MEASURING SUSTAINABLE DEVELOPMENT

APPLICATION OF THE GENUINE PROGRESS INDEX TO NOVA SCOTIA

The GPI Water Quality Accounts

Case Study: The Costs and Benefits of Sewage Treatment and Source Control for Halifax Harbour

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GPI *Atlantic*

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List of Acronyms Used

BOD - biological (biochemical) oxygen demand
CBA - cost-benefit analysis
CRAI - Corporate Research Associates Inc.
EPA - Environmental Protection Agency (U.S.)
GIS – geographic information system
GPI - Genuine Progress Index
HHCI - Halifax Harbour Cleanup Inc.
hhld - household
HRM - Halifax Regional Municipality
NPV - net present value
SLDF - Sierra Legal Defence Fund
UV - ultraviolet
STP - sewage treatment plant
WTP - Willingness-to-pay

Executive Summary

Halifax Harbour is home to the largest urban centre in Atlantic Canada, where the on-going disposal of 187 million litres of raw sewage each day has resulted in a poor public image for the municipality, and a failing grade in the Sierra Legal Defence Fund's second annual national sewage report card. Poor water quality and poor aesthetics have had negative effects on the harbour ecosystem, tourism, and urban quality of life. Additionally, recreational opportunities are curtailed because of the public health risks of illness resulting from contact with the water.

This case study illustrates the costs and benefits of sewage treatment as proposed in the Halifax Harbour Solutions Plan, and notes the necessity for the implementation of full source control. A cost-benefit analysis (CBA), the economic impacts, the financing costs, and a total net benefit analysis of the Halifax Regional Municipality's plan are presented to determine whether sewage treatment for the Halifax Harbour is economically, socially and ecologically beneficial.

The analyses provide net present values (NPVs) discounted at 8%, 4%, and 0% (i.e. no discounting), over a 60 year life-span for the four sewage treatment plants[1]. The estimated capital costs for the Halifax Harbour Solutions Plan are $307.9 million, the estimated operating costs are $8.8 million per year, and the estimated financing costs are $22.3 million per year[2]. A surrogate value of $58.1 million was estimated for the protection of the harbour's marine nutrient cycling capacity. Conservative NPVs are characterized by low estimates of willingness-to-pay ($99.40/household/year), property value increase (5%), tourism revenue increase (2%), and the percentage of shellfisheries re-opened (30%). The mid-range and high-end estimates consist of incrementally higher benefits.

The cost-benefit analysis (CBA) estimates the net present value (NPV) of the investment in sewage treatment using the capital costs, operating costs, the marine nutrient cycling benefit, household willingness-to-pay, tourism revenue increase, property value increase, and the landed value of re-opened shellfisheries.(Table 1). **The CBA results indicate positive net present value (NPV) estimates ranging from $38.5 million to $161.5 million, discounted at 8%, $162.6 million to $392.3 million, discounted at 4%, and $645.9 million to $1,227.8 million, discounted at 0% (i.e. no discounting).**

[1]All values are in 1997 Canadian dollars.

[2]Financing costs associated with borrowing are assumed to accrue on principal for 25 years using the mean of the Government of Canada long-term borrowing rates since 1991.

Table 1: Executive Summary, Cost Benefit Analysis (CBA) Results (millions 1997$)

CBA of the Halifax Harbour Solutions Plan	Conservative	Mid-Range	High-End
Net Present Value @ 8%	**$38.5**	**$100.0**	**$161.5**
Net Present Value @ 4%	**$162.6**	**$277.4**	**$392.3**
Net Present Value @ 0%	**$645.9**	**$936.8**	**$1,227.8**

In addition, the estimated economic impacts of the proposed Halifax Harbour Solutions Plan in terms of provincial labour income and spinoffs, and government tax revenue income are considered (HRM 1999a). The estimated net present value of the proposed project increases due to these positive benefits, but conventionally they are not added to a cost-benefit (CBA) format and thus they are reported separately. **The net present value of the estimated economic impacts is $237.1 million, discounted at 8%, $355.5 million, discounted at 4%, and $727.3 million, discounted at 0% (Table 2).**

Table 2: Executive Summary, Economic Impacts (millions 1997$)

Total Economic Impacts of the Halifax Harbour Solutions Plan	
Net Present Value, Discounted @ 8%	**$237.1**
Net Present Value, Discounted @ 4%	**$355.5**
Net Present Value, Discounted @ 0%	**$727.3**

Source: HRM 1999a

In a conventional cost-benefit analysis, the financing costs of a project are, likewise, not included, because decisions regarding investment all incur financing costs, and therefore, cancel out. However, it is useful from the GPI perspective of full cost and benefit accounting to consider the financing costs of a project, because they could be relevant for comparison with a debt reduction plan. The financing costs are estimated at $22.3 million/year[3]; a net present value of $238.0 million, discounted at 8%, $348.3 million, discounted at 4%, and $557.5 million, discounted at 0%. Financing costs and the economic

[3] Financing costs are based on the interest assumed to accrue on the capital costs ($307.9 million) minus the savings in the Environmental Protection Fund ($45 million),for 25 years using the mean of the Government of Canada long-term borrowing rates since 1991.

impacts are included in a total net benefit analysis. The total NPV of the costs is subtracted from the total NPV of the benefits[4]. **The total net benefit conservative estimates range from a net present value of $67.7 million, discounted at 8%, to a net present value $860.3 million, discounted at 0%, and the high-end estimates range from a net present value of $190.8 million, discounted at 8%, to a net present value of $1,442.6 million, discounted at 0% (Table 3).**

Table 3: Executive Summary, Total Net Benefit Analysis (millions 1997$)

Total Benefits minus Total Costs of the Halifax Harbour Solutions Plan	
Net Present Value, Discounted @ 8%	$67.6 - $190.8
Net Present Value, Discounted @ 4%	$202.8 - $436.1
Net Present Value, Discounted @ 0%	$860.3 - $1,442.6

The results of the cost-benefit analysis and the net benefit analysis indicate that the investment in sewage treatment for the Halifax Harbour is economically beneficial, and will provide several social, environmental and economic benefits. In fact, further significant and positive qualitative benefits such as improved recreational opportunities, avoided health costs due to water-related illness, and enhanced marine ecosystem quality, excluded in the above analyses can be realized (Table 4).

[4] Including the benefit of the $45 million in the Environmental Protection Fund ($45 million).

Table 4: Executive Summary, Qualitative Non-Market Benefits

Qualitative Benefits	Cost	Benefit
Marine Ecosystem Health		**Ö**
Avoided Health Costs due to Water-related Illness		**Ö**
Recreational Opportunities and Quality of Life		**Ö**

Necessity for Source Control

The wastewater flowing through sewer systems does not only consist of sewage wastes. Households, businesses, and industry contribute many other organic and toxic contaminants. As a result, source controls must accompany any sewage treatment plan to accomplish an improved environment for the Halifax Harbour. The amount of environmental and economic benefits gained depends ultimately on the degree of success in the clean-up and environmental restoration of the marine environment. The incremental benefits are evident from the comparison between the conservative, mid-range, and high-end estimates presented in Tables 1 to 3. Therefore, financing source control (e.g. prohibition of toxic substances from commercial and domestic sources, and prohibition of direct discharge from boats) will result in economic, social and ecological benefits.

The Halifax Regional Municipality (HRM) has implemented an educational programme and is in the process of presenting a new bylaw that will enforce compliance with source controls through planning, monitoring, and fines. Further action is needed for effective harbour restoration. Contaminants (e.g. endocrine disrupters) that cannot be effectively treated should not be allowed to enter the sewer systems. Education directed towards businesses, industry and households should include alternatives, methods to recover and reuse substances, and information on hazardous waste recovery programmes. A good existing example is the Nova Scotia Department of Environment's Pollution Prevention Guide for Printers[5].

Water conservation education directed at the municipality's residents and businesses is also recommended. Water conservation minimizes overflows to sewage treatment plants and avoids the need to dump untreated wastewater due to plant capacity overflows. In addition, we recommend that current plans to separate combined sanitary/storm water sewers should only be implemented when source control is in place and when the storm

[5] http://www.gov.ns.ca/envi/dept/rmep/p2/print_ck.htm

water discharges meet the Canadian Council of Resource and Environment Ministers guidelines for discharge into aquatic ecosystems[6].

In conclusion, the Halifax Harbour Solutions Plan complemented by full implementation of Halifax Regional Municipality's (HRM's) Source Control Implementation Strategy will result in positive economic, social and ecological benefits. Indeed, it is demonstrated by GPI analyses that the greater the improvement in the harbour's water quality and marine ecosystem health, the greater the concomitant economic and social benefits.

[6] Holmes et al. 1999

Introduction

Sewage treatment for the Halifax Harbour is examined as a case study for the Water Quality Account of the Genuine Progress Index of Nova Scotia. The costs of building and operating the current Halifax Harbour Solutions Plan for four sewage treatment plants around the harbour, and the estimated benefits from improved water quality are illustrated in the following study.

The Genuine Progress Index

The Genuine Progress Index (GPI) uses "full cost and benefit accounting" to evaluate alternative investment options and to monitor indicators of genuine progress in our society. Using these indicators, jurisdictions and communities can develop policies and projects that further genuine social and economic development. The goal of the GPI is to integrate the measurement of social, economic and environmental indicators to further sustainable progress, which includes the protection of natural assets (i.e. natural capital), and the maintenance of ecosystem services and functioning. From this perspective, Halifax Harbour is a natural capital asset that has depreciated in value due to the discharge of raw sewage and other contaminants into its waters.

The GPI measures sustainability using relative and absolute criteria. Thus, depreciation is measured in relation to change over time, namely how clean the harbour is compared to one year, ten years or twenty years ago, as well as in relation to an absolute criterion of the value of the harbour in its unpolluted or natural state. The GPI measures depreciation of natural assets (i.e. natural capital) against these standards. A cost estimate to restore the harbour to its natural state refers to the *investment* necessary both for remediation of past and present damage and for future pollution prevention.

The Genuine Progress Index (GPI) embraces the principle of “polluter pays” (i.e. “you make the mess, you clean it up”). Under this principle, Halifax Regional Municipality (HRM) residents are responsible for the costs of their sewage treatment. The GPI also embraces the philosophy of “prevention pays”. For example, a contaminant stopped at the source will cause less environmental damage, and will reduce treatment costs prior to disposal. Additionally, prevention avoids the costs of remediation that are extremely high when compared to the cost of investment in preventive measures. Water use conservation and pollution prevention are key criteria in measuring the maintenance of healthy water ecosystems. As a result, HRM’s source control strategy is considered to be an integral part of the plan for cleaning up and restoring the harbour.

Halifax Harbour and Wastewater Disposal

Halifax Harbour is the busiest harbour in Atlantic Canada, and is home to the largest urban centre in Atlantic Canada. Poor water quality and poor aesthetic properties have had negative effects on the harbour's ecosystem, tourism, and the urban quality of life. Consequently, the on-going disposal of raw sewage has resulted in a poor public image for the urban centre's environment. According to the 1999 National Sewage Report Card issued by the Sierra Legal Defence Fund, the Halifax Regional Municipality generates 68.2 billion litres of sewage annually (Holmes et al. 1999). Indeed, the dumping of raw sewage is in violation of the Fisheries Act.

> "Federal Fisheries Minister Herb Dhaliwal said recently he's prepared to put into effect rarely used powers under Section 36(3) of the Fisheries Act to take action against municipal, agricultural and industrial polluters. That could include fines of up to $1 million or jail sentences for polluters convicted of pumping matter into coastal waters that threatens fish and spawning grounds."[7]

In the 1980s, Boston Harbour was widely recognized as the most contaminated harbour in North America due to insufficient sewage treatment. As a violator of federal legislation that requires the treatment of all sewage entering a body of water, the municipality of Boston was tried in court in 1986 and ordered to rectify the harbour's water quality . The recovery of the harbour, due to improved sewage treatment (upgraded primary treatment followed by secondary treatment), and source control, has resulted in the return of porpoises, 8 miles of recreational beaches safe for swimming, recreational fishing (bluefish, smelt, cod, and bass), and a US$15 million/year (1999$) lobster and shellfish industry (Galbraith 1999). This is good news, indicating that recovery is possible.

250 years of untreated municipal wastewater disposal in Halifax Harbour has created serious water quality problems posing a threat to marine environmental health, the ability of the harbour to assimilate wastes, and a threat to recreational users (i.e. sailing, beach activities) due to potential water-related illnesses from microbiological contamination. The most common water-related illnesses are gastrointestinal illnesses (e.g. diarrhoea), upper respiratory tract, eye, ear, nose or throat infections, and skin ailments. Muddied and/or unclear waters due to contamination can also increase physical hazards such as rocks, as well as the rate of recreational injuries[8]. Potential health hazards have led to the periodic

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[7] Simpson, J. and Smith, A. 1999. "Mayor wants funds, not fines." *The Chronicle-Herald*. Dec. 7, p.A10.

[8] Health Canada. 1999. Recreational Water Quality. It's Your Health. http:// www.hc-sc.gc.ca/ehp/ehd/catalogue/general/iyh/recwater/htm

closure of Northwest Arm beaches and the discontinuation of windsurfing competitions in the Harbour.

Every day approximately 187 million litres of untreated wastewater is discharged to the harbour's waters (HRM 1999). In 1997, Environment Canada tested the harbour's waters and found faecal coliform levels (an indicator of bacterial contamination) of 23 organisms per 100 mL sample in the outer harbour, and up to 1,100 organisms per 100 mL sample in the middle harbour, more than five times the recreational limit (Galbraith 1999). The recreational maximum limit for coliform organisms is 2,000 per litre or 200 faecal coliforms per 100 millilitre sample (Health and Welfare Canada 1992).

Presently, the state of the Halifax Harbour has several environmental and economic consequences including:

- prohibition of shellfish harvesting
- contaminated sediment around forty separate outfalls
- poor water quality along shorelines and beaches
- widespread bacterial contamination
- reduced aesthetics along the Halifax and Dartmouth waterfronts (e.g. particulates, floatables and odour)
- contravention of Section 36(3) of the Fisheries Act (e.g. liability issues)

Millions of dollars have been invested in the waterfront by both government and the private sector to develop attractive areas for residence, businesses, and hotels. All these investments are negatively affected by poor water quality and will benefit from the improvement of proper collection and treatment of wastewater. According to a Corporate Research Associates (1999) survey, 73% of HRM residents rate the quality of water in the Halifax Harbour as poor, and most residents believe the poor quality affects the quality of life in the region. 35% believe the harbour presents a poor image to tourists, 24% indicate there is a loss in recreational opportunities, and 20% said there is a loss in tourism and an impact on fish and wildlife.

There is strong community support for the Halifax Regional Municipality (HRM) to go ahead with the Halifax Harbour Solutions Project. In fact, a recent public opinion poll administered by Corporate Research Associates indicates that 88% of respondents place a very high importance on implementing sewage treatment around the harbour (CRAI 1999). In the HRM, most residents are willing to pay an additional surcharge in support of a sewage treatment plan. CRAI (1999) reported that over 69% of residents who pay a water bill and 76% of residents who do not, are willing to increase their payments for the costs of sewage treatment.

Under the principle of “polluter pays”, HRM residents are responsible for the costs of their sewage treatment. Willingness-to-pay (WTP) surveys conducted in the HRM revealed that residents are willing to accept that responsibility and are willing to pay from $100/household/year to $235/household/year for sewage treatment over and above what they currently pay for water and property taxes.

The Effects of Wastewater on Marine Life

Untreated wastewater or sewage discharged into aquatic ecosystems has a detrimental affect on marine life. Firstly, suspended solids, the floating particles in sewage, prevent sunlight reaching underwater plant life affecting growth and productivity (Holmes et al. 1999). If the productivity of a food source such as algae is suppressed, food shortages can result for other living organisms. Suspended solids can also cause harm to fish gills as they flow through water; they cover and smother bottom-dwelling marine life as they settle to the bottom of sea beds; and, they create oxygen-deficient conditions, according to the National Sewage Report (Holmes et al. 1999).

In addition, toxic pollutants that are attached to the suspended solids cause further detrimental affects on the seabed. Moreover, untreated or inadequately treated sewage can cause disease or death to marine life due to the toxicity of particular pollutants and/or the pathogens and viruses carried in sewage effluent. For example, a recently published study documents that harbour seals now carry the ‘human’ influenza B virus (Foss 2000).

Sewage effluent discharged into a river or harbour places a demand on oxygen from the natural environment. Suspended solids partially consist of organic material. When sewage enters water, bacteria break down this organic material. In doing so, the activity of the bacteria depletes dissolved oxygen from the water. This is referred to as biological oxygen demand (BOD). Aquatic organisms are dependent on dissolved oxygen for life, so that very low levels of dissolved oxygen in a marine environment can be fatal to marine life. Furthermore, if oxygen is not available for the break-down of organic material, then non-oxygen processes (e.g. anaerobic) of decay will produce toxic compounds (e.g. methane, hydrogen sulphide, ammonia; Holmes et al. 1999).

Wastewater or sewage consists not only of human excrement and water, but also contains many chemicals and toxic pollutants from households, businesses, and industrial operations. The sources of contaminants in sewage wastewater depend on the make-up of the sewage connections in the municipality. In some cities like Halifax, urban run-off also discharges into the sewer system. If these contaminants are not removed prior to the discharge of the effluent, pollutants can bio-accumulate (i.e. toxins can build-up in longer-lived organisms, stored in fatty tissues) in fish and other aquatic organisms. These pollutants cause a health hazard for marine organisms (e.g. lesions, tumours), and cause a human health concern regarding the consumption of fish and lobsters from the Halifax Harbour.

Halifax Harbour Marine Environment

Halifax Harbour is an estuary where freshwater runs into and mixes with the ocean's waters. Parts of the harbour, in general, meet the U.S. Environmental Protection Agency's criteria for boating and other secondary recreational activities, and industrial cooling, however, the inner harbour has a poor rating because of oil slicks, flotsam and jetsam. The most serious problems occur on a localized scale within 50 to 200 metres of most of the major sewage outfalls. In these areas, depleted dissolved oxygen levels, high faecal coliform counts, and accelerated algae growth have been reported (HRM 1999b). The harbour differs from other normal marine bay fauna, because its benthic community is dominated by polychaetes (marine worms; HRM 1999b).

Currently, cod, herring, haddock, mackerel, pollock, flatfish, and grey sole are fished in the harbour, as well as an annual lobster catch estimated at 225 to 400 metric tonnes. Marine mammals observed in the outer harbour at various times of the year include fin whales, humpback whales, minke whales, several dolphin species, porpoises, and harbour seals (HRM 1999b).

The Need for Sewage Treatment

Liquid wastes from industrial and domestic sources must, in most cases, first be treated to remove the bulk of contaminants before disposal (McGhee 1991). Otherwise problems arise when excessive quantities of pollutants change pH, increase bacterial growth, and deplete dissolved oxygen resources (Appendix 1). When a healthy marine environment is maintained, it has a natural ability to assimilate some additional biological wastes without an adverse affect on normal marine species distribution. The degree of self-purification and waste that a water body can assimilate is dependent on its ability to dilute wastes, which in turn is affected by currents, sedimentation, sunlight, and temperature (McGhee 1991).

The U.S. EPA (Environmental Protection Agency) requires that, as a minimum, treatment of wastewater discharged to the sea from coastal cities should include the removal of all solids readily separable by sedimentation. This is to prevent solids that may float in salt water from flushing up on beaches and other coastal environments, as well as the harmful effects of suspended solids on marine life.

In addition, the need for wastewater treatment before disposal into coastal salt water environments is indicated by the following factors (McGhee 1991):

a) dissolved oxygen saturation concentration tends to decrease as the salt content in water increases, i.e. the saturation concentration of seawater is approximately 80% that of freshwater; and,

b) sewage may tend to spread, not mix, over the surface of seawater because the density of saline water is greater than that of freshwater.

Such a decline in mixing capacity means that less waste dilution occurs. Limited dilution coupled with the lower availability of oxygen found in salt water bodies can result in a lower assimilation capacity for wastes.

Types of Sewage Treatment Systems

Primary sewage treatment generally refers to a physical process, whereas, secondary and tertiary sewage treatment are biological treatments. Primary treatment is usually a simple sedimentation process to remove suspended solids (i.e. particles of matter that float in sewage) in wastewater prior to discharge into rivers, lakes or oceans (McGhee 1991). Sometimes fine screens are also used to remove smaller solids.

In addition, chlorine may be added to remove some of the smaller colloidal solids (e.g.

suspended particles in sewage that cannot be removed by sedimentation) and for disinfection (e.g. removal of pathogens). Chlorine, however, can be toxic to aquatic life. An alternative to chemical treatment such as chlorine is ultraviolet treatment. Ultraviolet treatment helps eliminate pathogens that can cause disease. Primary treatment plus ultraviolet disinfection is the method proposed in the Harbour Solutions Plan, and is referred to as Advanced Primary Treatment. According to the 1999 Sierra Legal Defence Fund Sewage Report Card, this method reduces BOD by about 50%, removes 90% of suspended solids, and reduces faecal coliform by 45-55% (Holmes et al. 1999).

Secondary treatment systems use biological oxidation to further reduce solids in sewage effluent. This means that oxygen is added to enhance micro-organisms which consume organic materials in the effluent prior to discharge. This process results in a decreased demand on the biological oxygen in the receiving water, and therefore results in less depletion of dissolved oxygen. Overall, secondary treatment reduces biological oxygen demand (BOD) and suspended solids by 85-90%, and removes 90-99% of coliform bacteria (Holmes et al. 1999). Toronto, Edmonton, and Brandon have implemented secondary treatment

Tertiary treatment is a more thorough form of secondary biological treatment that may also remove nitrogen, phosphorus and ammonia. Generally, the specific technology used is designed to meet the treatment needs of a particular sewage effluent. For example, micro-strainers or sand filters may be used to further reduce suspended solids and BOD, and advanced filtration may be used to remove some metals, chemicals, and other contaminants. For example, Calgary’s tertiary sewage treatment system includes clarifiers, digesters, and phosphorus removal.

An innovative alternative to tertiary treatment is the use of constructed wetlands, often called “Solar Aquatics”[9]. A constructed wetland reproduces the biological processes of a wetland in a series of greenhouses. In Bear River, Nova Scotia, an award-winning example of this technology is used for sewage treatment. Inside a greenhouse-like structure, plants, snails, micro-organisms and algae break-down the contaminants in the wastewater, using solar power for energy. The idea is to create a micro-ecosystem.

The process includes:

- air bubbles pumped into the tank containing the sewage;

[9] “Solar Aquatics”, Ecological Engineering Associates © 1996

- bacteria, algae and protozoa detoxify microbes;
- a habitat of wetland plants that also absorb toxins;
- a small engineered marsh of grasses and irises that remove the remaining toxins;
- a screen to remove the last of the suspended solids; and
- an ultraviolet light treatment to disinfect the water prior to discharge.

The Bear River system is capable of treating over 50,000 litres of sewage per day (Kelly and Redwood 1996). The discharge resulting from the "Solar Aquatics" process can be of drinking-water quality and can be used to replenish natural aquifers. As an added bonus, flowers can be grown in the tanks (e.g. orchids) to generate income and employment (Holmes et al. 1999). According to its developers, "Solar Aquatics" provides tertiary quality wastewater treatment at a cost less than or equal to traditional sewage treatment[10].

Benefits of Sewage (Wastewater) Treatment

At the moment, shellfish harvesting is prohibited in all areas of Halifax Harbour; large areas of contaminated sediment are present around the numerous separate outfalls; water quality is poor along the shorelines; bacterial contamination is widespread; and floatables, particulates and odour contribute to a poor aesthetic around the harbour (HRM 1999b).

Investments in sewage treatment plants (STPs) can have a variety of implications and beneficial effects (Table 5). There can be benefits due to the avoidance of clean-up or remedial expenditures that would be required in the future without investment today. For example, a serious depletion of available dissolved oxygen may occur in the harbour's waters in the future if sewage treatment is not implemented.

Sewage treatment can also produce benefits for resource users, such as the protection of the current $1 million lobster fishery in the outer harbour. Thirdly, there are benefits of a more intrinsic nature related to the value people place on a cleaner environment for its own sake and for the benefit of future generations.

Benefits can be indirectly estimated in monetary terms, using contingent valuation

[10] Ecological Engineering Associates. http://www.solaraquatics.com

techniques based on willingness-to-pay surveys of HRM residents, changes in property values, and travel costs. The value of positive implications or "outcomes" of the investments can be estimated on the basis of what people and businesses are willing to pay for them. In addition, there are positive effects on the economy. For example, direct and indirect generation of income and employment will result from the expenditures on STPs, and the potential for the development of new wastewater technologies or expertise will be enhanced.

In the case of the Halifax Harbour, major benefits of water quality improvements due to investment in STPs are:

a) protection of the harbour's nutrient cycling capacity,

b) increased property values;

c) the reopening of shellfishery areas; and,

d) increased tourism and recreational opportunities.

An indirect measure of the perceived benefit in terms of a clean harbour is reflected in the willingness-to-pay (WTP) for wastewater treatment. Additionally, the benefits of reduced health risk and other ecosystem and environmental benefits are important to consider despite the difficulty of measuring these benefits in monetary terms.

Table 5: Environmental and Economic Outcomes of Investments in STPs

Environmental Benefits
·Less contaminated sediment & sludge build-up
·Decrease in pathogens
·Less biological oxygen demand (BOD)
·Regulated water temperature
·Lower levels of toxic chemicals
·Lower nutrient loading
·Enhanced marine habitat
·Return of native marine life
·Maintenance and/or enhancement of current marine life (e.g. lobsters)
·Reduced chance of nuisance and toxic algal blooms (e.g.bluegreens, dinoflagellates)

Economic Benefits
·Increased recreational opportunities
·Increased property values
·Reduced human health risks
·Enhanced attractiveness for tourism
·Increase in commercial fisheries

Economic Impacts
·Employment due to construction of STPs
·Employment due to operation and maintenance of STPs
·Employment due to increased recreation and tourism

Source Control

The GPI recognizes that pollution prevention is a cost-effective means to reduce the impact of contaminants in the environment and to halt or decrease the deterioration of our natural water assets (i.e. natural capital). Pollution prevention is a defensive expenditure that prevents the future costs of remediation and clean-up. Prevention includes public education, information programmes, and controls through legislation, monitoring, and enforcement. Such expenditures are always a good investment in maintaining the quality of our natural assets, because the costs of remediation and restoration after contamination are relatively greater than the costs of prevention.

Source controls include the regulation (i.e. maximum limits or bans) of substances discharged to a sewerage system, as well as monitoring and enforcement mechanisms. They are a vital component of any long-term wastewater treatment plan, and they function as a cost-effective alternative to removing and treating pollutants at the 'end of the pipe' (Holmes et al. 1999). Source controls are beneficial because they:

- are more effective;
- are less expensive;
- reduce overall wastewater flow rendering sewage systems more effective;
- conserve water and energy
- prevent persistent toxic pollutants requiring additional chemicals to remove them at the end-of-the-pipe;
- discharge effluents that are significantly less toxic; and,
- result in sludge that contains less toxic or untreatable substances, which can be safely used as soil conditioner in agricultural fields, as landfill for mine reclamation, or composted for fertilizer.

Source control programs must include education, legislation and enforcement directed at households, industrial and commercial operations, and must embrace stormwater run-off to be effective. Examples of commercial activities that may contribute contaminants are: photo-finishing outlets (i.e. silver), electroplating plants (i.e. chromium), dry-cleaning services (i.e. solvents), and printing plants (inks and dyes). In addition to human excrement, households contribute organic kitchen wastes, solvents, oils, laundry detergent, bleaches, and other cleansers. Contaminants such as oil, grease, anti-freeze, and hydrocarbons (polycyclic aromatic hydrocarbons or PAHs; potential carcinogens) also enter the sewer systems as a result of deposits from cars and trucks that wash off road surfaces into sewer systems.

Finally, implementing source controls in concert with sewage treatment has several economic benefits such as reduced sewage treatment costs, a stable wastewater content, reduced costs to industry because of improved water intake quality, and a reduction of effluent treatment costs after use. Additionally, potential future clean-up costs for hazardous wastes will be avoided, and businesses that comply with source controls can advertise their company as an environmentally responsible member of the community. Finally, source controls coupled with sewage treatment will gradually restore environmental quality, and thus enhance opportunities for tourism, recreation, shell-fishing and lobster fishing, as well as decreasing public health and marine health concerns.

Endocrine Disrupting Chemicals

Recent research has identified some synthetic chemicals that are capable of disrupting the endocrine system in fish, reptiles, amphibians, birds, and mammals, including humans (see Appendix 3). The endocrine system is driven by natural hormones that control growth, development, reproduction, and the immune system. Organochlorines such as dioxins and PCBs, heavy metals, and products of incomplete combustion (PAHs) are known or suspected endocrine-disrupting chemicals. Other examples include nonylphenols and related chemicals, which are found in pesticides and as sudsing agents in some detergents, dish-washing soaps and shampoos.

Studies have found that some synthetic chemicals found in sewage treatment plant effluent cause gender confusion in fish (Holmes et al. 1999). For example, nonylphenols that are found in many plastics, pesticides, and other industrial and domestic detergents, have been identified as a cause of such hormonal confusion. Similarly, a study in New Brunswick found that nonylphenol disrupted the transformation juvenile salmon undergo when leaving freshwater rivers for the saltwater environment of the ocean (Fairchild et al. 1999).

There is already evidence of the effects of these substances on human and marine health (Box 1). Endocrine disrupting chemicals cannot be treated once they are released into the sewage system, so they must be stopped at the source. The National Sewage Report Card (Holmes et al. 1999) recommends that governments use legislation to eliminate the use of endocrine disrupting chemicals.

· **Box 1. Health Impact of Toxic Discharge to Aquatic Ecosystems**

- In the Great Lakes region, a study found that among mothers who ate 2-3 PCB contaminated fish meals a month during pregnancy, the most highly exposed children were more than 3 times as likely to have low IQ and low comprehension and to be highly distractible.
- Inuit women in the Arctic produce breast milk with the highest known levels of PCBs, DDT and other contaminants due to their marine-based diet
- Beluga whales in the St. Lawrence are so contaminated with organochlorine pollutants that their bodies must be treated as hazardous waste, according to official guidelines.
- Between 1969 and 1984, levels of PCBs in polar bears quadrupled. At this rate, the average bear will soon have 50 parts per million of PCBs in its fatty tissue and will also have to be treated as hazardous waste

Source: National Sewage Report Card (Number Two)

HRM's Source Control Implementation Strategy

The Federal-Provincial Environmental Assessment Panel for Halifax Harbour Cleanup Incorporated (HHCI), recommended that a comprehensive source control program be implemented to limit the input of toxic or noxious materials into the sewer systems (HRM 1999b). HRM has undertaken a source control project with local businesses to identify sources and limit their use or disposal (e.g. Bylaw W-100)[11], and the HRM will put forward a revised Bylaw to implement more effective controls on inputs. In addition, the HRM provides a Household Hazardous Waste Service for residents.

Based on the evidence in this study, GPI Atlantic strongly recommends that the HRM's Source Control Implementation Strategy's current components be continued. This would entail increased public involvement and information, legislation and enforcement, toxic and hazardous waste controls, and water conservation. GPI Atlantic further recommends implementation of the next planned phase, including pollution prevention information programmes, baseline data collection, and monitoring programs. Further education and improved legal mechanisms to implement and enforce source controls are integral to the restoration of the Halifax Harbour environment.

Most recently, the Halifax Regional Municipality has introduced a new draft bylaw to the municipal Council that will enforce the pollution prevention programme it began in 1998. The first phase included an education component outlining the economic and

[11] HRM Bylaw #W-100 Respecting Wastewater Discharge: restrictions of discharges into public sewers from industrial, institutional, and commercial sources.

environmental benefits of re-using and recycling chemicals. Although, the intent of the HRM is to encourage voluntary action, the municipality is proceeding with monitoring and enforcement to back up its education programme. Inspections of businesses will be undertaken to enforce the new bylaw, which includes concentration limits for 44 industrial chemicals, including arsenic, iron, sulfates and mercury, and fines ranging from $500 to $10,000 for violations (Flinn 2000).

Currently, HRM plans to separate combined sanitary/storm water sewers when repairs are made or when new pipes are installed. However, GPI Atlantic recommends that separation be implemented only when source controls are fully in place and when storm water discharges meet the Canadian Council of Resource and Environment Ministers' guidelines for discharge into aquatic ecosystems[12].

Water Conservation

An effective source control strategy also requires that water conservation education be fully implemented and directed at the municipality's residents and businesses. Water conservation minimizes overflows to sewage treatment plants and avoids the need to dump untreated wastewater due to plant capacity overflows.

The Halifax Harbour Solutions Plan

The HRM has adopted a Concept Plan based on the recommendations of the Harbour Solutions Advisory Committee, a broadly-based stakeholder group. The Halifax Harbour Solutions Plan comprises four advanced primary level treatment plants, phased in over time to reduce costs. Halifax Regional Municipality has committed to two-thirds of the capital cost requirement ($207.9 million, or $203.2 million in 1997$), and to 100% of the operating and maintenance costs.

HRM has evaluated several multi-plan scenarios regarding the costs of treatment plant construction, the costs of collection infrastructure, and siting constraints. The four-plant scenario was chosen as the best alternative. This scenario will include one plant to serve Dartmouth, two plants in Halifax, and a fourth plant at Herring Cove. The plan is projected

[12] Holmes et al. 1999; If source controls are not implemented, then the urban runoff will be discharged into the harbour with no treatment at all.

to meet the following desired water quality objectives as set by the Halifax Harbour Task Force (HHTF) and the Halifax Harbour Solutions Advisory Committee (SAC; Jacques Whitford Env. Ltd. 1998):

- **Outer harbour**: bathing and contact recreation, immediate shellfish consumption.
- **Middle harbour, Bedford Basin**: bathing and contact recreation, modified shellfish consumption.
- **Northwest Arm**: bathing and contact recreation, boating, good aesthetics.
- **Inner harbour and Narrows**: boating, industrial cooling, good aesthetics

Advanced primary treatment will be implemented in this plan for Halifax Harbour. The treatment system will include mechanical solids separation as well as chemical treatment for further solids removal, plus UV disinfection of effluent prior to discharge. The minimum process requirements for the new sewage treatment plants include (HRM 1999b):

- screening;
- grit removal;
- chemical flocculation and settling;
- followed by ultraviolet disinfection; and,
- on-site dewatering of biosolids, with transport of biosolids to an off-site processing facility.

Financing the Project

The former cities of Halifax and Dartmouth instituted an Environmental Protection Charge on local water rates in the early 1970s. Currently, there is approximately $45 million (1997$) in these accounts. This immediately reduces the $207.9 million capital cost to be financed by the HRM ($203.2 million, 1997$), to $161.9 million ($158.2 million, 1997$).

HRM Council has approved a moderate increase in the existing Environmental Protection Charge based on consumer water usage to cover the costs of sewage treatment. A household of four persons will incur an increase of $17/year based on an average current water bill of $270/year.

The HRM is approaching the provincial and federal governments for the remaining capital costs, $107.1 million ($104.7 million, 1997$). According to a recent survey, 71% of HRM residents feel that the provincial and federal governments have a responsibility to help cover the costs of sewage treatment (CRAI 1999). In this survey, residents agreed with the statement that both levels of government stand to benefit from the sewage treatment plan and a clean harbour because increased tax revenues will be realized.

The anticipated Infrastructure Plan, mentioned in the federal Throne Speech and the 2000 federal Budget Speech, provides a mechanism for a cost-share approach to financing the capital investments for the STPs between the three levels of government (municipal, provincial, and federal). In the past, such arrangements have often been evenly-shared among all three jurisdictions. As HRM is seeking only one-third of total capital costs from the provincial and/or federal governments, rather than two-thirds, HRM is a strong candidate for support from the Infrastructure Plan.

Provision for Future Potential Upgrade of Sewage Treatment Processes

The Halifax Harbour Solutions Plan includes a design for increased future flows due to residential growth, and the option to upgrade the treatment facilities to secondary treatment if necessary.

Costs and Benefits of the Halifax Harbour Solutions Sewage Treatment Plan

This section outlines the data sources and the assumptions of the cost-benefit analysis for the Halifax Harbour sewage treatment plan. Conservative, mid-range and high-end estimates are presented using a range of estimated benefits. All dollar values are in 1997 Canadian dollars unless otherwise specified.

Discounting Over Time

The discount period, discount rate, and community population are important elements of the overall analysis. The purpose of a discount rate is to convert future values into one monetary measure using today's dollar values. Discounting is based on the concept that goods and services are worth more today than in the future and the fact that man-made capital depreciates over time. Considering that environmental amenities and services generate benefits in perpetuity if used sustainably and do not depreciate over time, the application of discounting to natural capital has been argued to be illogical. Indeed, the use of discounting and cost-benefit analysis has been generally criticized by environmental scientists because ecological and social costs and benefits are frequently assigned no value or an incorrect value.

From the perspective of an index of sustainable development like the Genuine Progress Index, the future is worth at least as much as the present. The GPI assumption is, by definition, that we will live and consume resources in such a way that the next generation will not be worse off than the present one. Because the choice of a discount rate reflects the value we place on the future compared to the present, the GPI itself adheres to a 0% discount rate in assessing natural capital values and environmental costs and benefits. Unlike natural capital, manufactured capital does depreciate over time, so that use of a discount rate may be appropriate in assessing manufactured capital investments. Unfortunately, this distinction between natural and manufactured capital is generally overlooked in most cost-benefit analyses.

Because these issues are widely debated and because discounting is widely used, this study presents three discount rates (0%, 4%, and 8%), which are applied to all costs and benefits in the following analyses. A discount rate of 8% is presented as a conventional analysis. A 4% discount rate represents a compromise between conventional discounting and a sustainable development approach. The 0% discount rate favoured by GPI Atlantic assumes that the value of resources in the present is equal to their value in the future, and indicates a net present value with no discounting. Future research and analyses should consider whether discounting is appropriate for sustainable development indicators, and should differentiate clearly between man-made and natural capital.

Assumptions Used in the Analyses

1. The designed life cycle of the STPs is assumed to be 60 years (Halifax Harbour Solutions Project Team 1998).
2. The population to be served by the STPs is approximately 121,000 according to HRM (pers. communication).
3. Population growth is projected to be 1% per annum throughout the life of the project. The STPs will be designed to accommodate a growing population.

Capital and Operating Costs

The costs for the Halifax Harbour sewage treatment plan are (Table 7; HRM 1999):

- Total capital costs estimated at $307.9 million (1997$) over a 10 year period.
- Operating costs estimated at $8.8 million (1997$) per year (year 11 to year 60).

Financing Costs

The financing costs are $22.3 million per year over 25 years, based on the interest assumed to accrue on principal for 25 years using the mean of the Government of Canada's long-term borrowing rates since 1991.

Potential Prosecution Costs

Section 36(3) of the Fisheries Act enables prosecution of municipal, agricultural and industrial polluters (Holmes et al. 1999). Fines incurred can be up to $1 million or jail sentences for polluters convicted of pumping matter into coastal waters that threatens fish and spawning grounds. This is a potential additional cost that may be incurred if sewage treatment is *not* implemented, but is not included in the following analyses.

Willingness-to-pay for Improved Water Quality

Willingness-to-pay (WTP) is a monetary valuation method widely used as a surrogate for the value people place on a clean-up or restoration project. Willingness-to-pay (WTP) surveys have shown that people are willing to pay for improvements in the surface water quality of estuaries, rivers, and harbours (Bockstael et al. 1989, Hayes et al. 1992, Sheppard et al.1993). For example, a survey of the willingness of urban HRM residents to pay for improved harbour water quality was undertaken by Corporate Research Associates (CRAI 1998, 1999). In this case, the WTP reflects the monetary amount residents assign to the improvement in quality of life that will accrue from a cleaner harbour.

The results indicate that 71% of households would be willing-to-pay *at least* $99.35/year (1997$) for a cleaner harbour. Among the 71% of HRM residents willing-to-pay, the average WTP of these HRM residents varied between $99.35 and $149/household/year (1997$) for improved surface water quality. The study included urban and rural residents. However, only households serviced by HRM water services and, therefore, those directly affected by the increased water and sewage rates for the new STPs, were included in determining the WTP.

These estimates are in line with a similar study conducted in the Pictou Harbour area (Wood et al. 1996), which found that households valued incremental improvements in water quality that would reduce faecal coliform levels and increase allowable water uses like swimming and fishing. The results indicated that local residents in Pictou were willing-to-pay $129.50 per year (1997$) for improved surface water quality.

Based on these two local studies and the projected improvements in surface water quality due to investment in sewage treatment for Halifax Harbour, the following range of values[13] is used (1997$; Table 7):

- Conservative WTP: $99.35 per household
- Mid-range WTP: $114.30 per household
- Higher-end WTP: $129.20 per household

These WTP estimates are multiplied by the number of households receiving sewer services (approximately 121,000) to determine the projected benefits stemming from improved surface water quality to the urban households of HRM. Because benefits like improved recreational opportunities would be felt by residents outside the metro area of HRM, the WTP as a surrogate monetary estimate of the benefits of sewage treatment for the HRM region should be regarded as a conservative estimate, even at the higher-end. It can safely be assumed that Nova Scotians outside metro HRM would also be willing to pay for improved water quality in Halifax Harbour, though likely a smaller amount than HRM residents receiving sewer services.

Monetized Benefits

The benefits of sewage treatment for the Halifax Harbour include:

- improved water quality,
- restored aesthetic properties,

[13]WTP values are based on $100, $115, and $130 in 1999$.

- reduction in fecal coliform and potential human infection,
- additional recreational activities for local residents and opportunities for local businesses (i.e. swimming, windsurfing),
- enhanced tourist attraction,
- increases in property values in close proximity to the harbour,
- reduced pressure on the "waste assimilation" capacity of the harbour,
- enhanced marine environment and healthier marine life,
- potential re-opening of closed shellfishery areas,
- decreased chance of harmful and potentially toxic algal blooms

Property Value Increases

Several studies have demonstrated a positive relationship between water quality and housing prices (Epp and Al-Ani 1979, Wilman 1981, Kirshner and Moore, 1989, Page and Rabinowitz 1993). A 1986 study in the San Francisco Bay area found the implicit price (i.e. marginal price) of a property's proximity to higher water quality (as opposed to proximity to water of lower quality) to be 11% higher, or approximately $41,000 (U.S.1985$) of the property value (Kirsher and Moore 1989, using hedonic property valuation method).

In 1998, a fourteen-year study on the effects of environmental clean-up and restoration of Hamilton Harbour determined that investments in sewage treatment and parks increased residential property values by 18.5% within one kilometre of the harbour (Muir 1998). In this case, the strongest influence on housing prices was improved harbour water quality. In the Hamilton Harbour vicinity, statistical analysis demonstrated that proximity to the waterfront had no significant effect on property values prior to the harbour cleanup (Zegarac and Muir 1998). However, statistical analysis of the effect of proximity to water following the cleanup of the harbour increased over time and was statistically linked.

The Hamilton study used a one kilometre radius from the harbour to analyze changes in property values (Muir 1998), and previous studies in the U.S. have generally used a radius of one mile for similar estimates. Thus, a conservative radius of 0.8 km (one-half mile) around Halifax Harbour (including Bedford Basin and the Northwest Arm), has been used in this analysis. A GIS-based property value database indicates that a total of 13,700 properties are located around the harbour within this area. Percentage increases in property values of 5%, 7.5% and 10% were used to estimate the potential property value benefits of a cleaner harbour due to investment in STPs (Table 6). On average, each dwelling was, therefore, estimated to increase in value by a conservative $8,468 to a higher-end of

$16,935, based on current property values.

Protection of Marine Nutrient Cycling Capacity

Marine ecosystems provide essential life-support services because of their major role in the global cycling of carbon, nitrogen, oxygen, phosphorus, and sulfur. In addition, they decompose, transform, and detoxify wastes from human activities. These functions support coastal ocean-based recreational activities and businesses, and maintain coastal property values (Peterson and Lubchenco 1997). Most importantly, marine ecosystems directly support all life through the provision of essential ecosystem functions.

The services and functions of marine ecosystems have often been overlooked because human society is primarily terrestrial, however, societies use oceans to dispose of wastewater and other materials. In aquatic ecosystems, biological oxygen is used to decompose wastes (i.e. biological oxygen demand). Thus, increasing the rate of organic matter entering aquatic ecosystems induces oxygen depletion and can lead to eutrophication. In some cases, an overload of organic matter can lead to microbial production of toxic hydrogen sulfide and massive mortality of estuarine and marine mammals (Peterson and Lubchenco 1997). In addition, eutrophication stimulates growth of nuisance algae (e.g. blue-greens, dinoflagellates), which can be toxic to marine organisms and humans.

In the case of wastewater disposal, the allowable loading of nutrients is based on the capacity of aquatic ecosystems to degrade the organic matter without causing a detrimental affect on other marine organisms. Peterson and Lubchenco (1997) estimated the marginal economic value of using marine ecosystems to decompose nutrients from sewage wastewater based on the standard engineering costs of additional levels of sewage treatment above that of a plant with no nutrient removal capability[14]. Using their estimate of the additional construction costs for a sewage treatment plant with some nutrient removal capacity[15], a conservative surrogate estimate of the value of the harbour's nutrient cycling can be calculated. According to these estimates, a rough value of the service provided by Halifax Harbour in nutrient removal is estimated at $58.1 million (Table 6) based on the daily flow of 187 million litres of wastewater[16].

This estimated value is very crude and does not include the on-going annual benefits of nutrient cycling which marine ecosystems provide. It is also an incomplete estimate because operating costs are not included in the surrogate value. However, it does provide a preliminary monetary estimate of value for the ecosystem services that will be protected and enhanced by sewage treatment, source control and other means of pollution prevention around the harbour.

While monetary values are incapable of accurately describing the value of ecosystem functions, the failure to assign such monetary values has in the past led to their devaluation. If ecosystem functions have an arbitrary value of zero, they will be taken for granted and given insufficient attention in the policy arena. Given the dominance of monetary considerations in our budgeting and decision-making processes, even a crude and conservative estimate of the value of nutrient cycling services, based on potential human engineering replacement costs, is necessary to draw attention to vital marine ecosystem services that are frequently overlooked.

[14]U.S. EPA Advanced Treatment I

[15]Based on the costs of construction, alone, for additional treatment beyond U.S. EPA Advanced Treatment I plant and a flow of 5 million gallons per day

[16] see Appendix 2 for calculations; This estimate is only based on the capital costs of construction over 10 years, and therefore, does not account for the on-going services of the harbour.

Tourism

Sewage pollution affects recreational and aesthetic quality. Beaches around the harbour and the Northwest Arm are periodically closed to swimming during the summers because of bacteriological contamination. Sailing and windsurfing in the Northwest Arm put participants at risk of exposure to health hazards. In fact, windsurfing competitions in Halifax Harbour have been discontinued due to concerns of water-related illness.

Up to 1/3 of the litter found around the harbour's shorelines is from sewage discharge (Nantel 1996). In addition, odours and floating debris cause aesthetic problems that undermine the enjoyment of visitors, and the projected increases in future sewage flows will worsen the perception of the harbour for residents and visitors. Currently, 73% of HRM residents rate the harbour's water as poor. When residents were asked ,"What sort of impacts do you believe poor water quality in the harbour has on the quality of life in the area?", the top four responses were: 1) looks bad for tourists/bad image; 2) loss of recreational opportunities; 3) fish and wildlife impacts; and, 4) loss of tourism/keeps people away (CRAI 1999).

Peterson and Lubchenco (1997) state that

> "... excluding commercial fishing, the coastal industry most tied to a naturally functioning ocean ecosystem is probably the tourism industry.... One of the important amenities that helps value one tourist destination more highly than another is the availability of various, usually non-consumptive, uses of natural coastal marine ecosystems....These opportunities depend on sustaining function of the coastal marine ecosystem and provision of its services."

Based on U.S. and Canadian case studies, increases in tourism revenues are projected for Halifax in the wake of an improved harbour environment. The downtown and waterfront areas will be more pleasant places to spend time due to aesthetic improvements. Halifax beaches will be safer, and more recreational activities will be available. A cleaner harbour is projected to produce a marked increase in water-based tourism. Activities such as water tours and cruises, swimming and beach activity, sailing, windsurfing, and canoe rentals (e.g. Point Pleasant Park) will certainly be more attractive and better business ventures.

After the Boston Harbour cleanup, 8 miles of recreational beaches became safe for swimming, and recreational fishing in the area was revived. In addition, a recent study in Ontario estimated that the benefits due to surface water quality improvements are worth $70.15/household/year (1997$) to beach users (Ecologistics Ltd. 1990). This is an additional contingent value that could be transferred to the rural households of the HRM and surrounding areas. However, it is not included here because annual beach visit statistics are not currently available.

Both for aesthetic reasons and due to increased recreational opportunities, it is therefore reasonable to assume that improved surface water quality will increase tourism in the HRM, especially in the downtown and waterfront areas. However, the projected percentage increase is low for all estimates in this study (2.0% to 3.0%) because there are no direct local examples of the economic impact of improved water quality on tourism. Given the magnitude of present tourism expenditures in the HRM ($460 million in 1997[17]), a 2 to 3% increase, for years 11 to 60, results in additional annual revenues of between $9.6 million and $14.3 million (Table 6; 1997$).

Shellfish Harvesting

Several studies have estimated the economic benefits of re-opening shellfisheries as a result of improved water quality. In Upper Narragansett Bay, Rhode Island, improved water quality was estimated to generate benefits of $30 million to $70 million (US1992$) annually from shellfishing, and $30 million to $60 million per year from swimming (Hayes et. al. 1992.) Washington state's shellfisheries were closed for 12 years due to poorly treated waste contamination. Now, with pollution prevention and wastewater treatment in place, the state's oyster trade is the largest in the U.S., with each acre of oyster tideland generating $40,000 to $60,000 (US1997$) in revenues every 3 years. After the implementation of sufficient wastewater treatment for Boston Harbour, an annual $15 million (US$) lobster and shellfish industry sprang up in the harbour (Galbraith 1999).

In Atlantic Canada, most shellfishery closures are caused by bacteriological pollution (Nantel 1996). Sewage harms shellfish, especially bivalve molluscs (e.g. mussels), which feed by filtering water. As a direct result of bacteriological contamination, the harvesting of clams and mussels in the entire Halifax Harbour has been permanently closed since 1965 (Nantel 1996).

An area of approximately 93 square kilometers is closed to shellfish harvesting in the harbour. Because of the total area closed, $768,136 per year is foregone in landed shellfish value. Over 35 years (1965-2000), the amount of foregone shellfish revenue equals $27 million. Additional impacts of shellfishery closures include the increased demand for catches from the shellfishery areas remaining open, reduced employment opportunities,

[17]Nova Scotia Department of Finance.1999. Nova Scotia Statistical Review 1999.

increased consumer prices, and demands on enforcement agencies (Nantel 1996).

Calculations of the value of the harbour's shellfisheries are based on the average landed value of Nova Scotia's shellfisheries (1989 to 1992) per square kilometre of open shellfishing area ($8259.53/km^2; 1997$). In this analysis, the percent of shellfishery areas that could potentially be re-opened as a result of improved water quality in the harbour is predicted from a conservative 30% to a high-end of 50%, based on the U.S. case studies cited above. Based on the U.S. case studies, it is assumed that 50-70% of shellfish may still be unfit for human consumption even after the STPs are operational, due to remaining high coliform levels in some parts of the harbour, and due to contamination by heavy metals and chemicals. These estimated projections result in economic benefits of between $230,000/year and $380,000/year from the area that is re-opened (Table 6). More accurate assessments were not possible due to the lack of standing stock and growing area productivity estimates.

Household Labour Income and Spinoffs

HRM (1999) estimated the provincial economic impacts of the capital and operating expenditures for the Halifax Harbour Solutions Plan. Total labour income and spinoffs for Nova Scotians from capital investment are estimated to be $19.3 million/year (1997$) for years 1-10, and total labour income and spinoffs for Nova Scotians from operating expenditures is estimated at $6.1 million/year for years 11-60 (1997$; Table 6). Thus, the total provincial economic impact is estimated at $497.7 million over 60 years or $163.8 million (1997$), after discounting at 8% (Table 6).

Provincial and Federal Government Tax Revenue Income

HRM (1999) estimated government income due to capital and operating expenditures for the Halifax Harbour Solutions Plan. Total provincial income from capital investment is estimated to be $2.7 million/year (1997$) for years 1-10, and total provincial income from operating expenditures is estimated at $1.0 million/year (1997$) for years 11-60. Therefore, the total provincial government income is estimated at $77.2 million over 60 years or $23.9 million (1997$), after discounting at 8% (Table 6).

Total federal government income is estimated at $5.7 million/year (1997$) from capital investment in years 1-10, and $1.9 million/year (1997$) from operating expenditures in years 11-60. These give a total federal government income of $152.4 million over 60 years or $49.3 million (1997$), after discounting at 8%.

Table 6: Costs and Benefits of the Halifax Harbour Solutions Plan (millions$1997)

Costs	**millions 1997$**	**NPV @ 8%**	**NPV @ 4%**	**NPV @ 0%**
Capital costs	**$307.9; ($30.8/year over 10 years)**	**$206.6**	**$249.7**	**$307.9**
Financing costs*[1] for full capital costs	**$652.5 ($26.1/year over 25 years)**	**$278.7**	**$407.9**	**$652.5**
Env. Protection Fund (EPF) contribution	**$45**	**($45)**	**($45)**	**($45)**
Capital less EPF contribution	**$262.9 ($26.3/year over 10 years)**	**$176.4**	**$213.2**	**$262.9**
***Savings due to EPF contribution* (1)**	**$45**			
Financing costs for capital less EPF contribution	**$557.5 ($22.3/ year[1]over 25 years)**	**$238.0**	**$348.3**	**$557.5**
***Savings due to EPF contribution* (2)18**	**$95.0**			
Operating costs	**$440.0 ($8.8/year year 11 to 60)**	**$49.9**	**$127.7**	**$440.0**
Total Costs	**$1,400.4**	**$535.2**	**$785.3**	**$1,400.4**
Total Costs with EPF contribution	**$1,260.4**	**$464.3**	**$689.2**	**$1,260.4**
Total Savings	**$140.0**	**$70.9**	**$96.1**	**$140.0**
Benefits		**NPV @ 8%**	**NPV @ 4%**	**NPV @ 0%**
Protection of Marine Nutrient Cycling Capacity	**$58.1 ($5.8 over 10 years)**	**$39.0**	**$47.1**	**$58.1**
Willingness to Pay by Households	**$729.4 - $948.6; $12.2 -$15.8/year**	**$150.5 - $195.7**	**$275.0 - $357.7**	**$729.4 - $948.6**
Increase in Tourism	**$477.9 - $716.9; $9.6 - $14.3/year**	**$54.2 - $81.3**	**$138.7 - $208.1**	**$477.9 - $716.9**

18 This additional saving is a result of the reduced financing costs (i.e. less interest payments) due to the EPF savings to date.

Increases in Property Values	**$116.5 - $233.0**		**$50.0 - $99.9**	**$75.7 - $151.3**	**$116.5 - $233.0**
Landed Value of Re-opened Shellfisheries	**$11.5 - $19.1; $0.23 - $0.38/year**		**$1.3 - $2.2**	**$3.3 - $5.6**	**$11.5 - $19.1**
Household Labour Income	**$93.4 ($9.3/year for 10 years)+ $200 ($4.0/year for 50 years) = $293.4**		**$85.3**	**$133.8**	**$293.4**
Labour Income Spin-offs	**$99.3 ($9.9/year for 10 years) + $105 ($2.1/year for 50 years) = $204.3**		**$78.5**	**$111.0**	**$204.3**
	Capital	**Operations**			
Provincial Tax Revenue	**$27.2 ($2.7/year over 10 years)**	**$50.0 ($1.0/year over 50 years)**	**$23.9**	**$36.6**	**$77.2**
Federal Tax Revenue	**$57.4 ($5.7/year over 10 years)**	**$95 ($1.9/year over 50 years)**	**$49.3**	**$74.1**	**$152.4**
Total Benefits			**$532.0- $655.1**	**$892.0 - $1125.3**	**$2120.7 - $2703.0**

*Note: Financial costs associated with borrowing are assumed to accrue on principal for 25 years using the geometric mean of the Government of Canada long-term borrowing rates since 1991.

Qualitative Benefits

Health Benefits

The greatest human health risk posed by current harbour water quality is the potential exposure of the community to pathogenic micro-organisms through water-contact recreation and harbour shellfish consumption (Bio-Response Systems and Jacques Whitford Env. Ltd. 1992). The present use of the harbour for any recreational purpose that involves contact with the water results in risk of illness from pathogenic organisms. In particular, the risk is high for children because they are generally more sensitive to gastrointestinal symptoms than adults.

The STPs are planned to meet recreational objectives that will greatly reduce and/or eliminate these health risks (Jacques Whitford Env. Ltd. 1998). The reduced threat of illness will improve overall quality of life, and decrease potential pressures on Nova Scotia's health care system. The potential economic impact of water-related illnesses includes hospital admissions, diagnostic costs, treatment costs, lost productivity in the work place and the home, and the opportunity costs of an individual's lost time and talents. Fewer sick days mean that adults are more productive in their home-life and workplace, and that children are participating fully in their education and leisure time.

Nevertheless, because the potential costs of health risks due to continued dumping of untreated sewage into Halifax Harbour cannot be quantified with our current information, they have not been included in this analysis among the monetary benefits of a cleaner harbour.

Ecosystem Benefits

Ecosystem health improvements will follow the installation of STPs for HRM and Halifax Harbour. Healthy ecosystems provide many important functions and indirect benefits for humans and wildlife. Reducing municipal sewage loads to the harbour will facilitate environmental recovery from years of pollution and degradation. Although secondary or tertiary treatment is a goal for further restoration of a pristine harbour, the anticipated effects of the current plan are to decrease exposure to contaminants in municipal wastewater, thereby reducing pressures on the harbour's assimilative capacity and increasing the health of marine life.

The HRM Source Control Implementation Strategy also aims to restore marine health in the harbour. A study of the Halifax Harbour's marine species discovered that lobsters, mussels, and winter flounder have accumulated significant levels of heavy metals in their tissues (Jacques Whitford Env. Ltd. 1991a). The results indicate potential ecosystem stress and an increasing risk of disease and mutagenic effects in the harbour's marine species if raw sewage continues to flow untreated into the harbour. In addition, bio-accumulation of toxins can affect birds and mammals who rely on these species as a source of food. Many raptors and wading birds on McNab's Island, and small mammals such as otter and mink consume fish and other marine life (Jacques Whitford Env. Ltd. 1991b). Reduced pollutant deposition will help improve the Harbour's benthic habitats and provide a healthier and more secure food source for all marine and terrestrial species.

Improved water quality and enhanced habitat quality will likely attract a diversity of native marine species back into the harbour and the Bedford Basin. A healthier and renewed ecosystem in the Halifax Harbour, Northwest Arm and Bedford Basin will over time provide a wealth of benefits to the environment and the ecosystems they support, including the surrounding human communities. Again, because these benefits are difficult to quantify, they have not been included in the monetary cost-benefit analysis, (with the exception of the harbour's nutrient cycling capacity), though their long-range positive impacts are likely to be very significant and far-reaching.

Results

The analyses provide net present values (NPVs) discounted at 8%, 4%, and 0%, over a 60 year life-span for the four sewage treatment plants, as proposed in the Halifax Harbour Solutions Plan. Conservative NPVs are characterized by low estimates of willingness-to-pay ($99.4/household), property value increase (5%), tourism revenue increase (2%), and the percentage of shellfisheries re-opened (30%). The mid-range and high-end estimates consist of incrementally higher benefits. All dollar values are in 1997 Canadian dollars.

1) Cost-Benefit Analysis

Firstly, a cost-benefit analysis (CBA) of the Halifax Harbour Solutions Plan is used to demonstrate whether the project is economically beneficial. The traditional purpose of cost-benefit analysis (CBA) has been to compare alternative projects and to guide investment priorities. Ecological economics expands conventional CBA to include social and environmental costs and benefits.

The cost-benefit analysis (CBA) determines an estimate of the net present value (NPV) based on capital costs, operating costs, the marine nutrient cycling benefit, household willingness-to-pay, tourism revenue increase, property value increase, and the landed value of re-opened shellfisheries (Table 7). NPV estimates range from $38.5 million to $161.5 million, discounted at 8%, $162.6 million to $392.3 million, discounted at 4%, and $645.9 million to $1,227.8 million, discounted at 0% (Table 7).

Table 7: Cost-Benefit Analysis of the Halifax Harbour Solutions Plan (1997$millions)

	Conservative	Mid-Range	High-End
Total Capital Costs	$307.9	$307.9	$307.9
Operating Costs/ Year	$8.8	$8.8	$8.8
Marine Nutrient Cycling Benefit	$58.1; ($5.8/year over 10 years)	$58.1; ($5.8/year over 10 years)	$58.1; ($5.8/year over 10 years)
Willingness-to-Pay/Hhld/Year	$99.4	$114.3	$129.2
Property Value Increase	5%; $116.5	7.5%; $174.7	10%; $233.0
Tourism Revenue Increase	2.0%; $9.6/year	2.5%; $12.0/year	3.0%; $14.3/year
Shellfisheries Reopened	30%; $0.23/year	40%; $0.31/year	50%; $0.38/year
Net Present Value @ 8%	**$38.5**	**$100.0**	**$161.5**

Net Present Value @ 4%	**$162.6**	**$277.4**	**$392.3**
Net Present Value @ 0%	**$645.9**	**$936.8**	**$1,227.8**

2) Economic Impacts

The economic impacts include the potential economic benefits in provincial labour household income and spin-offs, plus provincial and federal government tax revenue income resulting from the economic activity due to the Halifax Harbour Solutions Plan (Table 8). The economic impacts were determined by Halifax Regional Municipality (HRM 1999a). The estimated net present value (NPV) of the proposed project increases due to these benefits. However the economic impacts of investment are not considered to be directly additive to the cost-benefit analysis model (i.e. conventionally, economic impacts are not added as benefits in the cost-benefit method). Thus, they are reported here as separate benefits resulting from the investment in the Harbour Solutions Plan. NPVs range from $237.1 million discounted at 8%, to $727.3 million, discounted at 0%.

Table 8: Economic Impacts of the Halifax Harbour Solutions Plan (1997$millions)

Economic Impacts	
Labour Income & Spinoffs from Capital Investment	$192.5; ($19.3/year over 10 years)
Labour Income & Spinoffs from Operating Investment	$305.0; ($6.1/year, year 11 to 60)
Provincial Income from Capital Investment	$27.4; ($2.7/year over 10 years)
Provincial Income from Operating Investment	$50; ($1.0/year, year 11 to 60)
Federal Income from Capital Investment	$57.7; ($5.8/year, over 10 years)
Federal Income from Operating Investment	$95; ($1.9/year, year 11 to 60)
Net Present Value of Economic Impacts @ 8%	**$237.1**
Net Present Value of Economic Impacts @ 4%	**$355.5**
Net Present Value of Economic Impacts @ 0%	**$727.3**

Source: HRM 1999a

3) Financing Costs

The financing costs of investment are not included in a traditional CBA because the primary objective is to compare options or alternative projects. In other words, a CBA asks whether a particular project will be beneficial or whether it would be more beneficial to invest in an alternative option or project. The costs to finance an investment (i.e. interest payments) are not included in a CBA because all investments incur interest to be paid. Therefore, these costs cancel out.

However, a basic GPI principle is to account for the full costs of public and private expenditures. For these reasons, financing costs have been determined. The issue of whether to include financing costs depends on whether the proposed capital investment is compared to alternative capital/infrastructure investments or to debt reduction/accrual of interest in bonds. It is in order to account for the latter scenario that financing costs are included in the following net benefit analysis.

The financing costs are calculated for the project's capital investment, less the savings of $45 million (1997$) earmarked for wastewater treatment in the Environmental Protection Fund (Table 7). The financial costs are estimated at $22.3 million/year over 25 years. The net present value of the financial costs range from $238 million discounted at 8%, to $557.5 discounted at 0% (Table 9).

Table 9: Financing Costs of the Halifax Harbour Solutions Plan (1997$millions)

Financing Costs **(on $262.9 million; capital costs less $45 million)**	$557.5; ($22.3/year, over 25 years)
Net Present Value @ 8%	**$238.0**
Net Present Value @ 4%	**$348.3**
Net Present Value @ 0%	**$557.5**

4) Net Benefit Analysis

The total sum of the net present value of the costs (Table 7) is subtracted from the total sum of the net present value of the benefits for a net benefit figure (Table 7)[19]. The conservative estimates of the total net benefit range from $67.7 million to $860.3 million, and the higher-end estimates range from $190.8 million to $1.4 billion, depending on the discount rate used (Table 10).

Table 10: Net Benefit Analysis of the Halifax Harbour Solutions Plan
(1997$ millions)

Total Benefits minus Total Costs[20]	
Net Present Value @ 8%	$67.7 - $190.8
Net Present Value @ 4%	$202.8 - $436.1
Net Present Value @ 0%	$860.3 - $1,442.6

5) Qualitative Benefits

Some social and environmental costs and benefits can be translated into quantitative, monetized units. However, money is not an adequate measure of many non-market qualitative values, which will certainly improve with a cleaner harbour. These benefits also need to be included as additional important measures of human health and environmental quality beyond the benefits listed in the cost-benefit analysis and economic impact statement. Such social and environmental factors that are difficult to quantify need to be represented qualitatively, in addition to the quantitative accounts, and must be monitored and evaluated in a qualitative manner. Table 11 shows the additional qualitative benefits.

Table 11: Non-market Qualitative Benefits of the Halifax Harbour Solutions Plan

Non-Market Qualitative Benefits	**Cost**	**Benefit**
Marine Ecosystem Health		**ö**

[19] Including the benefit of the $45 million (1997$) in the Environmental Protection Fund.
[20] See Table 7 for detailed costs and benefits

Avoided Health Costs due to Water-related Illness		**ö**
Greater Sailing, Swimming, and other Recreational Opportunities		**ö**
HRM Quality of Life		**ö**

Costs and Savings for HRM

The costs that have been accepted by the HRM are:

- 2/3 of the capital costs, $203.2 million (1997$), and
- Full operating and maintenance costs, $8.8 million (1997$) per year (years 11 to 60).

Capital costs can be reduced by the savings in the Environmental Protection Fund, to which HRM residents have contributed since the 1970s. These accounts now contain approximately $45 million (1997$). These savings decrease the combined overall capital costs and financing costs for the project by a total of $95 million (1997$; Table 6).

Conclusions

The positive results of the cost-benefit analysis indicate that the investment in sewage treatment for the Halifax Harbour is economically beneficial, and will provide several social, environmental, and economic benefits. It is quite probable that the net benefits will be greater than those predicted in the conservative NPV, because this analysis has used a number of conservative assumptions:

- Firstly, the percentage increase in property values was assumed to be 5%, when it may indeed be 10 to 20% (Kirshner and Moore 1989, U.S. EPA 1994, Muir 1998).
- Secondly, HRM residents living outside of the metro area will also experience a benefit from a cleaner harbour when they travel to work each day, visit the city, or participate in harbourfront activities (e.g. walking, swimming, sailing etc.).
- Thirdly, the cost-benefit analysis does not include significant and positive qualitative benefits such as avoided health costs and improved ecosystem quality.
- Finally, only a crude estimate of a small portion of the marine ecosystem services provided by a cleaner harbour are considered in the CBA.

In sum, it is likely that the overall economic return of a cleaner harbour is much greater than that predicted in the cost-benefit analysis.

In light of the robustness of the cost-benefit analysis results and the clear benefits to be gained from an improved harbour environment, the “cost” of the proposed sewage treatment plan for the Halifax Harbour with source controls, is in fact a very cost-effective investment with a positive rate of return. From the GPI perspective, such expenditures in environmental restoration are seen as investments rather than simply "costs", similar to the investment necessary to replace or upgrade worn out machinery or deteriorated equipment.

The range of discount rates used (i.e. 8%, 4%, and 0%) result in respectively greater benefit values as the discount rate declines. The choice of the percentage value discounted over time depends on the importance that we, as a society, assign to insuring environmental and social quality for future generations. However, in this case, all discount rate choices resulted in positive net present values. Future research and analysis should evaluate and determine whether discounting is appropriate for natural capital assets, and whether discounting is appropriate from a sustainable development perspective.

The GPI considers the well-being of future generations to have equal value to that of the present one, and therefore adheres to a zero percent discount rate in its own assessments. From the GPI perspective, discounting is inappropriate for renewable resource and ecosystem functions that can potentially provide services in perpetuity. GPI Atlantic therefore recommends that the results in this study that are associated with a 0% discount rate be the ones used by HRM for policy and information purposes.

The environmental and economic benefits that result from remediation and restoration of the harbour are demonstrated to increase in the analyses from the conservative to the higher-end estimates. The magnitude of these incremental benefits will be influenced by the ***degree*** of remediation and restoration of the harbour's environment, which is, in turn, dependent on the implementation of source controls to supplement the proposed sewage treatment plants.

Source control, including the prohibition of toxic discharges from commercial, industrial, and domestic sources, and the prohibition of direct discharges from boats, will proportionately increase the anticipated benefits and therefore warrant allocated financing. The potential economic benefits resulting from a clean harbour demonstrate both the economic feasibility and the political justification to implement strong source control programs and bylaws. Indeed, it is demonstrated by this CBA that the greater the improvement in the harbour's water quality, the greater the benefits.

Recommendations

The data and results in the GPI case study for the Halifax Harbour indicate that:

- Sewage treatment for the HRM should be provided;
- Advanced primary treatment with ultraviolet disinfection should be the minimal process provided;
- Alternatives such as "Solar Aquatics" should be considered in the final planning as an alternative to conventional treatment (e.g. perhaps as a pilot for one or more of the four sewage treatment plants);
- Source controls should be fully instituted for HRM households, businesses, and industry, as well as all visiting ships in the harbour;
- A full-fledged water conservation education and retro-fitting program should be put in place;
- HRM should consider banning substances that disrupt endocrine and reproductive functions; and,
- separation of combined sanitary/storm water sewers should only be implemented when source controls are fully implemented and the storm water discharges meet the Canadian Council of Resource and Environment Ministers guidelines for discharge into aquatic ecosystems[21].

The data and results in the GPI report support the positive potential impacts of the following initiatives already undertaken by HRM:

- the sewage treatment plan initiative;
- the Source Control Implementation Strategy;
- the introduction of their new bylaw to enforce source control and pollution prevention; and,
- opting for ultraviolet disinfection rather than the use of chlorine.

[21] Holmes et al. 1999

Appendix 1: Current Water Quality Problems Related to Sewage Discharge

(adapted from Jacques Whitford 1998)

Aesthetics and suspended solids

- specific impact on residents and tourists;
- particularly affect Halifax and Dartmouth waterfronts;
- water near major sewage outfall tends to be grey and cloudy, with a bad odour and visible floating objects.

Deposited Sediments

- sediment or sludge build-up smothers natural sediments and marine life;
- occurs near most of the sewage outfalls;
- sampling results show high concentrations of metals from a variety of sources.

Pathogens

- presence of pathogens poses threat of human infection;
- specific impacts on contact recreation activities, such as swimming, sailing;
- unacceptable levels present particularly near beaches and sailing routes in the Inner Harbour, at the mouth and head of the Northwest Arm, at the mouth of Sackville River, and at Herring Cove.

Biological (Biochemical) Oxygen Demand (BOD)

- BOD is a measure of the oxygen used for sewage decomposition;
- increases in BOD implies a reduction in availability of oxygen for marine life;
- generally sufficient for current sewage decomposition BOD, except in Bedford Basin;
- with projected increase in sewage outflows, BOD could be insufficient in near future.

Nutrients

- excessive nutrient loads can cause harmful algae blooms;
- high potential for excess nutrient loads in contained areas such as the Bedford Basin;
- can cause shellfish poisoning and fish and/or other marine life kills;
- sewage is a significant source of nutrient loads in the harbour.

Metals

- metals accumulate and contaminate marine organisms and people who eat them;
- existing levels in harbour water are very low, but metals have accumulated in the seabed sediments near outfalls.

Appendix 2: Calculation of the Marine Nutrient Cycling Benefit

The capital cost alone of additional levels of treatment that include some nutrient removal capacity is US$4.2 million per 5 million gallons, over and above the cost for Advanced Treatment I, which is US$23.9 million/5 million gallons (US EPA; Peterson and Lubchenco 1997).

Conversions:

a) 5 million gallons = 18.9 million litres

b) US$4.2 million (1996$) = CAD$5,756,940 (1996$)

c) CAD$5.8 million (1996$) = CAD$5,872,079 (1997$)

Calculations:

1) Therefore, additional level of treatment = CAD$5.9 million per 18.9 million litres (1997$) OR $310,692 per million litres.

2) The Sierra Legal Defence Fund's National Sewage Report Card (SLDF 1999) reports that 68.2 billion litres of sewage enter Halifax Harbour each year, so this estimates a daily flow of 187 million litres.

3) Based on this estimate, the capital costs for additional treatment are $58,099,404 or $58.1 million.

This is a crude estimate of the nutrient cycling service that is provided by aquatic ecosystems. The ability of the harbour's ecosystem to function and provide services is dependent on its health. Therefore, remediation and restoration of the harbour will protect its natural services. This estimate is a valuation based on a replacement cost for the additional capital to build a sewage treatment plant with some nutrient removal ability.

Thus, this estimate is a simple one-time capital cost estimate and includes neither the on-going annual service of nutrient cycling that is provided by the harbour, nor the numerous other ecosystem services provided by marine environments (see pages 33-34, and 40-41 above)**. It should therefore be understood as extremely conservative.**

Appendix 3: Chemicals That Have Known or Suspected Endocrine Disruptive and Reproductive Effects

(Report recommends discharge into Halifax Harbour should be prohibited)

Heavy Metals

- Cadmium - nickel/cadmium batteries, plastics (coatings, pigments), alloys
- Lead - lead batteries, paints, pipes, under-sealing of cars, leaded crystal, fishing sinkers and shotgun shot
- Mercury - some production of chlorine; and nickel/cadmium batteries

Pesticides (commercial and/or domestic)

- Fungicides - e.g. benomyl, hexachlorobenzene
- Herbicides - e.g. 2,4-D**,** atrazine
- Insecticides and Nematocides: - e.g. aldicarb, DDT/DDE/DDD, dieldrin, lindane

Persistent Organochlorines

- Dioxins and Furans - unwanted by-products of the manufacture and industrial use of chlorine (e.g. production of PVC plastic and chlorine-bleached paper, and incineration of chlorine contaminated waste, including sewage sludge)
- Polychlorinated biphenyls (PCBs) - production banned in many countries, but PCBs were widely used for decades in electrical transformers, varnishes, inks, carbon-less copy paper, pesticides, and weather-proofing and fire resistant coatings for wood and plastic
- Hexachlorobenzene (HCB) - by-product of processes involving organochlorines or elemental chlorine
- Pentachlorophenol - fungicide used on textiles and as a wood preservative

Plastics Ingredients and Surfactants

- Bisphenol A - a breakdown product of polycarbonate plastic (food cans, dental fillings);
- Phthalates/Polycarbons/Styrenes - used to make plastic soft and flexible;
- Penta- to Nonylphenols - used in detergents, shampoos and other personal care

products; pulp and paper, and textile industries; some plastic products, paints, pesticides, herbicides, and spermicides.

Aromatic Hydrocarbons

- Polycyclic aromatic hydrocarbons (PAHs) **-** products of incomplete combustion of fossil fuels.

Glossary

Aeration: Any active or passive process by which intimate contact between air and liquid is assured, generally by spraying liquid in the air, bubbling air through water, or mechanical agitation of the liquid to promote surface absorption of air.

Aerobic: Characterizing organisms able to live only in the presence of air or free oxygen, and conditions that exist only in the presence of air or free oxygen.
Contrast with anaerobic.

Aerobic processes: aerobic bacteria use oxygen to decompose organic matter, resulting in mostly organic cell mass and heat. Contrast with anaerobic processes

Algae: Simple rootless plants that grow in sunlit waters in relative proportion to the amounts of nutrients available, and provide food for fish and small aquatic animals.. Algae are photosynthetic microorganisms that can produce oxygen and organic mass from inorganic chemicals. When nutrient levels are elevated due to agricultural and urban run-off, they can affect water quality adversely by lowering the dissolved oxygen in the water.

Algae blooms: Rapid growth of algae on the surface of lakes, streams, or ponds; stimulated by nutrient enrichment.

Anaerobic processes: anaerobic bacteria use electron acceptors rather than oxygen to decompose organic matter, resulting in more end products such as methane, ammonia, and hydrogen sulfide than aerobic processes.

Aquatic ecosystem: Basic ecological unit composed of living and nonliving elements interacting in an aqueous environment.

Benthic community: All the plant and animals living on or closely associated with the bottom of a body of water.

Bioaccumulation: A term used to describe a process that occurs when levels of toxic substances increase in an organism over time, due to continued exposure. Sequestration of metals or chemicals in living tissue, such as PCBs in fatty tissue, increases over time with continued exposure.

Biological (Biochemical) Oxygen Demand (BOD) :The amount of dissolved oxygen required for the bacterial decomposition of organic waste in water. When bacteria come in contact with organic material they will utilize it as a food source. The amount of oxygen used in this process is called the biological or biochemical oxygen demand. It is considered to be a measure of the organic content of waste, and represents the amount of oxygen required to stabilize waste in a natural environment.

Carcinogen: Cancer-causing chemicals, substances or radiation.

Coliform bacteria: A group of bacteria used as an indicator of sanitary quality in water. Exposure to these organisms in drinking water causes diseases such as cholera.

Combined sewers: A sewer that carries both sewage and storm water runoff.

Contaminant: Any physical, chemical, biological, or radiological substance or matter that has an adverse affect on air, water, or soil.

Contaminated Sediments: Particles of matter on the bottom of water bodies that contain toxic contaminants.

Dioxin: Any of a family of compounds known chemically as dibenzo-p-dioxins. Concern about them arises from their potential toxicity and contamination in commercial products.

Discharge: In the simplest form, discharge means outflow of water. The use of this term is not restricted as to course or location, and it can be used to describe the flow of water from a pipe or from a drainage basin.

Dissolved oxygen (DO): The amount of oxygen freely available in water (not chemically combined), and necessary for aquatic life and the oxidation of organic materials. Oxygen dissolved in water, wastewater, or other liquid, is usually expressed in milligrams per liter, parts per million, or percent of saturation.

Dissolved solids (DS): Very small pieces of organic and inorganic material contained in water. Excessive amounts make water unfit to drink or limit its use in industrial processes.

Ecosystem: A system formed by the interaction of a group of organisms and their environment.

Effluent: The sewage or industrial liquid waste that is released into natural water by sewage treatment plants, industry, or septic tanks.

Estuary: Regions of interaction between rivers and near-shore ocean waters, where tidal action and river flow create a mixing of fresh water and saltwater. These areas may include bays, mouths of rivers, salt marshes, and lagoons. These brackish water ecosystems shelter and feed marine life, birds, and wildlife.

Fungi: Multi-cellular, nonphotosynthetic microorganisms.

Hazardous materials: Anything that poses a substantive present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.

Heavy metals: Metallic elements with high atomic weights, e.g., mercury, chromium, cadmium, arsenic, and lead. They can damage living things at low concentrations and tend to accumulate in the food chain.

Nutrient: As a pollutant, any element or compound, such as phosphorus or nitrogen, that fuels abnormally high organic growth in aquatic ecosystems (e.g. eutrophication of a lake).

Pathogenic microorganisms: Microorganisms that can cause disease in other organisms or in humans, animals, and plants.

Pathogens: Disease-causing agents such as bacteria, viruses and parasites.

PCBs: Polychlorinated biphenyls, a class of persistent organic chemicals that bioaccumulate.

Plankton: Tiny plants and animals that live in water.

Pollutant: (1) Something that pollutes, especially a waste material that contaminates air, soil, or water. (2) Any solute or cause of change in physical properties that renders water unfit for a given use.

Protozoa: Single-celled animals that reproduce by binary fission.

Recyclable: Refers to such products as paper, glass, plastic, used oil, and metals that can be reprocessed instead of being disposed of as waste (e.g. reuse of silver in photo-processing).

Restoration: The renewal or repair of a natural system so that its functions and its qualities are comparable to its original, unaltered state.

Salinity: The concentration of salt in a body of water.

Sewage: The waste and wastewater produced by residential and commercial establishments and discharged into sewers.

Sewage system: Pipelines or conduits, pumping stations, force mains, and all other structures, devices, and facilities used for collecting or conducting wastes to a point for treatment or disposal.

Sewer: A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream.

Sewerage: The entire system of sewage collection, treatment, and disposal.

Sludge: A semi-solid residue from any of a number of air or water treatment processes.

Solvent: Substances (usually liquid) capable of dissolving or dispersing one or more other substances.

Storm sewer: A system of pipes (separate from sanitary sewers) that carry only water runoff from building and land surfaces.

Suspended sediment: Sediment suspended in a fluid by the upward components of turbulent currents, moving ice, or wind.

Suspended solids (SS): Defined in waste management, these are small particles of solid pollutants that resist separation by conventional methods. Suspended solids (along with biological oxygen demand) are a measurement of water quality and an indicator of treatment plant efficiency.

Toxic: Harmful to living organisms.

Urban runoff: Storm water from city streets and gutters that usually contains a great deal of litter and organic and bacterial wastes that discharge into the sewer systems and receiving waters.

Wastewater: Water that carries wastes from homes, businesses, and industries; a mixture of water and dissolved or suspended solids.

Wastewater treatment plant: A facility containing a series of tanks, screens, filters, and other processes by which pollutants are removed from water.

Water (H_2O): An odourless, tasteless, colourless liquid formed by a combination of hydrogen and oxygen; forms streams, lakes, and seas, and is a major constituent of all living matter.

Water conservation: The care, preservation, protection, and wise use of water.

Water contamination: Impairment of water quality to a degree that reduces the usability of the water for ordinary purposes or creates a hazard to public health through poisoning or the spread of diseases.

Water Pollution: Generally, the presence in water of enough harmful or objectionable material to damage the water's quality.

Water quality: A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

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