SUMMARY AND UPDATE OF THE 1997 SCIENCE ASSESSMENT OF THE IMPACTS OF MUNICIPAL WASTEWATER EFFLUENTS (MWWE) ON CANADIAN WATERS AND HUMAN HEALTH

Municipalities across Canada emit effluents to nearby rivers, creeks, lakes, estuaries, and oceans. Municipal waste water effluents (MWWE) consist of discharges from stormwater sewers, combined sewer overflows (CSOs), and municipal wastewater treatment plants (MWTPs). The management of MWWE is important for the protection of the health of Canadians and their environment, and for the sustainability and continuing development of the country. The Science Assessment document prepared in 1997 reviewed the current status of MWWE discharges and impacts in Canada, and identified the main concerns in terms of human health and environmental effects.

MWWE, treated or untreated, represents, in quantity, one of the largest single effluent emissions in Canada. By global standards, MWWE management in Canada is very effective at eliminating life-threatening water-borne diseases. However, both human use of aquatic resources and ecosystem health may still be affected by the discharge of MWWE. Impacts from MWWE can lead to the following consequences: (a) restrictions on recreational water uses (e.g. beach closures); (b) restrictions on fish and shellfish consumption; (c) nutrient enrichment leading to eutrophication or undesirable algal growth; (d) degradation of aesthetics; (e) restrictions on drinking water consumption; (f) isolated and rare incidences of water-borne disease caused by sewage contamination of drinking water supplies; (g) added costs to agricultural, industrial and municipal users for treatment of unacceptable water; (h) degradation/loss of fish and wildlife habitat; (i) reduced aquatic and wildlife populations; (j) thermal enhancement; and (k) depletion of dissolved oxygen.

The impact of MWWE releases is affected by: climate and seasonality; the characteristics of the receiving environment, including its assimilative capacity and flow regimes; domestic and industrial inputs; type of treatment and disinfection; and the bioavailability of the effluent to the aquatic organisms.

Some of the constituents associated with MWWEs include: ammonia (and other nitrogenous compounds), suspended solids, choride, chlorine/chloramines, selected heavy metals, microorganisms, organochlorine compounds, phenolics, and sulphides. As monitoring programs have expanded, recognizing the host of substances discharged to sanitary and storm sewers, additional substances have been detected. Cyanide, other metals, surfactants, and organic contaminants are some added to the list of concern. Other effects of the effluent include bioaccumulation of toxic substances and decreased reproductive potential due to endocrine disruptors such as estrogenic compounds.

Municipal Wastewater Treatment Plant (MWTP) Discharges

In 1992, there were about 2,800 MWTPs in Canada which discharged approximately 10 million m^3 of municipal wastewater to the aquatic environment. Nearly 75% of all Canadians were serviced by municipal sewer systems as of 1994. The remaining 25% were serviced by individual septic tanks or private treatment systems. Of those serviced, 23% were serviced by primary wastewater treatment, 31% by secondary treatment and 39% by tertiary treatment.

The constituents of MWTP effluents in Canada are suspended solids, grit, debris, microorganisms, and approximately 200 chemicals. MWTPs receive wastewater from various sources including households, industries, commercial businesses, institutions and infiltration. Pollutant loads are dependent on the size of the population, number and size of industries serviced, and the ability of the MWTP to remove or reduce (or potentially contribute) pollutants. The effectiveness of industries and individuals in reducing inputs of substances, through best management practices and pre-treatment will also influence loading.

Stormwater and Combined Sewer Overflows (CSO) discharges

Stormwater drainage systems in urban areas transport and dispose of surface runoff, which can be equivalent to 30 to 50% of the total rainwater volume. The main constituents of concern in stormwater are suspended solids, nutrients (particularly phosphorus), heavy metals, organic chemicals, and fecal bacteria. A recent review of 140 studies from the USA, Europe, and Canada identified 28 water quality parameters in stormwater with the potential to affect human health (through the drinking water supply) and aquatic life and included total solids, total suspended solids (TSS), chloride, three types of microorganisms, 12 metals, nine organic chemicals, and reduced dissolved oxygen.

The constituents of CSOs have been studied less than those of stormwater, in part because CSOs are more difficult to monitor due to their engineering design. During the early phase of a runoff event, referred to as the first flush, the CSO characteristics resemble (if sewage sludge is scoured from the sewer bottom by high flows), or even exceed, pollutant concentrations in raw sanitary sewage. After this first flush, pollutant concentrations in CSOs subside. The main pollutants of concern are TSS, oxygen-demanding organics, chlorides (in winter), nutrients (nitrogen and phosphorus), fecal bacteria and other chemicals originating from local municipal and industrial sources. Stormwater and CSOs have similar levels of TSS but CSOs have higher levels of biological oxygen demand (BOD), total nitrogen and total phosphorus (sewage component) and lower levels of heavy metals, polycyclic aromatic hydrocarbons (PAHs) and organochlorine pesticides.

Stormwater outfalls are greatly dispersed throughout urban areas, with hundreds of outfalls in medium-sized communities. CSO outfalls are more consolidated to fewer locations, and further efforts to reduce the number of overflow points are continuing. Contaminant loadings from stormwater and CSOs to the environment depend on the size of the drainage area, the activities in that area, local climate, sewer design and drainage practices and, in the case of CSOs, the nature of the sewage that bypasses treatment. Stormwater discharges and CSOs are characterized by high flows during or shortly after periods of wet weather. Pollutant concentrations are particularly high during periods of snowmelt when the pollutants accumulated in snowpacks are rapidly released and conveyed by storm sewers to receiving waters. The frequency of overflows varies from several to 200 overflows per year. Smaller streams, lakes or reservoirs can be heavily impacted throughout urban areas whereas the effects of stormwater and CSOs in large water bodies are generally restricted to nearshore waters or embayments and harbours. During the last 20 years, new stormwater best management practices have been introduced that reduce surface runoff volumes by allowing more rainwater to infiltrate into the ground, balance runoff flows through storage, and improve runoff quality (e.g., stormwater ponds, infiltration facilities, constructed wetlands, filters, etc.).

Impacts of MWWE Discharge

Extensive environmental degradation associated with sewage discharge is rare. However, deleterious environmental and human health effects occur in areas downstream of specific urban communities that have minimal or no treatment of large quantities of sewage or stormwater, in receiving waters with low flushing rates, or in both. The most publicly recognized direct impacts of sewage discharge are shellfish harvesting restrictions and restrictions on recreational water uses such as beach closures resulting from microbial contamination. The ecological impacts resulting from MWWE include a decrease in wildlife populations, changes in biodiversity, and changes in community structure. Ecological impacts of nutrient loading, for example, include changes in energy dynamics and food web structure, and loss of species. Habitat degradation and contamination due to MWWE discharge have also reduced the abundance and diversity of organisms upon which wildlife feed. It is estimated that 15% of the river and lake areas in the Great Lakes basin have been damaged by MWWE, resulting in impaired nearshore wildlife habitats and feeding areas. Contamination by industrial chemicals and bacteria is a major factor in this damage.

Effluent from MWTPs has been reported to significantly alter community structure and composition, and decrease species diversity, richness, and evenness and the mean number of taxa. Acute impacts of MWTP effluents are generally caused by high levels of unionized ammonia (the most common case) and total residual chlorine, high BOD or chemical oxygen demand (COD) loads, high levels of fecal bacteria, or toxic concentrations of heavy metals and organic contaminants. The frequency of acute effects attributable to MWTP effluents are controlled by industrial and residential inputs, treatment type, disinfection regime and whether the MWTP capacity is surpassed. Cumulative impacts result from a gradual buildup of pollutants (e.g., heavy metals, toxic organics, and sediment-associated nutrients) in the receiving water, sediments or biota, and become apparent only after accumulation exceeds a critical threshold value. Disinfection of MWTP effluent by chlorination may increase its toxicity to aquatic organisms because of the introduction of residual chlorine and toxic chlorinated compounds.

For stormwater and CSOs, impacts are either acute and occur on a seasonal or wet-weather basis, or are cumulative and manifest themselves only after many years of uncontrolled or inadequately controlled discharges. The frequency of immediate impacts depends on the frequency of rain and snowmelt events causing overflows and can be estimated from local climatic data and wastewater collection/treatment system capacity. Stormwater and CSO effects are most serious in small urban creeks, which can be severely damaged by elevated runoff resulting in sediment erosion and deposition, and elevated temperature and concentrations of chemicals, fecal bacteria and pathogens. In these small streams, the dilution of stormwater and CSO discharges is minimal. Over extended periods, the morphology of these streams may change dramatically, and habitat is destroyed. Both acute impacts (caused by high flows, high concentrations of microorganisms, and low oxygen levels) and cumulative impacts (caused by morphological changes to aquatic habitats and accumulation of toxicants) are important.

In rivers, the mixing and dispersion of stormwater and CSO pollutants are important processes reducing pollutant concentrations. Stormwater and CSO effects on lakes and reservoirs depend on the size of the water body.

Small impoundments in urban areas are usually the most impacted, particularly by fecal bacteria (impairing recreational water uses), nutrients (causing eutrophication), and contaminated sediment (resulting in chronic toxicity). Influx of sediments also causes physical destruction of habitat. In the case of large lakes (e.g., the Great Lakes), stormwater and CSO discharges typically impact only the near-shore waters in the vicinity of urban areas, with most of the reported impacts relating to microbial water quality.

Potential effects of stormwater and CSOs on off-shore ocean waters are minimal. Generally, acute impacts are less important in large water bodies than in creeks because of dilution and self-purification. The toxicity of stormwater and CSOs is generally attributed to ammonia, toxic metals, hydrocarbons (particularly PAHs), chlorides and pesticides. However, the toxicity of CSOs and stormwater has not been studied as extensively as MWTPs .

A recently identified concern regarding MWWE is chemicals which can disrupt growth, development or reproduction by affecting the normal function of the endocrine system of biota (endocrine disruptors). Recent studies in the United Kingdom, Canada, and the United States reported estrogenic effects (e.g., vitellogenin induction and intersex in fish) several kilometres downstream of sewage outfalls. There are a variety of chemicals commonly found in municipal effluents that are capable of binding to the hormone receptors and causing endocrine disruption. These include alkylphenol polyethoxylates and their metabolites, which have been shown to cause vitellogenin induction, intersex, and impair growth and gonad development. Natural and synthetic estrogens (estradiol, estrone, ethinyl estradiol) have recently been identified in sewage effluents at concentrations that can cause vitellogenin induction and other estrogenic effects in fish. A recent survey in Canada suggests that both alkylphenolics and estrogens are common contaminants in final effluents. Although some chemical characterization of effluents has recently been undertaken in Canada, the extent and significance of estrogenic effects attributable to sewage effluents has not yet been established. A comprehensive toxicity (estrogenicity) analysis of MWWE coupled with a detailed survey of the physiological status of fish from receiving waters is required to fully evaluate the extent and potential impact of endocrine disrupting compounds in the Canadian environment.

Management of MWWE in Canada

At present, federal guidelines exist for the discharge of wastewater effluents to receiving waters. These are the *Guidelines for Effluent Quality and Wastewater Treatment at Federal Establishments* (1976) which are technology based and apply to effluent concentrations of suspended solids, fecal coliforms, residual chlorine, pH, phenols, oils and greases, total phosphorus, BOD and temperature. Some provinces have effluent standards for conventional parameters such as TSS, BOD, dissolved oxygen (DO), total phosphorus, ammonia and fecal coliforms. Effluent quality is often compared to the Canadian Water Quality Guidelines which are ambient concentrations (i.e., in the receiving water) recommended to protect various uses of water (Aquatic life, drinking, recreation, etc).

At the international level, there is a recognition that marine pollution is significantly affected by riverine sources of pollution, including municipal wastewater discharges. UNEP has launched the "Global Plan of Action for the Protection of the Marine Environment from Land-Based Activities". This initiative involves a Global Programme of Action which was endorsed by governments in 1995.

Conclusions and Recommendations from the 1997 Science Assessment

The 1997 review of the environmental consequences of MWWE discharge in Canada highlights the importance of addressing impairments to beneficial uses and environmental health. In doing so, consideration must be given to:

(i) *both acute and cumulative impacts of long-term chemical exposure and habitat degradation*. Whereas acute impacts are the more obvious consequence of pollution, cumulative responses to long-term loading of low doses of pollutants may pose an equal threat to aquatic communities;
(ii) *the need for further research to investigate the potential adverse effects of new or previously unrecognized pollutants*. At present, further research is needed on the ecological effects of

endocrine disrupting substances in municipal effluents;
(iii) *the need for additional information on the effects of MWWE loading on aquatic resources in Canada*.

Only scant information is available for assessing the impacts of MWWE on beneficial uses and environmental health. Although the limited Canadian data are consistent with the much larger body of evidence in the literature for other countries, further information is required to assess the full extent of the consequences of MWWE on Canadian waters; and *regional variations in municipal wastewater treatment*. This has evolved as a result of the abundance of high quality sources of potable water and the discharge of untreated or partly treated effluents (municipal, stormwater and CSOs) into large receiving waters (oceans, and large lakes and rivers).

Current Science Activities on MWWE

Environment Canada with the Canadian Council of Ministers of the Environment (CCME) is currently developing a new water quality guideline for ammonia. The applicable guideline will provide basic scientific information on the effects of ammonia on Canadian waters. The *CCME Canadian Environment Quality Guidelines* are developed to ensure that societal stresses, particularly the introduction of toxic chemicals, do not lead to the degradation of Canadian waters, including: raw water for drinking water supply; freshwater and marine life; agricultural uses; recreation and aesthetics; and industrial water supplies. These Guidelines are designed to assess water quality concerns and to assist in the establishment of site-specific water quality objectives.

Currently, the federal interdepartmental[1] 5NR Nutrient Science Study identifies MWWE as a major nutrient contamination source to the Canadian environment. The Nutrient Study is currently assessing the environmental impacts of all nutrient sources in Canada and will, therefore, evaluate the nature and magnitude of MWWE impacts to the Canadian environment and human health relative to other nutrient sources.

A federal working group the Federal Committee on Environmental Management Systems (FCEMS) Wastewater Management Working Group initiated a project titled: "Exploring options for environmental protection-based discharge limits for wastewater quality at Federal facilities".

Environment Canada develops national indicators for human activities or stressors (e.g., high levels of urban water use); environmental conditions (e.g., water quality); effects on the environment (e.g., on aquatic ecosystems, on tourism); and for societal responses to the issue (e.g., wastewater treatment, metering of water use to promote conservation). Indicators can be used to highlight key trends and issues in science assessments, and to track changes in some of these trends between assessments. The wastewater treatment indicator, based on the MUD (Municipal Utilities Database) Survey 1996 of 1 500 municipalities, for example, showed that over the 1983-1994 period, the Canadian population, living in municipalities, served by wastewater treatment through municipal sewer systems increased substantially in number (i.e., from 72% to 93%) and in the level of treatment (37% with tertiary treatment).

[1] Agriculture and Agri-food Canada, Department of Fisheries and Oceans, Environment Canada, Natural Resources Canada, and Health Canada

Recently, extensive studies in Quebec on the toxicity of stormwater and CSO effluents were completed at about 15 sites in Ontario. A fair percentage of stormwater samples were found to be acutely toxic, particularly at sites receiving winter snowmelt and runoff from highways. CSOs rarely exhibited acute toxicity, but demonstrated genotoxicity or chronic toxicity. In another study, the statistical properties of indicator bacteria samples were studied with respect to the Health Canada and Ontario guidelines for recreational waters. It was found that the probability of the samples being in compliance with the guideline values was affected by the size of the samples.