Outline of Presention
Phase II Walkerton Inquiry

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on behalf of Canadian Environmental Defence Fund

A. Introduction

1. I am an Environmental Scientist with expertise in:
    1. environmental science and teach courses in environmental science
    2. biology (B.Sc. in Biology, M.Sc. in Zoology)
    3. environmental engineering (M.Sc.Eng. in Mining Engineering, Ph.D. in Chemical Engineering) and now supervise graduate student research in environmental engineering and applied chemistry research
    4. mathematical modelling of environmental systems
    5. risk assessment, particularly chemical fate and familiarity with environmental toxicology (I teach a senior undergraduate and graduate course ?Contaminants in the Environment?, risk assessment short course for credit with the Professional Development Centre of the Faculty of Applied Science)
    6. limnology, water pollution and contaminant dynamics in lakes
    7. atmospheric pollution
    8. contaminant fate in urban areas, notably Toronto, Hamilton, Minneapolis/St. Paul

2. I am involved in the following research projects (please see CV for a more complete listing):
    1. develop mathematical models of how chemicals move in the environment, specifically among air, vegetation, soil, water, sediment (multimedia mass balance modelling)
    2. investigate how chemicals move through urban areas
    3. investigate water quality/contaminant dynamics in lakes
    4. investigate chemical concentrations and fluxes, and model chemical dynamics in stormwater detention ponds (SWM ponds)
    5. risk assessment, with a project on developing a model to estimate the risk to biota from transportation-related chemicals
    6. environmental toxicology, with two projects in collaboration with a researcher at the Hospital for Sick Children, examining the toxicology of the complex chemical mixtures derived from urban areas

3. My activities at the University of Toronto involve:
    1. conducting primary research into the areas listed in 2., which entails sampling in the field (e.g., surface water samples), analyzing samples for chemical constituents,

and developing mathematical models

2. most of the research activities are completed by my graduate students and others that I supervise (I now have 5 masters students, 1 doctoral student, 1 post-doctoral fellow, 1 research associate and 2 undergraduate students who work as technicians)
3. I teach undergraduate and graduate students in several courses
4. I teach a diploma short course in risk assessment as part of the Professional Development Centre, Faculty of Applied Science and Engineering
5. In addition, I conduct limited consulting work mostly for government agencies, as listed in my Curriculum Vitae. I am on the Board of Directors of a professional organization, the Society of Toxicology and Chemistry, and the Canadian Environmental Law Association.

B. Summary of Evidence

4. My opinions pertain largely to the effects of chemicals entering the environment and how those chemicals move through the environment.

5. There are widespread environmental and health impacts associated with urbanization, and specifically residential development. These impacts are difficult to prevent and difficult to mitigate once they occur. Consequently, we should not develop on sensitive lands, those that are internally draining or with provincially significant features such as wetlands and kettle lakes, or at the headwaters of river systems. At several places in my evidence, I will refer to proposed developments on the Oak Ridges Moraine ("ORM") to illustrate points regarding potential impacts of urbanization e.g. roof run-off. In most cases, these impacts refer specifically to the proposal to establish 8,200 homes on the properties commonly referred to as the Yonge West and Yonge East Lands, on the ORM.

6. Another dilemma posed by urban development is the need to maintain the water balance: this is the water quantity issue. However, with residential development the water that is used to maintain this balance will contain elevated concentrations of a wide range of chemicals: the water quality issue.

7. Given our understanding of the Oak Ridges Moraine and other internally draining lands, but our lack of understanding of the long term effects of current stormwater management ractices, residential development of these lands is unsustainable and should be avoided.

8. *It is preferable that urban development should be located on lands that have surface drainage*, but not on lands that are internally draining, have provincially significant features, and are at the headwaters of high quality cold water streams. Given present scientific knowledge and engineering practice, it is easier and more predictable to maintain the water balance and address water quality degradation due to development on lands that

are externally draining, do not contain provincially significant features, and are not at the headwaters of streams. There are three main reasons for favouring development on externally rather than internally draining lands, lands that do not contain provincially significant features and that are not at the headwaters of three high quality streams.

1. First, the degradation of surface groundwater is less likely in an externally draining area because, by definition, less water can infiltrate into the surface groundwater.
2. Secondly, the consequences of adverse effects on water quality, should they occur from urban/residential development, are less on lands without provincially significant features. Contaminants, once introduced, can impact the function of provincially significant wetlands and kettle lakes, and the stream headwaters.
3. Third, there is greater feasibility of developing contingency plans for dealing with water quantity/quality on externally rather than internally draining lands. The contingency plan is a centralized collection and treatment system with the discharge of treated stormwater into surface waters. This is feasible on externally draining lands because:
    1. The stormwater is not required for spatially distributed groundwater recharge as is necessary on internally draining lands; and
    2. A centralized treatment system achieves high removal rates of chemicals (organics and metals) and pathogens and thus produces high quality effluent in comparison to best management practices such as stormwater detention ponds.
4. It is also feasible, but not desirable, to remediate surface water bodies that have been contaminated (e.g., removal of contaminated sediment). In contrast, it is very difficult and costly to treat groundwater once it has been contaminated.

9. *Given the state of engineering practice in terms of stormwater control, stormwater managment plans, including Stormwater Management ("SWM") ponds, are presently an acceptable management approach for dealing with stormwater on externally draining lands and lands without provincially significant features.* In particular, SWM ponds have been proven to mitigate adverse effects on the quality of receiving surface water bodies and are a considerable improvement for stormwater management control in comparison to older practices of direct discharge into surface water bodies (Marsalek and Kok 2000).

10. Stormwater detention ponds (SWM ponds) are waste treatment facilities.
    1. As such, *SWM ponds should not be used as wildlife habitat* (Diamond and Helfield 1997, Bishop et al. 2000a,b).
    2. *Provincially significant wetland features should not be used as SWM*
    3. *SWM ponds should not be sited in wildlife corridors* since the facilities will be used by biota, with the potential of adverse health effects.

11. Stormwater from residential developments, even roof and lawn runoff, contain a complex mixture of chemicals derived from many sources. These sources are difficult to control

(e.g., application of pesticides to lawns, vehicle emissions to air and roadways). Numerous studies now coming from the United States, show a direct relationship between residential development and elevated chemical levels in streams, rivers and surface groundwater where soils have high permeability.

12. *Complex chemical mixtures, such as stormwater, and specific chemicals within the mixture of stormwater, can cause adverse health effects to wildlife.* Wildlife would be directly exposed to the complex chemical mixture in stormwater as a result of the stormwater management plans (e.g., stormwater management ponds or SWM ponds). Some of the effects found in other situations of wildlife exposure to complex chemical mixtures, as occurs in stormwater, include: reproductive disorders and reduced success at reproduction, birth deformities, tumours and lesions. These effects can be underestimated if the assessment is on a chemical-by-chemical basis, if comparisons are made with levels found toxic in short-term bioassays, or inappropriate testing is used (e.g., tests of lethality or death that use high chemical doses versus tests of birth deformities that exposes the fetus to low chemical doses).

13. Humans will not be typically directly exposed to urban stormwater. Should humans be exposed to the complex chemical mixture in urban stormwater over the long term, including exposure to low concentrations, adverse health effects could occur.

14. Given our lack of understanding of the potential health effects to wildlife and humans from the exposure to low levels of complex chemical mixtures, and past lessons learned from the impacts of chemicals used that we thought were safe (e.g., DDT, PCBs, lindane), *it is imprudent to release chemicals into a sensitive groundwater recharge areas that are headwaters of and the source of drinking water*.

C. Background Information

C1. Effects of Urban Development

15. *Urban development has the potential to significantly increase chemical concentrations and emissions to the soils, surface groundwater, wetlands and kettle lakes of Ontario*. The implications of increased chemical concentrations is potential acute and chronic toxicity to wildlife using the area and increased risk to human health for those people using the groundwater for drinking water.
I define significant according to the definition of toxic provided by the *Canadian Environmental Protection Act* (1989):
?... a substance is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions:

1. Having or that may have an immediate or long-term harmful effect on the environment;
2. Constituting or that may constitute a danger to the environment on which human life depends; or
3. Constituting or that may constitute a danger in Canada to human life or health.**?**

16. *Urban development, and specifically residential development, results in chemical emissions to all media*, e.g., air, water, soil.

    1. Emissions to air come from mobile (vehicles) and stationary (home and commercial heating, cooking) fossil fuel emissions, and other sources. These emissions to air increase chemical concentrations in precipitation that falls on soils, wetlands and the kettle lakes (e.g., Stackelberg et al. 1997, Panow et al. 1997, Squillace et al. 1996, Cahill et al. 2001).

    2. Emissions to urban surfaces (e.g., leakage from crank cases of vehicles, combustion emissions from vehicles, application of road de-icers, abrasion of tires) increases chemical concentrations in stormwater runoff (Delzer et al. 1996, Lopes and Bender 1998, Rogge et al. 1993). Runoff from roof tops contains chemicals scavenged from air as well as those leached from roofing materials (Bucheli et al. 1998).

    3. Emissions to soils occurs from the direct application of fertilizers and pesticides to lawns, and road allowances. Emissions to soils of chemicals such as chloroform also occurs from using drinking water for lawn watering and the discharge of water from domestic swimming pools (Stackelberg et al. 1997). Organic chemicals such as pesticides, can be highly persistent in urban soils (Wallman 2000).

    4. Emissions to soils results in the contamination of surface groundwaters, particularly when soils have high permeability (Stackelberg et al. 1997, Thomas 2000, Phillips et al. 20000, Bruce and McMahon yr?, Pankow et al. 1997, Squillace et al. 1996, Bucheli et al. 1998a,b), as is the case with the Yonge West and Yonge East lands.

    5. Emissions to surface waters (e.g., wetlands, kettle lakes) occurs directly from surface runoff from impervious surfaces, discharge of shallow groundwater and direct atmospheric inputs (Kimbrough 1995, Lopes and Bender 1998, Van Metre et al. 2000). Direct atmospheric inputs can have a considerable influence on inputs to surface waters (Lopes and Bender 1998), particularly those lacking permanent surface inflows and outflows (Cahill et al. 2001) such as Bond and Philips Lakes and the wetlands.

17. *Residential land use results in the release of many chemicals and substantial amounts of particular chemicals relative to agricultural practices.*

1. According to Struger et al. (1994), pesticide usage on residential lands is much higher than usage on agricultural lands,:

Pesticide	**Urban Residential**	**Agricultural**
Herbicides	1.73	0.57
Insecticides	0.62	0.11
Fungicides	1.36	0.295

Units of (kg/ha·yr)

2. In 1993, 1,300 tonnes of pesticides were applied to lawns in Ontario by licensed applicators and this amount does not include pesticides applied personally by homeowners (Struger et al. 2000).
3. ?Urban use for some [compounds] exceeds agricultural use? (Struger et al. 2000). About 1/4 of all conventional pesticide use in the United States is for non-agricultural purposes, of which urban use for home and garden care accounts for a significant proportion (Wotzka et al. 1998).
4. Chemicals such as pesticides and herbicides that are applied to residential land including home gardens, lawns and parks, have been measured in runoff at concentrations that approach or may exceed the Ontario Water Quality Objectives for the protection of aquatic life (Struger et al. 2000).

18. *The impact of urbanization on surface groundwater is the subject of intensive investigations because of emerging evidence of widespread contamination and the realization that freshwater supplies are limited and must be protected.* For example, in 1991 the U.S. Geological Survey funded the National Water-Quality Assessment (NAWQA) program that is aimed at providing information on the spatial extent of water quality problems and understanding the effects of human actions and natural factors on water quality. The budget for one NAWQA study is approximately US$400,000 and more than 50 sites are being assessed across the United States. The impact of urbanization on environmental quality will be the subject of a new U.S. Environmental Protection Agency research effort that will be announced shortly. In Canada, Environment Canada has identified urban stormwater management as an emerging issue that has the potential to degrade Canadian freshwater reserves.

D. Stormwater Composition and Sources

19. *Stormwater contains a complex mixture of compounds, some of which occur naturally but are at much higher concentrations in stormwater and others of which do not occur*

naturally.

1. Suspended solids concentrations in stormwater can be equal to or greater than that of untreated sanitary wastewater and the biological oxygen demand (BOD) is approximately equal to that of secondary effluent that has undergone sewage treatment (Field et al. 1993).
2. Concentrations of pathogens in stormwater is also an important concern. Spiegel et al. (1984a,b) found that 22% of urban runoff samples tested had detectable responses for the Ames Test which assays for mutagenicity. Research completed by the Ministry of the Environment in 1974 in Barrington Heights (Broadview and Danforth area) found that from September 1973 to May 1974, not one runoff sample was below the Metropolitan Toronto Bylaw value of 2400/100 mL coliform count. The study concluded that fecal coliforms came from animal (e.g., domestic dogs and cats) and bird faeces, not sanitary sewage.

20. Listed below is a <u>small</u> subset of *chemicals found in residential urban stormwater* at elevated concentrations (relative to background concentrations in surface waters) (Makepeace et al. 1995, Marsalek et al. 1997b, Licsko and Struger 1995, Lopes and Bender 1998, Lopes and Dionne 1998, Wotzka et al. 1998, Phillips et al. 2000):

? Nutrients:
- phosphorus
- nitrate, nitrite
- ammonia

? Major cations:
- calcium
- manganese
- magnesium
- sodium

? Microbiology
- fecal coliforms
- fecal streptococci
- enterococci
- viruses
- *Shigella*
- *Pseudomonas aeruginosa*
- *E. coli*

? Major anions
- chloride

? Metals and metalloids
- aluminum
- barium
- chromium
- copper
- iron
- lead
- zinc

? Organics
- polyaromatic hydrocarbons, including mutagenic benzo(a)pyrene
- polychorinated biphenyls
- hydrocarbons, e.g., BTEX
- trihalomethanes
- phenols and chlorinated phenols
- oil and grease
- chlorinated solvents
- phthalates

? Organic pesticides
- DDT, DDE and DDD
- hexachlorocyclohexanes such as lindane
- chlordanes
- diazinon
- malathion
- simazine

carbaryl
atrazine
metolachlor
prometon
2,4-D
MCPA
MCPP

27 Listed below are some of the health impacts that are associated with some of the chemicals and pathogens listed above:

Chemical	**Health Impact**
Phosphorus, nitrate, nitrate	Nutrient enrichment, depletion of dissolved oxygen and asphyxiation.
Ammonia	Highly toxic to fish with a lowest chronic concentration of 1.7 μg/L (i.e., will adversely affect fish at concentrations above this value).
Sodium	Hypertension.
Lead	Neurotoxin, behavioural problems and lower IQ in children. Adversely affects health of the waterflea (Daphnids) at concentrations above 12 μg/L.
Copper	Potently effects aquatic organisms at concentrations above 0.23 to 4 μg/L for Daphnids and fish, respectively.
Polyaromatic hydrocarbons or PAH	Mutagenic, carcinogenic; also implicated in reproductive dysfunction of the reproductive and immune systems at low concentrations. All PAH act in the same way, however some are more potent than others, e.g., benzo(a)pyrene is the most potent. Causes adverse effects in waterflea at concentrations above 0.3 μg/L.
Chlorinated solvents, phthalates	Endocrine disruption with effects on reproduction, immune system function, some phthalates suspected to mimic estrogen.
Chlordanes, diazinon, lindane	Potential carcinogens; at low levels adverse effects on reproduction, liver and immune systems.
Atrazine	Chromosomal damage.

Chemical	**Health Impact**
Shigella	Bacillary dysentery can result from even low doses.
Pseudomonas aeruginosa	Swimmer?s ear and other contact infections, resistant to antibiotics.

21. *There is not a single list of contaminants for which we should be concerned in stormwater*. The list of chemicals that one finds depends on the analytical methods used which are constantly being improved with time as well as the time over which the contaminants have accumulated, e.g., 1 year to 25 years.

22. *The number and range of chemicals in residential urban stormwater are greater than that in agricultural runoff* (Makepeace et al. 1995, Lopes and Bender 1998, Stackelberg et al. 1997, Phillips et al. 2000, Wotzka et al. 1998,).

23. *Sources of chemical contaminants in urban, residential runoff are varied and diffuse.* Below are listed the major sources and types of chemicals found in urban runoff from residential development. It must be emphasized, that the sources and emitted chemicals are from routine residential development, not industrial sources or due to historical accumulation. (e.g., Rogge et al. 1993, Mikkelsen et al. 1994, Hoff et al. 1996, Stackelberg et al. 1997, Lopes and Bender 1998, Rauch et al. 2000):
    1. Vehicle emissions from combustion, leakage and catalyst operation (e.g., PAH, oil and grease, MTBE in the U.S., platinum, paladium, etc.);
    2. Also from vehicles, abrasion of tires and brake linings (e.g., barium, *n*-alkanes, alkanoic acids, PAH);
    3. Home heating systems (e.g., PAH, oxides of sulphur and nitrogen);
    4. Corrosion of metallic roofing materials (e.g., Cu, Zn, Pb);
    5. Atmospheric deposition of chemicals originating from with urban areas (e.g., phthalates degassing from plastics, chlorinated benzenes degassing from deodorants, chlorinated phenols from treated wood, chlorinated solvents from paint strippers, degreasers, aerosols and adhesives);
    6. Chemical application to lawns and within the house (simzaine and prometon for weed control, diazinon and carbaryl used as household insecticides);
    7. Release of drinking water for lawn watering, from swimming pools, leakage from distribution system (chloroform and trihalomethanes); and,
    8. Atmospheric deposition of chemicals coming from regional and long range transport (e.g., DDT, DDE, DDD, chlordanes, hexachlorocyclohexanes).

24. It is very *difficult to control at source and after release*, those chemicals emitted from nonpoint sources, as occurs with residential development. This contrasts with point source emissions coming from a single source that are much easier to control because it is

a single, identifiable source.

25. Examples of *widespread contamination from urban chemical release* include lead concentrations that exceed the Provincial soil guideline of 200 µg/g soil in over 80% of the old City of Toronto's soils. The lead originated from its use in gasoline. The widespread contamination of surface groundwaters with MTBE (methyl-*tert*-butyl ether) is now being documented in the U.S. (Pankow et al. 1997, Squillace et al. 1996). MTBE has been detected in 27% of 210 wells and springs sampled in 8 widely separated geographic urban areas as compared with 1.3% of 549 wells sampled in 21 agricultural areas (Squillace et al. 1996).

26. The *timing of chemical releases* in urban areas increases the potential for soil and shallow groundwater contamination (e.g., through the dry kettles), and for adverse effects to aquatic biota in wetlands.
    1. Because so much salt is used, stormwater runoff contains salt year-round as rain removes the salt stored in soils, with the highest pulses occurring in spring (Vickers 1999, Howard and Haynes 1993).
    2. Urban pesticides are applied most during spring, but usage in residential gardens continues throughout the biologically productive periods of summer and fall unlike agricultural pesticide application that is restricted to spring usage (Wotzka et al. 1998). Thus, runoff of pesticides from soils in residential areas into surface waters, such as the wetlands, will occur through the biologically productive period.

27. *Roof runoff is not "clean" water*. Roof runoff is often described as a source of clean water that can be used for groundwater recharge:
    1. Data indicate elevated concentrations of certain constituents such as Zn, Fe, P and N relative to "clean" water (Cosburn Patterson Mather Ltd et al. August 2000) These higher concentrations are from urban sources (Halverson et al. 1984), not soils eroded from agricultural fields or other non-urban sources.
    2. Pesticides and other chemicals originating from urban usage are found in roof runoff (Wotzka et al. 1998, Bucheli et al. 1998b). As discussed below (#39), the use of roof runoff can potentially degrade groundwater quality should if this water is used to recharge groundwater.

E. Stormwater Management

E1. Stormwater Management Plans: Efficiency of Treatment

28. *Stormwater management ponds are wastewater treatment facilities intended to improve the quality of stormwater.* As such, stormwater is regulated under Section 53 of the *Ontario Water Resources Act*. The stormwater management facilities, including the

detention ponds, are considered “treatment works”. Under this provision, the Province requires a Certificate of Approval, that could include provisions for monitoring.

29. *SWM ponds are designed to improve water quality, and specifically for control of Total Suspended Solids* (TSS) (MOEE 1994). It is important to emphasize in terms of water quality, the ponds are designed for TSS control.

30. Level 1 protection, the design criterion for stormwater ponds, is to protect downstream Type 1 habitat as defined by the Ministry of Natural Resources such as:
    1. highly productive feeding areas such as wetlands
    2. habitats supporting endangered, threatened or vulnerable species
    3. groundwater recharge areas in coldwater streams

31. *Level 1 protection only refers to TSS*. It does not provide protection for chemicals in the dissolved phase and non-settling particles and pathogens such as viruses. Suspended solids were modelled since they are a primary concern in terms of lethality and chronic effects. Nutrients, metals, and oil/grease were not modelled since they are considered secondary concerns which predominantly result in chronic effects. In addition, nutrients, metals, bacteria, and oil/grease are generally regarded as sediment associated indicating that the effectiveness of an end-of-pipe SWMP with respect to these parameters is proportional to the suspended solids removal results (MOEE 1994, p. 168). This latter statement indicates that it is assumed that nutrients, metals, bacteria, etc. will be removed at the same efficiency as TSS; this statement is not backed up with evidence.

32. *Evidence does not support the assumption that nutrients, metals, bacteria, etc. will be removed from stormwater within the pond with the same efficiency as TSS.* Many of the chemicals in urban runoff are in the *dissolved phase* (not attached to particles that settle) and thus *can pass directly through a SWM facility*.

    1. In our work in Harding Park wet detention pond, we found that 60 to 100% of barium, sodium and strontium and 80% of copper and zinc were in the dissolved phase and can pass through the pond **?**untreated**?** (Vickers 1999).
    2. Chemicals that are removed with TSS can return to the water column in the dissolved phase during summer and then leave the SWM pond outflow (Vickers 1999).
    3. Mayer et al. (1996) did not find significant removal of metals attached to particles in their study of four SWM ponds in the GTA, **?**No substantial decrease in metals concentrations in suspended sediments was observed between the inlets and outlets of the ponds suggesting continous transport of heavy metals through these structures, during the sampling episodes.**?** (P. 355).
    4. The proportion available to flow out of the stormwater ponds increased during winter when the pond was ice-covered (Vickers 1999).

5. The implication is that the *dissolved phase will flow out of the stormwater detention ponds.*

33. *Evidence indicates that not all TSS are removed as intended*.

1. Some TSS do not settle and thus are exported from SWM ponds (VanLoon et al. 2000).
2. TSS that previously settled can be resuspended during storm events (Marsalek et al. 1997a, VanLoon et al. 2000).
3. It is the course fraction of TSS that are removed most efficiently, however these particles contain the lowest concentration of contaminants **?**...heavy metals tend to associate with fine grained particles, and coarser particles settle preferentially in stormwater detention ponds, the removal of heavy metals in these ponds, with short detention times, may not be adequate.**?** (Mayer et al. 1996, p. 355). The ponds to which they are referring includes Heritage Estates Reservoir that is located in a typical residential area of Richmond Hill.

34. *SWM pond efficiency*, or the ability to maintain Level 1 protection (which only pertains to retention of TSS), decreases with the age of the facility (VanLoon et al. 2000).

1. Load reductions of suspended solids are generally greater than 50% but range from 20-98% (e.g., Schueler et al. 1992). Tanner et al. (1998) found that the removal efficiency declined from 75 to 80% within the first year of operation to 55-70% after 5 years.
2. Tanner et al. (1998) found a 50% reduction in the ability of a constructed wetland to retain phosphorus over a 5 year period.

35. *SWM ponds are a relatively new technology*. The data on the performance of SWM ponds is limited in terms of:

1. The number of applicable studies conducted (by applicable I mean of comparable climate and conditions);

2. The duration over which the studies have been conducted since a time course of at least 10 years is necessary to determine their long term performance; and
3. The chemicals and pathogens monitored since most studies have been restricted to TSS and “conventional” parameters such as nutrients.

36. *It is questionable that Level 1 protection will provide adequate protection for Type 1 habitats in the long term, based on existing evidence*. The evidence suggests that the ponds may confer Level I protection for TSS and some particle-associated chemicals and pathogens for one to three years after construction. However, this capture efficiency will decline with time and this capture efficiency does not extend to chemicals and pathogens associated with fine particles or that are not associated with particles.

37. Outflow from SWM ponds will introduce TSS, chemicals and pathogens into receiving water bodies.

38. *The introduction of TSS, chemicals and pathogens from the SWM ponds into provincially significant features runs contrary* to the MOEE Stormwater Management Practices Planning and Design Manual, the Provincial Policy Statement and the Region of York Official Plan.

39. *The maintenance of SWM ponds is rarely addressed adequately in development plans given that SWM pond efficiency appears to decline over short periods of time (for example, within 5 years).*
    1. The limited evidence that exists (Tanner et al. 1998) indicates significantly reduced SWM pond efficiency for TSS retention after 5 years.
    2. The Ontario Ministry of Environment guidelines suggest dredging at 10 to 25 year intervals (MOEE 1994). The Canadian Wildlife Service recommends dredging at 5 year intervals to minimize adverse effects to biota from chemicals that accumulate in the sediments.
    3. I understand that current practice in the Town of Richmond Hill does not include close monitoring of SWM ponds efficiency or a regular maintenance schedule. I have been unable to obtain direct information from the Town regarding the maintenance schedule.

E2. Stormwater Management Plans: Ecosystem Impacts TSS, chemical and pathogen outflow from the SWM ponds into dry ravines and receiving water bodies pose a potential risk to fish.

40. TSS, chemical and pathogen outflow from the SWM ponds into wetlands and dry kettles can adversely effect the vegetative community.

41. *There is a serious knowledge gap in toxological implications of SWM ponds for biota* (VanLoon et al. 2000). SWM ponds are a relatively new technology for which there is

limited information on the risk to wildlife using the ponds due to TSS and chemical accumulation, and the occurrence of pathogens in pond water and sediments.

42. *The appropriate safety factors that would be applied to estimate potential toxicological impacts are:*
    1. 10 to account for extrapolating from acute effects (death as measured by, for example, EC_{50}, LC_{50}) to chronic effects which are environmentally relevant;
    2. 10 to account fro extrapolating from laboratory tests to field application; and,
    3. 10 to extrapolate from ?average? individuals in a population to ?sensitive? individuals in a population.

    The safety factors are multiplied giving a total safety factor of 1000 (e.g., 10 H 10 H 10).

43. Concern over potential toxicological risk arises when Q is >0.2 and major concern is indicated when Q is >1.

E3. Stormwater Management Plans: Ecosystem Impacts from Chemicals in Stormwater Pond Water

44. *Canadian Water Quality Guidelines and Provincial Water Quality Objectives are often exceeded in SWM ponds indicating that biota living in the pond water are at potential risk.*
    1. Exceedences occurred in residential SWM wet detention ponds in Guelph and the GTA are as follows: copper (9 out of 16), lead (4 out of 16), zinc (3 out of 16), chromium (7 out of 16) (Bishop et al. 2000b).
    2. In Harding Park, effluent concentrations exceeded the Provincial Water Quality Objectives for total phosphorus, lead, iron and *E. coli* over the two years following the conversion of the pond from a dry to wet facility (Nemeth MS).
    3. In Harding Park, we found that pond water exceeded the Provincial Water Quality Objectives for copper, iron and zinc 21, 84 and 16% of the times sampled over 1 full year (1998-99) 3 years after conversion of the pond from a dry to wet facility.

E4. Stormwater Management Plans: Ecosystem Impacts from Chemicals in Stormwater Pond Sediments

45. *Many SWM pond sediments exceed Ontario Ministry of the Environment guidelines for the protection of aquatic biota for several metals and PAH.* These exceedences indicate that ecological receptors, notably benthic invertebrates (bugs that live in the mud) are at toxicological risk (Wren et al. 1997).
    1. In a study of four wet detention ponds in the GTA, Mayer et al. (1996) found that zinc, lead, copper, cadmium, nickel and chromium exceeded the lowest effects level (LEL) and in some cases (zinc and copper) exceeded the severe effects level (SEL) of the MOE Provincial sediment quality guidelines.

2. Bishop et al. (1999) found that oil and grease, copper, zinc, lead and cadmium in most stormwater detention ponds studied in Guelph and the GTA exceeded the LEL, and in a few ponds the LEL was exceeded for total PCBs, total PAH and chromium.
3. Marsalek et al. (1997a), in a study of a stormwater detention pond in Kingston, Ontario, receiving runoff from a shopping plaza, found exceedance of the MOE guidelines for a similar suite of metals (Cr, Cd, Cu, Fe, Pb, Mn, Ni and Zn).

46. *Data from SWM ponds indicate that metals and PAH accumulate rapidly in SWM ponds sediments.* The sediments are habitat for benthic invertebrates that are, in turn, food for fish, and habitat for amphibian eggs and larva.

47. *Chemical concentrations will increase over time as sediments and sediment-associated chemicals accumulate* (Rosenberry et al. 1999). These sediment-associated chemicals increase chemical concentrations in water as well as posing a risk to biota that live in or near the sediments.

E5. Stormwater Management Plans: Ecosystem Impacts from Salt

48. *Very high concentrations of salt* occur seasonally in SWM pond water creating estuarine-like conditions (Vickers 1999, Mayer et al. 1999).

    a. Concentrations that we measured in Harding Park wet detention pond, in a residential area of Richmond Hill, and after 3 years in operation, were as high as 1500 mg/L in January. Concentrations varied between 800 and 200 mg/L from February until mid-April in the pond. Mid-summer concentrations of Cl, months after application of road salt, were near the Maximum Acceptable Concentration for drinking water of 250 mg/L.
    b. Mayer et al. (1996) measured concentrations as high as 1000 mg/L in a wet detention pond in Markham.
    c. Mayer et al. (1997) measured concentrations of 3000 mg/L Cl and about 2000 mg/L Na in pore water at the sediment-water interface in Rouge Park wet detention pond. Concentrations of Cl remained high (1500 mg/L) at 40 cm below the sediment-water interface, indicating the mobility of Cl in wet detention pond sediments.

49. *Salt concentrations increase with time as salt is retained in SWM pond water and sediment.* This observation runs contrary to the conventional view that salt is not retained in soils and sediments. The work of Howard et al. and our research shows supports the contention that salt is retained in SWM pond water and sediments despite the characteristic of salt of not attaching to particles.

    a. Howard and Haynes (1993) found that year-round surface groundwater in the

Highland Creek area retained elevated concentrations of salt (e.g., 200 mg/L). The authors projected that Cl concentrations in surface groundwater would rise to 426 mg/L within 20 years assuming constants rates of salt application.

b. Data from Barrington Heights (Broadview and Danforth area of Toronto) also show elevated NaCl concentrations year-round in stormwater runoff (Mills 1977).

c. Data from Harding Park indicate that a minimum concentration of 100 mg/L remained in the pond during fall when the water should have been flushed by stormwater with low Cl concentration (Vickers 1999). This concentration was measured after 3 years of operation as a wet pond.

50. *Salt concentrations pose a toxicology risk to biota in or using the SWM facility*. The environmental concentrations used are a high of 1500 mg/L that would occur in winter and the range of 800 to 100 mg/L that were measured during the spring and summer year at Harding Park wet detention pond in Richmond Hill operating for 3 years as a / operation for 3 years a wet detention pond (Vickers 1999).
A safety factor of 1000 is used to account for the use of a toxicological benchmark for acute lethality (e.g., LC_{50}), extrapolation from laboratory testing to field conditions, and to be protective of sensitive individuals within the total population.

Species	**Life Stage**	**Endpoint**	**Tox Conc (mg/L)**	**Q**
waterfleas, *Daphnia* & *Ceriodaphnia*	adult	1d LC_{50}	1652	1. 908** 2. 484** 3. 120**
benthic invertebrate, *Chironomus attenatus*		1d LC_{50}	5318	1. 282** 2. 150** 3. 19**
Bluegill sunfish		4d LC_{50}	8553	1. 175** 2. 93** 3. 23**
waterfleas, *Daphnia* & *Ceriodaphnia*		4d LC_{50}	1652	1. 908** 2. 484** 3. 60**
Indian carp	fry	4d LC_{50}	4,550	1. 330** 2. 176** 3. 22**
Bluegill sunfish	adult	4d LC_{50}	8553	1. 175** 2. 93** 3. 23**

Species	Life Stage	Endpoint	Tox Conc (mg/L)	Q
waterfleas, *Daphnia* & *Ceriodaphnia*		7d LC_{50}	1261	1. 1,190** 2. 634** 3. 79**
waterflea, *Daphnia magna*	mean brood size	7d EC_{50}	2451[4]	1. 61** 2. 33** 3. 4.1**
Fathead minnow	embryo	7d LC_{50}	874	1. 1716** 2. 915** 3. 230**
Rainbow trout	egg embryo	7d LC_{50}	1595	1. 940** 2. 500** 3. 63**
Clawed toad	embryo, survival	7d LC_{50}	1523	1. 984** 2. 525** 3. 66**
Fathead minnow	larvae	7d EC_{50} growth	3029[4]	1. 50** 2. 26** 3. 3.3**

Footnotes: Level of concern indicated by Q is high when Q >1, (**) or moderate when Q is between 0.2 and 1(*).
1. Cl concentration of 1500 mg/L indicative of maximum concentration during winter in SWM pond water.
2. Cl concentration of 800 mg/L indicative of high concentration during spring in SWM pond water.
3. Cl concentration of 200 mg/L indicative of low concentration from spring to fall in SWM pond water.
4. Safety factor of 100 was used to account for chronic endpoint.

51. *The timing of highest Cl concentrations in SWM ponds during late winter and early spring could adversely effect aquatic biota.* Chloride concentrations in snowmelt can range from 4930-14,000 mg/L in winter (Barrington Heights, East York, Mills 1977). These environmental concentrations result in very high toxicity quotients, Q, which indicate a very high probability of toxicity.
The timing of highest salt concentration coincides with sensitive life stages of some amphibians. As discussed by Ms. Natalie Helferty, amphibians eggs and the tadpoles of some species, which are the most vulnerable to salt toxicity, may be in the ponds at the time of high concentration pulses. Some species use spring runoff as their source of water

in which to lay eggs in vernal pools such as the kettle wetlands. In this case, the spring runoff is most likely to contain very high concentrations of salt (e.g., Labadia and Buttle 1996).

52. *Elevated salt concentrations in wetlands and kettles receiving stormwater runoff will put terrestrial vegetation at risk.* Concentrations of chloride to which herbaceous and woody species are tolerant range from 110 mg/L (Tamarack and Mountain Holly) to 420 (purple chokeberry, marsh St. John's wort, Wilcox 1982). These concentrations for species tolerance are well below maximum stormwater ponds water and pore water concentrations the are applicable here, indicating that the present vegetative community in the wetlands and kettles receiving stormwater runoff may experience dieback.

E6. Stormwater Management Plans: Potential Health Risks to Biota

53. *Toxicological assessments in the environment should account for exposure of biota to the complex mixture, not just on a chemical-by-chemical basis.* We can underestimate the toxicity of complex mixtures by comparing single chemical "effects levels" (e.g., EC_{50}) with ambient concentrations of the single chemical. There are many examples where toxicity of complex mixtures has been underestimated relative to adjudication on a single chemical basis (e.g., Gardner et al. 1998, Marinovich et al. 1996).
The inadequacy of adjudicating on a chemical-by-chemical basis is the motivation to use whole effluent testing procedures by the Ontario Ministry of the Environment (e.g., MISA and other agencies). Unfortunately this approach has not been adopted for urban stormwater, unlike other complex effluents.

54. *Residential urban runoff and stormwater detention pond water, sediment and sediment pore water is toxic to aquatic biota*, when assessed as a complex mixture (Hall and Anderson 1987, Maltby et al. 1995a,b, Bishop et al. 1999, 2000b, Mayer et al. 1997, Marsalek 2000).
    a. Mayer et al. (1997) reported 0% survival of the benthic organism *Hyallela azteca* exposed over 7 days to undiluted pore water (the water within the sediments) taken from the Rouge River wet detention pond. The authors ascribed the toxicity mostly to metals in the pore water, notably cadmium (which exceeded the 1984 Ontario Provincial Water Quality Objective of 0.2 μg/L), iron and manganese.
    b. Marsalek (2000) reported preliminary results that suburban catchment runoff was toxic to approximately 40% of samples tested using a battery of tests including toxicity to the waterfleas, *Daphnia magna* and *Ceriodaphnia dubia*, and chronic testing of fathead minnow.
    c. Bishop et al. (2000b) found statistically lower hatching success and longer time to metamorphose of the northern leopard frog (*Rana pipiens*) at two out of four stormwater detention ponds.

55. *Secondary toxicological effects to wildlife can occur due to exposure to stormwater*. If

adverse effects are not directly attributable to contaminant exposure (e.g., acute toxicity), wildlife can be rendered more vulnerable to secondary diseases due to exposure to chronic contaminant levels (Frederick and Spalding 1994, Friend 1985). This is of particular importance since stormwater contains bacterial and viral pathogens that can cause infection.

56. *Field studies of SWM ponds indicate that these ponds do not provide high quality habitat*. Thus, it is imprudent to site stormwater detention ponds in lands that do or could function as a wildlife corridor, and contain provincially significant wetlands, given the potential for adverse toxicological effects on biota.
   a. Bishop et al. (2000a) reported low diversity of benthic invertebrates (bugs in the sediment that are food for fish) in residential areas in the GTA. They also reported lower re-productive success among frogs. Thus **?**We conclude that stormwater ponds do not offer clean ecosystems for wildlife and the monitoring of contamination and its effects within stormwater ponds is necessary.**?** (P. 438)

57. *The evidence for the potential risk to biota due to chemical and pathogen exposure at SWM ponds suggests that the proponents planned use of SWM ponds as habitat is ill-advised:*

F. Stormwater Infiltration

F1. Stormwater Infiltration at RIBs and Dry Kettles

58. *Numerous studies have shown that conservative chemicals, notably road salt, are not attenuated appreciably by soils and are highly mobile in groundwater* (e.g., Howard and Haynes 1993).

59. *Salt* (*Cl) concentrations remain high in stormwater detention ponds in receiving residential stormwater during spring, summer and fall, months after the application of road salt.*

60. *Once introduced into groundwater, chemicals found in "treated" stormwater pose a greater risk of contamination than in surface waters.*
   a. Organic chemicals are more persistent than in surface waters. For example, organic, toxic chemicals such as PAH, pesticides that would degrade in surface waters are very slow to degrade in groundwater.
   b. Once introduced into groundwater, chemicals can not be geographically contained.
   c. Once introduced into groundwater, it is very difficult, time consuming and costly to remove chemicals.

   This is a concern because these chemical inputs could potentially degrade a high quality groundwater system, especially groundwater feeding the headwaters of streams.

61. *Surface groundwater is vulnerable to contamination due to leakage of SWM ponds*. This is of particular concern in locations with high permeability soils (Stackelberg et al. 1997).

F3. Critique of infiltrating stormwater for the purpose of groundwater recharge

62. *Recent studies of the impact of stormwater infiltration on the chemical composition of surface groundwater conclude that there is minimal surface groundwater contamination* (Mikkelsen et al. 1994, 1996, 1997, Barraud et al. 1999, Appleyard 1993).

63. *In contrast to the evidence of minimal surface groundwater contamination found at sites with stormwater infiltration, other studies that have found widespread contamination of surface groundwaters not necessarily receiving stormwater through an infiltration facility*. This is particularly important in areas with high permeability soils, with chemicals applied to soils (e.g., pesticides), chemicals found in residential stormwater runoff (e.g., BTEX), or generally emitted to air and then subject to washout by rain and infiltration to soils (e.g., the U.S. gasoline additive MTBE) (Squillace et al. 1996, Stackelberg et al. 1997, Pankow et al. 1997, Thomas 2000, Philips et al. 2000, Bucheli et al. 1998a,b).

64. *The seemingly different conclusions drawn by the authors investigating stormwater infiltration and those investigating widespread surface groundwater contamination can be explained by the chemicals investigated.*
    a. Widespread groundwater contamination due to residential development is found with more water soluble chemicals (current-use pesticides atrazine, simazine, prometon, etc., BTEX, MTBE, chlorinated organics such as PCE, TCE, chloroform). These chemicals are mobile in soils and surface groundwater.
    b. Studies that have not found elevated chemical concentrations in groundwater receiving stormwater infiltration have looked at chemicals that sorb to soils: metals (e.g., Cu, Cr, Co, Ni, Zn, Cd and Pb), polyaromatic hydrocarbons or PAH, and a general measure of halogenated organics known as AOX (adsorbable organically bound halogens such as chlorinated solvents).
    c. This discrepancy is acknowledged by Mikkelsen et al. (1997, p. 329) in their study of metals, PAH and AOX in groundwater surrounding two stormwater infilration facilities in Switzerland **?**it is stressed that soluble components such as many pesticides, deicing salts, etc. may pass directly through the infiltration system.**?**

65. *There is currently minimal information on the mobility of pathogens (bacteria and viruses) in groundwater*. “Development of the “natural disinfection” criteria is in progress. However, this has proven difficult because the processes governing virus transport and inactivation in the subsurface are poorly understood at the present time.” (Jin et al. 2000).

a. The attenuation of bacterial and viruses appears to depend on the particular pathogens (their surface charge characteristics), the receiving substrate (surface charge characteristics of soil), and the degree of saturation (greater mobility under saturated conditions) (Jin et al. 2000).

b. Contrary to the assumption of rapid attenuation, bacteria can be transported by means of macropore flow in surface soils and thus can be transported greater distances than expected based on an assumption of homogeneous soil permeability (Smith et al. 1985).