invertebrates and early life stages of fish would not be able to escape to waters free of chlorine. The effects of chlorine residuals in wastewater are more severe on small bodies of receiving waters, because the chlorination systems generally do not have the controls to "fine tune" the disinfecting operations and thus over-chlorination is more likely to occur.

(2) Reversibility: Rank = B

After dilution in the receiving waterbody, TRC dissipates through chemical demand, photo transformation, and volatilization. Instream variables to consider are the physical characteristics of the receiving stream, the species of residual chlorine present in the wastewater treatment plant effluent, and the pH, temperature, turbidity, and chlorine demand of the receiving water. Because TRC is not persistent within the ecosystem and will dissipate within a matter of minutes to hours, the effects of chlorine toxicity would be readily reversed once the stressor source was eliminated.

(3) Ecological Significance: Rank = C

Ecologically and economically significant species living in the immediate vicinity of a TRC-contaminated outfall would likely be adversely affected. However, because of the DEC chlorine discharge policy, these effects would be limited to the mixing zone of the effluent with the receiving stream. Little if any adverse effects are expected.

Nonetheless, the New York Natural Heritage Program has identified a number of rare species in the state that inhabit wetlands and other aquatic communities, any of which may be subject to chlorine discharges. These include 26 species of mullusks, 34 species of dragonflies, seven species of amphibians, 54 species of fish, and one species of mayfly. Of these, 13 are considered endangered and six are threatened. In addition, there are 251 species of rare aquatic plants, of which 33 are endangered, 30 are threatened, nine are vulnerable and 66 are rare.

(4) Geographic Scale: Rank = A

New York State comprises more than 49,500 square miles, which contain or border a myriad of freshwater and marine resources such as rivers, lakes, streams, ponds, wetlands, aquifers, and the Atlantic Ocean. Approximately 70,000 miles of rivers and streams and 7,500 lakes and ponds are spread across the state. Wetlands cover an additional 1,500 square miles. Sources of chorine discharge occur in all six ecoregions of New York State, but existing regulations minimize the impacts of those discharges on aquatic ecosystems.

(5) Final Ranking: Rank = C

While chorine discharges in the past significantly affected aquatic ecosystems, present regulatory practices have minimized or eliminated the toxicity of chlorinated discharges to New York State waters.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Halogens		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**C**	chlorine is very toxic to aquatic life, but effects are controlled by current regulatory practice
2. Reversibility	**B**	effects are readily reversible after chlorine source is eliminated
3. Eco-significance	**C**	potential for minor impact within discharge mixing zone, but ecosystem not affected
4. Geo-scale	**A**	chlorine discharges are present in all six ecoregions
Overall Rank	**C**	problem in the past, but effects are controlled by current regulatory practice

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4. Metals and Cyanide

a. Stressor Characterization

(1) What stressors are included?

There are 105 fundamental kinds of matter called elements which make up all substances. These elements may be divided into two groups: metals and nonmetals. About 80 elements are considered to be metals, and of them, less than 30 are reported to be toxic. Metals are generally solid and shiny, whereas, nonmetals are most often dull gases or liquids. Some elements, such as arsenic, display properties of both metals and nonmetals. The metallic substances in common use are alloys or mixtures of two or more metals. Metals in elemental form are widely distributed in nature, and are all toxic at sufficiently high concentrations, so as to receive significant attention by pollution control agencies (Amdur et al. 1991; Manahan 1992).

Human activities increase and redistribute metals in the environment, making the toxic metals more bioavailable and toxicologically disruptive to ecosystems. At a high enough concentration, almost any substance can be toxic. This is certainly true of metals, even though many metals are essential trace elements required for metabolism. Included in that group are cobalt, copper, chromium, iron, magnesium, manganese, molybdenum, nickel, selenium, tin, vanadium, and zinc, all of which may be both toxic and essential. The Environmental Protection Agency lists 13 metals, antimony, arsenic, beryllium, cadmium, trivalent and hexavalent chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc, in the list of Clean Water Act Priority Pollutants.

Cyanide exists in the form of gaseous hydrogen cyanide (HCN) or cyanide ion (CN^-). Cyanide ion is present in cyanide salts, which tend to be water soluble, and in water may combine with hydrogen ions to produce HCN (Manahan 1992).

Breteler et al. (1984) assessed and ranked the relative aquatic toxicology of metals and concluded that for ecosystem concerns, 10 metals posed the most threat. They are copper, mercury, silver, cadmium, lead, zinc, arsenic, chromium, nickel, and selenium. This risk assessment will address cyanide and the six metals - arsenic, cadmium, chromium, lead, mercury, and zinc. They were chosen because of the availability of literature reviews and for the purpose of reducing the scope of this assessment. The metals not chosen could be addressed in future assessments.

(2) What do they do ecologically?

The bioavailability and biological response to metals in the environment is dependent on the concentration of metals in a variety of chemical forms, including free ions, inorganic and organic complexes, and metals adsorbed or incorporated into particulate matter. The toxicity of metals has been studied extensively, and various criteria and action levels have been established to guide in the assessment of metal impacts, and the determination of discharge and clean-up levels.

Metals in the environment are partitioned in water, sediment, and biota. Therefore, metals may be bioavailable from sediments and via the food chain, as well as directly from water. Bioaccumulation from sediment sources occurs most readily with silver, followed in descending order by cadmium, zinc, arsenic, copper, mercury, nickel, lead, and chromium.

The U.S. Fish and Wildlife Service publishes a Contaminant Hazard Review Series (Eisler), which addresses the ecotoxicological aspects of selected chemical pollutants to fish and wildlife resources. Cyanide and the six metals included in this risk assessment are all included in this review series. For example, arsenic is noted by Eisler (1988) to be a teratogen and carcinogen. It can cross the placenta, and cause fetal death and malformations in many species of mammals. It is toxic to a variety of plants, invertebrates, amphibians, fish, and birds. Lead is well known for its toxicity to birds, mostly from ingestion of lead shot. Mercury and its compounds have mutagenic, teratogenic, and carcinogenic effects, which are very wide spread in fish and wildlife. Overall, the ecotoxicological effects of metals have been extensively researched, and the literature has been thoroughly searched and summarized by Dr. Eisler. His reviews form a convenient basis for the assessment of metals and cyanide.

Some of the ecological effects of cyanide and the six metals being addressed here were summarized by Eisler and in toxicity profiles for the federal Superfund process by Conestoga-Rovers & Associates (1997), as follows:

(a) Cyanide: In higher terrestrial plants, elevated cyanide levels inhibited respiration and ATP production, eventually leading to death (Towill et al. 1978). At lower concentrations, effects can include inhibition of germination and growth.

Adverse effects of cyanide on aquatic plants are unlikely at concentrations that cause acute effects to most species of freshwater and marine fishes and invertebrates (USEPA, 1980). Water hyacinth (*Eichhornia crassipes*) can survive at 300 mg CN/l for at least 72 hours. Cyanide can alter plant community structure. Some algae will metabolize cyanide at water concentrations of < 1 mg/l, but are inhibited at concentrations of 1 to 10 mg/l. This inhibition enables other tolerant biota to dominate (Eisler 1991).

Data are scarce for terrestrial invertebrates. Exposure to 8 mg HCN/l air, inhibited respiration in the granary weevil (*Sitophilus granarius*) within 15 minutes, and killed 50% in 4 hours (Towill et al. 1978).

Aquatic invertebrate LC50s for the daphnids ranged from 83 to 160 ug HCN/l over a 96-hour period, while that for the amphipod *Gammarus pseudolimnaeus* ranged from 58 to 184 ug CN/l for a 96-hour exposure (Eisler 1991).

Fish were the most sensitive aquatic organisms tested. Cyanide adversely affects fish reproduction by reducing the number of eggs spawned and the viability of the eggs (Lesniak and Ruby 1982). These effects were observed in rainbow trout and bluegills following exposure to 10 ug HCN/l for 12-days, and 5.2 ug CN/L for 289-days (USEPA 1980). Concentrations as low as 10 ug/l of HCN caused development of abnormalities in embryos of Atlantic salmon after extended exposure (Leduc 1978). Other adverse effects of cyanide on fish include delayed mortality, pathology, impaired swimming ability, performance, susceptibility to predation, disrupted respiration, and altered growth patterns. Free cyanide concentrations between 50 and 200 ug/l were fatal to more sensitive fish over time, and concentrations >200 ug/l were rapidly lethal to most species of fish (USEPA 1980). Cyanide induced pathology in fish includes subcutaneous hemorrhaging, liver necrosis, and hepatic damage. Free cyanide concentrations as low as 10 ug/l can rapidly and irreversibly impair the swimming ability of salmonids in well aerated water. In general, fish experience a significant reduction in relative performance at 10 ug HCN/l (Leduc 1978).

In birds, acute oral LD50s for the mallard *Anas platyrhynchos*, the Japanese quail *Coturnix japonica*, and the American kestrel *Falco sparverius* were found to be 1.43, 4.5, and 2.12 mg CN/kg body weight, respectively (Eisler 1991). Birds that feed predominately on flesh, such as vultures, kestrels, and owls, were more sensitive to cyanide than were species that feed mainly on plant materials, with the possible exception of the mallard.

(b) Arsenic: Although arsenic seems to benefit some species at low doses, it tends to act more as an environmental contaminant than as an essential element. At low concentrations, it stimulates plant growth, but at higher concentrations it has severe adverse effects. In aquatic systems, adverse effects of arsenic may occur at concentrations of 19 to 48 ug/l in water. Documented effects include reduced growth in three species of marine algae, embryo toxicity in a toad, growth retardation in a freshwater algae, amphipod and copepod mortality, and reproductive failure in a marine red algae.

Bioaccumulation of arsenic occurs from water in a variety of species, but there is no evidence of biomagnification along the aquatic food chain. A freshwater food chain showed the highest accumulation in algae, followed by daphnids, and lastly by fish. Arsenic herbicides used to control submerged aquatic vegetation have been shown to be harmful to fathead minnows, bluegills, green sunfish, and rainbow trout. Effects include hemorrhagic gills, fatty infiltration of liver, organ necrosis, and hepatocyte changes.

Bird arsenic toxicity has been well documented in laboratory testing, and includes acute toxicity to adults, embryo toxicity, and teratogenicity. However, many bird species failed to display adverse effects from exposure to a variety of arsenic compounds. Bobwhites, mockingbirds, robins, and other songbirds were fed arsenic contaminated grasshoppers with no adverse effects. It appears that arsenic is rapidly excreted by many bird species.

Inorganic arsenic compounds are more toxic than organic arsenic compounds, and they can cross the placenta in most species of mammals, where they can be embryotoxic, especially at early development stages. Excretion is much faster with inorganic arsenic compounds. Death or malformation in mammals has been documented at single oral doses of 2.5 to 33 mg arsenic/kg body weight, and at chronic doses of 1 to 10 mg arsenic/kg body weight. These exposures can result in elevated arsenic tissue concentrations, appetite loss, reduced growth, loss of hearing, dermatitis, blindness, degenerative changes in liver and kidney, cancer, chromosomal damage, birth defects, and death (Eisler 1988a).

(c) Cadmium: Although cadmium is considered to be a nonessential element for plants, it is effectively absorbed by both the root and leaf systems. Symptoms induced by elevated cadmium contents of plants are growth retardation and root damage, chlorosis of leaves, and red-brown coloration of leaf margins or veins. The cadmium content of plants is, however, of the greatest concern as a cadmium reservoir, and as the pathway of cadmium to animals. The highest cadmium values reported for wheat grains and brown rice were 14.2 and 5.2 mg/l, respectively (Kabata-Pendias et al. 1985).

Cadmium is taken up in large amounts by aquatic plants, but very little evidence was found for biomagnification (CCME 1993). Based on available information on the toxicity of cadmium in sediments, Long and Morgan (1991) report adverse biological effects associated with cadmium concentrations in sediments ranging from 4.3 to 96 mg/kg.

In rats and mice, acute oral LD50 values for cadmium range from about 100 to 300 mg/kg. Oral doses of 100 mg/kg or higher have been observed to cause testicular damage in laboratory animals (ATSDR 1992).

(d) Chromium: In the aquatic environment, the toxicities of chromium vary widely due to temperature, pH, valence of the chromium, and synergistic or antagonistic effects (especially water hardness). There is no evidence to suggest that hexavalent chromium is more toxic to fish than trivalent chromium. Fish are relatively tolerant of chromium, but lower forms are rarely sensitive.

The concentration of hexavalent chromium causing toxicity to the early life stages of the rainbow trout and the brook trout was 264.6 ug/l. Similar tests with less sensitive fathead minnows resulted in much higher concentrations. The daphnid invertebrate is more sensitive, where six chronic tests with 5 species of daphnids yielded toxicities at less than 2.5 to 40 ug/l (CCME 1992).

Data on acute toxicity of trivalent chromium for freshwater animal species reveal 96 hour LC50 values ranged upward from 2,221 ug/l for the mayfly *Ephemerella subvaria*.

Phytoplankton have been shown to be more sensitive to chromium than are fish. Toxic concentrations of hexavalent chromium ranged upward from 2 ug/l for the bluegreen alga *Microcystis aeruginosa*.

A study was performed with rats to determine effects of trivalent and hexavalent chromium. A group of control rats received distilled water, while another group of rats received dosages of 11 mg/l of chromium for a year. Other tests were run with chromium concentrations of 25 mg/l. No significant changes in weight, food intake, water consumption, or blood analyses were observed between the two groups. At the concentration of 5 mg/l or lower, little chromium was found, indicating that chromium was not being retained within the body. The group receiving 25 mg/l of hexavalent chromium had an average tissue chromium concentration about eight times higher than the group receiving trivalent chromium. However, there was no significant difference in body weight or food consumption. At the same time, a study of dogs over a four year period was performed. No pathological changes were noted, even up to 11 mg/l of chromium. A concentration of 5 mg/l has been reported not to interfere with stock and wildlife watering.

(e) Lead: Bioavailability of lead in soils to terrestrial plants is limited, but in soils of low pH or low organic content, plants readily accumulate lead. Lead is usually tightly bound to soil particles, and must accumulate significantly before it affects the growth of higher plants. Lead inhibits plant growth, reduces photosynthesis, and reduces mitosis and water absorption (Eisler 1988b). For two species of roadside weeds, pollen germination was reduced by 90% and seed germination by 87% at lead concentrations of 500 mg/kg dry weight in soil. Lead content in aquatic plants collected from heavily hunted areas, where lead shot can accumulate in sediments, did not differ from those collected in unaffected areas.

Responses of aquatic species to lead differ markedly. Trends from several studies revealed that dissolved waterborne lead is more toxic than total lead, and that organic lead compounds are more toxic than inorganic forms (Eisler 1988b). Daphnid reproduction was adversely effected at concentrations of 1 ug/l. Tetramethyllead was acutely toxic to rainbow trout at 3.5 ug/l in a 72-hour exposure. Brook trout, *Salvelinus fontinalis*, were observed to have an LC50 of 4,100 and 3,362 ug/l of total lead and dissolved lead, respectively, over a 96-hour exposure period.

The 30-day LC50 value for the leopard frog, *Rana pipiens*, was 105 mg/l. Some marbled salamanders, *Ambystoma opacum*, exposed to 1.4 mg/l died in 8 days (Eisler 1988b).

The primary toxic effects associated with exposure to lead are alterations in the hematopoietic, nervous, and cardiovascular systems. Intermediate-duration studies in animals indicate that adverse hematological effects occur following oral exposure. Adverse effects were observed in rats administered 318 mg/kg/day in their daily diet. The literature on the neurobehavioral effects of oral exposure to lead in animals is extensive. Reported LOAELs (lowest observed adverse effect levels) for serious effects in rats range from 0.05 to 50 mg/kg/day (ATSDR 1992). There is a large database that describes cardiovascular effects in laboratory animals resulting from exposure to lead. Reported LOAELs in rats range from 0.009 to 873 mg/kg/day (ATSDR 1992).

(f) Mercury: Plants differ in their ability to take up mercury and can develop a tolerance to high mercury concentrations in their tissues when grown in soils contaminated with mercury (Kabata-Pendias et al. 1985). The most sensitive plant species generally appear to be less sensitive than sensitive animal species to both inorganic mercury and methylmercury, although the growth of *Chlamydomonas sp.* is severely retarded at a methylmercury concentration of 0.02 ug/l (Lock 1975). Toxic effects in young barley were observed at a mercury level of 3 mg/kg dry weight (Kabata-Pendias et al. 1985).

In the aquatic environment, toxic concentrations of mercury salts ranged from less than 0.1 ug/l to more than 200 ug/l for representative species of marine and freshwater organisms (Eisler 1987). Long and Morgan (1991) report mercury concentrations in sediment ranging from 0.032 mg/kg to 13.1 mg/kg to be associated with adverse biological effects. Concentrations of inorganic mercury in water that were acutely toxic to invertebrate species ranged from 2.2 ug/l for *Daphnia pulex* to 2.0 mg/l for the mayfly *Ephemmerella subvaria* (USEPA 1984). Concentrations causing acute toxicity to fish ranged from 30 ug/l for the guppy *Poecilia reticulata*, to 1 mg/l for the tilapia *Tilapia mossambica*. Methylmercury appears to be the most chronically toxic of the different mercury compounds. Tests with the waterflea *Daphnia magna* and brook trout *Salvelinus fontinalis*, resulted in chronic toxicities occurring at less than 0.04 and 0.52 ug/l, respectively (Biesinger et al. 1982).

In mammals, the central nervous system is the critical organ upon long-term exposure to toxic levels of mercury vapor. Organomercury compounds, especially methylmercury, were the most toxic mercury species tested. Among sensitive species of mammals, death occurred at daily organomercury concentrations of 0.1 to 0.5 mg/kg body weight, or 1.0 to 5.0 mg/kg in the diet. Larger animals, such as mule deer and harp seals, appear to be more resistant to mercury than smaller mammals, such as mink, cats, dogs, pigs, monkeys, and river otters. The reasons for this difference are unknown, but may be related to differences in metabolism and detoxification rates (Eisler 1987).

(g) Zinc: It has been reported that small amounts of zinc are required for nutrition by most crops. A deficiency in zinc causes poor growth, dwarfing leaves on fruit trees, and chlorosis in corn. It has been found that 0.1 mg/l zinc in nutrient solution sustains normal growth in two species of pine trees as seedlings. Toxicity can result in some crops when zinc concentrations exceed low levels. A concentration of 3 mg/l of zinc will cause toxicity in oranges and mandarins, and greater than 10 mg/l affected water hyacinths. The presence of 2 mg/l of a zinc solution suppressed a fungus disease that infected the roots, but didn't harm the watercress plant. During an observation of 18-days, delayed germination and retarded growth of cress and mustard seeds were reported at concentrations of 54 to 436 mg/l of zinc nutrient solution.

A study on rats fed water containing 50 mg/l of zinc showed no harmful effects, and an average daily dose of 2 mg/l was not detrimental. Other tests on rats showed that a concentration of 1,000 mg/kg did not cause any observable effects, 5,000 mg/kg was slightly toxic, and 10,000 mg/kg caused some deaths and cessation of growth when zinc was given as chloride or carbonate in the diet. A much lower concentration of 5 mg/l of zinc on a high selenium diet caused mortality among the rats. Other studies showed that a concentration of 10,000 mg/l administered to hens resulted in reduced body weight, and a drop in egg production and water consumption. Pigs receiving about 3.9 grams zinc per day over a period of three-months showed no ill effects. However, ingestion of milk containing 1,000 mg/l of zinc as lactate resulted in lameness and malnutrition.

The sensitivity of aquatic organisms to zinc depends on the species, age, and condition of the organism, as well as the physical and chemical characteristics of the water. In general, zinc was more toxic to embryos and juveniles than to adults, at elevated temperatures, in the presence of cadmium and mercury, in the absence of cheating agents, at reduced solenoids, at decreased water hardness and alkalinity, and at low dissolved oxygen concentrations (USEPA 1987). Fish are relatively unaffected by suspended zinc, but many aquatic invertebrates, and some fish, may be adversely affected from ingesting enough zinc-containing particles (USEPA 1987). Significant adverse effects of zinc on growth, survival, and reproduction occur in sensitive species of aquatic plants, protozoans, molluscs, fish, and amphibians at nominal water concentrations between 10 and 25 ug/l (Eisler 1993). Acute LC50 (96-h) values for freshwater invertebrates were between 32 and 40,930 ug/l. In fish, this range was 66 to 40,900 ug/l (USEPA 1987).

Zinc affects freshwater fish by the destruction of gill epithelium, and consequent tissue hypoxia. Other signs of zinc poisoning included hyperactivity followed by sluggishness, shedding of scales, and extensive body and gill mucus. Lethal or sublethal effects in most freshwater species at the embryo-larvae stage were in the range of 50 to 235 ug/l, and at 4.9 to 9.8 ug/l for the brown trout (*Salmo trutta*). LC50 (96-h) values for the adult bluegill, *Lepomis macrochirus*, were reported at 5,400 and 40,900 ppb in water at 20 and 360 mg calcium carbonate/l, respectively (Spear 1981). Adult fathead minnows, *Pimephales promelas*, were reported to have an LC50 (96-h) value ranging from 4,700 to 6,100 ug/l at 50 mg calcium carbonate/l. No signs of synergism were observed in rainbow trout exposed to zinc sulfate and copper sulfate at a ratio of 6:1 in a hard water solution. In soft water, most of the fish died when exposed to a 1 mg/l zinc and 0.025 mg/l copper solution for eight-hours. Fish display behavioral modifications, such as avoidance, at concentrations as low as 5.6 ug/l.

Zinc does have a toxic effect towards protozoa and bacteria. A concentration of 0.1 mg/l of zinc will cause an observable decline in the biological oxygen demand (BOD) of the water, and a 50% drop in BOD will occur from a concentration of 62.5 mg/l of zinc. Zinc has been reported to stimulate nitrification at a concentration of 1.0 mg/l, but at a concentration of 10 mg/l it inhibits nitrification.

Zinc in small quantities have been reported to be toxic to shellfish. In studies involving snails, zinc toxic action levels have been reported to be 1.0 mg/l in natural waters.

(3) What are the important sources and pathways of this stressor group?

Geological metals are distributed throughout the environment by natural processes. Human activities serve to increase the levels and distribution of metals, and their many chemical forms.

Waste water discharges account for 40 - 60 percent of the metal loadings in surface water. Urban runoff accounts for 10 - 39 percent, and atmospheric input is less than 5%. Even so, air pollution can transport metals to remote areas.

Metals are cycled through a wide variety of human activities including: manufacturing, electroplating, pesticides, and predator controls for cyanide; smelting, coal burning, and pesticides for arsenic; sewage sludge, fertilizers, smelting, industrial discharges, and landfills for cadmium; chrome plating, inks, and paints for chromium; mining, paints, fuels, and ammunition for lead; mining, smelting, and slime control for mercury; and galvanization, fungicides, and medicines for zinc.

(4) What systems or species/organisms are particularly sensitive or affected?

(a) Population impacts: Metals are bioaccumulated and have documented toxic effects on many species. Metals cause increases in the incidence of lesions, tumors, abnormal behaviors, and other non-lethal effects in many species. Metals cause a reduction in the population size of many species.

(b) Community Impacts: Metals cause the absence of many normally occurring species, and reduce species diversity. They change population sizes in communities, which can result in non-stressor induced population changes within communities.

(c) Ecosystem Impacts: Metals are persistent, and are transported to other ecosystems abiotically and biotically. Some metals are biomagnified in ecosystems and exert effects at multiple trophic levels in ecosystems.

b. Analysis of Problem

(1) Severity: Rank = B

This assessment addresses cyanide and six of the most ecologically significant metals. Cyanide and chromium are not routinely monitored by NYSDEC. Arsenic was monitored in the water column, and cadmium, lead, mercury, and zinc were monitored in water and sediment. Macroinvertebrate and fish residue monitoring programs include metals. Of those monitored, cadmium and mercury present the most serious contamination. Cadmium is usually associated with specific sources. It is not widespread at high concentrations, so its severity is limited to scattered areas of the state. Mercury has shown the highest severity, and studies are showing that it may be more toxic than was previously thought. Mercury can be methylated to form organic compounds that are bioaccumulated and are very toxic.

Mercury is the top metal of concern, and is extremely significant ecologically, because it is so widespread. It has resulted in fish contamination, which is likely causing problems in fish-eating birds. Central nervous system (CNS) effects, reproductive disorders, genotoxicity, and immunosuppression are common. In loons, immunosuppression by mercury makes them more susceptible to infections such as aspergillosis.

Because mostly higher predator populations are affected, this criterion was ranked B. Ecosystem structure and function is not severely damaged. However, the cumulative impact of metals can cause a reduction in species diversity if the metal concentrations are high enough. This is more of a site specific problem than it is a general problem. The possible airborne nature of mercury pollution, and its ability to biomagnify, make it a persistent, long-term threat.

(2) Reversibility: Rank = A

Metals do not degrade, although in the environment they may become bound up in soil or sediment making them less bioavailable. Generally, metal contamination is not reversible. Hazardous waste sites with metals can be remediated. From point sources, metals are best managed by treatment and pre-treatment techniques. These will not be of much help in controlling the mercury contaminating New York State, which is most likely airborne. This is demonstrated by the very remote areas that are contaminated with mercury. Natural recovery of ecosystems if the metal sources were eliminated could be greater than twenty years, thus warranting the A ranking for reversibility.

(3) Ecological Significance: Rank = B

The ecological significance of mercury is considered to be moderate. Mercury is known to affect endangered and threatened species such as the bald eagle. It also affects other sensitive species, especially other fish-eating birds. Mercury and its compounds have no known normal metabolic function. Their presence in living organisms represents contamination from natural and anthropogenic sources, and must be regarded as undesirable and potentially hazardous. Mercury is a cumulative poison and is the metal most toxic to fish. Elevated concentrations of mercury in water are particularly toxic to many species of algae, crustaceans, and salmonids.

Mercury is one of the few metals which: strongly biomagnifies; has only harmful effects with no useful physiological functions when present in fish and wildlife; is carcinogenic, mutagenic, and teratogenic; and is easily transformed from a less toxic inorganic form to a more toxic organic form in fish and wildlife tissues. When exposed to mercury in both mediums, fish accumulate more mercury from sediments than from water. Lower pH levels (indicating increased acidification) are correlated with increased mercury accumulation in fish. Recent work has discovered high levels of mercury in remote lakes of the northeast at sites far removed from any point source.

Animals take up mercury from contaminated water and contaminated food. Preliminary data in the literature suggests the potential for bioaccumulation or biomagnification of mercury is high to very high for the following biota: mammals, birds, fish, mollusks, crustacea, and lower animals; and is relatively low for mosses, lichens, algae, and higher plants.

(4) Geographic Scale: Rank = A

Problems identified in monitoring result in certain pollutants being identified as parameters of concern (Myers - personal communication). Metals are parameters of concern in several areas around the state. They tend to be of concern in areas of high urbanization and industrial development. Cadmium is problematic due to specific sources in scattered areas of the state. Zinc is very common due to the geology of the state, but is not highly toxic at the concentrations found. Lead was very widespread due to the use of leaded fuels, but with the use of unleaded fuels concentrations are decreasing. By far the metal presenting the greatest concern is mercury. It is widespread and its source is unknown, although airborne sources are suspected. In many Adirondack lakes, high mercury levels have resulted in fish consumption advisories (Sloan - personal communication). The Lower Hudson - New York Harbor region generally has higher metal concentrations than in other areas in the state. Hot spots such as the Buffalo and Niagara Rivers, Onondaga Lake, and areas near hazardous waste sites show elevated metals. Overall, metal contamination is considered to be extensive in geographic scale.

(5) Final Ranking: Rank = B

Many metals are geological in origin and coexist in healthy ecosystems, but the increases in metals in the environment due to anthropogenic sources exceeds ecological defense mechanisms. If the ecological impacts of mercury and other metals become worse, the overall ranking of metals could go up in future assessments.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Metals and Cyanide		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**B**	Mercury is the metal of most concern because it is so widespread and can be methylated to form organic compounds that are bioaccumulated and are very toxic.
2. Reversibility	**A**	Remote areas are contaminated with mercury from airborne sources. Natural recovery of those ecosystems could be greater than twenty years.
3. Eco-significance	**B**	Mercury strongly biomagnifies; has only harmful effects; and is mutagenic, teratogenic, and carcinogenic.
4. Geo-scale	**A**	Mercury is widespread. In many Adirondack lakes mercury levels have resulted in fish consumption advisories. Other hot-spots include the lower Hudson River-New York Harbor region, the Buffalo and Niagara Rivers, and Onondaga Lake.
Overall Rank	**B**	Increases in metals in the environment due to anthropogenic sources exceed ecological defense mechanisms. If the ecological impacts of mercury and other metals become worse, the overall ranking of metals could go up in future assessments.

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5. Non-volatile Halogenated Organic Compounds

a. Stressor Characterization

(1) What stressors are included?

This very large and diverse group is primarily composed of three types of synthetic chemicals well represented among the USEPA's Priority Pollutants (Callahan et al. 1981) and other toxic threats (ATSDR 1994):

(a) chlorine-containing aromatic compounds such as PCBs, DDT, and chlorinated styrenes deliberately or accidentally released after manufacture and use, perhaps created inadvertently as byproducts of chemical manufacture or formed from wastes, such as polychlorinated dibenzodioxins (e.g., TCDD) and hexachlorobenzene;
(b) polychlorinated alicyclic compounds, typified by pesticidal chemicals such as toxaphene, mirex (declorane), hexachlorocyclohexane (lindane), chlordane and dieldrin;
(c) highly chlorinated paraffins (carbowaxes).

Related but smaller sized members of these groups are included with the volatile and semi-volatile organics (see Non-volatile and Semi-volatile Organic Compounds, and Volatile Organic Compounds stressor groups), even though there is a continuum of properties and agents over a wide range of molecular weight (up to about 600-750). Many of these compounds are or were used as solvents, pesticides, plasticizers, and fire-suppressing agents, but they have been banned, restricted or are no longer imported into or manufactured for use this country. Some are still manufactured for export. Because of their properties, however, all of these chemical groups tend to co-occur throughout New York State in soils, sediments, and surface waters and thus are linked with a series of health and ecological problems.

Other halogenated organics are excluded. For example, many fluorocarbons (Teflon™, halothane, and pesticides such as trifluralin) behave and react in the environment so differently, that they do not fit into this group. Many of the thousands of natural halogenated compounds are of little environmental interest. The chlorination by-products formed during bleaching, drinking water processing, and sanitation are discussed under the halogen stressor group.

The sanitizer 2,4-dichlorophenol (DCP) can be manufactured as such, produced as a byproduct (e.g., in the manufacture of the herbicide 2,4-dichlorophenoxy acetic acid), and obtained naturally as a breakdown intermediate from 1,3-dichlorobenzene. Each of these direct and indirect means of generating DCP is readily classified as a halogenated organics source. Numerous other compounds could serve as similar examples of the difficulty in just accounting for sources in this group (Rice and O'Keefe 1995).

(2) What do they do ecologically?

Halogenated organics have had an important role in the history of ecotoxicology (Suter 1994), for it was the impact of DDT on eggshell thinning in birds and then of PCBs on mink reproduction which changed pesticide registration, industrial chemical testing, hazardous waste management, and many other activities affecting the environment. Depending on dosage, these chemicals can cause:

(a) High doses (10-1000 mg/kg), obtained by exposure to water concentrations of 2-200 µg/L, are selective toxicants to insects and other invertebrates, and acutely toxic to many aquatic species, thereby changing community structure (ATSDR 1994);
(b) Lower doses (0.1-10 mg/kg) can affect the immune, nervous, and reproductive systems of sensitive species, contribute to cancer promotion, and selectively cause birth defects (Savitz et al. 1996);
(c) At even lower doses, there is mounting, but yet incomplete, evidence that they can alter hormonal function by either mimicking estrogen or being anti-androgenic and by affecting reproduction, development, and learning in mammals and other vertebrates (Savitz et al. 1996).

Ecologically, they are held responsible for elimination of fish-eating predators (osprey, bald eagle, pelicans, mink, and otter) and birds of prey (peregrine falcon and Harris' hawk) over wide areas, and for adversely affecting many other aquatic species (herons, cormorants, terns, gulls, salmon, sturgeon, alligators, and frogs) (Rice and O'Keefe 1995). Much of the ecological impact stems from low, non-toxic levels in plants and lower animals in the food web being bioaccumulated by their predators to much higher, more effectively toxic levels (Suter 1994). Among the earliest such victims were the Atlantic salmon and lake trout, in which the embryo form was sensitive to accumulated body burdens passed on in egg yolks, especially when augmented by further exposure.

(3) What are the important sources and pathways of this stressor group?

The most important chemicals of this group have been banned, or are not manufactured here any more, although they may be made and used overseas. Nevertheless, they appear destined to be with us for decades, if not centuries (Lake Ontario Committee 1992a & b). Many were deposited in the sediments of our lakes, rivers, estuaries, and oceans, or remain distributed in soils (Rice and O'Keefe 1995). Significant portions are still carried around by people, farm animals, and wildlife, as they have accumulated in the fat of practically all species (Ram and Gillett 1992; Schantz et al. 1994; Rice and O'Keefe 1995; Comba et al. 1996; and Haffner et al. 1997). From these sources they are mobilized into air by several means, then deposited on soil and leaf surfaces. They can be mobilized into surface waters by erosion, and by organisms burrowing in soils and sediments, the largest and most important reservoirs containing about 80 percent of the residues of all PCBs ever manufactured (Rice and O'Keefe 1995). Although Lake Ontario is the smallest of the Great Lakes, it receives the air-borne and sediment burden for the whole system, in addition to municipal and industrial releases along the waterways. Annually, about 1 percent of the halogenated organic load goes to the Gulf of St. Lawrence, where it can threaten beluga whales and other marine species, and another 1 percent recycles back and forth from the surrounding watersheds via biota. Apparently about 1 percent comes in via drift and dryfall from other airsheds, because residual levels of these compounds in soil and water have declined relatively slowly after a large initial drop associated with the bans. Thus, there is about a 2 percent mobile environmental residue (Rice and O'Keefe 1995) available to biota at any instant. Of continued concern are releases from abandoned waste sites (ATSDR 1994); production and accumulation during waste processing (e.g., disturbance or sediments, foodwebs, low temperature incineration, or composting of yard waste or sewage sludge)(Harrad et al. 1991; Lisk et al. 1992); and unintercepted point-source permitted discharges (e.g., sewage treatment plants)(Savitz et al. 1996) and non-point source runoff from urban areas via storm sewer bypass (Rice and O'Keefe 1995).

The movement of chemicals in the environment is termed chemodynamics (Suter 1994), and it was the halogenated organics which forced understanding of chemodynamic processes. The most important property in regard to these processes is related to the water solubility, sorption onto soil and sediments, and bioaccumulation, and is termed the partition coefficient or K_{ow}. The halogenated organics have high K_{ow}, very low water solubility, great resistance to biodegradation, and a tendency to become pervasive in the environment (Suter 1994; ATSDR 1994).

(4) What systems or species/organisms are particularly sensitive or affected?

Fish-eating carnivores [e.g., mink and otter (Foley et al. 1988), human beings (Schantz et al. 1994), and birds (pelicans and eagles)] are among the most sensitive, long-lived targets (Suter 1994). Because reproduction fails, there will continue to be aged, infertile adults long after the rate of adding new individuals via reproduction has dropped below a critical value, deceptively hiding the impact. Peregrines have been restored in New York City, but not in upstate areas, such as the Adirondacks and the Lake Ontario floodplain, where they once flourished.

These agents can be acutely toxic to young fish, disrupting the food web, and wiping out migratory salmon and striped bass. In New York State, the St. Lawrence River-Lake Ontario basin and the Mohawk-Hudson River basin have been hard hit by past releases during manufacture, farming, and waste processing (Savitz et al. 1996). The Southern Tier, along the Delaware, Susquehanna, and Allegheny Rivers, lacks such impacts, undoubtedly because of the absence of significant sources of halogenated organics (Foley et al. 1988; Savitz et al. 1996).

b. Analysis of Problem

(1) Severity: Rank = A

Effects can be both locally severe in one system or group of organisms, and relatively benign in a nearby group under different conditions. Because the chemicals tend to be eliminated from commerce, the piscivore-based communities along the St. Lawrence remain limited (Lake Ontario Comm. 1992a & b; DeVault et al. 1996). There are more peregrines in New York City than in the entire Great Lakes Region. Nevertheless, releases of this group are finally declining, at least as compiled by Savitz et al. (1996) using USEPA's Toxic Release Inventory data.

(2) Reversibility: Rank = A

Many systems seem to respond to remediation, and certainly controls on halogenated organics have vastly improved the situation in many sites. A very important feature is the gradual burial of existing sources in waterways (overburden). Sequestration of materials into soil and sediment particles is another, poorly understood process from which release is too slow to affect potentially exposed organisms (Alexander 1995). However, long-range transport apparently continues to add to the soil-sediment reservoirs, and sequestration limits the usefulness of many remediation methods (Haffner et al. 1997). The acute lethal and chronic health effects may be overcome as sequestration eventually limits exposure, but problems such as altered development may be difficult to correct, and may continue for some time.

(3) Ecological Significance: Rank = A

These chemicals do not obliterate the landscape as badly as do smelters, but they work subtly and quietly, diminishing capacity of systems and populations to thrive and even survive (ATSDR 1994). Where valuable and vulnerable species are exposed to these agents, food web bioaccumulation (Ram and Gillett 1992) invariably spells serious and pervasive trouble. Those troubles have been with us for over three decades, and seem to require continued effort to reduce or eliminate (Haffner et al. 1997).

(4) Geographic Scale: Rank = A

As noted above, highly impacted areas around New York State include the Lake Ontario shore and embayments (in both the U.S. and Canada), the St. Lawrence, Hudson and Mohawk Rivers, and the Lake Champaign-Lake George basin (Foley et al. 1988, Savitz et al. 1996). Some of the Adirondack lakes are affected. Many of the several hundred New York State Superfund sites involve one or more (usually >7) halogenated organics. Almost all regions have (and continue to receive) contamination by atmospheric transport, meat, and fish imported from elsewhere in the country, and leakage/release from old and discarded equipment.

(5) Final Ranking: Rank = A

No other group of chemical classes so universally represents the problems originating from modern life and resulting in inadvertent, but nonetheless very serious, ecological impacts. Many components saved lives and money, prevented injury, and otherwise seemed splendid, particularly since they were non-flammable, not highly toxic to humans, and appeared so benign. Clearly, the scale of the problem (e.g., numbers of agents, strength, and distribution of sources), the chemodynamic pathways often ending in bioaccumulation in sensitive species, and the ecological scale of impacts which are often severe and irreversible, define a stressor group that is causing serious ecological impairment in New York State.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Non-Volatile Halogenated Organic Compounds		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**A**	numerous species and ecosystems affected
2. Reversibility	**A**	impacts have lasted for decades from last major releases
3. Eco-significance	**A**	because action is largely through foodwebs and taking place on diverse organisms at several levels of development and functionality
4. Geo-scale	**A**	widespread impacts, foodweb contamination in all ecoregions; impacts most severe along Lk. Ontario-St. Lawrence-Lk. Champlain-Lk. George-Hudson frontiers
Overall Rank	**A**	NYS could well be the state most impacted by this group of stressors

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6. Non-volatile and Semi-volatile Organic Compounds

a. Stressor Characterization

(1) What stressors are included?

This stressor group (SVOCs) is largely a great variety of organic compounds not included in other stressor groups. The list below has been simplified to include stressors for which release data are significant (>25 million lbs./yr) as well as certain agents primarily of human health concern but with known action toward fish and wildlife populations. The list also includes Priority Pollutants (Callahan et al. 1979) for which human health is the primary concern and materials cited by ATSDR (1994) and reported to U.S. EPA (Savitz et al. 1996).

*Acetophenone - solvent and waste product
*Alkyl benzenes - C_4 through C_{44} alkyl derivatives of benzene used as insulating oil (underwater electric cables), chemical intermediate/feedstock, paint solvent
*Alkylbenzenesulphonates - synthetic detergent
Alkylphenols and alkylphenol ethoxylates - chemical intermediate/feedstock; plasticizer; surfactant, detergent, or wetting agent in household products and agricultural and industrial applications; spermicidal contraceptive [NB: In 1983, Schenectady Chemical (Rotterdam Junction, NY) manufactured nonylphenol with annual capacity of 25 million pounds]
Aniline - synthetic intermediate and solvent
Benzyl chloride -synthetic intermediate
Cresols - solvents, by-products, disinfectants, pesticides
*Dimethylformamide - solvent
Dioxane - solvent
Glycols and glycol ethers - antifreeze and de-icing formulations; food and cosmetic additives; solvent for surface coatings, cleaners, brake fluids, adhesives
*Methyl pyrrolidinone - chemical catalyst and solvent
Naphthylamine - a chemical intermediate/feedstock
Phenol - chemical intermediate/feedstock, disinfectant, one of top 50 chemicals by volume produce in US
Phthalates - as *bis*-esters of phthalic acids (usually methyl, ethyl, butyl, or ethylhexyl): plasticizers; solvents in inks, paints, pesticides and cosmetics; another high volume chemical group
Pyridine - solvent and dyestuff component
O-Toluidine - solvent and synthetic intermediate
*Triarylphosphates (or mixed arylalkyl triphosphates) - solvents; plasticizers; fire retardants; hydraulic fluids or cutting oils (non-flammable substitutes for PCBs, petroleum products)

* Not reported as released in NYS during 1990-1994 (Savitz et al. 1996).

The compounds in the SVOC group are moderately water soluble (low to intermediate octanol-water partition coefficient, K_{ow}) and not generally very volatile (as the descriptor implies), and thus have low Henry's Law constants, reflecting a tendency to stay in water and not be either strongly sorbed to sediments nor vaporized in to the air. Persistence in the environment is thus largely dependent on the extent of transformations, which can include abiotic photolysis and hydrolysis or biotic oxidation and adduct formation. To a considerable extent these processes depend on favorable microbial genetics, available reactants, and conditions (oxygen availability, acidity, temperature) and thus can vary between sites and over time. When releases are large, some undegraded material could persist by being sequestered into sediment or soil (Alexander 1995), even though tendency to sorption is not as strong as for PAHs and chlorinated aromatics.

Several groups of chemicals in this category have value because of their surface active properties (alkylbenzene sulfonates, alkylphenols and phenol ethoxylates, glycol ethers), so that their primary biological actions are with membranes or lipid-protein interactions (Cserháti 1995). Substituted amines and anilides have somewhat similar properties and are included here as well. The widespread use of ethylene and propylene glycols as aircraft de-icing agents and increasing air traffic are marked by the notable increased release of these agents near airports (Savitz et al. 1996).

Many of these compounds are also naturally available from live and decaying plants or in soils (oil seeps, microbial action). However, the scale and wide-spread nature of the numerous anthropogenic sources of these compounds creates concerns for total loadings. The lack of ready detectability except by more recently developed analytical techniques (e.g., mass spectroscopy combined with gas or high performance liquid chromatography, GC-MS or HPLC-MS) means that our ecological knowledge of these materials is more limited than that regarding environmental distribution of the readily measured halogenated aromatics, PAHs, and VOCs.

(2) What do they do ecologically?

The wide range of structures involved in the catch-all category of SVOCs makes generalizations difficult. As with many such groups of chemicals, knowledge is largely in the form of *in vitro* test systems, with much less attention and information in *in vivo* systems and practically nothing at the level of populations and communities. The wide spectrum of uses, however, attests to the desirable relationship of many properties to outcomes, such as surfactant use in promoting drug uptake and pesticide effectiveness. In a limited number of cases, molecular interactions with lipids and proteins in organisms have been thoroughly investigated and indeed are routinely used each day (cell disruption and organelle extraction techniques). In other cases, as with the estrogenic action of certain plasticizers, the discovery came as a rude surprise after years of undetected contamination. Even so, extrapolation from these molecular level effects to populations and intact systems has been even more limited than observation of effects in the field attributable to these stressors.

Because of the very number of chemicals and the scale of their releases, the impact of SVOCs may be greatest as mixtures of wastes emitted from water treatment plants and the seeps of buried wastes, where they create biological and chemical oxygen demand (BOD and COD) which in turn limit aquatic habitats to insensitive invertebrates (e.g., tubificid worms, a marker organism for contaminated sediment and water). Because chemicals such as phenol and cresols can be reactive with enzymes of oxidative processes in both plants and animals, they not only interfere with metabolism, growth and reproduction, but can have genotoxic effects. Pyridine, dioxane, aniline and *o*-toluidine are probable carcinogens, while phthalates and alkylphenols demonstrate a wide range of genotoxic and reproductive effects in individual species in the laboratory. *Daphnia* spp. were among the first observed to be so affected by phthalates, while tissue culture responses to nonylphenol and other plasticizers have raised numerous concerns about estrogenicity. Triarylphosphates are associated with delayed type neurotoxicity (a crippling spinal injury) and peripheral neuropathies (numbness in the extremities) in people, but ecological effects are unclear because of species selectivity in toxic response. A number of the SVOCs are believed to have behavioral effects, perhaps because they are similar to natural products involved in chemical ecology as signals and karyiomones (chemicals acting over a distance between the same or different species). The absence of studies to define the more subtle impacts on reproduction and behavior is thus a particularly serious matter for the SVOCs.

Acute toxicities are typically not extreme, but considerable inter-species variability makes selective chronic toxicity, and impacts on diversity are a broad concern where exposures may be frequently repeated at high doses. Thus, it is hardly surprising that among the earliest steps in water quality management and in waste management have been efforts to reduce inputs of these stressors. Initially that was by reducing BOD and COD, a step which greatly improved the ecological health of numerous stream reaches, then followed up in NYS by generic standards for mixed emissions (<100μg/L for mixed components or 50μg/L for an individual component without a standard or guidance value).

Recent attention to the environmental damage associated with exposure to hormonal mimics and antagonists within this category of stressors has refocused both human and ecological effects on subtle changes rarely evidenced by wide-spread fish kills (as were experienced in the `50s and `60s prior to Clean Water Act efforts). Instead, wildlife damage has emerged as a putative sentinel or biomarker for potential health effects (e.g., birth defects, breast cancer, reproductive impairment). Other groups of stressors, such as PAHs and halogenated aromatics, have similar or related ecological effects which depend on the persistence and pervasiveness of those agents. The SVOCs achieve such impacts by frequency and intensity of release coupled with modest degradability and potency for particular compounds. The estrogenicity of nonylphenol and related compounds is not very high (about $4x10^{-3}$ to $1x10^{-6}$ that of estrogen in various assays), as reviewed by Nimrod and Benson (1996). Many natural phytoestrogens and fungal products are much more potent, with established roles in the chemical ecology of plant-animal relationships. Robinson et al. (1994) attributed toxicity of unchlorinated paper pulp wastewater to concentration of these phytoestrogens in effluents. An ecological role for a number of the SVOCs thus does not emerge as clearly as might be anticipated by the recent furor.

(3) What are the important sources and pathways of this stressor?

The widespread and variable intensity of releases of these stressors are associated with waste treatment (waste water and solid waste management) and to a lesser extent with atmospheric releases. Of course, release from consumer products during use or disposal is an important source which is rarely tracked. Robinson et al. (1994) noted that these types of compounds are released from wood pulp processing and papermaking when a strong oxidant (e.g., chlorine or ozone) is not used in the bleaching of pulp. Probably similar plant products could be released by commercial fruit and vegetable processing. Solvents and plasticizers literally ooze out of buried and discarded materials, eventually forming a surface monolayer as a light Non-Aqueous Phase Liquid [NAPL] (e.g., phthalates) or a pool in the sediment as a heavy NAPL (e.g., arylphosphates). NAPLs become mixtures in which other SVOCs and highly fat-soluble chemicals may dissolve and thereby be protected from microbial degradation (Alexander 1995). The NAPLs potentially control exposure in aquatic (Huckins et al. 1991) and perhaps even soil systems.

Once released to the environment the SVOCs are subject to degradation, but that can be highly variable. Because of their resemblance to many natural products, the use of plant to eliminate buildup in soils and as a remediation technology is being proliferated (Walton et al.). In the conditioned waste stream of a manufacturing plant, where bacteria and other microorganisms have an opportunity to adapt genetically to such releases, the rate of degradation may be many times faster than, say, in the relatively naive environment in which an object is used, discarded or disposed of [end-user inputs]. To the extent that specialized enzymes or even transport systems for uptake into a degrading organism are required for environmental degradation, the end-user inputs reduce the opportunity to maintain that genetic capacity. Abiotic transformations thus can be very important in preventing build up of some stressors among the SVOCs, especially the aromatic compounds (phenols and cresols) and the esters and ethers (phthalates, triarylphosphates) which are oxidized or hydrolyzed in sunlight to less toxic and readily degraded compounds.

The ready biodegradability, as well as low affinity for fat, generally prevents SVOCs from being bioaccumulated extensively and passed through foodwebs. However, when exposure is frequent then small amounts can be sequestered in soil, sediment and fat to be released to biota. Moreover, the solubility properties make possible what can be described as “systemic movement”, that is, relatively easy movement throughout plants and animals because the SVOCs are not so polar as to be prevented from crossing the fat-rich membranes and to be readily excreted nor are they so non-polar as to be trapped in fat or those membranes. The molecular size is small enough so that they can pass through pores without requiring specific transport mechanisms. In other words, they have a potential for being more or less ubiquitous, but not at high concentrations in any particular spot.

The sources and pathways of SVOCs clearly diverge from ready control as they pass from the manufacturer to the consumer, so that actions at the early stages of a chemical’s life seem to be extremely important for risk reduction for this class of stressor. Steps in toxicity reduction (substitution or use limitation) and identification of the value of recovery (recycling, re-use) have been applied well for SVOCs, but obviously more needs to be done.

(4) What systems or species/organisms are particularly sensitive or affected?

Demonstration of impacts in the field has been limited to chronic emissions in wastewater treatment and spills/careless disposal, typically in the presence of numerous other agents (Savitz et al. 1997). Invertebrates are sensitive to phenols and phthalates; vertebrates seem especially vulnerable to impacts of hormonal mimics on a very selective basis. This is even more true for triarylphosphate neurotoxicity, which can be demonstrated in primates (including human beings), water buffalo (and perhaps cattle), cats, and chickens, but not in dogs, rodents, or quail and pheasants. Waterfowl have been subjected to light NAPL exposure at the surface of lakes and streams, adding further credibility to the reproductive damage and hormonal mimicking action of the phthalates, but this is difficult to distinguish from the action of bioaccumulated polyhalogenated materials in waterfowl from those environments. It is likely that estuarine and coastal areas may be affected by the throughput from many communities upstream, partly because the halocline (interface between salt water and fresh water) may act to force some of the material out of the water and into the light or heavy NAPLs or into sediments.

b. Analysis of Problem

(1) Severity: Rank = B

Selected populations can be eliminated locally or chronically depressed by high BOD/COD levels, respiratory enzyme inhibition, or the reproductive effects of hormonal mimics (as with continuous discharge) or by frequent releases sufficient to cause mortality. Ecological diversity may be reduced. Releases remain highly variable, creating potential for problems which are poorly understood and rarely monitored. Documented ecological damage by specific SVOCs is limited and infrequent.

(2) Reversibility: Rank = B

Even when populations are eliminated by spills or untoward releases, recovery is reasonably rapid, although some members of the community recover more slowly. The impacts of more pervasive stressors can be tolerated via development of genetic resistance in microbiota and invertebrates. However, it is difficult to identify agents responsible for certain reproductive impacts which appear to be very slowly reversed.

(3) Ecological Significance: Rank = C

No areas in New York of high or moderate ecological significance are shown to be adversely affected by SVOCs per se, although that is more a reflection of not having looked than not finding problems. In a number of cases potential SVOC effects from large releases may be masked by the presence of relatively high amounts of persistent halogenated compounds (e.g., in the Mohawk-Hudson region and Lake Ontario plain).

(4) Geographic Scale: Rank = B

Only localized areas may be currently affected by SVOC releases by manufacturers. Even though New York State is threatened by these compounds in practically every venue via consumer use and disposal, municipal wastewater treatment, and spills of various kinds, the scale and scope of industrial and municipal releases have dropped dramatically in recent years (Savitz et al. 1996). The attempts by Rohmann (1985) to characterize releases int the Hudson-Mohawk Basin provides an interesting set of benchmarks for comparison. Focusing on phthalates, the only SVOC considered, there were about 23 of the 190 plants releasing at least 5,000 lbs/yr in 1985. By 1990 all but one had either gone out of business or corrected the release problem; by 1994 that one source was below 1,000 lbs/yr. Similar trends are apparent for the entire state.

(5) Final Ranking: Rank = B

Even though SVOCs may produce severe local effects, none have yet been identified as a significant ecological problem in New York State at this time. The nature of their chemo-dynamic behavior and toxicity should alert us to the need and indeed appropriateness of continued risk reduction actions. Continuous or frequent environmental releases have been successfully controlled or remediated for production and waste disposal sites, but controls at the use/disposal end are unlikely to be as effective. Because very large quantities of these materials are used in and transported through New York, constant vigilance and attention to safety are needed to prevent accidental releases and continue the successful history of control of this environmental stressor group.

(6) Ranking table showing ranks for each criterion and overall rank assignment:

Non-volatile and Semi-volatile Organic Compounds		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**B**	Local effects can be severe, but are infrequent and not widespread
2. Reversibility	**B**	Most effects are readily reversible, but reproductive impacts may be more difficult
3. Eco-significance	**C**	Absence of demonstrable impacts beyond local outfalls limits threats
4. Geo-scale	**B**	Major releases are concentrated in only two ecoregions, but end user releases are ubiquitous
Overall Rank	**B**	Sheer scale and diversity of actions keeps stressor group at level of concern, but actual realized impacts are poorly documented

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7. Nutrients

a. Stressor Characterization

(1) What stressors are included?

The primary ecological stressors in this group are nitrogen and phosphorus compounds. In freshwater ecosystems, the limiting nutrient to plant growth is usually phosphorus. In salt water ecosystems, the limiting nutrient is usually nitrogen, although nitrogen-phosphorus ratios and other elements (e.g., iron) may be important as well. Ecologically important nitrogen forms, listed in order of decreasing oxidation state, are nitrate, nitrite, ammonia, organic nitrogen, and nitrogen gas. These forms are biochemically interconvertible components of the nitrogen cycle (APHA 1995). Phosphorus occurs in freshwater primarily as orthophosphates, condensed phosphates, and organically-bound phosphates.

(2) What do they do ecologically?

Nitrogen and phosphorus are not inherently bad, because some level of both are necessary to sustain ecosystems. Nutrient inputs can change freshwater, marine, and terrestrial ecosystems from one trophic state to another. In instances where nitrogen and/or phosphorus are growth-limiting nutrients, the discharge of these stressors may stimulate the growth of photosynthetic micro- (e.g., algae blooms) and macro-organisms (e.g., rooted aquatic vegetation) in nuisance quantities. For example, excessive concentrations of phosphorus led to the famous "death" of Lake Erie ecosystem in the 1960s and 1970s. But Lake Erie, thankfully, is a good example of how ecosystems can recover from excess nutrient pollution when the controlling nutrient concentrations are reduced.

Excess nutrient stressors act on aquatic communities by:

(a) Reducing or depleting the dissolved oxygen concentration;
When excessive blooms of aquatic vegetation exceed their life-sustaining nutrient supplies and die off, bacterial decomposition of this dead plant material reduces/depletes the dissolved oxygen. This can result in highly visible fish kills and less visible, but equally important, death of their invertebrate food supply. Dissolved oxygen reductions-depletions resulting from blooms occur both in freshwater and marine ecosystems.

(b) Producing toxins;
In freshwater ecosystems, excessive nutrients can stimulate plankton algae to produce toxins. These toxins can cause fish and invertebrate mortalities, and some may be toxic to other wildlife and humans that consume fish from these waters. In marine ecosystems, excessive nutrients may stimulate dinoflagellates (e.g., *Pfiesteria piscicida*) to produce neurotoxins that cause fish kills and possible neurological symptoms in humans that contact infected fish or water (University of Maryland 1997).

(c) Creating excessive swings in diurnal pH and dissolved oxygen concentrations; Blooms of plankton and rooted vegetation can strip carbon dioxide from the water causing the pH to rise dramatically during daylight hours. These plants produce oxygen during the daylight hours, and consume it for respiration purposes at night. This can create supersaturated dissolved oxygen concentrations during the day and depressed levels at night. These diurnal fluctuations in pH and dissolved oxygen can cause stress and mortality in freshwater and marine ecosystems.

(d) And creating elevated ammonia concentrations in benthic sediments. Ammonia concentrations in freshwater and marine sediments can reach concentrations that are stressing or lethal to fish, shellfish, and other invertebrates in freshwater and marine ecosystems.

The effects of excessive nutrients on terrestrial ecosystems are not well documented.

(3) What are the important sources and pathways of this stressor group?

Sources and pathways of these stressors include municipal and industrial discharges; agricultural and urban runoff of fertilizers and animal wastes; recycling of sediment-stored nutrients during seasonal turnover in freshwater and offshore marine upwelling events; wet and dry air deposition (especially nitrogen in marine waters)(USEPA 1997); and home wastewater disposal systems.

(4) What systems or species/organisms are particularly sensitive or affected?

Any aquatic or marine endangered species could be adversely affected by toxicity, habitat change, or low dissolved oxygen situations resulting from excessive phosphorus and nitrogen. This would include amphibians that have aquatic lifestages and other animals that eat aquatic organisms. Oligotrophic and mesotrophic lakes that thermally stratify and have cool and cold water fish species (e.g., walleye, trout, and salmon) are particularly vulnerable to eutrophication (aging). Increased phosphorus means additional demand on the limited dissolved oxygen during periods of thermal stratification, and loss of cool and coldwater species when dissolved oxygen concentrations are depleted. Rivers and streams are vulnerable to reductions in biodiversity due to diurnal pH and dissolved gas stresses. Populations of commercially and recreationally important species of fish, shellfish, and invertebrates can be reduced in freshwater and marine ecosystems.

b. Analysis of Problem

(1) Severity: Rank = A

Excessive concentrations of limiting nutrients can seriously alter the structure and function of aquatic ecosystems. In New York State, examples of the disruptive power of excess limiting nutrient concentrations are Onondaga Lake (freshwater ecosystem) (Onondaga Lake Management Conference 1993) and Long Island Sound (marine ecosystem) (USEPA 1997). The aquatic ecosystems in these waterbodies have been dramatically altered due to low dissolved oxygen concentrations brought about by excessive limiting nutrient concentrations. Although these examples are dramatic, more subtle ecosystem degradation is occurring throughout New York State. The Priority Water List (PWL) published by NYSDEC (1996) lists 1,426 waterbody segments in New York State with impaired water quality. Behind acid rain (395 segments) and siltation (294 segments), nutrients (293 segments) are listed as the third largest cause of water quality impairment.

(2) Reversibility: Rank = B

After the limiting nutrient source(s) are abated, aquatic ecosystems with high flushing rates (e.g., streams, smaller reservoirs, smaller lakes, ponds, bays, and estuaries) will recover in a few years. Systems with lower flushing rates (e.g., larger lakes, bays, and estuaries) may take decades to recover, especially if sediments are a major source of recycled limiting nutrients.

(3) Ecological Significance: Rank = A

The aquatic ecosystems in extensive areas of Long Island Sound (USEPA 1997) and Onondaga Lake (Onondaga Lake Management Conference 1993) have experienced dramatic reductions in biodiversity due to nutrient stressors. Similar disruption has occurred across New York State in smaller lakes, ponds, reservoirs, and streams, which make up the majority of the 293 PWL segments (NYSDEC 1996). While in good condition now, the coldwater ecosystems of the Finger Lakes are at risk of cultural eutrophication due to nutrient enrichment from sewage and fertilizer usage within these watersheds. These ecosystems contain unique natural communities, important salmonid spawning habitat, and are highly sensitive to nutrient enrichment because of their oligotrophic trophic state. These unique ecosystems deserve protection from the effects of excess nutrients.

(4) Geographic Scale: Rank = A

To one degree or another, excessive limiting nutrients adversely affect aquatic ecosystems across all six ecoregions of New York State.

(5) Final Ranking: Rank = A

Excessive nutrients cause significant changes in freshwater and marine ecosystems in New York State. They reduce biodiversity, and adversely affect unique and economically important populations of fish and shellfish. Although some high flushing rate habitats can be naturally cleansed in a matter of years, habitats with low flushing rates and with sediments that are contaminated with limiting nutrients may take decades to recover. Still other aquatic ecosystems may be permanently damaged.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Nutrients		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**A**	affects primarily aquatic communities; community structure of freshwater and marine ecosystems can be dramatically altered; species of economic importance and threatened/endangered species lost
2. Reversibility	**B**	systems with high flushing rates (e.g., streams, small ponds) may recover quickly; systems with low flushing rates and/or sediment enrichment (e.g., large lakes, bays, estuaries) may take decades to recover
3. Eco-significance	**A**	unique coldwater ecosystems such as the Finger Lakes are at risk
4. Geo-scale	**A**	all six ecoregions of NYS experience nutrient related effects on ecosystem function
Overall Rank	**A**	population increases and global climatic change are likely to increase nutrient enrichment; best management technologies are available to reduce nutrient loading to aquatic ecosystems

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8. Particulates

a. Stressor Characterization

(1) What stressors are included?

This stressor group includes a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a wide range of sizes. These stressors include dust, pollen, asbestos, soot, and certain pollutant gases such as sulfur dioxide, nitric oxide, nitrogen dioxide, and ozone.

While considered particulates, the above mentioned stressor gases will not be assessed in this characterization (see Atmospheric Gases stressor group). Trace heavy metals are also transported as particulates, but will not be fully discussed here (see Metals and Cyanide stressor group).

This stressor group characterization will focus on solid particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers (PM-10), although some of the affects cannot be easily separated from the involvement of the above mentioned atmospheric gases and heavy metals.

(2) What do they do ecologically?

Harmful effects to birds and mammals in North America, Europe, Africa and Japan have been observed for a variety of airborne pollutants. Injury and death of terrestrial animals from pollution have been reported since the 1870's (Barker and Tingey 1992). Bioaccumulation or tissue contamination has been one of the most commonly reported air pollution effects (Barker and Tingey 1992).

Photosynthetic capability and nutritional value of vegetation used by wildlife may be adversely influenced by acid deposition (Barker and Tingey 1992)(see Atmospheric Gases stressor group).

For aquatic animals, the primary modes of exposure have been in response to the direct deposition of acidifying air pollutants, such as sulfates and particulate matter. Subsequent alteration of the aquatic environment, by acidified water for example, causes changes in species composition, community structure, energy transfer and nutrient cycling (Barker and Tingey 1992)(see Atmospheric Gases stressor group).

Particulates may not be lethal by themselves, but may cause injury or death by lowering the resistance of animals to natural stresses, such as drought, diseases, and natural pest infestations. Adverse ecological effects to animals may result from contamination of terrestrial and aquatic food webs, and alteration of habitat by air pollutants (Barker and Tingey 1992).

Wildlife that depends upon the soil environment, such as burrowing and litter-inhabiting species (e.g., beetles, millipedes and earthworms) are sensitive to soil contamination by air emissions. For example, the density of insectivorous bird species has been found to be correlated with arthropod biomass in the New Jersey Pine Barrens (Barker and Tingey 1992).

Chronic exposure may occur locally to plant and animal individuals, populations, and communities from particulate deposition from point sources such as coal-fired power plants and refuse burning plants, or regionally from ozone resulting from distant urban sources. Particulates that can be transported long distances are of particular biological concern (e.g., as respirable contaminants and as indirect threat to animals through bioaccumulation).

In general, it can be concluded that coarse dusts may have an adverse effect on the growth of forest vegetation, mainly attributable to crust formation on foliage. Heavy accumulation of cement kiln dust have been shown to reduce early growing season elongation of coniferous twigs and foliage. Limestone dust resulted in a reduction in radial growth of at least 18 percent in red maple, chestnut, and red oak while increasing the growth of yellow poplar by 76 percent (Smith 1990).

Reproduction of forest trees may be adversely impacted by a variety of air-contaminants at numerous points in the reproductive cycle (Smith 1990).

In forest ecosystems, in excess of 90 percent of the heavy metals deposited from the atmosphere may not be available for root uptake. Acute, direct toxicity caused by heavy metal deposition and /or mobilization by acidification, probably does not occur in forest trees located outside urban, roadside, or selected point source industrial and electric-generating environments (Smith 1990).

Habitat loss or alteration occurs as the result of injury or death to vegetation that provides cover, reproductive habitat, and food for wildlife. This loss of habitat can affect the numbers and types of animals present, and the biodiversity of the affected area (Barker and Tingey 1992).

(3) What are the sources and pathways of these stressors?

Natural sources of particulates include volcanic and other geothermal eruptions, forest fires, gases released from vegetation, wind-blown soil and other debris, pollen, spores, and sea spray particles. Anthropogenic sources include a variety of combustion, industrial, and farming activities (Smith 1990).

Coarse particles (larger than 2.5 microns) come from: windblown dust; dust generated from vehicles traveling on unpaved roads; materials handling, crushing and grinding operations; and agricultural plowing and harvesting operations.

Fine particles (less than 2.5 microns) are generated from: fuel combustion from motor vehicles, small gasoline engines, power generation, industrial facilities; residential fireplaces and woodstoves; and agricultural burning (USEPA 1996a).

Particulates can be deposited by the following processes:

(a) wet deposition by rain or snow with dissolved (soluble) or undissolved content,
(b) dry deposition (sedimentation) of particles, other than rain or snow, by gravity,
(c) impaction of aerosols, including mist, fog, or cloud droplets, and
(d) absorption of gases on wet surfaces like foliage or bark, inside plant stomata, or on plant cell surfaces (Ulrich and Pankrath 1982).

Human activities introduce heavy metals to the atmosphere primarily in particulate form. During high temperature combustion (coal, industrial, or motor vehicle), metal elements and their oxides become volatilized. The elements of high volatility (e.g., cadmium, chromium, nickel, lead, thallium, and zinc) show a pronounced concentrating effect as they condense on fine particle surfaces. Preferential association of heavy metals with small particles is not only significant because these small particles may escape emission control, but because small particles have the longest atmospheric residence times, and therefore can be carried long distances (Smith 1990).

Smith (1990) attempted to characterize heavy metal deposition in rural New York State during the growing season by human source. They suggested an association of: antimony and zinc deposition with refuse incineration; chromium, iron, and manganese deposition with iron and steel industrial activity; and iron and manganese deposition with soil disturbance (Smith 1990).

Fine particles can also be formed in the atmosphere from gases such as carbon dioxide, nitrogen oxide, and volatile organic compounds as a result of chemical transformations in the air (USEPA 1996c).

Primary modes of exposure of terrestrial animals to air pollutant particulates are inhalation, adsorption, and ingestion. Adsorption of particulates may involve the adhesion to the external surfaces or membranes (e.g., to the cornea of eyes in mammals). Some terrestrial animals may swallow contaminants during grooming, and through surface contamination of food (plant and animal tissues) (Barker and Tingey 1992).

Soil ecosystems are a sink for many air pollutants. Particles are transferred from the atmosphere to forest soils directly by dry deposition and precipitation scavenging, and indirectly via leaf and twig. A very large number of human activities generate small particles with high concentrations of trace metals. Depending on weather conditions, these particles may remain airborne for days or weeks, and be transported 100-1000 km from their source. Extensive evidence is available to support the suggestion that heavy metals deposited from the atmosphere to forest systems are accumulated in the upper soil horizons or forest floors (Smith 1990).

As in the case of soil, a complex variety of biological, chemical, and physical processes are involved in the transfer of pollutants from the air to surfaces of vegetation. Vegetation provide a major filtration and reaction surface to the atmosphere, and importantly function to transfer pollutants from the atmosphere to the biosphere. Under certain environmental circumstances, especially when tree surfaces are wet and when leaves are metabolically active, biologically and medically significant reductions in ambient levels of sulfur dioxide, nitrogen dioxide, ozone, and hydrogen fluoride may be realized by stands of trees for extended periods, as long as the atmospheric loading of the contaminant gases is not excessive (Smith 1990).

(4) What systems or species/organisms are particularly sensitive or affected?

There are few definitive studies in New York State on the impact of solid particulates on individual species or organisms or on specific plant and animal communities. However, from the literature and studies done around the world, it appears that impacts would be localized to plant and animal individuals, and communities immediately downwind of point sources such as power-generating plants (acidifying gaseous pollutants), construction sites (dust), unpaved roads (dust), and refuse burning plants (heavy metals).

Animal biodiversity is affected by acidifying air pollutants, including sulfur dioxide and derivative acids, particulate matter (including radioactive particulates), photochemical oxidants, and organic compounds (e.g., airborne pesticides). The effects to animals from these pollutants can be direct (e.g., bird mortality from inhalation of hydrogen sulfide) or indirect (e.g., change in pH of streams and adverse physiological effects to fishes). The effects can be physiological (lower reproduction) or ecological (e.g., loss of food resources). As a result of the exposure and hazard from particulates, there are animal species at risk to particulates because they are more physiologically sensitive to particulates than other species (e.g., embryonic mortality in amphibians), as well as other species at risk because they are ecologically sensitive to particulate effects (e.g., change in local distribution in the river otter) (Barker and Tingey 1992).

Ecosystem impacts from particulates are difficult to assess and little understood. Particulates may adversely impact ecosystems and reduce biodiversity in that they contribute to acid rain, ozone problems, and potentially to global warming. Changes in vegetative cover types, and subsequent habitat modification, can affect food webs, food chains, and whole communities.

b. Analysis of Problem

(1) Severity: Rank = C

There are few definitive studies linking particulates to significant effects on individual organisms or ecosystems in New York State. Setting aside gaseous particulates and heavy metals (that are addressed as other stressor groups), solid particulates seem to have little effect on the functional or structural integrity of terrestrial and aquatic communities or ecosystems.

(2) Reversibility: Rank = C

There are few definitive studies linking solid particulates to significant effects on individual organisms or ecosystems in New York State. Effects on plants and wildlife appear localized downwind of dust, smoke, and soot sources.

(3) Ecological Significance: Rank = C

There are few definitive studies linking solid particulates to significant effects on New York State ecosystems.

(4) Geographic Scale: Rank = A

Particulates are pervasive throughout New York State. However, there are few definitive studies linking solid particulates to significant effects on individual organisms or ecosystems. Even if adverse impacts do occur, they would tend to be localized to sites downwind of the particulate sources.

(5) Final Ranking: Rank = C

There are few definitive studies linking particulates to significant effects on individual organisms or ecosystems. It may be presumed that there may be local impacts to plants and wildlife where human activities generate sufficient dust, smoke, and soot.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Particulates		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**C**	uncertain. DEC Air Quality staff indicated that no definitive studies have been done by DEC to assess the impacts of particulates on wildlife or ecosystems. EPA Air Quality staff also indicated that they have not specifically studied the impact of particulates on wildlife or ecosystems, even though they are proposing new National Air Quality Standards for Particulate Matter.
2. Reversibility	**C**	uncertain
3. Eco-significance	**C**	uncertain. The effects of air pollution on sensitive species, and therefore biological diversity, may be very subtle. Variation in populations or in the spatial displacement of affected communities may be relatively small and statistically undetectable. The changes induced by particulates and other air pollution may, in some instances, be overwhelmed by other causative factors. These include climatic variations and natural and man-made disturbances such as fire, insects, diseases, and grazing (Barker and Tingey 1992).
4. Geo-scale	**A**	statewide occurrence, but significant adverse impacts have not been documented and are presumed to be localized
Overall Rank	**C**	few definitive studies have been completed in New York State to establish whether or not solid particulates have any significant impacts on natural ecosystems. Further study regarding particulate effects on biotic communities and ecosystems appears warranted.

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9. Pesticides

a. Stressor Characterization

(1) What stressors are included?

Pesticides are a large and diverse group of chemicals. They are defined by the Federal Insecticide, Fungicide, and Rodenticide Act as “any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, or weeds, or any other forms of life declared to be pests; and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant” (Meister et al. 1997). Pesticides include insecticides, herbicides, fungicides, and rodenticides, with chemical structures of various types. The structure of the largely banned chlorinated hydrocarbon pesticides places them in the non-volatile halogenated organics stressor group. Because of the large number of substances included in this stressor group, eight compounds and their primary degradation products have been selected for analysis. Their selection was based on wide scale use in New York State (Cornell University 1995; Metcalfe - personal communication), and/or their frequent detection in environmental monitoring (Wall and Phillips 1997a). These are atrazine, cyanazine, metolachlor, and alachlor (all herbicides); and diazinon, chlorpyrifos, carbaryl, and esfenvalerate (all insecticides). These compounds serve as surrogates for other pesticides having similar chemical structures and toxicities. In selecting these eight, hundreds of other compounds used in New York State in agricultural and residential situations are not being directly considered. These particular compounds are used either in urban/residential situations or on corn, the agricultural crop with the greatest acreage in the state. Other classes of pesticides, such as the sulfonyl urea herbicides, are not represented here, because they are not as commonly used as the selected groups. This may change in the future. In addition, commercial formulations of pesticides contain chemicals labeled as “inert ingredients,” that function as carriers or surfactants for the active ingredient. These may or may not be toxic, but they generally have not been evaluated as carefully as the pesticidal ingredients. In New York State, since 1989, all pesticides being registered for the first time or undergoing major label changes are subjected to human and ecological risk assessments.

(2) What do they do ecologically?

The ecological effects can be categorized by compound type. Unlike the chlorinated hydrocarbons, the effects of the pesticides considered here are not generally related to bioaccumulation (Eisler 1986; Eisler 1988).

Herbicides:
(a) Triazine herbicides, such as atrazine and cyanazine, inhibit photosynthesis. Because of this mode of action, herbicides are much more toxic to plants than to animals. In aquatic environments, phytoplankton are the group most sensitive to atrazine (Solomon et al. 1996). Reduced photosynthesis can result in decreased phytoplankton populations,

and reduce food resources for invertebrates and fish. Reduction in the size and extent of macrophyte beds, which provide habitat for fish, can occur (Eisler 1989).

(b) Acid amide herbicides, such as metolachlor and alachlor, interfere with cell division. While the exact mechanism is not known, it appears that protein synthesis and nucleic acid formation are affected (Jordan and Cudney 1987).

(c) In terrestrial ecosystems, drift or improper application practices can result in toxicity to non-target plant communities. Since many herbicides inhibit photosynthesis or other processes specific to plants, toxicity to animals is low at normal application rates, but at higher concentrations toxicity to terrestrial animals can occur.

Insecticides:
(a) Direct neurotoxic effects on terrestrial and aquatic non-target organisms can reduce diversity in an ecosystem, by reducing populations of sensitive species if repeated frequently. For the organophosphate (diazinon) and carbamate (carbaryl) classes of insecticides, toxicity is caused by inhibition of cholinesterase activity, an enzyme that is responsible for the breakdown of the neurotransmitter acetylcholine. Esfenvalerate (pyrethroid) affects a different nerve cell site, but the results are similar.

(b) Diazinon, which in New York State is now restricted from use on turf farms and golf courses, is extremely toxic to birds, and has been documented in many cases of large-scale kills of different species, including Canada geese, turkeys, and blue jays (Eisler 1989; Metcalfe - personal communication).

(c) Diazinon, although having relatively low mammalian acute toxicity, has been shown to have teratogenic effects on some animal groups, particularly bird embryos (Fukuto 1987).

(d) Community level effects in both terrestrial and aquatic ecosystems result from shifts in community composition when sensitive species are eliminated, age/size classes are altered, or dominant species are impaired. Many of these effects are subtle and difficult to detect.

(3) What are the important sources and pathways of this stressor group?

The main sources of these compounds to the environment are the result of agricultural and urban/residential applications for pest control. This can be as a result of drift following registered applications, improper applications, spills, and most importantly in aquatic systems, runoff from agricultural fields and residential or commercial areas during heavy rains. Volatilization, airborne transport, and redeposition can also be responsible for dispersion in the environment (Spencer 1987). The highest levels of pesticide residues in aquatic ecosystems are known to exist following storm runoff events occurring after application (Spalding and Snow 1989). While agricultural and urban/residential areas are generally highly modified ecosystems, plants and animals within these areas can be directly affected (e.g., birds in farm fields or residential areas being killed by insecticide applications).

(4) What systems or species/organisms are particularly sensitive or affected?

Aquatic systems, streams, rivers, lakes, estuaries, and wetlands, that receive runoff from agricultural fields or residential lawns, are potentially most affected by the herbicides and insecticides considered here. These systems receive periodic pulses of these stressors, especially during spring and storm event runoff. For diazinon, bird populations are particularly sensitive, and with carbaryl applications, bees and related terrestrial insect populations are considered to be sensitive groups. Synthetic pyrethroids, such as fenvalerate and esfenvalerate, are extremely toxic to fish.

b. Analysis of Problem

(1) Severity: Rank = B

In New York State, it is documented that pesticides do move from the agricultural and urban/residential areas to which they are applied. Numerous compounds are routinely identified from water column samples collected in the Hudson and Mohawk River basins (Wall and Phillips 1997a & b), and have been collected in smaller watersheds in the state (Foley et al. 1994). Once in the environment, these pesticides have the potential of not only killing target and non-target organisms, but also, by killing individual organisms, changing food and shelter resources, and thus, affecting community composition. Atrazine, for example, has been shown to suppress growth rates of certain plant species at concentrations of 1 to 10μ/L (Larsen et al. 1997) in laboratory tests, and atrazine has been detected in the Mohawk River basin at concentrations as high as 4.2μ/L (Wall and Phillips 1997b).

However the effects are not as severe as might be expected, due to several mitigating factors:

(a) Triazine herbicides, such as atrazine and cyanazine, do not appear to bioaccumulate (Solomon et al. 1996).

(b) Triazine herbicides have low mammalian and fish toxicity (Jordan and Cudney 1987).

(c) The inhibition of photosynthesis for some herbicides (triazines) is reversible. Others, such as the growth regulators and acid amide herbicides (alachlor and metolachlor), interfere with cell division by limiting protein synthesis and nucleic acid formation; these effects may not be reversible (Solomon et al. 1996).

(d) Food-chain biomagnification for the eight selected pesticides is not shown to be significant (Solomon et al. 1996).

(e) Half lives of these representative compounds, in general, are much shorter than chlorinated hydrocarbon pesticides (e.g., DDT), although breakdown does result in metabolites, some of which persist in both terrestrial and aquatic ecosystems.

(f) Organophosphate insecticides, typified by diazinon and chlorpyrifos, can be highly toxic to selected groups of organisms, such as birds, but are not thought to affect reproductive success as the chlorinated hydrocarbons (e.g., DDT) do.

There is a great deal of uncertainty about the effects of these pesticides on endocrine function and other sub-lethal effects on non-target organisms, and how these effects may change reproductive patterns and ultimately, population structure and community composition of certain ecosystems. The lack of bioaccumulation and biomagnification, and shorter half-lives of most currently used pesticides, decreases the potential for severe ecosystem effects. But given the uncertainty about effects on endocrine function, the overall severity for this stressor group is considered moderate.

(2) Reversibility: Rank = B

Populations may be significantly affected or lost due to pesticide applications, both in highly modified artificial agricultural ecosystems where there are direct effects, or in more ecologically significant areas, such as estuaries and wetlands, to which pesticides are transported by runoff or volatilization and deposition. Upon removal of pesticide inputs, affected areas may naturally recover by recolonization and reintroduction of affected species from adjacent areas. In aquatic ecosystems, recolonization of invertebrates could occur within a period of several years or less, since many of these organisms have life cycles of one year. If the affected populations were vertebrates, especially species with longer life spans, such as raptors, recovery might take longer, but most likely still in the range of three to twenty years. Therefore, the reversibility of the effects of pesticides is considered to be moderate.

(3) Ecological Significance: Rank = B

The ecological significance of pesticides entering the environment depends on whether the effects are direct or indirect. In general, the direct effects of pesticides, that is the exposure of non-target organisms in the area where the compounds are applied, have a lower ecological significance, because agricultural and urban/residential ecosystems are highly modified artificial systems.

However, indirect effects of pesticide applications, via drift, volatilization and airborne transport can introduce these chemicals into non-agricultural, non-urban terrestrial ecosystems or aquatic ecosystems, including esturaries, bays, and spawning areas for fish. Under these conditions, the ecological significance may be high, since some of the areas have high biodiversity, and are very sensitive to perturbation.

Since there are potential effects on rare and sensitive ecosystems with high ecological significance, and effects on modified artificial ecosystems of limited ecological significance, the overall potential ecological significance is moderate.

(4) Geographic Scale: Rank = A

Agriculture is an extremely important and widespread industry in New York State. Throughout the state, approximately 7,700,000 acres are in agricultural use, with 3,640,000 acres of harvested cropland. Field crops, including corn, hay, small grains, potatoes, and soybeans, account for 93.5 percent of the total cropland harvested. Vegetable crops make up 3.8 percent, and fruit crops 2.7 percent (New York Agricultural Statistics 1995). Corn (field corn for grain or silage and sweet corn for processing and fresh market) is the crop grown in greatest quantity. In 1995, 51 of the state’s 62 counties reported field corn production (New York Agricultural Statistics 1995). New York State ranks third in the nation for field corn production for silage, fourth for fresh market sweet corn production, and fifth for processing sweet corn production (New York Agricultural Statistics 1995). Several of the representative pesticides are commonly used in corn production, including atrazine, cyanazine, alachlor, metolachlor, and esfenvalerate; with extensive corn acreage in the state, large quantities of these pesticides are applied annually. Estimates of atrazine formulations (active ingredient and inert ingredients) applied range from 1.1 million to 2.5 million pounds annually (Columbus - personal communication; USEPA 1991).

Urban and residential use of pesticides, represented here primarily by diazinon and carbaryl, is a statewide occurrence, potentially affecting all regions of New York. Because of its severe toxicity and availability to birds, diazinon has been banned for use on golf courses and turf, but other pesticides continue to be used for these applications. Diazinon remains an important chemical for home lawn use. In a study of an urban watershed, diazinon was detected in 80 percent of samples collected in the period from May through August, and in more than 60 percent of samples collected in September through April (Wall and Phillips 1997b).

In addition to the potential effects to ecosystems at the point of pesticide application, with some compounds and methods of application, drift or volatilization can carry materials to surrounding or distant areas. Volatilization and airborne transport are important means by which pesticides are dispersed (Spencer 1987).

Because of widespread pesticide use throughout New York State, both in the agricultural industry and in urban and residential areas, the geographic scale for this stressor group remains extensive, with all regions of the state affected.

(5) Final Ranking: Rank = B

The severity of effects of most currently used pesticides is less than that which existed with chlorinated hydrocarbons. Bioaccumulation does not occur with the representative compounds. At least for some compounds there is reversibility directly on affected organisms, but the geographic scale is large, since all areas of the state receive pesticide inputs. The ecological significance is mixed; agricultural and urban/residential ecosystems are highly modified, but runoff and volatilization to ecologically sensitive areas can and does occur. There is some uncertainty about some effects of pesticides. Some, such as endocrine disruption effects, are not completely understood.

Considering all pesticides together, here represented by eight individual compounds in wide use throughout New York State, the ecological risk is moderate.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Pesticides		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**B**	most pesticides, such as chlorinated hydrocarbons, that bioaccumulated and persisted in the environment are now banned
2. Reversibility	**B**	mixed--some effects reversible (such as atrazine) on individual organisms; reversibility of community level effects probably possible in a time frame of three to twenty years
3. Eco-significance	**B**	some affected ecosystems are highly modified; but pesticides can be transported to very sensitive ecosystems; some effects, such as endocrine disruption, are poorly understood
4. Geo-scale	**A**	widespread use and detection throughout New York State
Overall Rank	**B**	the most persistent and bioaccumulative compounds have been banned; regulatory controls are in place for use and transport; however, effects can be severe when improperly used or when spills occur

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10. Petroleum Products

a. Stressor Characterization

(1) What stressors are included?

Crude petroleum is of geological origin and consists of a wide variety of chemical compounds. Petroleum products are manufactured from crude petroleum by refining during which the hydrocarbon components of petroleum are separated by fractional distillation into products such as fuels, lubricants, preservatives, construction materials, medicines, and starting materials for petrochemicals (Malins 1977).

Petroleum is composed of hydrogen and carbon organized in many different chemical chains and rings called petroleum hydrocarbons. These compounds often contain small amounts of oxygen, sulfur, nitrogen, and mineral salts. Crude petroleum is the most complex, containing the highest molecular weight compounds with the highest range of carbon atoms. The most complex are asphalts, coke, and tar. At the other end of the spectrum of petroleum products, are the highly refined gasolines. In between, in order of increasing complexity, molecular weight, and boiling temperature are kerosine, heating oil, diesel fuel, lubricating oils, and, wax. All these petroleum products may be broken down to their basic hydrocarbon compounds, which number in the hundreds of compounds. These include classes of hydrocarbons such as cycloalkanes, branched alkanes, n-alkanes, and polycyclic aromatic hydrocarbons (PAH). This section of the comparative risk assessment will not address the basic chemical compounds. It will assess the ecological risk associated with four types of petroleum products, as follows: very light oils (gasolines and jet fuels); light oils (diesel fuel, No. 2 fuel oil, and light crudes); medium oils (most crude oils); and heavy oils (heavy crude oils, No. 6 fuel oil, bunker C oil, asphalt and tar).

When petroleum products are released to the environment, their concentration is often measured as total petroleum hydrocarbons or oil and grease. In this analysis, the hydrocarbons are extracted from the environmental sample using a solvent and the extract is either dried and weighed or analyzed by infrared spectrophotometry (Breteler 1984).

(2) What do they do ecologically?

(a) Very Light Oils: Included in this type of petroleum product are the gasolines and jet fuel. They are highly volatile and should all evaporate within 1-2 days. They have high concentrations of toxic compounds which are soluble in water and as a result can cause severe impacts in the water column and nearshore areas.

(b) Light Oils: Included in this type of petroleum product are diesel fuel, No. 2 fuel oil, and light crude oils. They are moderately volatile and will leave a residue of up to one-third of their original amount a few days after a spill. They will result in moderate concentrations of toxic, soluble compounds from the more refined products. They are more persistent than very light oils and will oil stream bank and nearshore areas. Also, they have the potential to mix in the water column and contaminate sediments.

(c) Medium Oils: Included in this type of petroleum product are most crude oils, which are highly variable in their composition depending on where they are from. About one-third will evaporate within 24 hours and they are less soluble than the light oils. Contamination of shore areas can be severe and long-term as can be the impact to birds and aquatic mammals.

(d) Heavy Oils: Included in this type of petroleum product are the heavy crude oils, No. 6 fuel oil, bunker oil, asphalt, and tars. They do not tend to evaporate or dissolve in water. Heavy persistent contamination and wildlife damage and long-term contamination of sediments is possible.

The effects of petroleum products occur throughout the food chain. They can have toxic effects, physical effects such as oiling, and habitat effects caused by persistent products destroying or making habitats unsuitable for use. Some of the effects of petroleum products on components of the food chain follow:

(a) Plants: Lethal and sublethal effects can occur with recovery up to 5 years for wetland plants. The PAH component can affect aquatic bacteria and algae and at high concentrations can lead to death.

(b) Invertebrates: Oil spills can significantly affect invertebrate populations. Recovery can take up to 10 years for mollusk populations. PAHs can be lethal to invertebrates at high concentrations and can cause sublethal effects at low concentrations.

(c) Fish: Although adult fish can be killed when large quantities of oil are spilled into shallow water areas, larvae and juvenile stages are the most sensitive. PAHs associated with oil spills and industrial discharges of petroleum products have been shown to cause tumors in wild fish populations.

(d) Birds: Oiling of feathers and ingestion of oil are one of the most frequent causes of bird mortalities when petroleum products, especially oil, are released to the environment. Bird populations can be reduced by major oil spills. Their recovery is a function of the reproductive capability of the survivors.

(e) Mammals: Aquatic and marine mammals such as otters, seals, and muskrats can be killed from being oiled. Ingestion of oil can also cause morbidity and mortality. Exposure to the toxic and carcinogenic components of petroleum products can have long-term adverse health effects on mammals (Hoffman et al. 1995).

(3) What are the important sources and pathways of this stressor group?

There are six major <u>sources</u> and pathways for petroleum products to enter the environment. They are as follows:

(a) industrial discharges and urban runoff (37%);
(b) vessel operations including tank cleaning discharges, de- ballasting, and oily bilge water releases (33%);
(c) tanker accidents including collisions, groundings, loading, and discharging (12%);
(d) atmospheric discharges from vehicle exhaust (9%);
(e) natural seepage and erosion (7%); and
(f) oil exploration and production releases (2%).

A petroleum spill on water will spread rapidly to cover a large area depending on the type of product. The layer of product will also vary from micrometers to centimeters thick depending on the type of product. Heavy crude oil may sink to the bottom of a body of water. Wave and current action may cause the product to mix with the water and produce an emulsion (Hoffman et al. 1995). Over time air, water, and sunlight will degrade petroleum products released to the environment. Microbial action can degrade 40 to 80% of crude oil. Oil is frequently ingested by invertebrate and vertebrate organisms which attempt to metabolize the hydrocarbon compounds present. If they are unable to metabolize and rid themselves of the ingested petroleum products, the products can be bioaccumulated in some species. Biomagnification, however, has not been observed in aquatic systems (Hoffman et al 1995). In the environment petroleum products can have both adverse physical (oiled birds and mammals) and toxicological effects. Petroleum products and components can persist in the environment for as long as 20 years.

(4) What systems or species/organisms are particularly sensitive or affected?

(a) Population Impacts: Petroleum products have documented toxic effects on many species. They can have long-term sublethal effects on many species. They cause a reduction in the size of the populations of many species.

(b) Community Impacts: Petroleum products cause the absence of many normally occurring species and result in the loss of species diversity. They also change population sizes in communities, which can result in non-stressor induced population changes within communities.

(c) Ecosystem Impacts: Petroleum products are persistent and may be transported to other ecosystems in currents and by wind and waves. They are bioaccumulated, but are usually not biomagnified. Petroleum products do exert effects at multiple trophic levels in ecosystems.

b. Analysis of Problem

(1) Severity: Rank = B

At some very severe oil spills ecosystem function can be affected when the food base of the ecosystem is damaged and higher trophic levels cannot function normally, but for most spills populations can be significantly affected and recovery is dependent on their reproductive capability. Effects can include chronic depression of populations. The documented toxic effects on many species from exposure of petroleum products can result in population reductions.

Over 2,000,000 gallons of petroleum products on average have been spilled in New York State each year for the past three years. These statistics do not include over 300,000,000 gallons spilled in three separate very large incidents during this time period. The NYSDEC (1997) in its Annual Spill Reports maintains excellent records of spills. Also, petroleum products are a frequent constituent in regulated point source discharges and in non-point source pollution especially associated with transportation vehicles including trains, boats, and cars and trucks. Additional gallonage of petroleum products released to the environment come from unreported spills. The threat of major marine oil spills is real and ongoing.

(2) Reversibility: Rank = B

Most ecosystems can naturally recover from the effects of a spill incident in less than three years, but the chronic releases of petroleum products from point and non-point pollution compounded by the large number and volume of spills adversely affects reversibility. It is therefore estimated that it would take three to twenty years for the ecosystems in New York State to recover from petroleum pollution were all releases to cease. In further support of this opinion consider the information below.

Of the 8168 spills reported last year, 57% involved gasoline, #2 fuel oil, and diesel fuel. These petroleum products fall into the very light and light oil categories. Very light oils have high concentrations of toxic compounds which are soluble in water, but they all evaporate within 1-2 days. Light oils are more persistent and have toxic, soluble compounds, but they are also volatile and are generally short-term. Medium, heavy, and waste oils spilled are not as volatile, but tend to be more persistent which helps in their clean-up. So, there is reversibility in the short-term for the majority of spilled product and medium-term reversibility for many more. Unfortunately, the ongoing large amount of petroleum product in the environment results in substantial chronic toxicity.

(3) Ecological Significance: Rank = B

This ranking of moderate ecological significance was given based on the wide distribution of petroleum releases throughout the state. Petroleum product pollution is not unique to high biodiversity areas any more than it is to low biodiversity areas. Spills have a greater potential to impact aquatic ecosystems because water areas concentrate some types of transportation and commerce that is associated with large volumes of petroleum and water can spread spills rapidly making clean-up more difficult and widespread. Marine areas are more prone to petroleum pollution, however, only a small percentage of spills reach water.

Only 7% of the 12,230 petroleum spills in the last reporting year resulted in contamination of surface waters. The vast majority of spills are on the land surface. It is assumed in this assessment that land surface spills are readily cleaned-up with minimal migration of product and ecological significance. Even so, a substantial gallonage of oil is spilled into surface waters each year. Effects occur throughout the food chain and in habitats affected by persistent residuals or ongoing discharges the effects can be long-term with low recovery rates. The ecological effects of catastrophic oil spills on surface waters remain a very serious threat to New York State and from the standpoint of pollution control strategies considerable resources are dedicated to preventing spills and minimizing ecological damage. Nonetheless, the shear volume of petroleum releases from all sources continues to cause significant ecological impacts.

(4) Geographic Scale: Rank = A

All the ecological regions of the state are affected, so a ranking of A for geographic scale is appropriate.

NYSDEC does not routinely monitor for oil and grease. So, comprehensive data do not exist for petroleum contamination. Even so, we assume that petroleum contamination occurs throughout New York State and that there is some chronic petroleum toxicity throughout the state. Each ecosystem and every NYSDEC Region reports many spills, but 60% of the spills (7243 in the last reporting year) occurred in the Lower Hudson River, New York City, and Long Island region. Allegheny and Cattaraugus Counties also have a serious ongoing problem with oil well drilling operations which result in continuing pollution of streams in that area.

Generally, oil pollution is most common in developed areas near water.

(5) Final Ranking: Rank = B

The overall ranking score was the result of one rank of A and the rest of B. A single large spill of catastrophic proportions always is possible and could in itself elevate the ranking for the criteria of severity and ecological significance. Hopefully, this event will not occur or if it does the advance planning to contain and clean-up such a spill will limit its damage.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Petroleum Products		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**B**	Ecosystem function can be affected when the food base of the ecosystem is damaged. Effects can include chronic depression of populations.
2. Reversibility	**B**	It would take three to 20 years for the ecosystems in New York State to recover from petroleum pollution were all releases to cease.
3. Eco-significance	**B**	Effects occur throughout food chains. In habitats affected by persistent residuals or ongoing discharges the effects can be long-term with low recovery rates.
4. Geo-scale	**A**	All ecological regions of the state are affected.
Overall Rank	**B**	A single large spill of catastrophic proportions always is possible and could in itself elevate the rankings for severity and ecological significance

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11. Polynuclear Aromatic Hydrocarbons (PAHs)

a. Stressor Characterization

(1) What stressors are included?

Polycyclic aromatic hydrocarbons (PAHs), also called polynuclear aromatic hydrocarbons, are a large group of organic compounds with a multiple ring structure, commonly formed during combustion processes. There are thousands of PAHs, sixteen of which have been designated as priority pollutants by the United States Environmental Protection Agency under the Clean Water Act and its amendments, and which will be considered: acenaphthene, acenaphthylene, fluorene, naphthalene, anthracene, fluoranthene, phenanthrene, benzo [A] anthracene, benzo [B] fluoranthene, benzo [K] fluoranthene, chrysene, pyrene, benzo [A] pyrene, benzo [G,H,I] perlyene, dibenzo [A,H] anthracene, and indeno [1,2,3,-CD] pyrene.

(2) What do they do ecologically?

PAH effects are documented for both plants and animals. At the organism level, the effects of PAHs vary with the structure and molecular weight of the compound:

(a) Terrestrial plants absorb PAHs from soils and translocate them to stems and leaves. Adsorption through atmospheric deposition has also been documented. Higher plants can metabolize some PAHs (Eisler 1987).

(b) In aquatic ecosystems, stimulation of algal growth has been observed with exposure to some PAHs. However, at different concentrations with certain compounds (e.g., naphthalene) inhibition of photosynthesis and growth occurred (Neff 1979).

(c) In animals, PAH effects are related to structure. Smaller compounds (lower molecular weight, fewer, and unsubstituted rings) tend to be acutely toxic, while the larger compounds have been shown to have carcinogenic, teratogenic, and/or mutagenic effects (Eisler 1987). Toxicity can be increased by photoactivation (Monson et al. 1995).

(d) In aquatic invertebrates, acute toxicity varies with classes of organisms. Crustaceans and mollusks seem to be more sensitive to PAHs than many other groups (Eisler 1987).

(e) Fish tumors are known to be caused by exposure to certain PAHs (Hawkins et al. 1988; Eisler 1987).

(f) Chronic effects, such as decreased reproduction, have been demonstrated in aquatic systems in which the PAH is bound in sediments (Lotufo and Fleeger 1996).

(g) Some behavioral effects, such as changes in burrowing behaviors and decreased feeding activity in aquatic worms, have been observed (Lotufo and Fleeger 1996).

(h) PAHs are metabolized in both vertebrates and invertebrates, but sometimes the metabolic products produced are as toxic or more toxic than the parent compounds. Mollusks and some other invertebrates are able to metabolize PAHs only on a limited basis, probably because of a lack of the proper detoxification systems (Eisler 1987). Because most animals are able to metabolize these compounds to more soluble forms, and excrete them, bioaccumulation of PAHs and biomagnification in the food chain does not occur to a great extent.

Information about ecological effects becomes more uncertain as one moves up the hierarchy of biological organization. At the organism level, numerous effects have been observed for many different PAHs, but effects on population, community, and ecosystem levels are more difficult to document. If there are effects such as acute toxicity, tumor production, reproductive effects, and behavioral changes that occur in terrestrial or aquatic animals, these processes can result in changes to populations and community compositions. However, bioavailability may be reduced by binding of these largely hydrophobic compounds to particulate matter, both in terrestrial and aquatic systems. Metabolism of PAHs by both plants and animals may reduce the potential for serious community or ecosystem effects.

(3) What are important sources and pathways of this stressor group?

The main sources of PAHs to the atmosphere are natural and anthropogenic processes that result in incomplete combustion, although small amounts of these compounds are synthesized by terrestrial and aquatic plants and microbial organisms. Natural combustion sources include forest fires and volcanic activity. The larger sources are anthropogenic, and include activities such as coke production in the coal and steel industry, asphalt production, heating and power generation, emissions from internal combustion engines (Eisler 1987), and as by-products of petroleum refining (USEPA 1993a, b, & c). PAHs enter the environment via release to the air from these manufacturing and transportation processes.

By far the largest source of PAHs in freshwater and marine environments is spillage of petroleum products (Eisler 1987). Atmospheric deposition, industrial landfill leachate (e.g., coal fired power plant), discharge of domestic and industrial wastes, and surface land runoff contribute quantities of PAHs to these systems.

PAHs tend to become adsorbed onto particulate matter, both in the atmosphere and in freshwater and marine environments (Eisler 1987). Contact with, or ingestion or inhalation of particulates may result in uptake of PAHs. Direct discharge via pipes from domestic sewage and industrial sources can carry PAHs into bodies of water, as can non-point source runoff over ground. Petroleum spills deposit materials directly into the water. PAHs may be assimilated by plants from soils, then translocated throughout the plant. In animals, PAHs may be taken up by ingestion (e.g., herbivores eating plants with quantities of PAHs).

(4) What systems or species/organisms are particularly sensitive or affected?

At the organism level, it is known that PAHs are taken up by algae, higher plants, invertebrates, and vertebrates, both terrestrial, freshwater, and marine. There are large interclass and interspecies differences in toxicity, and the ability of organisms to metabolize PAHs. Mollusks seem to bioaccumulate more than most organisms, perhaps because of a lack of enzyme systems necessary to metabolize PAHs (Eisler 1987). PAHs are more acutely toxic to some crustaceans than to many other classes of organisms (Neff 1979). Because of such differences, vulnerable ecosystems may include those freshwater, estuarine, and marine areas where these groups are important components of the benthic community, since these species may be eliminated or reduced in numbers.

At least in freshwater and marine ecosystems, it appears that the majority of PAHs entering the water environment remain close to sites of deposition, and are concentrated around metropolitan areas (Eisler 1987).

b. Analysis of Problem

(1) Severity: Rank = B

The U. S. Environmental Protection Agency has established sediment quality criteria for some PAHs for the protection of aquatic benthic organisms (USEPA 1993a, b, & c). In New York State waters, PAHs have been found in bottom sediments, invertebrates, and marine and freshwater fish (NYSDEC 1997; Skinner et al. 1997).

In aquatic ecosystems, PAHs are found in the tissues of invertebrates collected in New York State rivers and streams, and are associated with measurable changes in benthic community composition (Bode - personal communication). However, distinguishing community changes that are a direct result of the PAH effects on organisms, rather than the effect of an associated contaminant such as petroleum, has not been possible.

(2) Reversibility: Rank = B

There is uncertainty about the ecological effects of PAHs and, therefore, about the reversibility of ecosystem effects of PAHs. Since bioaccumulation is probably less of a threat than with chlorinated hydrocarbons or PCBs, removal of inputs from affected areas should result in recolonization and reintroduction of species from adjacent areas. The potential for reversibility of the effects of PAHs is considered to be moderate.

(3) Ecological Significance: Rank = C

The potential exists for PAHs to be present in ecologically sensitive locations in the state, such as wetlands and estuaries. However, PAHs are produced by natural as well as anthropogenic processes, so even with complete removal of anthropogenic sources, some PAHs will continue to be present in the environment. The ecological significance for this stressor group is considered to be low.

(4) Geographic Scale: Rank = A

Several polycyclic aromatic hydrocarbons (naphthalene and anthracene) are among the chemicals listed on the NYS Toxic Release Inventory for 360 compounds that are released to air, water, or land by industries throughout New York State. Naphthalene and anthracene quantities released are relatively small compared with some of the other reported chemicals. Nearly all of the naphthalene and anthracene reported is released via stacks to the air (NYSDEC 1995).

PAHs are found routinely in sediments and invertebrate tissues collected and analyzed as part of the statewide ambient water quality monitoring program. A few locations where there are no known sources that could contribute PAHs to the waterbody have been found to have organisms carrying a body burden of some PAHs, indicating that airborne transport is a possible mechanism dispersing these compounds.

In the New York State Great Lakes Sediment Inventory Progress Report (NYSDEC 1996), it was reported that phenanthrene was found in concentrations exceeding the EPA sediment quality criterion in 7 of 25 waterbodies sampled.

The above three reporting mechanisms indicate that PAH dispersion in the state is widespread. The geographic scale for this stressor group is considered to be high.

(5) Final Ranking: Rank = B

There is a very high degree of uncertainty associated with information on ecosystem effects of PAHs. While mutagenic, carcinogenic, and teratogenic effects on individual organisms have been documented in the literature, and while measurable concentrations of PAHs are found in organisms in the state, documenting changes to community structure and function has not been done. The ecological risk associated with PAHs is considered to be moderate, but there is a high degree of uncertainty involved.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Polynuclear Aromatic Hydrocarbons (PAHs)		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**B**	some PAHs are known carcinogens, teratogens, mutagens, but effects on populations and community composition are poorly understood; PAHs often associated with petroleum products, which are considered in a separate stressor group; much uncertainty about long term effects on ecosystems; can be metabolized to some degree by many plants and animals; crustaceans and mollusks are not able to metabolize as well as many other groups
2. Reversibility	**B**	possible mutagenic effects might make reversibility for individual organisms very unlikely; extent of possible reversibility on communities and ecosystems is poorly understood
3. Eco-significance	**C**	potential exists for PAHs to be found in ecologically sensitive locations in the state; however, PAHs produced by natural as well as anthropogenic processes
4. Geo-scale	**A**	found in bottom sediments and animal tissues in different areas of the state, documented in industry releases to air and water in the NYS Toxic Release Inventory report
Overall Rank	**B**	very high degree of uncertainty associated with information on ecosystem effects of PAHs; much extrapolation necessary to go from known mutagenic, carcinogenic, teratogenic properties to large scale changes to community structure and function

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12. Radionuclides

a. Stressor Characterization

(1) What stressors are included?

This stressor group includes radioactive materials released by human activities that are licensed or regulated by the New York State Departments of Health, Labor, or Environmental Conservation or the New York City Department of Health and the U. S. Nuclear Regulatory Commission. It does not include radon, or other naturally-occurring radioactive materials (NORM) or materials containing NORM, unless processed and concentrated (i.e. - technologically enhanced).

(2) What do they do ecologically?

Radioactive materials contain atoms (radionuclides) that spontaneously decay to a different nuclide, and, in so doing, produce radiation, defined as the emission and propagation of energy through space, or a material medium in the form of waves and subatomic particles. The three most common forms of radiation are alpha particles, beta particles, and gamma rays:

(a) Alpha particles travel a few centimeters in air from the source, and are readily stopped by a sheet of paper, clothing, or the outer layer of skin. However, if radionuclides emitting alpha particles are ingested or absorbed, they can be significant sources of internal exposure.

(b) Beta particles travel longer distances than alpha particles from the radioactive source but less than gamma rays. However, they are easily stopped by a thin sheet of aluminum, glass, or plastic. Like alpha particles, beta particles are of greater concern if the radioactive material is ingested or absorbed. Very intense sources of beta radiation can cause skin damage by external exposure.

(c) Gamma rays are electromagnetic radiations with great penetrating power, and are similar to x-rays. Gamma rays can travel considerable distances, and can cause radiation exposure to all portions of an organism without the source being ingested or absorbed. Concrete and lead are commonly used to shield against gamma radiation.

High acute doses of ionizing radiation produce adverse biological effects at every organizational level: molecule, cell, tissue-organ, whole animal, population, community, and ecosystem. Typical adverse effects of acute exposures include cell death (McLean 1973; Severa and Bar 1991), decreased life (Brown 1966; Hobbs and McClellan 1986; Kiefer 1990; Rose 1992), increased frequency of malignant tumors (Lorenz et al. 1954; Hobbs and McClellan 1986; UNSCEAR 1988), inhibited reproduction (Barendson 1990; Kiefer 1990; Rose 1992), increased frequency of gene mutations (Whicker and Schultz 1982b; Hobbs and McClellan 1986; Kiefer 1990; Rose 1992), altered blood barrier functions (Trnovec et al. 1990), and reduced growth and altered behavior (Rose 1992).

Many radionuclides preferentially accumulate in certain organs or tissues, but the critical organ is different for different radionuclides. Uptake and retention of radionuclides, along with essential biological nutrients (i.e. - H, C, P ,I, K, Ca, Mn, Fe, Co, Zn), are largely controlled by biological processes (Whicker and Schultz 1982a).

Low doses of ionizing radiation have been reported to produce positive effects, and some of the negative effects caused by acute doses (Rose 1992). Hormesis, the beneficial physiological stimulation of a potentially harmful agent, is documented for ionizing radiation in many species of terrestrial plants and invertebrates (Luckey 1980). Some species of terrestrial invertebrates show increased fecundity, growth, survival, disease resistance, and longevity after exposure to low sublethal doses of ionizing radiation. The growth and development of some terrestrial invertebrates are stimulated at comparatively high sublethal acute doses, but survival is reduced.

(3) What are the important sources and pathways of this stressor group?

Sources and pathways of radionuclides include:

(a) Biological and chemical research (e.g., from animal carcasses),
(b) Consumer products (e.g., radioluminous products and smoke detectors),
(c) Industry (e.g., discharges from mining, milling, fuel fabrication, radiopharmacies, incineration, municipal waste treatment, and production of oil and gas, phosphates, and nuclear power plants),
(d) Nuclear medicine (e.g., medical isotopes), and
(e) Military weapons tests.

Radioactive materials are cycled throughout the environment by physical, chemical, and biological processes. Dispersion through the atmosphere is governed by the magnitude, frequency, and direction of the wind, and atmospheric stability (Whicker and Schultz 1982b). Transport in the hydrosphere is modified by water depth, motion, temperature, winds, tides, and groundwater. Deposition from the atmosphere is a function of particle size, precipitation, and dry deposition. Resuspension is a function of disturbances by wind at the soil surface, atmospheric variables, and soil-ground variables (e.g., texture cohesiveness, moisture content, density, vegetation cover, ground surface roughness, and topography). Dispersal by biological organisms occurs through migrations and movements, and is related to biomass, feeding rates, conversion efficiencies, and chemical properties of trace elements.

(4) What systems or species/organisms are particularly sensitive or affected?

In general, more advanced complex organisms (e.g., mammals) have higher sensitivity to ionizing radiation than more primitive organisms (e.g., insects). Also, rapidly dividing cells, characteristic of embryos and fetuses, are most sensitive to radiation. Developing eggs and young of freshwater fishes are among the most sensitive aquatic organisms (Bonham and Welander 1963, Templeton et al. 1971). The radiation sensitivity among five plant communities suggested that pine forests were the most sensitive, and that deciduous evergreen forests, tropical rain forests, herbaceous rock-outcrop communities, and abandoned cropland were increasingly less sensitive (McCormick 1969).

b. Analysis of Problem

(1) Severity: Rank = C

To date, no extinction of any animal population has been linked to high background concentrations of radioactivity. Furthermore, at levels of radioactivity of interest to this project, radiation exposure is expected to have no detectable adverse effects on organisms or ecosystems.

(2) Reversibility: Rank = B

Mutagenic effects of radiation cannot be reversed. However, acute effects, if not fatal, are reversible.

(3) Ecological Significance: Rank = C

Radionuclides have not been documented at sites with characteristics of those having high ecological significance.

(4) Geographic Scale: Rank = A

Releases of radionuclides exist in all ecological regions.

(5) Final Ranking: Rank = C

At present, no radiological criteria or standards have been recommended or established for the protection of fishes, wildlife, or other natural resources (Eisler 1994). However, radiological criteria promulgated or proposed for protecting human health should also protect sensitive ecosystems.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Radionuclides		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**C**	No loss of populations have been linked to high background concentrations of radioactivity. Furthermore, at levels of radioactivity of interest to this project, radiation exposure is expected to have no detectable adverse effects on organisms or ecosystems.
2. Reversibility	**B**	Mutagenic effects of radiation cannot be reversed. However, acute effects, if not fatal, are reversible.
3. Eco-significance	**C**	Radionuclides have not been documented at sites with characteristics of those having high ecological significance.
4. Geo-scale	**A**	Releases of radionuclides exist in all ecological regions.
Overall Rank	**C**	Based on non-catastrophic events, radionuclides do not pose a significant ecological risk in the state at this time.

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13. Suspended and Settleable Solids

a. Stressor Characterization

(1) What stressors are included?

This stressor group includes suspended solids, defined as materials removed from water by a standard glass filter, and settleable solids, defined as materials that settle out of suspension within a defined period, usually one-hour (APHA 1995). These solids can be organic (e.g., algae, detritus) or inorganic (e.g., clay, silt, sand) in nature. They are the major contributors to turbidity and siltation.

(2) What do they do ecologically?

There is unequivocal evidence demonstrating that suspended/settleable solids alter species composition and abundance in aquatic ecosystems including plankton, macroinvertebrate, and fish communities (Chapman and McLeod 1987; USEPA 1979). This stressor acts on aquatic communities through alterations in physical habitat and biological impairments including:

(a) Stream substrate embeddedness;
Stream substrate embeddedness is generally defined as the amount of fine sediment that is deposited in the interstices between the larger substrate particles (Burns 1984; Burns and Edwards 1985). This filling of the interstices with sand, silt, and clay particles reduces the in-substrate water velocity and decreases the delivery of dissolved oxygen to developing salmonid embryos and fry (Shumway et al. 1964), thus reducing egg and fry survival (Brusven and Prather 1974; Lisle and Lewis 1992). Embeddedness reduces winter hiding locations that protect juvenile salmonids from instream ice formations (Chapman and Bjornn 1969). Although less well studied, other fish, amphibian, and invertebrate species appear to be affected similar to salmonids (USEPA 1979; Cunjak and Power 1986). Embeddedness reduces benthic macroinvertebrate diversity and changes species composition (Williams and Mundie 1978; Chutter 1969), and decreases abundance (Alexander and Hansen 1983; Hynes 1961). Embeddedness alters streambed morphology and hydrology, reducing bedload transport and cleansing of the substrate during high stream flow events (Chapman and McLeod 1987).

(b) Reduced photosynthesis and primary productivity;
Turbidity produced by suspended solids shades aquatic plants and algae by decreasing water transparency, and settleable solids shade plants by covering their surface with silt (USEPA 1983 & 1993). The net result is less energy being passed up the food chain for aquatic (macroinvertebrate, fish, and amphibians) and terrestrial (fish-eating wildlife) communities.

(c) Clogged gills;
Suspended/settleable solids can clog the gills of aquatic organisms (invertebrates, fish, and amphibians) resulting in stress, disease, and mortality (USEPA 1983 & 1993).

(d) Interfere with feeding habitats;
Turbidity from suspended solids can interfere with sight-feeding fish species (USEPA 1993).

(e) Increase water temperatures;
Suspended/settleable solids absorb more sunlight, resulting in increased water temperature and changes in species composition.

(f) Cover bottom substrates;
The covering of bottom substrates with sand and silt favors fish species such as carp, goldfish, and bullheads (USEPA 1993).

(g) And contaminated sediment problems.
Pollutants such as pesticides, industrial chemicals, and nutrients are adsorbed to suspended/settleable solids particles, and are transported and redeposited. In depositional areas of streams, lakes, and ponds, contaminated sediment deposits can form. These contaminated sediments can exert toxic effects on benthic macroinvertebrates and fish; act as sources of toxic bioaccumulative chemicals; and adversely affect aquatic and terrestrial communities during dredging and disposal activities (USEPA 1994).

(3) What are the important sources and pathways of this stressor group?

Sources and pathways of these stressors include:

(a) surface runoff from construction sites, roadway and right-of-way maintenance, paved surfaces, silviculture and agricultural land uses;
(b) excessive planktonic algae caused by nutrient enrichment from urban and agricultural runoff;
(c) stream bank erosion from removal of riparian vegetation and altered watershed hydrology from anthropogenic activities;
(d) industrial and municipal wastewater discharges; and
(e) wet and dry deposition of airborne particulates.

(4) What systems or species/organisms are particularly sensitive or affected?

Suspended/settleable solids adversely affect oceans and bays, estuaries and tidal wetlands, freshwater wetlands, streams and rivers, and lakes and ponds. Endangered species threatened by suspended/settleable solids in New York State include the pugnose shiner (*Notropis anogenus*) and the Eastern sand darter (*Ammocrypta pellucida*). Wetlands are filled and become uplands, along with the loss of important wetland functions such as flood control, water cleansing, and maintaining biodiversity. Lakes and ponds become wetlands at an accelerated rate. Habitat quality is reduced in rivers and streams. The net result is the loss of habitat quality and diversity, and thus reduced biodiversity.

b. Analysis of Problem

(1) Severity: Rank = A

The Priority Water List (PWL) published by NYSDEC (1996) lists 1,426 waterbody segments in New York State with degraded water quality. Behind acid rain (395 segments), the second largest stressor group is siltation (294 segments) caused by suspended/settleable solids. This stressor group dramatically alters community structure and diversity in freshwater and marine ecosystems.

(2) Reversibility: Rank = B

In most stream habitats of moderate to steep gradient, high flow scouring of the stream bed will cleanse the substrate in less than three years. Effects on low-gradient stream, lake, pond, reservoir, bay, and estuary ecosystems are long-term or permanent. In cases where sediments are contaminated with persistent organic or inorganic contaminants, harm to wildlife populations, and their impaired use by humans, may last for decades or more.

(3) Ecological Significance: Rank = A

Siltation from suspended/settleable solids is threatening endangered fish species such as Easter sand darters and pugnose shiners (Scott and Crossman 1973; Smith 1985). This stressor group reduces biodiversity in urban and agricultural drainages, and destroys fish spawning and nursery habitat in trout streams (Personal Communication - Schoch). In marine bays and estuaries, siltation reduces habitat for economically important shellfish (Personal Communication - Chytalo). Contaminants from in-place sediments impair wildlife reproduction and their consumption by humans.

(4) Geographic Scale: Rank = A

This stressor group adversely affects ecosystems in all six ecoregions of New York State.

(5) Final Rank: Rank = A

Suspended/settleable solids cause widespread changes in freshwater and marine ecosystems throughout New York State. They reduce biodiversity, and adversely affect populations of endangered and economically important species of fish and shellfish. Although some stream habitats can be naturally cleansed in a matter of years, habitats with low flushing rates, and those impacted by contaminated sediments, may take decades to recover or be permanently damaged.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Suspended and Settleable Solids		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**A**	dramatically alters community structure and diversity in freshwater and marine ecosystems; populations of endangered/threatened and economically important species are reduced or lost
2. Reversibility	**B**	floods cleanse streams; damage to lakes, ponds, reservoirs and estuaries may be permanent due to filling; contaminants in sediments may harm wildlife populations for decades
3. Eco-significance	**A**	endangered species like Eastern sand darters and pugnose shiner populations are threatened; severely reduces biodiversity; destroys fish spawning and shellfish habitats
4. Geo-scale	**A**	effects all six ecoregions of NYS
Overall Rank	**A**	suspended/settleable solids cause widespread changes in freshwater and marine ecosystems; best management technologies are available to reduce nutrient loading to aquatic ecosystems

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14. Volatile Organic Compounds (VOCs)

a. Stressor Characterization

(1) What stressors are included?

Volatile Organic Compounds (VOCs) comprise a large and varied group of low-molecular weight, carbon-based chemicals that share the trait of being highly volatile, that is, they evaporate easily. Some are gases at room temperature and atmospheric pressure (Art, 1993). They are widely used in industrial processes, commercial enterprises, household products, and consumer goods.

Typical examples of VOCs include: trichloroethylene (TCE), trichloroethane, tetrachloroethylene (PCE), methylene chloride, chloroform, carbon tetrachloride, benzene, toluene, 1,2-dichloroethene, and bromodichloromethane.

(2) What do they do ecologically?

As with other environmental stressors, the ecological problems associated with VOCs are related to both exposure and toxicity. VOCs have varying but weakly acute toxicity, but they also are highly volatile, and consequently organisms generally are not exposed to high levels of VOCs. VOCs can cause lethal and sub-lethal effects depending on concentration, duration of exposure, and age of the effected organism. Many VOCs are weakly carcinogenic in chronic exposure and some may show irreversible delayed-type neurotoxicity (a crippling condition). In particular, the reversible neurotoxic effects may seriously impair the ability of many organisms to compete for food, avoid predation or effectively reproduce. The specific responses of organisms to low level exposures over the long-term, however, is not well known or documented. Those with either no or one chlorine atom can participate in photochemical smog generation in the lower atmosphere, but the gases can diffuse to the stratosphere where through ozone depletion, VOCs also have been implicated as a constituent in atmospheric quality deterioration and global warming.

Terrestrial Ecosystems: Terrestrial organisms can be exposed to VOCs in air from releases to the atmosphere, in chlorinated drinking water from sources contaminated with dissolved organics, from VOCs spilled into water bodies, and by direct contact with soil contaminated from spills. Air is the most likely avenue of exposure for terrestrial wildlife, but this direct exposure is limited. Data from toxicity tests (listed below) show that animals must be exposed to fairly high concentrations for extended periods of time. The lowest value listed, exposure to 280 ppm of PCE for two hours, resulted in a toxic response in mammals (humans). For this type of exposure to occur, an organism would have to be situated near a continuous source of the substance, or in a closed location where the vapors could not dissipate. A spill in soil could inflict toxicity to the organisms there, similar to pesticide fumigations. However, we lack evidence of such happenings in any proportion to VOC releases. VOCs also tend to be irritants, so it is also likely that exposed organisms would depart locations where they were exposed to continuous releases. Birds that nest in industrial facilities could be put at risk from such releases.

Most VOCs are sparingly soluble in water, so if a spill or release occurred into a water body, significant quantities could remain in the water and result in animal exposure by drinking contaminated water. VOCs will volatilize out of water, so unless the release is continuous, the concentration in water will quickly abate. The risk would depend on the size of the release, the volume of water into which the release occurred, and the flow rate of the water body. Available toxicity data show that relatively high oral doses are needed to cause toxic effects. Accumulation for chronic lethality is unlikely, since VOCs are readily exhaled. However, breakdown products formed from VOCs, such as carbon tetrachloride (CCl_4), are poisonous to the liver and result in cumulative damage, and such damage is aggravated by the total solvent burden borne by the liver. Other breakdown products cause delayed-type neurotoxicity, impaired metabolism, and reduced thriftiness (ability to gain weight in proportion to nutrient caloric intake). The greater the intensity and duration of VOC exposure, the more likely that the mix of agents will cause chronic problems, but these have not been documented in the environment for animals or people outside of occupational exposures.

Organisms like earthworms, salamanders, and frogs can absorb VOCs directly through their skin. Such organisms would be at risk if they burrowed through or dwelt directly in VOC-contaminated soil. These areas are likely to be relatively small, and the VOCs will eventually volatilize out of the contaminated soil. Rather, organisms are likely to be repelled by the chemicals and abandon an area, thereby decreasing diversity and stability in the area of a leak or spill.

The worst-case scenario would result from the release of large volumes of VOCs from solvents in transit, underground storage tanks, or inactive hazardous waste sites. Such sites could result in soil being contaminated as the VOCs diffuse, and ground water being contaminated from liquid VOCs. Concentrations of VOCs could permeate through the soil and enter surface water bodies or wetlands. Aquatic and terrestrial life could be harmed in the general vicinity of the hazardous waste site, but the impacts tend to be limited to that immediate area if only VOCs are involved. Unfortunately, their occurrence in such sites is typically as solvents contaminated or mixed together with PAHs, heavy metals, and pesticides. The formation of non-aqueous phase liquids (NAPLs) from the VOCs may help transport other compounds or prevent their degradation in the environment. When NAPLs are more dense than water, they sink into the bottom sediment as a pool, continuing to release toxicants to aquatic and terrestrial organisms long after the source has been abated or cleaned up.

Aquatic Ecosystems: VOCs could be continuously released into aquatic ecosystems directly from publicly owned wastewater treatment works (POTWs), industrial facilities, leaky pipelines, or storage facilities. VOCs could also be spilled into water bodies. VOCs will volatilize out of the water over a period of time. The half-life of VOCs in water ranges from a few minutes to many days. VOCs may be relatively water-soluble, and some concentrations will remain in the water column for extended periods of time.

Precipitation will also wash VOCs out of the troposphere back down into lakes and streams.

Fish and aquatic invertebrates will absorb lipophilic VOCs out of the water through their gills, and bioaccumulate them in fatty tissues. Ofstad et al (1981) reported finding concentrations of chloroform, trichloroethylene, and tetrachloroethylene in fish in coastal Norwegian waters at levels of 10 - 1000 ppb. Bioaccumulation factors for chloroform and trichloroethylene were found to be 200-500 and 1400 respectively. This reversible accumulation may have chronic consequences similar to those in terrestrial animals, but they have not been documented.

The longer the exposure, the lower the toxicity threshold. For example, the carbon tetrachloride 24 hour LC_{50} for *Daphnia magna* is > 770,000 ug/l, but the 48 hour LC_{50} is 35,000 ug/l. Toxicity thresholds for VOCs are fairly high, ranging from 96 hour LC_{50} of 13300 ug/l for trichloromethane in bluegills to 150,000 ug/l of carbon tetrachloride in inland silversides. Given the high concentrations and long durations needed to cause acute toxicity, impacts are primarily likely to result from large spills into small water bodies, unpermitted discharges, and frank failures of treatment technologies. If not chronic and if uninvolved with other chemicals (i.e., NAPLs are not formed) the VOCs will dissipate and volatilize, so ecosystems will recover. Continuous leaks could result in localized aquatic impacts.

Other environmental impacts: Because VOCs migrate quickly to the atmosphere, two concerns are generated: impacts of photochemical smog formation (including ozone) in the lower atmosphere, and damage to the earth's ozone layer. Ironically, ozone formation below cannot offset declines above. Each VOC must be individually evaluated to determine if that compound has the potential to impact the ozone layer. Of the VOCs mentioned in this review, only carbon tetrachloride has the potential to migrate to the stratosphere where it is degraded by high energy radiation to release ozone-depleting radicals, but most VOCs can participate in photochemical smog.

Toxicity Concerns: VOCs are primarily absorbed through inhalation. They can also be absorbed directly through the skin. They primarily affect the central nervous system, probably by changing the permeability of central nervous system cell membranes to ions. Most VOCs are not excreted readily through the kidneys, although some can pass out of the body through the lungs. Alkanes can be metabolized to alcohols, and more dangerously, ketones. VOCs are lipophilic and can dissolve in fats and lipids.

The impact of VOCs seems to be related to the molecular pattern of chlorination in the molecules. Unsymmetrically substituted ethylenes (e.g., 1,1,-dichoroethylene, vinyl chloride, TCE) formed more unstable epoxides than did symmetrically substituted congeners (e.g. 1,2-dichloroethylene, tetrachloroethylene). The unsymmetrically substituted ethylenes were found to be mutagenic to *E. coli,* while the symmetrically substituted compounds were not. Vinyl chloride was the most potent mutagen. One of the well-documented degradation transformations is that of PCE to vinyl chloride which is: tetrachloroethylene > trichloroethylene > cis/trans 1,2 dichloroethylene > vinyl chloride. Such chemical transformations make it more difficult to track specific VOCs in the environment and to draw cause and effect conclusions because the chemical itself changes and the original source may be misidentified.

(3) What are the important sources and pathways for this group?

VOCs are generated by many sources and can enter the environment by many routes. In addition to various natural VOCs (e.g., terpenes, alcohols, acetone and other ketones), they are used as industrial solvents and raw chemical feed stock for products; as cleaning agents in industrial and commercial applications (e.g. dry cleaning chemicals, metal plating cleaner, paint thinner); as fuels; and as a pesticide soil fumigant. They are also present in fugitive air emissions from numerous industrial, commercial, residential, governmental, institutional and military sources and from volatilization from terrestrial spills, volatilization from water from spills and leaks, and leaks from storage facilities. VOCs can enter water from spills and leaks, from terrestrial spills being transported via ground water to surface water bodies, and from atmospheric concentrations being transported to water bodies via precipitation. Both anthropogenic and natural processes can produce VOCs. There are a few natural sources of VOC emissions that are now being investigated, such as specific marine algae (e.g., red kelps off California).

VOCs typically evaporate out of water or soil into the air, where they are first transported to the troposphere. Some VOCs such as chloroform are attacked by hydroxyl radicals in the troposphere, where they are broken down into phosgene ($COCl_2$), which in turn breaks down rapidly or reacts with other atmospheric pollutants. VOCs can be widely dispersed by dissolving in atmospheric moisture and later be redeposited in precipitation. Other VOCs, such as carbon tetrachloride, are stable to photolysis in the troposphere. They eventually move by diffusion into the stratosphere where they can be broken down by high energy wavelengths of light. Carbon tetrachloride is stable in the troposphere; 90 percent will eventually migrate to the stratosphere, where short, high energy wavelengths break the molecule down into CCl_3 radicals and chlorine atoms, thereby damaging the ozone layer.

VOCs exhibit a considerable range of solubility in water. They can dissolve in rain water, and be transported back down to the earth in precipitation. The primary fate of VOCs in water is volatilization. The rate of volatilization for different VOC compounds can vary considerably.

1. Trichloromethane: An initial concentration of between 0.1-1 mg/l in 20 L of water was found to decrease 50-60% after eight days. Solubility in water = 8200 mg/l; K_{OW} = 1.97 (EPA 1979)

2. Tetrachloromethane: Evaporative half-lives of 25 - 28 minutes for concentrations of 0.90 mg/l were observed. Solubility in water = 785 mg/l; K_{OW} = 2.64 (EPA 1979)

3. 1,1,1-trichloroethane: Evaporative half-life of 17-25 minutes for 0.97 mg/l. Solubility in water: 480 - 4400 mg/l; K_{OW} = 2.17

4. Benzene: The half-life with respect to volatilization from a water column one meter thick was estimated to be about 4.8 hours. Solubility in water = 820 - 1800 mg/l; K_{OW} = 2.13

VOCs are easily transported through all media: land, air, surface water and groundwater. Some, such as acetone and to a lesser extent chloroform, dissolve in water and can be conveyed in water and wastewater discharges. In groundwater, high concentrations of VOCs can become DNAPLs (dense non-aqueous phase liquids). In this setting, VOCs moving under the influence of gravity can separate from the main part of a contamination plume.

VOCs will sorb to organic matter in sediment and soil proportionately with their K_{OW} (octanol-water partitioning coefficient). The higher the K_{OW}, the greater potential for a VOC to bioaccumulate. Chlorinated alkanes such as carbon tetrachloride, chloroform, and 1,1,2 trichloroethane are not readily metabolized to CO_2 and water, but have toxic intermediates. Some aromatic VOCs may be subject to microbial degradation.

A recent study of wastewater quality in the New York City waste water treatment plant found that the most frequently occurring organic priority pollutants (OPPS) in sewage were VOCs. Fourteen out of 29 OPP compounds were found. Examples of detected VOCs are: chloroform, tetrachloroethene, toluene, methylene chloride, trichloroethene, & 1,1,1-trichloroethane. Because sewage treatment plants convey large quantities of water to surrounding water bodies, they have long been suspected as the source of a variety of toxics in the environment but also present a real opportunity for pollution prevention and reduction. New York City alone treats 1.4 billion gallons of wastewater per day. Furthermore, VOCs are not destroyed by the sewage treatment process and are released into the environment via air and water pathways.

Stormwater runoff may be another significant pathway for carrying toxic contaminants into waterways. A study of the quality of suspended sediments in the St. Lawrence River found them to contain a range of toxics, including VOCs. The contaminated sediments were linked to sharp increases in sediment loads after storm events.

(4) What systems or species/organisms are particularly sensitive or affected?

Because VOCs volatilize quickly, most terrestrial systems are not at high risk from releases of this stressor group. Aquatic systems are more at risk because VOCs can dissolve in water, although most rapidly volatilize. There are no documented examples of particular aquatic communities or species that are at risk at this time from VOC emissions, but VOC participation in smog formation in southern California was decreased by abatement procedures protecting plant and animal life.

b. Analysis of Problem

(1) Severity: Rank = C

Individuals or populations are only severely affected by prolonged exposure to high levels of VOCs, which is a relatively unusual event. Even concentrated spills volatilize quickly. There are no documented examples of ecosystem structure or function being adversely impacted, nor of individual populations being stressed from VOCs *per se*. Impacts of VOCs via ozone degradation are of concern however, and should continue to be researched and monitored. Their effects may ultimately warrant re-evaluation for this criterion for New York State.

(2) Reversibility: Rank = C

VOCs volatilize quickly and their effects generated in the lower atmosphere on aquatic and terrestrial ecosystems are relatively short-term. If it is determined at some future time that VOCs significantly contribute to ozone depletion and the ecological effects therefrom are unacceptable, this ranking may warrant reconsideration, since the ecological effects of ozone depletion may extend beyond three years.

(3) Ecological Significance: Rank = C

There are no documented examples of ecosystems with high or moderate ecological significance being adversely impacted by VOCs, nor are there documented examples of sensitive, endangered, or unique species or communities affected, at this time.

(4) Geographic Scale: Rank = B

Although some VOCs are released in all areas across the state, it is likely that effects would occur primarily in those four regions with significant areas of urbanization; significant impacts, even localized, in the Adirondacks and Catskill Regions are unlikely.

(5) Final Ranking: Rank = C

VOCs have relatively high toxicity thresholds. For toxic exposures to occur, organisms must be exposed to high concentrations in enclosed spaces or to continuous releases. Local impacts to terrestrial and aquatic life are possible in the vicinity of spills or inactive hazardous waste sites. VOCs probably do not cause widespread ecological harm.

(6) Ranking Table showing ranks for each criterion and overall rank assignment:

Volatile Organic Compounds		
Ranking Criteria	**Rank**	**Comments**
1. Severity	**C**	there are no documented examples of ecosystem structure or function being adversely impacted, nor of individual populations being stressed from VOCs
2. Reversibility	**C**	VOCs volatilize quickly and their effects on aquatic and terrestrial ecosystems are relatively short-term
3. Eco-significance	**C**	there are no documented examples of ecosystems with high or moderate ecological significance being adversely impacted by direct exposure to VOCs, nor are there documented examples of sensitive, endangered, or unique species or communities affected, at this time
4. Geo-scale	**B**	it is likely that effects would occur in those four regions with significant areas of urbanization
Overall Rank	**C**	VOCs have relatively high toxicity thresholds. For toxic exposures to occur, organisms must be exposed to high concentrations in enclosed spaces or to sustained releases. Local impacts to terrestrial and aquatic life are possible in the vicinity of spills or inactive hazardous waste sites. VOCs probably do not cause widespread ecological harm.

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Appendix A

Adopted January 31, 1997

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION COMPARATIVE RISK PROJECT

CHARGE TO WORK GROUPS

Purpose and scope of Project

All work groups will complete their work in a manner consistent with the purpose and scope of the Project which were adopted by the Steering Committee on August 30, 1996, as follows:

1. The purpose of this Project is to evaluate, characterize, and compare the risks associated with releases to the environment of substances that have the potential to harm human health or the environment in New York State, taking into account both scientific data and public values; and to recommend a strategy for reducing those risks through the multimedia pollution prevention (M2P2) program of the New York State Department of Environmental Conservation (NYSDEC). This strategy will be based on the priorities identified by a characterization and comparison of risks and will consider public values and, for each risk reduction method identified, its expected cost-effectiveness, practicality, and equity. The Project will be evaluated as a potential model for other priority setting and strategic planning efforts carried out by the NYSDEC.

2. The scope of this Project will be limited to risks caused by releases to the environment of substances that have the potential to harm human health or the environment, and will focus on pollution prevention as the primary method of reducing the risks caused by these releases.

3. The Project will only evaluate residual risks as they exist at this time. Residual risk is the risk that remains given current levels of environmental regulation and control. Past practices or projections of future conditions will not be considered.

Roles of Steering Committee and work groups

1. The Steering Committee will be the primary decision-making body for this Project. It will have the responsibility to make final decisions regarding the selection, characterization, and comparison of issues, the identification of priorities, the selection of risk reduction strategies, and any other issues that come before it. The Steering Committee will report to the Commissioner of the NYSDEC.

2. There will be five work groups convened for this Project: Human Health, Ecosystems, Quality of Life, Public Participation, and Risk Reduction Strategies. The Steering Committee is responsible for selecting the work group participants and establishing the methodologies and ground rules under which the work groups will operate.

3. The work groups will be established for the purpose of completing background research and data evaluation for use by the Steering Committee. The Steering Committee may make specific requests for information from the work groups. All work groups report to the Steering

Committee. Work group chairs will be selected by the Steering Committee, and will be invited to participate in Steering Committee meetings.

Scope of work

A. Identification of environmental problems

The Steering Committee, after obtaining recommendations from the work groups, will approve a list of problem areas to be evaluated in this Project. The work groups may not add problems to the list unless approved by the Steering Committee.

B. Evaluation of environmental problems

1. The work groups must attempt to evaluate every problem on the list. If a problem cannot be evaluated, the reasons must be explained in their report to the Steering Committee. The work group may identify data and information gaps that preclude a full evaluation and characterization of the risks associated with a given problem.

2. Each work group will determine the criteria that it will use to evaluate the problem areas. The Steering Committee will be provided an opportunity for review and may suggest revisions to the criteria.

C. Reports

1. The Human Health, Ecosystems, and Quality of Life Work Groups will each evaluate, characterize, and compare risks and relevant effects for their respective areas and will issue a report to the Steering Committee that includes a description of their methods, findings, and supporting documentation. The reports will characterize each problem area and will compare each problem relative to the other problems. These comparisons will be completed for each criterion selected for evaluation by the work group. The primary product of the work group will be a thorough, clear, and accessible presentation of the information gathered by the work group, in a manner that illuminates the major characteristics of each problem area and highlights the substantive differences in the risk posed by each. The work group will also perform an overall comparison of the degree of risk posed by each problem area. The Public Participation Work Group will issue a report to the Steering Committee that includes the results of their investigation into public values and public comment regarding this Project. The Steering Committee will use the four reports noted above to produce an integrated risk characterization and comparison.

2. All work group reports will include summary charts, in a format selected by the Steering Committee, which graphically display the major decisions of the work group.

3. The Risk Reduction Strategies Work Group will issue a report to the Steering Committee that details all risk reduction methods considered, including the results of research and supporting documentation for each, and recommendations on the implementation of such measures.

Work group descriptions

A. Human Health Work Group

The Human Health Work Group will evaluate for each problem area all known health risks, including both cancer and non-cancer effects. The socio-economic and hardship impacts of health effects will be evaluated by the Quality of Life Work Group.

B. Ecosystems Work Group

The Ecosystems Work Group will evaluate risks to the ecosystems that exist throughout New York State. The health and preservation of the plants, animals, and aquatic and terrestrial landscapes that make up the ecosystem, as well as ecosystem processes, will be considered. Use of the ecosystem by humans and risk to human health that results from ecosystem damage will not be part of the analysis.

C. Quality of Life Work Group

The Quality of Life Work Group will evaluate risks or damages resulting from the problem areas that are not considered by the Human Health or Ecosystems Work Groups. The Quality of Life Work Group will strive to incorporate the values of New York State residents into its analysis through cooperative efforts with the Public Participation Work Group.

D. Public Participation Work Group

The Public Participation Work Group will provide advice and identify appropriate strategies to disseminate information and solicit input from the public. They will work with the Steering Committee and other work groups to develop processes and to select and carry out activities to facilitate a dialogue between the public and the Project participants.

E. Risk Reduction Strategies Work Group

The Risk Reduction Strategies Work Group will develop a list of pollution prevention measures that can be taken to reduce the risks identified by the other work groups and the Steering Committee. Each proposed strategy will be evaluated by a set of criteria developed by the work group.

Ground rules for work groups

A. Process

1. When making decisions, work group members will strive for the most broad, inclusive, and informed consensus possible. When consensus is not reached, decisions will be based on majority vote. A vote will be taken only when a majority of the members in attendance agree that active, open, and constructive participation by all members has occurred and that consensus is not possible.

2. At least 2/3 of the members of the work group must be present for a vote to take place. Voting will be completed by a show of hands, or, in the case of a very close vote, a roll call. Members are encouraged to carefully consider all viewpoints before deciding how they will vote.

3. All written reports concerning this Project will include a discussion that expresses both the majority and minority viewpoints whenever disagreement still exists.

4. The work group chair will be present at each meeting to enforce the ground rules, ensure that the agenda is followed, and make certain that work is accomplished in the most efficient and effective manner possible. If the chair must miss a meeting, he/she will appoint a substitute to take his/her place.

5. Minutes will be taken at all work group meetings and will be provided to the Steering Committee and other work groups upon request.

6. Work group members will strive to keep all discussions on track and will come to each meeting prepared to participate in the discussions that have been planned for the day. Only one person will speak at a time and all participants will have an equitable and fair opportunity to speak. The chair will recognize participants in order.

7. The work groups may form subcommittees as needed to accomplish business in the most effective manner. All subcommittees will report back to the work group.

8. All work group members are expected to be active participants in the work group's data analysis and deliberations and are expected to carry out a reasonable share of the overall work effort. The consensus to be sought and any written work produced will only be a product of the work group members.

9. Work group members will cooperatively share data and information with members of other work groups to facilitate communication and ensure consistency in their evaluations.

B. Attendance

1. Work group members must make a good faith effort to attend all work group meetings. If a member must miss a meeting, he/she may designate a substitute to represent his/her position. This substitute must be well informed on the issues to be discussed and may vote on issues on the member's behalf. Members that must miss a meeting may submit written comments on the topic that will be discussed at that meeting for consideration by the work group. However, these written comments will not be used as a vote on any issue.

2. A work group member that does not attend (either in person, via conference call, or by sending a substitute) three consecutive work group meetings will be asked to resign.

3. All meetings of the work groups will be open to observers. However, only work group members or their substitutes may participate at meetings or vote on issues. Observers must identify themselves to the work group chair and may request and be invited to speak from time to time upon approval of the work group. Written comments from observers may be submitted at any time.

4. Representatives from the USEPA, the Green Mountain Institute for Environmental Democracy (GMIED), and staff from the NYSDEC that are not members of a work group will be considered advisors and are invited to participate in all meetings. However, advisors will not be allocated a vote on any decision.

5. The work groups will meet as often as necessary to accomplish the work group's objectives. Additional meetings will be arranged between work group chairs or members of different work groups as needed to facilitate communication and reduce duplicate efforts between the groups.

C. Public statements and documents

1. The public will be given opportunity to comment on all work group reports before they become final. Public comment will be both solicited and welcome throughout the duration of the Project.

2. All final meeting minutes, work group reports, and other documentation prepared in conjunction with this Project will be made available to the public upon request.

3. Work group members may speak to the public or the press regarding this Project, however, it must be clear that they are stating only their own views and not those of any other work group member or the NYSDEC or work group as a whole. Work group members may discuss the outcome of decisions that have been made, however, they will not speculate publicly about decisions that the work group has yet to make.

4. Work group members should notify their work group chair of any significant communication with the public or press.

Appendix B

Work Group Members

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Appendix C

Adopted May 2, 1997

New York State Department of Environmental Conservation Comparative Risk Project Work Group Methods for Analysis

This document contains information and guidance for the Human Health, Ecosystems, and Quality of Life Work Groups to use when completing their evaluations.

Definitions - In all reports prepared for this Project, the following terms will be used and will have these meanings:

> **"Groups of stressors"** will be used to refer to the groupings of items (for example, nutrients, particulates, pesticides, etc.) for which the associated risks will be evaluated.
>
> **"Stressor"** will be used to refer to a specific substance or individual chemical that potentially produces an impact on human health or the environment. Most stressors are contained within one of the groups of stressors that have been selected for this Project.
>
> **"Residual risk"** refers to the risks that continue to exist even though regulatory and other measures that reduce risk may be in place. This is the risk that exists right now, with currently practiced environmental management procedures and current degrees of environmental regulation and compliance. No assumptions are made about what the risk levels might be if regulations were stronger or weaker, or if different technology were used to control releases.

Work group responsibilities - Each work group will determine the degree of detail of their evaluations and characterizations in terms of stressors (based on the list of groups of stressors provided by the Steering Committee) and data richness, according to the Charge to Work Groups adopted January 31, 1997. Each work group should provide a work plan to the Steering Committee by June 27, 1997. All of the analyses and conclusions presented in the work products should be as complete and transparent as possible.

Geographic considerations - The work groups will give primary consideration to the effects of the groups of stressors on New York's population and ecosystems, however releases in New York that cause effects only in other states and releases in other states that cause effects in New York may be noted in the report. In addition, the work groups will explain how the effects of each group of stressors is geographically distributed throughout the State.

Combinations of stressors - Some stressors may produce particular adverse effects only when in combination with other stressors. When these effects are considered significant, and the stressors are part of different groups of stressors, then the effect may be included in the characterization for both groups.

Uncertainty - Each work group will report on the degree of scientific certainty of their conclusions, and will indicate those areas where a characterization cannot be made due to lack of sufficient data or information.

Sources of harmful releases - Each work group will attempt to identify the important sources of stressors that pose a risk to the area they are studying. Information on sources will be included in each work group report if available and appropriate.

Glossary - A single glossary of terms will be developed for this Project to ensure that the various reports produced reflect the same understanding of terminology. The glossary will appear in the back of every report. Work groups may suggest additions to the glossary at any time during their analysis.

Project timetable - Each work group will be expected to have a draft report ready for review by the public and the Steering Committee by December 31, 1997. The Human Health and Ecosystems work groups will provide the Quality of Life Work Group with early drafts or findings so that this information may be incorporated into their analysis.

Outline of report - The primary product of the work group will be a thorough, clear, and accessible presentation of the information gathered by the work group, in a manner that illuminates the major characteristics of each problem area and highlights the substantive differences in the risk posed by each. Each work group report will include a Table of Contents, an Executive Summary, and a body that presents the information that has been gathered and the work group's conclusions based on that information. The work groups are encouraged to provide as much information as is needed to provide the reader with as complete a picture of the problems caused by a stressor or group of stressors as possible.

Appendix D

New York State Department of Environmental Conservation Comparative Risk Project

ENVIRONMENTAL PROBLEM LIST:
Stressors that are released into the environment, grouped into chemical categories
(listed alphabetically)

1. **Acidic and alkaline substances**
   This category includes substances that have a pH less than 2 or greater than 12.5. It does not include substances that react once in the environment to form acids or bases or to cause acid rain.

2. **Atmospheric gases (NO_x, SO_2, CO, CO_2, and CH_4)**
   This category includes nitrogen oxides and sulphur dioxide, which are common by-products of combustion and which contribute to acid rain. They are also precursors to ambient ozone, which is considered in this category. Greenhouse gases, except for CFCs, are also included in this category. CO and CO_2 are combustion by-products and CH_4 is emitted from various sources, including landfills.

3. **Halogens**
   This category includes elemental halogens, such as chlorine and bromine. Drinking water chlorination by-products and waste water disinfection by-products, such as trihalomethanes, are included in this category.

4. **Metals and cyanide**
   This category includes both elemental and organic forms of metals. Lead, mercury, and cadmium are the three that are most often cited as posing environmental risk. Other metals, such as silver, nickel, chromium, and manganese, have sometimes been implicated as causing harm and may be considered as well. In addition, cyanide will be considered here because of its similar properties. These substances enter the environment through a wide variety of sources, including combustion, wastewater discharges, and manufacturing facilities.

5. **Non-volatile halogenated organic compounds**
   This category includes dioxin, certain pesticides, PCB's, and a variety of other compounds that are generally of high molecular weight and contain at least one halogen atom. These compounds are likely to be both highly bioaccumulative and toxic.

6. **Non-volatile and semi-volatile organic compounds**
   This category includes phthalates, alkylphenols, and glycol ethers, among other compounds, that may produce harmful effects such as endocrine disruption. This category includes all non- and semi- volatile organic compounds that are not halogenated.

7. **Nutrients**
   This category includes substances containing various elements, such as phosphorous, potassium, and nitrogen, that act to promote the growth of certain unwanted aquatic species, often to the detriment of other beneficial species. These primarily reach the environment through non-point sources, including agricultural activities.

8. **Particulates**
   This category includes dust, soot, and other small particles (PM-10) that become suspended in the air. Asbestos will be considered as well. Combustion is the primary source of particulates. Toxic substances that are associated with particulates, such as benzo(a)pyrene, are not included here.

9. **Pesticides**
   This category includes all pesticides, including insecticides, herbicides, fungicides, and others, that are not included in other categories on this list. Certain pesticides are found in the non-volatile halogenated organic compounds and heavy metals categories. This category includes carbamates and organophosphates.

10. **Petroleum products**
    This category includes petroleum product mixtures such as oil, gasoline, and diesel fuel. It does not include the substances that are released when these products are burned or the individual components such as benzene, toluene, and xylene which are considered in the VOC category.

11. **Polynuclear aromatic hydrocarbons (PAHs)**
    This category includes aromatic compounds that contain three or more closed rings. A typical example is benzo(a)pyrene, which is a potent carcinogen. The primary source of these compounds in the environment is combustion. Styrene, a PAH, is also included in this category.

12. **Radionuclides**
    This category includes radiation released by human activities, but not radon or other naturally-occurring radiation.

13. **Suspended and settleable solids**
    This category includes non-toxic solid particles, such as silt, that have the ability to cause physical or mechanical damage to surface waters.

14. **Volatile organic compounds (VOCs)**
    This category includes many low molecular weight solvents used in a variety of commercial processes, such as dry cleaning, degreasing, manufacturing, painting, and printing. Common solvents include perchloroethylene, TCE, and benzene.

Appendix E

ASSESSMENT CRITERIA: Ecosystems Work Group

Criterion 1: **Severity of Effect**

This criterion measures the actual, residual ecological severity of the effect of a stressor.

A. Ecosystem structure or function affected or severely damaged.

B. Populations significantly affected (eg. chronically depressed), lost or excluded.

C. Essentially no effect or non-lethal effects on individual organisms, and the effect on ecosystem structure and function is not measurable; or loss of individual organisms, however, the structural and functional integrity of the ecosystem remains intact.

Criterion 2: Reversibility of Effect

This criterion is a measure of the time it takes for a system to naturally recover from the effect if the stressor is eliminated.

A. Greater than twenty years

B. Three to twenty years

C. Less than three years

Criterion 3: Ecological Significance

This criterion seeks to factor in the ecological significance of a site or system actually being affected by current releases. This criterion should adjust an overall ecological score when applying the ranking criteria. Areas with particular sensitivity or special ecological attributes and functions will receive an elevated score through the application of this criterion.

A. **high** ecological significance
* high biodiversity
* globally or regionally rare or unique natural communities
* state listed endangered or threatened animals or plants
* important spawning grounds or migratory pathways
* highly sensitive to perturbation

B. **moderate** ecological significance
* moderate biodiversity
* locally rare or unique natural communities
* state listed species of special concern (animals)
* state listed rare or exploitably vulnerable plants
* moderate sensitivity to perturbation

C. **limited** ecological significance
* monocultures or low biodiversity
* non-native or artificial systems
* small, degraded, highly developed, and isolated systems
* common species and communities
* minimal sensitivity to perturbation

Criterion 4. Geographic Scale

The purpose of this criterion is to evaluate the number of ecological regions of the state that are affected or likely to be affected. These regions are shown on the attached map.

A. **Extensive**, with five or six regions affected or likely to be affected.

B. **Broad**, with three or four regions affected or likely to be affected.

C. **Limited**, with one or two regions affected or likely to be affected.

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Appendix F

Glossary of Terms for the Ecosystems Work Group

Acid Precipitation: rain, snowfall, or atmospheric moisture with a pH reading below 5. Natural rain is slightly acidic, so 4.8 to 5.5 pH is considered natural for most parts of the world.

Bedload: stream substrate that moves by sliding, rolling, or bouncing along on or near the stream bottom.

Bioaccumulation: the increase in concentration of an agent (or its metabolites) in an organism caused by uptake and storage at a rate faster than the combined rates of metabolism, excretion, and passive loss. The measure of bioaccumulation (concentration in organism/concentration in its environment) approximates K_{ow} in fish. The mechanisms of bioaccumulation of DDT and vitamin A are similar, but have different outcomes.

Blooms: an excessive abundance of plankton algae, usually the result of excess limiting.

Nutrients: these blooms often die, causing low dissolved oxygen concentrations in the water column (hypoxia).

Chemodynamics: the movement of chemicals from a source to a target organism or system; typically outside of that target but including organisms the chemical moves in or through to the target. The term covers physical processes (diffusion, advection) as well as biological processes (uptake, storage, metabolism and excretion) and abiotic transformation (e.g., photolysis).

DDT: *p,p'*-dichlorodiphenyl-trichloroethane or 1,1-(4-chlorophenyl)-2,2,2-trichloroethane.

Drift: the movement of aerosols and sprays from the intended point of application or release (as for a pesticide spray) into some non-target area.

Dry Deposition: the transfer of trace species (gases or particles) that occur with uptake by vegetation on Earth's surface under non-precipitating conditions. It results when an airborne particle comes into contact with a surface and is lost to it.

Dryfall: the deposition of particles of soot, dust, microscopic plant and animal bodies settling out of the atmosphere.

Ecotoxicology: the study of the fate and effects of chemicals in and on natural systems, their component species and processes. This overlaps with human health toxicologic aspects via Foodweb impacts, by exposure through chemodynamic processes, and in mechanisms of action of agents, but differs in not having an anthropocentric view.

Embeddedness: the amount of fine sediment that is deposited in the interstices between the larger substrate particles.

Eutrophication: the phenomenon by which water bodies age or go through succession. This is a natural process that can be accelerated by cultural actions, usually by the addition of limiting nutrients.

Greenhouse Effect: the trapping by atmospheric gases of outgoing infrared energy emitted by Earth. Part of the radiation absorbed by the atmosphere is returned to Earth's surface, causing it to warm.

Greenhouse Gases: a gas with absorption bands in the infrared portion of the spectrum. The principal greenhouse gases in Earth's atmosphere are H_2O, CO_2, CH_4, N_2O, $CF_2Cl_2CFCl_3$. Only carefully designed anthropogenic molecules have the potential to be added to the current greenhouse gas list.

Henry's Law Constant: the relation of vaporization to water solubility at a given temperature.

Interstices: the pores between the particles in a bottom substrate.

Invertebrates: animals without backbones (crayfish, grasshopper, earthworm) but with an exoskeleton, a nervous system, and a rudimentary circulatory system.

K_{ow}: octanol-water partition coefficient (solubility in octanol/solubility in water).

Mesotrophic: term used to describe moderate biological productivity ("nicely nourished") lakes that typically exhibit slightly reduced dissolved oxygen concentrations near the bottom.

NPS: non-point source, such as a farm field or city street system, as compared to a *point source* such as a smokestack or sewer pipe.

Oligotrophic: term used to describe low biological productivity ("poorly nourished") lakes that have high dissolved oxygens concentrations from surface to bottom.

Partition Coefficient: solubility in octanol/solubility in water.

PCB: polychlorinated biphenyls, a set of 209 similarly derived chemicals.

Pervasive: tending to be moving into other, heretofore pristine or under-exposed areas, into most biota in those areas, and so forth. Agents such as DDT are aided by global and marine circulations which enable their distribution on a truly global scale.

Piscivore: fish-eating animal, such as a salmon or otter.

Promotion: (cancer) causing a cell with a replicated cancer-causing mutation to grow in size and numbers at the site of initiation (the act of mutation) prior to spreading (proliferating) to other sites.

Salmonids: coldwater fish species of trout and salmon groups.

Settleable Solids: organic or inorganic materials that settle out of water suspension within a defined period of time.

Sight-feeding Fish: those fish that rely primarily on their eye-sight to seek out and capture food.

Siltation: fine inorganic and organic materials that settles out of water onto aquatic vegetation and bottom.

Sorption: the undifferentiated affiliation of a chemical *on* the surface of a particle (*adsorption*) or *within* the interior of that particle (*absorption*).

Superfund: the trivial name for abandoned hazardous waste sites coming under the Comprehensive Environmental Remediation, Compensation and Liabilities Act of 1979 (CERCLA) as amended in the Superfund Amendments and Reauthorization Act of 1986 (SARA) and incorporated as federal statute under 40 CFR 300. The term has become associated with waste sites generally.

Suspended Solids: organic or inorganic materials that are removed from water by a standard glass filter.

SVOC: semi-volatile organic compound (such as phenol, dichlorobenzene).

TCDD: 2,3,7,8-tetrachloro-dibenzo-*p*-dioxin.

THM: trihalomethane, such as chloroform and dibromochloromethane.

Turbidity: a measure of reduced water transparency due to light scattering and absorption by suspended/settleable solids in water.

Upwelling event: a natural event where generally colder, deeper water is brought to the surface. They are usually associated with windy conditions, and can occur in oceans and freshwater lakes.

VOC: volatile organic compound (such as chloroform and trichloroethylene).

Appendix G

New York State Department of Environmental Conservation
Comparative Risk Project Information Sheet

PROJECT TITLE: Comparative Risk: Multimedia Pollution Prevention Strategic Planning

PROJECT SUMMARY: The Comparative Risk Project will help to identify those problem areas where current regulatory and pollution prevention efforts have so far failed to adequately reduce risk to human health, ecosystems, and quality of life for New Yorkers. Only problem areas that can be addressed through pollution prevention will be considered in this project. The problem areas will be characterized and compared based on residual risk, that is, the risk that remains given current levels of regulation and control. Each of the problem areas, but especially those determined to be higher risk, will be closely examined for pollution prevention opportunities that will reduce the risks. All identified pollution prevention measures will be evaluated on the basis of cost, expected effectiveness, practicality, and fairness; and those that are determined to be most worthwhile will be recommended to the Commissioner for implementation.

Comparative Risk will serve as one of the agency's primary mechanisms to building better understanding, positive relationships, and support for DEC's mission and goals by soliciting broad public input throughout the project. It will assist in providing education to increase public awareness and understanding of agency programs and will create partnerships among those groups and agencies that participate in the project. The project will involve many people both within and outside of DEC, and will seek to achieve consensus from a broad range of viewpoints.

ORGANIZATION OF PROJECT: The New York State Comparative Risk Project is broken into two phases. Phase I will identify the most significant threats to human health, ecosystems, and quality of life that result from toxic releases to the environment. Phase II begins once these risks are characterized. In Phase II, management strategies that incorporate pollution prevention methods will be developed and prioritized for implementation. The project will be led by a Steering Committee, which will oversee all aspects of the project. Their work will be supported by four technical work groups, which will focus on: human health, ecosystems, quality of life, and public participation. The NYSDEC Pollution Prevention Unit will have lead responsibility for the project and will provide management and logistical support.

PUBLIC PARTICIPATION: Members of the public are invited to participate on the work groups and will be invited to comment on all aspects of the project. The Public Participation Work Group will ensure that public participation plays a prominent role in the project. A public opinion poll, a public summit or meeting, and other methods of public outreach will be considered by this work group.

PROJECT SCHEDULE: This project is expected to take approximately two years to complete. Phase I will last approximately 15 months, and Phase II will last approximately 9 months.

PROJECT PROCESS AND SCOPE: Phase I of the Project will be the Risk Characterization Phase. The Steering Committee will begin the process by deciding which issues will be characterized and compared, keeping in mind that the recommendations resulting from the project will be made to the Commissioner of the Department of Environmental Conservation. The Steering Committee must agree upon specific definitions for these issues and a risk evaluation protocol.

The technical work groups must study the availability of information and must compile and analyze all relevant data. The work groups will prepare a preliminary characterization of the issues with respect to human health, ecosystems, or quality of life, as appropriate. A report, detailing the data and analysis that was performed and justifying the preliminary characterizations, will be prepared by each work group. The Public Participation Work Group will be responsible for presenting the technical information gathered by the other work groups to the public and soliciting public comment. This Work Group will prepare a compilation of the public comments to the Steering Committee, which will complete an integrated risk characterization and comparison.

Once the comparisons are complete, the project enters the Risk Management Phase. To complete this phase, a new work group may be convened, made up in part of members of the original work groups, and in part of new members. The Risk Management Phase will provide an analysis of various measures that can be implemented to reduce the risks identified in Phase I. This evaluation will focus on the use of pollution prevention techniques to reduce risk. The risk reduction measures will be based on recommendations from the work groups and the public (compiled by the Public Participation Work Group). The recommendations that result from this analysis will form the basis for a risk-based pollution prevention strategy for the DEC's Environmental Quality programs and can also be used in the DEC's overall strategic planning.

October, 1996