FRAMEWORK FOR EVALUATING RESPONSE OF AQUATIC TOXICITY AND FISH HABITAT TO WATER QUALITY CONTROL IN THE DON RIVER – SUPPORTING DOCUMENT #2: STRATEGY FOR IMPROVEMENT OF DON RIVER WATER QUALITY

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Report prepared for:
Steering Committee
Toronto Area Watershed Management Study

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EXECUTIVE SUMMARY

The study "Strategy for Water Quality Management in the Don River" evaluates the costs and effectiveness of different source control strategies in the Don River Watershed. The change in concentration of 6 water quality parameters is used as the main instrument for evaluating effectiveness.

This supporting document presents a framework for evaluating the effectiveness of control from a broader perspective. The potential response of the Don River Fishery and the potential response of toxicity to water quality management are evaluated. The framework uses an ecosystem-based set of goals for management of the watershed. The framework is the basis for developing a levels of protection approach to establishing targets for auditing water quality improvement.

The following concepts are developed in this report:

1. Realistic fisheries objectives are developed for the Don River Watershed (see Chapter 2).

2. A toxicity model is developed to evaluate the response of the watershed to water quality control. Copper, nickel, zinc, total residual chlorine, ammonia, phenol and pentachlorophenol are included in the model (see Chapter 3).

3. A habitat suitability index (HSI) model is established as the framework for evaluating the response of the fishery to water quality management (see Chapter 4).

4. Toxicity, spills, and barrier effects are incorporated into the HSI model to make the evaluation of water quality and fisheries management more complete and robust (see Chapter 5).

5. The toxicity model is related to pathways concepts and to kinetic models of contaminant uptake (see Chapter 7).

The evaluation of aquatic toxicity is based upon chemical concentration data, threshold values for acute or chronic toxicity, and the hypothesis that overall solution toxicity can

be quantified using a linear addition of toxicity associated with the individual chemicals. The aquatic toxicity model and the effects of spills and barriers were incorporated into the HSI model using the same hypothesis of the HSI model involving numerical multiplication of various factors included in the model.

Based upon the analysis of this report, the following conclusions are drawn (see Chapters 5, 6 and 8):

1. Smallmouth bass are a good fish species to be used as an indicator of a guild of quality, warmwater fish species.

2. The overall habitat of the upper and middle Don River is moderately suitable for a target warm water fish species, smallmouth bass. The habitat of the lower river is unsuitable for smallmouth bass.

3. The major limiting factor to the fishery of the lower river is toxic components. These include sub-lethal concentration effects associated with total residual chlorine and ammonia from the STP, spills and combined sewer overflow discharges.

4. A second major limiting factor is the bottom physical habitat of the middle and lower river including concrete lined open channels in the middle river, and the silty bottom in the back water areas of Lake Ontario. Otherwise, the bottom physical habitat is reasonably good due to the gradient of the river.

5. Toxic components in other portions of the river system (due to metals and ammonia) have some impact upon the habitat of the fishery, but they are approximately of equal importance to other habitat factors such as variations in water levels and canopy in limiting the fishery.

6. Management of the STP effluent, CSO's and spills in the lower river will have the largest immediate impact upon improving the habitat of the lower river.

7. Mitigating measures involving restoration of canopy and riparian vegetation should have a significant effect upon improving the quality of the fishery.

Additional analyses would improve the information presented in this report. They include the following:

1. The effectiveness of stormwater management needs further modelling analyses to confirm the changes postulated to occur in this report. It would appear to be particularly important for metals in the upper and middle zones of the river and for turbidity control throughout the river system.

2. Water quality management of stormwater has a significant effect upon other water resource issues than strictly water quality, fisheries and ecosystem health. These issues include the effects of water quantity control upon:

   - baseflow rates, and groundwater hydrology;
   - baseflow temperatures;
   - peak flow rate, volume of flow, and magnitude of flow; and
   - streambank erosion (using frequency of bank-full flow as an indicator).

   These issues have been assessed in a screening way in this study but additional analysis is required.

3. The measurement of aquatic toxicity and chemical characterization of water samples from various sources in the Don River watershed (riverine water; CSOs, stormwater discharges, North Toronto STP) is required to check the toxicity unit model presented in this report and to assist in interpreting whether a TU value of 1.0 or other values represent toxic conditions.

4. Additional verification data are required to confirm the importance of spills and toxicity relative to other physical and chemical habitat variables in the HSI model.

5. A comprehensive fisheries management plan should be developed for the Don River. It could use the HSI model as the management tool and the IBI model as the measure of the success of the plan. The fisheries management plan would need to include changes in water quality, since water quality components are major limiting factors in the health of the fishery in the Don River. The work of this report provides a basis for developing such a plan.

6. An ecosystem-based strategy for the Don River System involving evaluating all biological niches and their interrelationships to human beings in an integrative framework would be an appropriate method for improving the findings of this study. An ecosystem-based framework was used to develop a levels of protection approach to establishing targets for improvement in water quality in this report. A continual updating and rephrasing of both the ecosystem-based framework and levels of protection approach, especially after public comment upon this study, "A Strategy for Improvement of Water Quality in the Don River", is recommended.

FOREWARD

Study Background

In 1981, the Ontario Ministry of the Environment (MOE) began a study of water quality in the Don River, Humber River and Mimico Creek to provide baseline data to guide future studies. The following year, the Toronto Area Watershed Management Strategy Study (TAWMS) was initiated as a comprehensive and co-operative multi-agency undertaking towards the attainment of water quality improvements.

The TAWMS study objectives are:

- To better define water quality conditions with the study area;
- To analyse the cause and effect relationships for problem constituents and areas; and
- To develop cost-effective measures for controlling pollutant loadings to the study area's receiving waters based on watershed needs and users.

Although wholly funded by MOE, TAWMS receives extensive co-operation and support from the Metropolitan Toronto and Region Conservation Authority (MTRCA), Metropolitan Toronto and area municipalities.

The TAWMS study is managed by a Steering Committee which includes representatives of the following:

Ontario Ministry of the Environment
Ontario Ministry of Natural Resources
Metropolitan Toronto & Region Conservation Authority
Environment Canada
Metropolitan Toronto
Borough of East York
City of Etobicoke
City of North York
City of Scarborough
City of Toronto
City of York
Regional Municipality of York
Regional Municipality of Peel
Town of Richmond Hill
Town of Vaughan
Town of Markham

A detailed study of the Humber River was carried out during the period 1982 to 1985. In 1986, the TAWMS Steering Committee released a Management Plan for the Humber River. Recommendations which were outlined in this plan are presently being implemented.

The TAWMS Don River Water Quality Improvement Study was commissioned as an external contract to Paul Theil Associates Limited and Beak Consultants Limited in the spring of 1988. The study's mandate was to summarize water quality problems, relate these problems to sources and to provide a range of improvement actions leading to various levels of control for water quality improvements. Options investigated for water quality improvement range from no further degradation to the full restoration of water quality in the Don River. The findings were presented as alternatives or staged management strategies which will lead to several milestones or levels of water quality improvement.

The improvement strategy incorporates findings from previous investigations of low flow and storm event conditions, snow melt, the status of biological communities and general water quality conditions within the Don River.

Public consultation on a number of strategies for water quality improvement for the Don River, combined with inputs from a range of municipalities and agencies will provide valuable direction for drafting the final Don River Management Plan. Improvement strategies outlined in this report for the Don River and other rivers which drain into the waterfront will be considered in context of the Metro Toronto Remedial Action Plan (RAP), a provincial-federal initiative for protecting water quality in Toronto's waterfront.

Implementation considerations and costs are important components in this option selection/consultant process, since they identify in simple terms what it will take to achieve a range of improvements and benefits or designated uses of the Don River. This consultation process will also recognize the will of municipalities, government agencies, developers and the public to support selected undertakings to protect and enhance water quality in the Don River.

The time span in which water quality improvements are to be derived and the ultimate costs will depend upon the levels of protection and the phasing of controls selected on the basis of public feedback and agency and municipality endorsement. It is recognized that effective improvement actions in the Don River watershed will also require creative solutions and new approaches by the municipalities and government agencies.

In addition to the remedial measures proposed in the strategy, a number of immediate actions are presently underway to address water quality problems by means of regular municipal and conservation authority works and maintenance programs, or through Ministry of the Environment programs such as the Waterfront Water Quality Improvement Program which funds physical work on the watercourses, waterfront or sewers yielding immediate benefits.

This document is Supporting Document 2 for the study. The complete set of study reports are as follows.

1. STRATEGY FOR IMPROVEMENT OF DON RIVER WATER QUALITY: SUMMARY REPORT

2. SUPPORTING DOCUMENT NO. 1: QUANTITATIVE METHODOLOGY FOR ESTIMATING RESPONSE OF DON RIVER TO WATER QUALITY CONTROL

3. SUPPORTING DOCUMENT NO. 2: FRAMEWORK FOR EVALUATING RESPONSE OF AQUATIC TOXICITY AND FISH HABITAT TO WATER QUALITY CONTROL IN THE DON RIVER

4. SUPPORTING DOCUMENT NO. 3 METHODOLOGY FOR EVALUATING IMPACTS OF SPILL REMEDIATION AND OTHER REMEDIAL OPTIONS UPON DON RIVER WATER QUALITY

5. SUPPORTING DOCUMENT NO. 4: PROBLEM DEFINITION: PRESENT STATE OF WATER QUALITY IN THE DON RIVER

6. SUPPORTING DOCUMENT NO. 5: ANALYSIS OF WATER QUALITY DATA FOR THE DON RIVER

Availability of Reports

Copies of the Supporting Documents and the Summary Report for the Strategy for Improvement of Don River Water Quality are available through the:

Public Information Centre
Water Resources Branch
135 St. Clair Avenue W.
Suite 100
Toronto, Ontario
M4V 1P5
(416) 323-4321

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APPENDIX 2: Environmental Pathways Modelling as a Tool for Assessing the Response of Fisheries Resources and of Human Health to Water Quality Control in the Don River Watershed

1.0 INTRODUCTION

1.1 Ecosystem Based Water Management Plan

There are a number of alternative approaches to setting environmental criteria against which future changes can be assessed or measured and accepted or rejected. The one most commonly used is to establish individual criteria for a number of physical or chemical parameters of water quality or flow regulation at levels which are arbitrarily felt to be "environmentally acceptable". A more contemporary approach has been to adopt the ecosystem concept for natural systems in which plant or animal communities or individual species are identified as being representative of a set of environmental criteria to be maintained or established. This has the advantage of integrating physical, chemical and biological elements of the environment toward a measurable and desirable endpoint, that of supporting a biological community or species. Physical or chemical criteria are not set arbitrarily, but rather relate to the habitat needs of the representative species selected.

1.1.1 Definition of Ecosystem Approach to Planning

An ecosystem is composed of various biological niches within the watershed and the interacting elements of water, air, land and living organisms, including man. An "Ecosystem Approach" to Planning is based upon using these various biological/physical niches as the fundamental building blocks for planning.

An ecosystem approach may be defined as the following:

(i) it uses the various biological niches of the watershed as the basic building blocks of the plan;

(ii) it uses natural rates of cycling of material between water, air and land as one basis for defining unpolluted conditions;

(iii) it views various living organisms including man as the basic biological building blocks of the plan;

(iv) it defines pollution as an unbalanced ecosystem resulting from accelerated rates of cycling of matter or from the entry of toxic substances into these cycles which cannot be tolerated by particular plants or living organisms including man; and

(v) the ecosystem provides the integrative framework for relating various human activities to the non-human parts of the ecosystem.

1.1.2 Cycles of Mass Between Water, Air and Land

An ecosystem approach to water quality planning recognizes the effect of cycles of material upon the various biological niches of the watershed and the linkage of humans to these cycles. It describes the elements of an ecosystem approach; the social, philosophical and ecological basis for the approach; and its advantages.

It necessitates explicit recognition of the exchange of materials between these building blocks. The exchange of material which has conventionally been recognized in Water Resources Planning is the transport of water through the atmosphere, and subsequent rainfall.

The material exchange explicitly recognized in water quality management is the discharge of fecal material, nutrients, suspended solids, trace metals and toxic organics to the receiving water after partial or incomplete treatment. Implicitly recognized is food production, mining, paper production etc. in other watersheds and the transport of these "raw materials" into an urban basin to form building blocks for the wastes subsequently discharged.

An ecosystem approach to planning "necessitates explicit recognition of the transport of materials such as atmospheric pollutants into and out of the Basin". The ecosystem approach provides the philosophic basis for a view of man as part of nature. It directs the efforts of 'different human institutions, industries and government agencies' toward treatment of the patient (the Ecosystem) rather than the symptoms of the disease. It relates the biological and technological activities of man to the carrying capacity of the Ecosystem".

These transfers of matter have led the International Joint Commission and others to advocate the use of Ecosystem principles for establishing and effecting management plans.

1.1.3 Aspects of Ecosystem Approach Evaluated in this Document

The application of an Ecosystem Approach to the Don River Water Quality Improvement Strategy requires that a holistic Ecosystem based strategy first be adopted. The ecosystem based strategy would take the perspective of perhaps a 50 year planning horizon. Then from this plan, a short term plan (with perhaps a 5-10 year planning horizon) and a long-term plan (with a 20 year planning; and/or a 50 year planning horizon) would be developed for Water Quality Management.

An Ecosystem Approach to planning is difficult to do unless it includes all elements of the ecosystem. A complete analysis is based upon fisheries, water quality, terrestrial habitat, human values (such as human health, human safety, economic development and recreation), and erosion and flood control. It sets priorities for these ecosystem and human values.

The study, documented in this supporting document, evaluates two crucial elements of the riverine portion of the ecosystem.

- o fisheries
- o aquatic toxicity (as a surrogate for deleterious impacts of degraded water quality upon biota in the riverine ecosystem)

Ecosystem principles were used to develop a framework (see Table 1.1) to assist in evaluating the Don River fishery in the form of water quality and environmental quality goals for the Don River system. These are given in Appendix I in the form of a discussion which resulted from several meetings of a fisheries working group.

TABLE 1.1: CONCEPTUAL DIVISIONS FOR ECOSYSTEM-BASED MANAGEMENT PLAN

1. Quality of Life Within Great Lakes Ecosystem

- linkage to Great Lakes ecosystem
- pride in Don River ecosystem
- balance of economic and environmental value
- quality of life and land ownership

2. Fisheries, Riparian and Terrestrial Habitats

- river beds as fish habitat
- angling
- enjoyment of pants, wildlife
- wildlife and waterfowl and their habitats

3. Water Quality, Public Health and Aesthetics

- contact, non-contact recreation
- drinking water
- fish consumption
- aesthetics

4. Public Safety

- erosion and flood protection
- risk to life in valley lands

1.2 Fishery As An Integrator of Ecosystem Quality

1.2.1 The Fishery as an Element of the Ecosystem

A food web involving various biological niches interacting in a balanced way is an indication of a healthy aquatic environment. The presence of abundant numbers of various predatory fish species are also key indicators, as it is essential that the food web be balanced and that the habitat be suitable in order to sustain and nurture such a fishery.

The fishery in a river system and the associated water quality are elements of the riverine ecosystem which are contained in the water flowing within the river banks. The river system also interacts with other ecosystem components. This occurs through the hydrological cycle, transfers of matter through atmospheric pathways, discharge of the riverine water to a Lake Ontario, importation of various raw and finished products into the watershed by humans, and discharge of wastes from human systems to the river.

1.2.2 Framework for Evaluating Response of Fishery to Water Quality Management

There are various models which can be used as indicators of a quality environment, including biological models such as the Index of Biologic Integrity (IBI), and habitat models such as the Habitat Suitability Index (HSI) model.

The Habitat Suitability Index model provides a tool for management by being able to relate instream conditions to causes of poor or good water quality, causes of poor or good flow rates and the presence or absence of suitable physical habitat. The IBI is not a management tool. Rather, it is response variable, a measure of a successful management plan. Accordingly, the HSI approach is used in this report as the tool for evaluating the present fishery in the Don River and the potential effectiveness of water quality control upon enhancing the fishery.

In previous work on several rivers in the Toronto Watershed area, (e.g. Steedman, R.J.; 1987; BEAK, 1988) it is clear that there is a strong correlation between the HSI model for several species and the IBI. Where there is excellent habitat with ample food and good clear water flowing over the bottom habitat, a well balanced ecosystem exists (e.g., the Rouge River). Where there is poor habitat and poor water quality, then the IBI describes a poor, improvershed biological system devoid of many fish species (e.g., various sections of the Don River).

1.2.3 Description of Habitat Suitability Index Models

In the fisheries management field, a set of Habitat Suitability Index (HSI) models have been developed for major North American fish species which incorporate virtually all habitat information available in the scientific literature. The purpose of the HSI model is to identify important habitat variables for each species which can be used for impact assessment.

The HSI model provides a habitat information for evaluating impacts on fish habitat resulting from water or landuse changes. The impetus for the development of these models was the Habitat Evaluation Procedures (U.S. Fish and Wildlife Service, 1980), a planning and evaluation technique that focuses on the habitat requirements of important fish species.

Most fisheries databases contain an array of habitat and population information, but are descriptive in content. The HSI models are unique in that they are constrained to habitat information only, with an emphasis on quantitative relationships between key environmental variables and habitat suitability. In addition, the HSI series synthesizes habitat information explicity into habitat models useful in quantitative assessment.

The series of HSI models reference numerous literature souces in an effort to consolidate scientific information on species-habitat relationships. The models provide a numerical index of habitat suitability on a 0.0 to 1.0 scale, based on the assumption that there is a positive relationship between the index and habitat carrying capacity. The models vary in generality and precision, due in part to the amount of available quantitative habitat information and the frequent qualitative nature of existing information. When possible models are included that are derived from site-specific population and habitat data.

The models present hypotheses of species-habitat relationships, which vary from one geographical area to another, and must be adapted to the specific environmental conditions being considered. As well, the models consider habitat needs for different life stages or functions, such as spawning, juvenile rearing or migration.

1.2.4 Application of HSI Model to Don River

To apply the HSI model to a watershed, either one or more fish species must be selected for evaluation, as the HSI model is species specific. In the report, one species is selected which represents a group of quality fish species. The selection of target species are given in Sections 2 and 4.

1.2.5 Addition of Aquatic Toxicity Concepts to HSI Model

For evaluating the Don River, the HSI model has one major limitation, it does not evaluate all toxic substances found in a river. It includes the primary toxic condition - the lack of adequate oxygen resources for respiration. A toxicity model for several substances is formulated in Chapter 3 and incorporated into the HSI model in Chapter 5.

1.3 Relationship of Fisheries Management to Human Based Beneficial End Uses

The fishery of the Don River is one major beneficial end use of any water quality improvement strategy. Coupled with swimming and drinking water objectives, the protection of aquatic biota are then three of the major bases which are used to set water quality guidelines (criteria or objectives). Aesthetics is a fourth major basis for water quality management.

Based upon these considerations, an approach of different levels of protection has been developed for three major areas of water quality protection. They are:

(i) Public health (contact, non-contact recreation; drinking water).
(ii) Fisheries.
(iii) Aesthetics.

The suggested levels of water quality required to achieve different degrees of water quality are given in Tables 1.1, 1.2 and 1.3. These levels were developed in part as a result of the discussion paper given in the Appendix. The philosophy used is that, due to the extreme deterioration of water quality in the Don, an incremental approach to attaining PWQO's is in order. These levels of protection then provide one with an ability to measure achievements over time.

1.4 Physical Setting for Water Quality Evaluations

The Don River has a variety of watershed characteristics and branches. The two principle branches are the West Don and East Don which join near the confluence with Massey Creek to form the Lower Don (see Figure 1).

1.4.1 Reaches Used in Study for Water Quality Evaluation

The following reaches were used for evaluation of their water quality (see Summary Report):

Area of Don	Reach	
West Don	1.	West Don Above Langstaff Road
	2.	West Don to Confluence with Wilkett Creek
	3.	Wilkett Creek
	4.	West Don from Wilkett Creek to Main Don Confluence
East Don	5.	East Don Above Langstaff Road
	6.	Little Don Above German Mills Creek
	7.	German Mills Creek
	8.	Lower East Don, German Mills to Confluence
Lower Don	9.	Massey Creek
	10.	Lower Don from confluence to STP
	11.	Lower Don from STP to Keating Channel

The Keating Channel and Inner Harbour were not considered directly in this study. They are considered indirectly by the study objective of achieving water quality objectives at the upper end of Keating Channel and the role they play in influencing fish migration from the lake to the river.

1.4.2 Priority Reaches

To allow us to relate the effectiveness of water quality to other factors, these 11 reaches were futher prioritized (see Supporting Document 1). They are a representative

DON RIVER WATERSHED
FIGURE 1

----WATERSHED BOUNDARY

TABLE 1: LEVELS OF PROTECTION FOR CONTACT AND NON-CONTACT RECREATION

Degree of Protection	WQ Parameters of Concern	Level of Water Quality Control	Control Options or Further Studies Required to Achieve Degree of Protection
1. Status Quo - Incidental contact with water produces skin rashes etc. but no direct, known human diseases.	o Fecal coliforms	o Existing WQ in river with no further decline to development. o No increase in loadings to lake.	o Control FC discharges with ponds in new developments to less than 100 FC/100 mL, 90% of the time. This may involve full capture of small events; and disinfection of overflow in each pond by U.V.
2. Limited Aesthetic and Water Quality Improvement - Incidental contact produces no skin rashes nor known human diseases. - Non body contact recreation. - Increase compliance with RAP.	o Fecal Coliform	o Improvement in colour and turbidity. o Minimize discharges of rash causing substances. o 10% decrease in FC discharges to lake.	o Carry out studies to evaluate the risk of non-contact recreation. o Ponds or infiltration trenches in new developments. o Control 50% of CSO discharges. o Ponds or infiltration trenches in redevelopment (e.g. St. Lawrence Square).
3. Substantial WQ Improvement A. Incidental swallowing of water during non body contact recreation in river. (e.g. wind surfing, canoeing) B. Body contact recreation in reservoirs and ponds. C. Partial compliance with RAP.	o Fecal Coliforms	o Decrease FC levels in river by 50%. o Meet quality standards in reservoirs for all conditions except after 10 mm rainfall and greater. o 50% decrease in FC discharge to lake.	o Carry out studies to evaluate the risk from incidental swallowing of river water. o Control 90% of CSO discharges. o Reduce bacti discharges from 25% of storm o sewers o apply above options for industrial, new and redevelopment.
4. Body Contact Recreation A. Reservoirs - short term and long term B. River - dry weather periods C. Lake - meet RAP objectives	o Fecal Coliforms o Pseudomonas Aeurginosa OR	o Meet quality standards in reservoir swimming areas 90-95% of the time. o Meet quality standards in river 48 hr. after rain storm. o Decrease FC discharge to L. Ontario by 90%. o Meet RAP objectives for Island Beaches (this may involve a discharge of 3000-5000 FC/100 mL at mouth of Don River).	o Determine which of the WQ control levels is limiting. o Disinfection of discharges from new developments and reservoirs. o CSO discharges limited to 1-5% of time. o Control bacti discharges from 50% of storm sewers. o Establish appropriate RAP objectives; change 90% as necessary.
5. Body Contact Recreation At All Times A. Meet standards in river - Everywhere - All the time B. Meet RAP Objective	o Fecal Coliform o E. coli o Pseudomonas Aeurginosa	o Meet quality standards for all conditions except certain small fraction (e.g. 5%).	o Control of all CSO's. o Control of all storm sewers.

TABLE 2: LEVELS OF PROTECTION FOR FISHERY ENDUSE

Degree of Protection	WQ and HSI Parameters of Concern	Level of WQ and Fishery Control	Control Options or Further Studies Required to Achieve Degree of Protection
1. Status Quo	o Aesthetic Parameters o DO o TP o SS o Metals	o Existing WQ without further decline due to development.	o No infilling of intermittent order 1 streams and order 1 streams to provide food source for downstream fishery. o Protection of existing red side dace habitat and MNR maple hatchery areas. o Wet ponds in new development.
2. Limited WQ, Fishery and Aesthetic Improvement	o Aesthetics - lumps - colour - smell o Conventional WQ parameters o TP o BOD	o No transmittable diseases in fish. o Continue present BOD control. o Reduce TP 20%. o No visible solids/lumps/debris/scum. o No significant smell. o Reduce.	o Improve spills control. o Minimize frequency of CSO's discharges. o Reduce TP discharges through ponds or other devices. o Enhance canopy cover in upper and middle watershed.
3. Urban Sports Fishery in Upper River, Reservoirs and Ponds	o Fish Habitat - physical . Q, temp. . rubble; pool riffle o Chemical - Metals: Cu, Zn, Hg - Organics - PCB's - DO, pH - TRC, NH_3	o No fish tainting. o Adequate bottom habitat for internal migration. o Meet HSI parameter levels. o Non toxic water in relevant water bodies. o Adequate food sources. o Meet fish consumption guidelines for smallmouth bass most of the time.	o No spills in upper watershed. o Control of 90% of CSO discharges. o Rubble, pool/riffle habitat throughout upper watershed. o Removal of all concrete channels. o HSI study to define other needs. o Enhance canopy cover over 75% of watershed.
4. Warm Water Fishery Throughout Don River	o Fish Habitat - physical . Q, temp. . rubble; pool riffle o Chemical - Metals: Cu, Zn, Hg - Organics - PCB's - DO, pH - PRC, NH_3	o Same as 3 above throughout Don River. o Meet PWQO's for warm water fishery for protection of aquatic life. o Non-toxic water throughout watershed. o Meet fish consumption guidelines for smallmouth bass.	o No spills throughout watershed except 5%. o CSO removal from watershed. o Appropriate bottom habitat throughout the whole river. o HSI study to define other needs. o Enhance canopy cover over whole watershed.
5. Migrating and Warm Water and Hatchery Maintained Cold Water Fishery in Lower Reaches; Self-Sustaining Cold Water Fishery in Particular Tributaries (i.e., Maple MNR)	o Same as 3 above	o Same as 3 above for warm water fishery. o Meet PWQO's. o Temperature less than 22°C at all times in major pools of river reaches containing a cold water fishery o Reduce sublethal toxic.	o Same as 4 above, plus o Canopy cover along all order 2 and 3 streams (including channelized and storm sewered areas).

TABLE 3: LEVELS OF PROTECTION FOR AESTHETICS

Degree of Protection	WQ and Other Parameters of Concern	Level of Water Quality and Landscape Architecture Control	Control Options or Further Studies Required to Achieve Degree of Protection
1. Status Quo	o Riverine aesthetic parameters - colour during dry weather - spills and event related colour - turbidity o Valley aesthetics - vegetative cover - cleanliness - decrease of debris	o Existing WQ without further decline due to new development.	o Develop plan involving landscape, vegetation, land-based biota, ESA's, and any marshes. o Establish aesthetic standards required for level 5.
2. Limited WQ and Aesthetic Improvements	o Riverine aesthetic parameters - colour during dry weather - spills and event related colour - turbidity o Valley aesthetics - vegetative cover - cleanliness - decrease of debris	o No visible solids/lumps/debris/scum. o No significant smells. o Partial improvement of valley aesthetics. o Decrease slimes and other growths. o Limited canopy improvement.	o Improve spills control o Minimize frequency of CSO discharges. o Reduce TP discharges through ponds or other devices. o Decrease TP discharge from STP by 50%.
3. Significant Improvement in Aesthetics of River and Water and Valley	o Riverine aesthetic parameters - colour during dry weather - spills and event related colour - turbidity o Valley aesthetics - vegetative cover - cleanliness - decrease of debris	o Reduce SS discharges from all construction. o Reduce SS discharges by 50% for storms of 5 mm and smaller. o Eliminate 50% of slimes. o Establish required canopy in 50% of valley system.	o No spills in upper East/West Don; spills control in Lower Don. o Control 90% of CSO discharges. o Reduce TP discharges from 25% of storm sewers. o Vegetation, setbacks, and shoreline enhancements.
4. Valley Aesthetics Acceptable, Periodic Problems With Aquatic Aesthetics	o Riverine aesthetic parameters - colour during dry weather - spills and event related colour - turbidity o Valley aesthetics - vegetative cover - cleanliness - decrease of debris	o Reduce SS discharges by 90% for storms of 10 mm and smaller. o Reduce slimes by 90%. o Improve water colour from grey colour. o Establish required canopy in all of valley system.	o Spills throughout watershed minimized to 1-5% of current levels. o CSO discharges minimized to a few events/year; partial treatment of these overflows o Reduce TP discharges from 50% of storm sewers o Complete vegetation installation, recreatio[illegible] development.
5. Aesthetically Acceptable by All Conventional Standards	o Riverine aesthetic parameters - colour during dry weather - spills and event related colour - turbidity o Valley aesthetics - vegetative cover - cleanliness - decrease of debris	o Control of all SS, colour, spills. o Improve valley canopy as per level 4.	o Improved spills control above level 4. o Minimize CSO discharges to one overflow/year, partial treatment of that overflow. o Reduce TP, discharges from all storm sewers by 90%. o Reduce SS solids discharge by 80-90% for all storms smaller than 20 mm by sizing ponds on all stormwater outlets. o Control of all sources.

upper non-urban catchment (West Don above Langstaff Road), a representative middle reach catchment (West Don at confluence with East Don), a representative priority tributary (Massey Creek) and the Lower Don from the STP to Keating Channel.

Similarly, for purposes of the fishery evaluation, it is impractical to cover this large number of reaches. Reaches representative of the Upper, Middle and Lower reaches accordingly were selected (see Chapter 2).

1.4.3 Water Quality Variables Selected

Six variables were selected for evaluation of the effectiveness of water quality control (see Supporting Document 1) in a quantitative manner. They are: suspended solids, total phosphorus, fecal coliforms, ammonia, copper and zinc. Only four of these variables have a direct effect on the fishery: ammonia, copper, zinc, and suspended solids (through the variable turbidity).

For evaluation of toxicity of a water to a fishery, other parameters need to be considered. They include: nickel, total residual chlorine, phenol, dissolved oxygen, pentachlorophenol, and hardness.

Other parameters required for assessment of the habitat include water temperature.

1.4.4 Evaluation of Effectiveness of Water Quality Control

All parameters are considered in the toxicity model and in the HSI model. Due to the lack of a modelling evaluation of the magnitude of the latter parameters (nickel, TRC, phenol, DO, PCP and hardness) originating from different sources, the effectiveness of water quality control can only be evaluated qualitatively for these parameters.

Accordingly, in this report only a scoping level qualitative evaluation of the effectiveness of water quality control and upon the fishery of the Don River is presented. More indepth analyses are required to produce assessments which would form the basis for implementation of fish management in the Don River system.

1.5 Emphasis of This Report

This report, thus emphasizes the following aspects of water quality related to the riverine biota:

- o A quantitative framework is developed for assessing the present fishery of the Don River, as it relates to habitat factors and aquatic toxicity factors (The emphasis is upon "framework").

- o A new idea (hypothesis) for incorporting the effects of aquatic toxicty into a quantitative fisheries model (HSI) is presented.

- o The science for quantifying aquatic toxicity is critiqued to substantiate the hypothesis; however, additional work is required to calibrate the interpretation of the quantitative relationship used to incorporate aquatic toxicity into the HSI model.

- o The potential effects of further urban developments and water quality control upon fisheries habitat and aquatic toxicity are illustrated qualitatively.

- o The framework is used to prioritize directions for water quality control for alternative disinifection methods.

1.6 Structure of Report

The evaluation of the present fishery and the effectiveness of management are developed in this report as follows:

Chapter 2: The present characteristics and management objectives for the Don River are developed in this report.

Chapter 3: A model for evaluating toxicity of the waters of the Don is developed.

Chapter 4: The HSI model for a target fish species (smallmouth bass) is applied to the Don River.

Chapter 5: Toxicity components are added to the HSI model.

Chapter 6: Impacts of further development and remediation are presented for the target fish species.

Chapter 7: The impacts of water quality control upon chemical burdens in fish are considered.

Chapter 8: An approach for integrating water quality objectives with a fish management plan is presented.

2.0 FISHERIES OBJECTIVES FOR THE DON RIVER

This section:

- identifies features limiting the distribution and abundance of fish in the Don River;

- divides the watershed into relatively homogeneous reaches; and

- develops fisheries objectives for the watershed in general, and reaches in particular.

These fisheries objectives can then be used within the framework of the Don River Water Quality Management Plan in the development of water quality and hydrologic objectives for the Don.

2.1 Background

The Don River is highly urbanized, and fisheries resources have been adversely affected by barriers, turbid waters, and siltation for well over a century. The lower watershed has been urbanized for the longest period. The upper watershed in the Town of Richmond Hill and the Town of Vaughan is strongly influenced by rapidly increasing urbanization (this area contains one of the fastest growing populations in the country) and by agriculture.

Based on D. Martin-Down's recent research and report on the Don River fishery (Martin-Downs, 1988), few of the species historically present in the river remain today. The dominant species are white sucker, blacknose dace, longnose dace and creek chub (dubbed by Martin-Downs as the "big four"). Carp enter the lower river from Lake Ontario seasonally for spawning, and other lake species such as emerald shiners also stray into the Keating Channel area. The upper river (generally north of Highway 7) is still dominated by the "big four", but a few other species are also present (McKee and Parker, 1986) including redside dace, a minnow recognized as sensitive to the effects of urbanization. A population of largemouth bass survives in the Richmond Hill Mill pond, and rock bass occur in the G. Lord Ross Reservoir on the West Don. Mottled sculpin, a species preferring cooler, high quality water and natural habitat conditions is found only in isolated headwater areas where these conditions are still found. Other species native to clean, cool southern Ontario streams, such as the brook trout and atlantic salmon, no longer occur in the Don River, except for MNR lands at Maple and isolated head water tributaries (particularly sections of the Little Don, East Don).

The Don River, particularly the lower river (south of Steeles Avenue), supports primarily small adult individuals of the "big four" species (i.e., small individuals of species which would normally grow to large adult size). It appears that this is due to the lack of physical habitat (e.g., pools, in-stream cover) for larger individuals. For example, suckers and creek chub could grow larger, but do not. The lack of adequate fish habitat, in turn, is also influenced by the high flow conditions following storm events, resulting in scouring of the stream bed.

The size of the fish is also influenced by the size of the stream. For example, blacknose dace never seem to grow larger than the type of habitat present. That is, small streams do not have the physical scale of habitat required for fish to grow to a larger size. Whether lack of habitat (pools, instream cover) or physical scale of the tributaries are the limiting factors to size of fish present requires further assessment.

Fish communities in some of the smaller streams, most notably Massey Creek, Wilkett Creek, and German Mills Creek, appear to be affected by periodic toxic spills. These have included blockages of sewers and injection of chlorine to alleviate resultant problems. The watersheds of Massey and German Mills Creeks are highly industrialized, and suspicious slugs of discoloured water have been observed during fish collection programs. Some of these areas appear to be devoid of fish life, despite apparently suitable habitat conditions for members of the "big four".

2.2 Watershed Reaches for Fisheries Objectives

The Don River watershed may be divided into several sections, based on watershed and fisheries characteristics, habitat types and stream gradient:

- Lower River - Bloor Street to Keating Channel; Keating Channel
- Middle River - Langstaff Road to Bloor Street

- o Upper River - North of Langstaff Road
- o Tributaries - Massey Creek, Wilkett Creek, German Mills Creek

The characteristics of these river sections are now described below in Sections 2.3 (Lower River), 2.4 (Middle River), 2.5 (Upper River) and 2.6 (the Tributaries). A summary of background data, etc., for each river section is given in Table 2.2.1 to 2.2.4.

In general, the fishery is limited by existing land use and its influence upon river morphology and water quality, stream gradient, and lack of riparian vegetation. The upper tributaries are agricultural lands being rapidly urbanized. Adjacent vegetation is generally non-existant. Middle sections of the river are fully urbanized while lower sections are bordered by discharges from old industrial areas, CSO and storm sewer discharges, and major transportation corridors. Some sections of the middle river have substantial canopy but not overhanging the river; the lower river is almost devoid of riparian vegetation.

2.3 Characteristics of the Lower River

The Keating Channel affords little true riverine habitat, and in some respects is like an extention of the inner harbour. The physical configuration of the channel may make the Don River unrecognizable as a river to various species. The channel is relatively uniform and there is no riparian riverbank cover. Sediments in the channel are heavily contaminated with oily residues. With its present configuration, the channel should not be expected to support a population of riverine fishes.

An appropriate fisheries objective for Keating Channel would be to provide a more stabilized flow regime and a reduction in contamination from combined sewer overflows (CSOs) and other sewers so that fish can move more readily between the lake and the river. For purposes of this study, the Keating Channel was determined to be outside the study scope and hence, is not included herein.

Upstream of the Keating Channel, the Don River passes through a parkland belt in the city core. White suckers migrate from the lake through this section in spring and successfully spawn in the riffle habitat found near Bloor Street. Carp also migrate through this section for spawning (Martin-Downs, 1988) although no evidence for successful reproduction has been found.

The minimum fisheries objective for this section is the maintenance of the status quo. Much more is required to improve the existing fishery. Achievement of this objective would require that no further increases in stream flow variation occur, and that existing riparian vegetation in the park belt be maintained. It would probably also require that loadings of contaminants that are causing apparent toxic effects in upstream tributaries, particularly Wilkett Creek and Massey Creek, not be permitted to increase and, preferably, be reduced or eliminated.

Habitat suitability index (HSI) models have been developed for various fish species by the U.S. Fish and Wildlife Services (USFWS, 1980). Habitat requirements for maintenance of the status quo or improvements in the Don River fish community can be rigorously identified using an HSI for a target species, so that the sensitivity of the lower Don fish community to changing habitat quality (streamflow, water quality) can be evaluated. The HSI identifies physical-chemical habitat features that can be predictively modelled, so that HSI sensitivity to changing streamflow-water quality can be determined. A predicted drop in HSI for any watershed development/control scenario would be incompatible with the minimum fisheries objective.

An achievable fisheries objective for this section would be the establishment of a piscivore fish population which is an indicator of a restored balanced ecosystem. A piscovore fish is one which consumes smaller fish as its main food source. Largemouth or smallmouth bass appear to be relatively tolerant of organic pollution, and may be a reasonable indication of a restored ecosystem because:

(i) they used to be there historically;

(ii) they are either not present, or have a very limited distribution presently;

(iii) the habitat conditions are appropriate for the whole life cycle of fish (spawning, rearing, feeding);

(iv) by feeding upon other fish, a balanced ecosystem/food web is required to sustain their existance.

The limiting factors for these species in the lower Don are probably the extreme variation in flows and the lack of instream cover (pools, undercut banks, brush piles, large rocks, aquatic vegetation, etc.). These species could probably be re-established through the implementation of measures to reduce peak flows and increase minimum flows, as well as to create appropriate instream habitat features in the river. The HSI can be used to define the required flow regimes for possible target species such as largemouth or smallmouth bass. An initial characterization of limiting factors is given in Section 4 by application of an HSI model.

Other limiting factors in this river section are influenced by aquatic toxicity, particularly ammonia and total residual chlorine (TRC) discharges from the North Toronto Treatment Plant. Fish have an avoidance reaction to TRC in the discharge plume before volatilization and other reactions destroy the TRC. Since the HSI model does not include toxicity, substantial efforts, documented below, were spent to include toxicity into the HSI model.

It may also be appropriate to consider the suitability of the lower Don River for seasonal use by migrating salmonid species from Lake Ontario, such as the Rainbow Trout and Chinook Salmon, as a water quality and river habitat criteria. This would provide further enhancement to the recreational fishery and the aesthetic value of the river. These species currently migrate into all tributaries of Lake Ontario where habitat conditions permit.

2.4 Characteristics of the Middle River

The characteristics of the Don River fish community in the Middle River here are similar to those in the lower river (south of Bloor Street). Throughout most of this section, the Don River consists of two major branches - the West Don and the East Don. It was felt that the same fisheries objectives identified for the lower river should apply to this stretch.

The optimum fish habitat requirements for this section require further evaluation. An initial characterization of limiting factors is given in Section 4 through application of an HSI model.

It was noted that the G. Lord Ross Reservoir on the West Don near Dufferin Avenue and Finch Avenue should be evaluated in terms of its present operation and morphometry. These two factors sigificantly influence the reservoirs habitat, but these data were not obtained at the completion of this study. Any means of optimizing its operation for controlling downstream flow and water quality should be identified, thereby helping to achieve downstream habitat conditions to meet fisheries objectives.

2.5 Characteristics of the Upper River

The upper Don River watershed is becoming rapidly urbanized. Many of the smaller streams (first and second order) are being channelized, and gently sloping floodplain areas filled in for residential, commercial and industrial development. Many of the non-developed stream valley areas are agricultural, with relatively little riparian vegetation. These streams are important in the maintenance of natural fish species and communities which continually augment or sustain fish populations in lower reaches of the river. As well, these smaller tributaries serve to regulate river flows and water quality conditions further downstream. Because of intense development pressure, as well as the higher diversity of fish in the community of the upper watershed, maintenance of the status quo will be more difficult. In many of the smaller tributaries, recent urban development (e.g., in the past 5 years) will likely require an "enhancement objective", rather than a "maintenance of the status quo" objective.

Development plans often approved several years ago also involve activities such as channelizing or piping of small streams. In many cases, developers are proposing to fill in portions of floodplain areas adjacent to small order 1 and 2 streams during construction. This strong development pressure, extremely high land values in the area, and the in-grained development practices and approvals procedures that permit the destruction of stream valleys are causing increasing losses of fish species from individual stretches and tributaries.

Implementation of the mitigative strategies in this area will be the most challenging of all areas of the Don River. A more proactive stance on the part of MTRCA, MNR, AND MOE would appear to be in order.

The MNR has a proactive stance through,

- o buffer strips,
- o no net loss policy, and
- o a commentary upon development

In addition, priority to enhancing riverine fisheries may be given to river system such as the Credit, Rouge and Duffins in comparison to the Don due to the relative quality of the existing fishery in these watersheds. A substantial problem for these agencies appears to be development of guidelines which are wholestic from an ecosystem point of view, and subsequent inspection and enforcement of these guidelines. An additional need is the development of master drainage planning areas which use a subwatershed basis (i.e., a hydrological basis) as the planning basis, rather than political boundaries (which cross subwatershed boundaries) as the planning basis.

Maintenance of the status quo should be based on the habitat requirements of the most sensitive species recognized in this area - the redside dace. A rare status has been assigned for this species to the Committee on the Status of Endangered Wildlife in Canada (MNR, internal memo, April, 1988). In all of Canada, the redside dace is known only from the Golden Horseshoe area. This species requires extensive riparian vegetation and relatively low turbidity. It is probable that the status quo can only be maintained in the upper river through elimination of channelization practices, the maintenance of buffer strips along streambeds, control of massive sediment loadings from construction areas, and the maintenance of current hydraulic regimes. The redside dace should be considered in the fish management evaluations, at least as a criteria. Final decisions upon its use whether as an indicator species or criteria need to be made in the future.

2.6 Characteristics of the Tributaries: Massey Creek, Wilkett Creek and German Mills Creek

These small streams all appear to have habitat appropriate for fish. But they have all been found to have stretches that are devoid of fish life, and are apparently affected by toxic discharges of unknown substances. The status quo option is considered unacceptable for these streams. Because habitat appears suitable but no fish are found in some reaches, re-establishment of conditions suitable for some of the more tolerant endemic fish species such as one or all of the "Big Four" is desirable for these tributaries.

The HSI approach, as it is not based on chemical toxicants, is inadequate in defining habitat requirements for these streams. The incorporation of aquatic toxicity into the HSI in this study provides a basis for evaluating habitat requirements. Meeting all PWQO's for individual chemicals (metals, etc.) most of the time, and elimination of toxic events, will probably permit the achievement of this objective since other habitat requirements appear adequate. This may be through source control, if possible, elimination of CSOs, or capture and treatment of stormwaters released between peak flow periods (when dilution may be adequate).

2.7 Fisheries Objectives for the Don River

Based upon these characteristics and targets, fishery objectives were established for each section of the Don River and are given in Tables 2.2.1 to 2.2.4. The section headings of each table are:

1. Section Boundaries
2. Fisheries Objective for Section
3. Limiting Factors to Existing Fishery
4. Collected Species
5. Target Species
6. Current Water Quality Impacts Upon Fisheries
7. Management Requirements/Focus
8. Broad Management Criteria
9. Management Philosophy for River Section Within Overall Watershed Perspective
10. Tools Available for Quantifying Impacts
11. General Priorities for River Section

TABLE 2.1: DON RIVER ABOVE LANGSTAFF

1.1 Section Boundaries

- head water reaches above Langstaff

1.2 Fisheries Objective

- status quo - fish species/habitat
- no further degradation in community structure or habitat

1.3 Limiting Factors

- riparian vegetation removal
- base flow - change small marginal stream to intermittant
- barriers to movement of fish - physical and chemical

1.4 Collected Species (Martin-Downs, 1988)

- White sucker
- Redbelly dace
- Pumpkin seed
- Yellow perch
- Mottled sculpin
- Brooke trout
- Common shiner
- Bluntnose minnow
- Fathead minnow
- Rainbow darter
- Johny darter
- Redside dace
- Large mouth bass
- Blacknose dace
- Longnose dace
- Creek chub
- Brook stickleback

1.5 Target Species

- redside dace - infrequently found due to cooler habitat/water temperature requirements - indicator of quality habitat
- sculpin - cooler water requirements and instream cover
- creek chub-plausible target species because HSI exists.

1.6 Current Water Quality Impacts

- no direct impacts discernable; indirect - loss of streams, order 1 to 3
- turbidity from construction activities will be a major future impact
- urban development impacts - temperature, decrease in low flow

1.7 Management Requirements/Focus

1) maintain buffer strips at streams for riparian vegetation/canopy

2) use of ponds to manage flows
   - reduce flood flows to lower river
   - maintain base flows to lower river
   - provide fisheries/recreational use potential
   - water quality improvement
   - sediment trap, toxic spill retention

3) limit barriers to fish movement

1.7 Management Requirements/Focus - Continued...

4) BMP's (Best Management Practice) for industrial areas - no direct industrial inputs to stormwater flows, i.e., floor drains in factories, gas stations, etc.

5) restrict stream channelization/burial

6) channel redesign to address fish habitat criteria as well as optimize land use
   - retain those channels which are natural and stable
   - redesign those which are degraded and unstable - agricultural, gravel extraction areas, etc.

7) retain existing water quality - control sedimentation during construction, eliminate chemical spills.

1.8 Broad Management Criteria - For Headwater Streams

1) maintain or improve fisheries potential of headwater streams to improve food sources delivered to middle or lower reaches

2) create "artificial" fisheries potential in headwater areas - such as in new ponds.

3) protect and enhance existing fisheries potential (the existing potential is being rapidly lost due to urbanization).

1.9 Management Philosophy of Upper Don Within a Watershed Perspective

1) Fish species selected are an indication of good water quality and a balanced ecosystem.

2) Fish species such as minnows are a food source for downstream fishery.

3) The scope for management is limited because the riverine fishery of order 1 and order 2 streams never have more than a small number of several species.

4) Use a top down watershed approach for managing headwater areas to assist in improving the lower river.

1.10 Tools Available for Quantifying Impacts

- IBI data of Steedman (1987)
- HSI for Creek Chub (USFWS, 1980)

1.11 General Priorities for Headwater Stream

1) maintain flow
2) maintain habitat
3) maintain water quality

TABLE 2.2 TRIBUTARIES: GERMAN MILLS, WILKETT CREEK, MASSEY CREEK

2.1 Section Boundaries

- Individual creeks; generally in the middle/upper reaches of the Don.

2.2 Fisheries Objective

1) improvement in stream habitat (creek chub indicator)
2) mitigate water quality impacts to main river

2.3 Limiting Factors

- chemical spills major problem
- habitat loss - channelization extensive
- barriers to fish migration (e.g., culverts; Geman Mills piped through Richmond Hill)
- high peak flows (note: base flows appear adequate for sustaining a fishery)

2.4 Collected Species (Martin-Downs, 1988)

- White sucker
- Blacknose dace
- Longnose dace
- Cheek chub
- Goldfish (exotic, but naturalized)
- Pumpkinseed

2.5 Target Species

- target species creek chub

2.6 Current Water Quality Impacts

- water quality and flow conditions major issues. This limits fish fauna even where suitable habitat remains. Some good habitat sections remain in park areas (e.g., Edwards Gardens in Wilkett Cr.)
- the major effect may be spills of toxic substances such as ammonia and other chemicals which result in a lack of fish.
- the possibility of ammonia avoidance needs further analysis since the unionized ammonia levels in monitoring data are below PWQO's.

2.7 Management Requirements/Focus

1) spill control by ponds and other devices (see Supporting Document 3)
2) water quality improvement - industrial sources.
3) responses to above limiting factors.
4) maintain/improve riparian vegetation.

TABLE 2.2 TRIBUTARIES: GERMAN MILLS, WILKETT CREEK, MASSEY CREEK

2.8 Broad Management Criteria for Tributary Streams

- maintain or improve fisheries potential in tributary streams.
- re-establish missing species; (note: habitat appears to be there, but fish are missing).

2.9 Management Philosophy of Tributaries Within a Watershed Perspective

1) Many fish species which should be present, are not. The habitat appears adequate, suggesting that barriers or water quality may be the major limiting factor.
2) Proposed target fish species are an indicator or good water quality and a balanced ecosystem.
3) While the area requiring management is limited because of the small sizes of these creeks, the scope for management is large in terms of re-establishing a fishery resources, especially in stretches which are devoid of fish.

2.10 Tools Available for Quantifying Impacts

- IBI data of Steedman (1987)
- HSI for Creek Chub (USFWS, 1980)
- Toxic chemical concentrations by mass balance

2.11 General Priorities for Tributaries

The general approach is to remove all known limiting factors and stock or allow recolonization as appropriate. An experimental approach to reintroduction of species is required, since there is considerable uncertainty about limiting factors and the success rate of recolonization is not well documented in the literature. The general priorities are:

1) Eliminate chemical spills and other toxic substances.
2) Modify barrier to allow fish passage or stock stream sections. (Certain barriers are desirable, as they prevent upstream migration of lamprey eels.)
3) Reduce flashiness of peak flows.
4) Retrofit channelized areas.

TABLE 2.3: MIDDLE REACHES OF DON RIVER

3.1 Section Boundaries

- Langstaff Road to Bloor Street (west and east Don branches)

3.2 Fisheries Objective

1) Status quo as the minimum - creek chub
2) largemouth and small mouth bass capability - ecosystem criteria

3.3 Limiting Factors

- excessive peak flows - effects on river channel and habitats - eroded channels.
- areas of good riparian vegetation and canopy exist in the extensive park systems.
- poor instream habitat - shallow flows, wide channel, no instream cover, poor stream morphology (riffles/pools).
- water quality problems - excessive silt loads, some toxic inputs (spills).
- some channelization.
- weir at Pottery Road is a migration obstacle for lake migrant populations, but also prevents lamprey movement.

3.4 Collected Species (Martin-Downs, 1988)

- White sucker	Blacknose dace	Johnny darter
- Goldfish	Longnose dace	
- Redbelly dace	Creek chub	
- Fathead minnow	Pumpkinseed	

3.5 Target Species

- creek chub - status quo.
- smallmouth/largemouth bass
  - potential capability
  - represent ecosystem restoration
  - predator for "big four" resident species.
  - indicator of acceptable water quality/balanced fish community/food chains.

3.6 Current Water Quality Impacts on Fishery

- turbidity and silt loads.
- chemical spills.
- high temperature; this is probably not a major impact on a warmwater fishery.

TABLE 2.3: MIDDLE REACHES OF DON RIVER

3.7 Management Requirements/Focus

1) spill control
2) water quality improvement
3) habitat remediation for above limiting factors
4) maintain/improve riparian vegetation
5) investigate benefits of flow control upon erosion, since flow velocities are strongly influenced by the stream gradient

3.8 Broad Management Criteria for Middle Sections

1) maintain status quo
2) make habitat and water quality improvements to:
   - improve fishery
   - act as an integrator of a more balanced ecosystem.

3.9 Management Philosophy of Middle Reaches Within a Watershed Perspective

1) It would be difficult to substantially alter the design of the urban areas and their impacts upon flow and turbidity (bank erosion). Some benefits from flow control may be obtained for erosion protection and the associated impact of turbidity upon fish. Long-term siltation is a lesser issue than normal due to the stream gradient.
2) There are opportunities for achieving significant improvement by:
   - improving riparian habitat.
   - controlling water quality excesses associated with spills and other types of extrema.

3.10 Tools Available for Quantifying Impacts

- IBI data of Steedman (1987)
- Fluvial - fish linkages established by Morris (Master's Thesis, Trent University)
- HSI for creek chub, smallmouth and largemouth bass.

3.11 General Priorities for Middle Reaches

1) Control peak flows and erosion potential.
2) Improve fishery access for migratory purposes.
3) Improve habitat.
4) Control spills.

TABLE 2.4: LOWER REACHES OF DON RIVER

4.1 Section Boundaries

- Bloor Street to Keating Channel

4.2 Fisheries Objective

1) As in middle reaches.
2) Suitability for seasonal use by anadromous salmonids from Lake Ontario (brown trout, chinook salmon)

4.3 Limiting Factors

- water quality - stormwater (CSO) discharges to lower river, STP input, industrial spills.
- channeled lower section and estuary (harbour).
- major siltation of river habitats.
- riparian vegetation minor factor.
- channel morphology major limitation - substrates, lack of riffles/pools, shallow depths (wide scoured channel).
- no migration obstacles (physical) currently exist.

4.4 Collected Species (Martin-Downes, 1988)

- White sucker
- Emerald shiner (lake species)
- Spottail shiner (lake species)
- Fathead
- Blacknose dace
- Longnose dace

Creek chub
Brook stickleback
Pumpkinseed
Carp (migratory)

4.5 Target Species

- creek chub - status quo indicator.
- largemouth bass - ecosystem restoration (as for middle reaches).
- brown trout - representative for anadromous salmonids.
  - more tolerant species for temperature and turbidity.
  - for anadromous run only - not self-sustaining.
  - indicator for chinook salmon, coho, etc.

4.6 Current Water Quality Impact on Fishery

- turbidity some impact.
- temperature limits fishery to warm water species.
- perceived impact of CSO's, STP's, industrial discharge and spills; exact impact is not quantified.

4.7 Management Objective/Focus

1) achieve water quality conditions suitable for fish movement through river below Bloor.
2) Short-term habitat: improvement of channel aspects related to flood control (channelization) below Bloor.
3) Long-term babitat: as redevelopment occurs over the next 50 years, improvement should be sought.
4) Maintain/improve riparian vegetation.

4.8 Broad Management Criteria for Lower Reaches

1) Maintain status quo.
2) Make modest improvements in:
   . habitat where practical.
   . water quality.

4.9 Management Philosophy of Lower River Within a Watershed Perspective

1) There is not much scope for management in the short term, particularly in the backwater areas of the Lower Don because:
   - much of the lower river is extensively channelized and protected by dikes/retaining walls.
   - fishing access is essentially non-existant along Keating Channel.
   - the physical habitat does not provide much opportunity for hatching/rearing.
   - the major function of the lower river is as a passage way for:
     . upstream migration.
     . temporary living space for species such as carp.
   - cost of extensive rehabilitation would be quite expensive and require many alterations to present uses of shore-line property.
2) There is scope for management in non backwater areas, and in the long-term because:
   - there is a substantial valley land area which could be revegetated.
   - there are substantial areas in bike paths and other publically accessible areas. These activities may cause increased public pressure to improve these regions of the valley land and of the River.
3) There is, and probably will never be into the foreseeable future, an extensive recreational fishery.
4) The immediate approach should be to maintain the status quo and establish an improvement in the fishery which is an indicator of improvement in aesthetics.
5) For the long term (50 to 100 year planning horizon), a change in the urban/industrial design as old buildings are replaced by new buildings will allow for habitat improvements which assist the development of the channel into habitat appropriate for the whole life cycle of the fishery of the Lower Don.

TABLE 2.4: LOWER REACHES OF DON RIVER

4.10 General Priorities For Lower Reaches

1) Improve water quality.
2) Establish target species which can be used as an indicator in the improvement of habitat conditions and aesthetics and monitor their response.
3) Improve fish habitat as urban design changes (over long term planning perspective).

3.0 TOXICITY MODEL

3.1 Introduction

Toxicity is measured by exposing sensitive life stages of aquatic organisms to a chemical solution or mixture and determining the concentration that produces a response in half the population (lethality - LC50; sublethal effect - EC50) or identifying the highest concentration that produces no effect (highest no observed effect concentration - NOEC). It is used routinely among all industrial sectors to measure effluent toxicity and to estimate discharge mixing zones and identify areas where mixing would conflict with more sensitive biological or human uses in receiving waters. National tests have been documented and are continually being updated by Environment Canada which will cite specific organisms and sensitive life stages of aquatic organism that can be used to evaluate acute, lethal and sublethal toxicity.

Biological tests are fully integrative of the toxicity of all compounds present in a sample and the influences that the physical and chemical conditions of the sample (pH, temperature, hardness) have on the potency of the chemicals and their mixtures. The exposed organism expresses the total toxicity and therefore represents a comprehensive manifestation of the effects of a sample. However, it is not always possible to conduct toxicity tests nor is it always necessary, in order to determine whether ambient waters might be toxic to or limit the use of, sensitive life stages of aquatic life. Chemical analysis is often conducted on site and often provides information on water quality. This chemical information can also provide a rough indication of toxicity based on known toxic levels of compounds and the influence of chemical and physical conditions on their toxicity.

This chapter summarizes the toxicity of frequently monitored chemicals in ambient waters and describes how their potency is affected. The toxicity of the compounds and their interactions have been described mathematically so that useful estimates of toxicity (to fish) can be generated from chemical measurements. These models require testing on actual samples to calibrate their interpretation in a highly accurate manner. It is probable that toxicity testing of complex effluents will be required for the forseeable future to give full accuracy. These models, while incomplete, clearly identify critical data required for ambient water quality assessment and they may be useful for watershed management when applied via indicators such as the HSI, (Habitat Suitability Index) model.

3.2 Toxicants

The toxicity of the following compounds has been described in great detail in the open literature even if the mechanisms are not well understood. This section is not intended as a review but a concise outline of the latest descriptions of the behaviour of their toxicity. The intent is to focus on the estimate of toxicity for each compound and identify the factors influencing their potency and finally to highlight data requirements essential to estimating their toxicity. Two measures of toxicity have been presented in this overview which are related to duration of exposure, acute (short term) and chronic (long term).

Acute toxicity is generally regarded as lethality that will occur in trout after an exposure period of 96 hours (four days). In reality most mortality occurs within the first 24-48 hours. As an alternative to using the LC50 estimate for lethal response, the "no observed effect concentration" (NOEC) level was used, where possible, to provide a greater level of confidence in predicting non-lethal conditions. The use of the NOEC is more appropriate, in that, when used in a prediction model, the estimated cumulative effect concentration to produce no mortality is calculated. If only LC50's are used, the cumulative toxic units estimate whether 50% mortality might occur. Since there is greater concern in avoiding fish mortality altogether rather than sustaining 50% mortality, the use of NOEC values is of greater interest.

The use of NOEC has several potential drawbacks. From a modelling or predictive point of view it would be most useful to use the most robust population estimator. This is clearly the LC50, and not a NOEC. Utility of a NOEC depends strongly on experimental design (i.e. interval of test concentrations). If "avoiding fish mortality" is the aim, then a safety factor should be applied to the cumulative toxic units based TUs derived from LC50s.

The use of two different estimates of acute lethality (LC50 and NOEC values) does not violate the requirement of combining similar data into a model. The final estimated value becomes lower and therefore more conservative as additional NOEC values are incorporated.

The purpose of using lethality data in this way is to estimate whether the chemical quality of a water sample containing a mixture of low level toxicants. is likely to be lethal to fish life.

Chronic toxicity estimates are drawn from water quality reviews that describe the chemical concentrations above which sublethal effects are likely to occur in sensitive life stages of aquatic life. The sublethal responses include early life stage survival, hatching, growth, and reproduction. The organisms include fish and invertebrates. Chronic effects might be anticipated if ambient water concentrations continuously exceed the chronic effect level for a critical period coinciding with sensitive life stage development of target organisms. This period will vary according to the time of the year but might consider any 20-30 day duration. This is particularly appropriate for cool water species.

Copper

Copper is one of the most extensively studied metals and is the best described toxicologically. The toxicity of copper is most influenced by water hardness.

A thorough evaluation of the available aquatic toxicity database has been completed by the U.S. EPA (1986). One hour and four day average values have been derived to protect freshwater aquatic life and effect levels are influenced by water hardness. Dissolved copper is the predictor of toxicity. Note that this differs from data available in the PWQMN data base which measures total metal rather than dissolved forms. Hence dissolved forms cannot be measured accurately. Procedures for estimating dissolved forms are given in Chapter 7.3. The U.S. EPA recommends measurement of "acid soluble" copper but the method has not been developed.

The following relationships (USEPA, 1986) estimate the NOEC values of dissolved (0.45 um filtered) copper to protect aquatic life.

$$\text{1 hour average} = e^{(0.9422\,(\ln(\text{hardness})) - 1.464)}\ \text{ug/L}$$

$$\text{4 day average} = e^{(0.8545\,(\ln(\text{hardness})) - 1.465)}\ \text{ug/L}$$

Either value can be used in the model according to type of sample collected.

The Canadian Water Quality Guidelines (CCREM) to protect aquatic life against chronic exposure to copper ranges from 0.002 - 0.004 mg/L as a function of hardness (errata sheet, Dec. 1989). These values are adopted as the chronic value in the model.

Nickel

The U.S. EPA (1986) has extensively reviewed the toxicity of nickel to freshwater organisms and identified water hardness as the factor most affecting expressed lethality. Increased water hardness decreased toxicity (EPA, 1986). It is most important to measure nickel after the water sample has been acidified to pH 1.5-2.0 and filtered with a 0.45 um filter (USEPA, 1986). The derived estimate of nickel (acid filtered) above which may be lethal to aquatic life is as follows:

Nickel NOEC (acid-filtered) $= e^{(0.846 \ \ln(\text{hardness}) + 3.3612)}$ ug/L (EPA, 1986)

A similar relationship to estimate the level above which sublethal effects may result after chronic exposure was developed by the U.S. EPA (1986). It is:

Nickel Chronic Limit (acid-filtered) $= e^{(0.846) \ \ln(\text{hardness}) + 1.645)}$ ug/L (EPA, 1986)

Zinc

Zinc has also been widely studied and toxicity has been reported to vary according to fish size, temperature, pH, water hardness and dissolved oxygen (Spear, 1981). Changes in zinc speciation affected by pH have also complicated identification of toxic levels of zinc.

Data generated by Bradley and Sprague (1985) showed that zinc toxicity increased as pH increased from pH 5.5 to 9. The general slopes of the toxicity-pH relationships were similar for the two different water hardness conditions tested which suggested that a descriptive model might be developed. The data produced by other authors (Meisner and Hum, 1987) was at an intermediate water hardness to those tested by Bradley and Sprague (1985) and was used to complete the data matrix for development of a toxicity model. Increased water hardness clearly decreased the toxicity of zinc.

The following model for the toxicity of dissolved (0.45 um filtered) zinc appears to fit the data sets provided by the two studies:

$$\text{LC50 Zinc} = \frac{\text{Hardness}\,(93.3\, e^{-0.85\, pH})}{25} \quad \text{mg/L}$$

The CWQG guideline to protect aquatic life against chronic exposure to zinc is 0.030 mg/L, which is used as the chronic value in the model.

TRC Toxicity

Many experiments have been conducted to determine the toxicity of chlorine residuals (TRC) to aquatic organisms. Reviewers of the subject (Brungs, 1973) concluded that residual chlorine is acutely toxic at levels as low as 0.01 or 0.02 mg/L, although most LC50's reported for fish and invertebrates are as much as 0.08 and 0.3 mg/L, respectively. Chronic effects are reported to occur as low as 0.001 mg/L (behavioural avoidance), but again, most effects were observed at higher concentrations (greater than 0.01 mg/L). The majority of data were from studies of chlorine in wastewaters where possible additive or synergistic effects from other contaminants (particularly ammonia) were ignored and the toxic effects of TRC may even have been overestimated.

Laboratory toxicity tests conducted with clean dilution water are in fairly good agreement, however. Arthur and Eaton (1971) identified the acute LC50 between 0.085 and 0.154 mg TRC/L for fathead minnows, while the LC50 for amphipods was 0.22 mg TRC/L. The chronic threshold values from the same study were 0.043 mg/L for amphipods (reduced survival and impaired reproduction). Larson et al. (1978) tested chloramine toxicity to adult rainbow trout and found no evidence of harmful effects at 0.05 mg/L, but threshold concentrations for growth of alevins and juveniles were between 0.01 and 0.022 mg/L.

Considering all the available data, especially those based on amperometric measurements, the acute and chronic thresholds for aquatic toxicity of total residual chlorine can be estimated as approximately 0.04 (lowest LC50 of 0.085 x safety factor of 0.5) and 0.01 mg/L, respectively.

Acute lethal threshold = 0.04 mg TRC/L

Chronic threshold = 0.01 mg TRC/L

Ammonia

Ammonia dissociates into molecular (NH_3) and ionic (NH_4^+) forms according to the pH of the solution. The molecular form is the more toxic to fish and is therefore the species to be monitored to estimated toxicity.

The relationship between pH and ammonia ionization is:

$$\text{Fraction of Total Ammonia as un-ionized } (NH_3) = \left[\frac{1}{1 + 10^{(pKa-pH)}} \right] \quad \text{(Emerson et al., 1975)}$$

where

$$pKa = 0.09 + \left[\frac{2{,}730}{273 + \text{temperature (C)}} \right]$$

The U.S. EPA (EPA, 1984) and the International Joint Commission (IJC, 1985) have published reviews of ammonia toxicity to aquatic life to develop water quality criteria and objectives. These reviews indicate that while temperature and pH control the degree of ionization of total ammonia only pH truly affects the potency of the un-ionized form. Un-ionized ammonia is more toxic under low pH conditions than under higher pH conditions. Lower temperatures may also increase the potency of un-ionized ammonia although this relationship is not developed. There has been no indication that water hardness influences ammonia toxicity.

Evaluation of the available ammonia toxicity data by the U.S. EPA (1984) resulted in the following relationship to estimate the toxicity of un-ionized ammonia to rainbow trout. Based on concentration-lethality relationships a factor of 0.3 was applied to the LC_{50} estimate (IJC, 1985) to calculate the concentration above which lethality was expected to occur.

$$\text{96 hour non-lethal } NH_3 = (0.3)\left[\frac{0.66}{1+10^{1.03(7.32-pH)}}\right] \text{ mg/L}$$

A similar relationship has been developed by the U.S. EPA to describe chronic protective limits for salmonid fisheries.

$$\text{Chronic } NH_3 \text{ no-effect level} = \left[\frac{0.033}{1+10^{1.03\,(7.32-pH)}}\right] \text{ mg/L}$$

Phenol (4 AAP Measurement Method)

Phenolic compound concentrations are routinely estimated by the 4-aminoantipyrine method which is non specific and will react with any ortho or meta and some para substituted phenolics plus the parent compound phenol (mono-hydroxy benzene). Phenol is the most common of the phenolics and is generally produced as an intermediate in the preparation of other chemicals. Methyl substituted phenols are used as food antioxidants, and are present in asphalt runoff, metal cleaning, petroleum refining, formed in the manufacture of pharmaceuticals, wetting agents, dyestuffs and are present in domestic sewage (Craig, 1987). Nitro substituted phenols are intermediates in the manufacture of organic chemicals and dyestuffs.

Review of phenolics acute toxicity indicates that the NOEC levels for dimethyl and nitro substituted phenolics is very similar and therefore the same value can be used for all those most likely to be found in ambient waters. The most protective non-lethal limit for the methyl and nitro substituted phenols was 1 mg/L (Craig, 1987).

Phenol (4 AAP) NOEC = 1 mg/L

Phenol and 2-methylphenol are an order of magnitude more toxic to aquatic life than dimethyl and nitro substituted phenols and therefore selection of the recommended criterion of 0.02 mg/L would protect against chronic toxicity for other phenolics (Craig, 1987).

Phenol chronic protection = 0.02 mg/L

The chronic protection level is within the direct photometric measurement detection method of 0.01 mg/L. Chloroform extraction can increase detection limits to 0.0005 mg/L.

Pentachlorophenol

Pentachlorophenol (PCP) has been detected in the Don River. PCP is a weak acid which results in both toxicity and bioaccumulation decreases as pH increases. The U.S. EPA (1986) has extensively reviewed the acute and chronic toxicity of PCP and developed pH dependent relationships to estimate effect levels for aquatic biota. They are:

$$\text{PCP Acute NOEC} = e^{1.005(pH) - 4.908} \text{ ug/L}$$

$$\text{PCP Chronic NOEC} = e^{1.005(pH) - 5.368} \text{ ug/L}$$

Other Chlorinated Phenols

The MOE (Craig, 1987) water quality development document reviewed the sources and ambient levels of chlorinated phenols in Ontario and cited only a few cases where levels exceed the proposed objectives. It is therefore reasonable to conclude based on this data that any contributions to the total phenolics level would likely be insignificant. Only PCP deserves special consideration.

Dissolved Oxygen

Dissolved oxygen while not a toxicant does influence the potency of available toxicants. Since most toxicants act on metabolic systems all of which require oxygen for normal function and energy transfer (ATP cycle), there is a level of dissolved oxygen in water below which metabolic needs will be restricted.

The U.S. EPA (1985) has reviewed ambient dissolved oxygen requirements of aquatic biota and determined that certain levels will affect acute survival and be protective against sublethal effects during chronic exposure.

Survival of many fish species is reduced when dissolved oxygen falls below 3.0 mg/L. Salmonid growth and reproduction is impaired when chronic dissolved oxygen exposure falls below 6 mg/L. The thresholds (EPA, 1985) are accordingly:

Dissolved Oxygen	NOEC ACUTE	=	3 mg/L
	NOEC CHRONIC	=	6 mg/L

3.3 Estimating Mixture Toxicity

Toxicologists have long attempted to estimate the toxicity of a chemical mixture based on knowledge of the constituents and their individual toxicities. The theory of toxicant interaction has been intensively reviewed (EIFAC, 1987; deMarch, 1987a, b; Anderson and Weber, 1976) and no satisfactory alternatives to the strict addition approach have been proposed. Current thinking is that while none of the theories will provide a precise or reliable estimate of toxicity they may have a qualitative application.

3.3.1 Model Formulation

Strict Addition Estimate of Toxicity

The simplest approach to estimating the toxicity of mixtures is to sum the proportion of toxicity expected based on the fraction of the effect concentration present. If the summed value exceeds unity (1.0), it is likely that the mixture will induce the lethal or sublethal effect estimated.

$$\text{Cumulative Toxicity} = \frac{\left[\text{chemical 1}\right]}{\text{toxic}\ \left|\text{chemical 1}\right|} + .. + \frac{\left[\text{chemical n}\right]}{\text{toxic}\ \left|\text{chemical n}\right|}$$

The first step is to measure the toxicant of concern and divide that value by the concentration known to be toxic. This produces what is known as the toxic unit contribution for that chemical. The toxic contributions, or toxic units, of each chemical will proportionately contribute to the total toxicity of the mixture.

Adjustments to the Model

Phenol

Phenolics have a varied interaction with the other toxicants with regard to acute lethal effects (EIFAC, 1987). When the calculated phenol toxic unit is less than 0.1 the contributory effect is antagonistic and the negative value of the toxic unit should be included in the summation. Phenol toxic unit values between 0.1 and 0.3 should be halved before inclusion into the summation. Toxic unit values greater than 0.3 can be included directly into the summation.

Toxicity Level	Phenol Toxic Unit	Treatment
Acute	L 0.1	change sign and add
	0.1 to 0.3	add one half TU value
	G 0.3	add directly
Chronic	all	add directly

Dissolved Oxygen

Because dissolved oxygen influences toxicity only below critical levels it is proposed that adjustment of the cumulative toxic unit value be made to allow for potential oxygen effects. This adjustment can be easily incorporated for both the acute and chronic cases by expressing the ambient dissolved oxygen levels as a fraction of the minimum optimal value (eg 3 mg/L for acute; 6 mg/L for chronic). The cumulative toxic unit is then divided by the fraction of the critical oxygen requirement to proportionately increase the cumulative value. There is no need for adjustment if the critical oxygen value is met. When dissolved oxygen approaches zero the cumulative toxic unit would approach infinity indicating an exceedingly toxic condition for both acute and chronic impact.

If: ambient D.O. is less than critical D.O

Then: fraction of critical D.O. = $\left[\frac{\text{Ambient D.O.}}{\text{Critical D.O.}}\right]$ (3 mg/L acute)
(6 mg/L chronic)

And: adjusted cumulative T.U. = $\left[\frac{\text{Cumulative Toxic Unit}}{\text{Fraction of Critical D.O.}}\right]$

The Model

Consider the following environmental conditions for a certain stretch of the Don River:

pH	=	7.8
Hardness	=	180 mg $CaCO_3$/L
Temperature	=	12,C
Dissolved Oxygen	=	5 mg/L

The toxic unit contributions for various compounds found in the Don River are calculated and given in Table 3.1. Data from the Provincial Water Quality Monitoring Network (PWQMN) are not used for total phenols due to indications that is not reliable due to methods problems. Rather values measured by this study team for the Don River (detection limit) are used in Table 3.1. Based upon the definition of TU, a value of 1.0 is a threshold for toxicity. Accordingly, a value of 8.5 for acute response would suggest that the mixture is toxic. Calibration of this interpretation with actual test data is required to establish confidence in a reference value of 1.0.

3.3.2 Limitations of the Model

There are certain limitations to this approach of estimating toxicity.

- the total toxicity estimate is only as good as the estimates of toxicity for the individual chemicals. This is particularly critical when toxicants are influenced by physical chemical conditions which are not well described.

- the more numerous the number of chemical components that are incorporated into the model, the larger the sum of the toxic units is likely to be. Even small toxic unit contributions numerically increase the total unit value and may increase it above unity and suggest lethal conditions when none are exhibited. The opportunity for a false positive (determination of a non-lethal mixture to be lethal) estimate increases as the number of constituents incorporated into the calculation increases.

- the inherent lack of precision in estimating the toxicity of mixtures makes the probability of differentiating between marginally toxic and marginally non-toxic mixtures very low. These mathematical estimates cannot replace actual toxicity tests.

3.3.3 Data Requirements

It is apparent from the proceeding discussion that it is critical that the proper data be used to estimate toxicity. The following summarizes important data components:

- the pH, temperature and hardness (as CaCO3) of the sample must be measured to estimate the toxicity of many of the chemical components.

- only the un-ionized concentrations of ammonia must be used in the toxicity calculations.

- only the dissolved (0.45 um filtered) concentrations of copper and zinc must be used in calculations. Only acid filtered concentrations of nickel must be used in calculations. Total unfiltered metal concentrations will produce over estimates of toxicity.

3.4 Validation of the Toxicity Model

Unfortunately the model cannot be confirmed with documented toxicity test data. The necessary complement of input data which includes chemical measurements and toxicity testing on the same water sample are lacking, particularly sample hardness which is critical to the calculation of metal toxicity. Toxicity test data when published also frequently lacks description of solution pH which influences the ionization of ammonia.

One water sample for the Don River was chemically characterized and its toxicity tested. The TU model qualitatively agreed with the test results, but such a database is of limited value - many samples need to be tested to determine confidence in the model.

Despite the lack of validation, the TU model has substantial value. The model indicates the need for measuring and documenting specific test conditions in toxicity or chemical reports. It allows one to assess the potential impact of toxicity upon fish habitat.

3.5 Applications of the Mixture Toxicity Model

The input of chemical and physical data (pH, temperature, hardness) will allow the resource manager to project how the river water quality might be affected by seasonal changes in temperature, pH and hardness. The potential impact of discharged effluents or the extent of impact from spill incidences can be estimated with the model to allow expeditious direction of remedial measures where possible.

The simplicity of the described mathematical relationships can also be easily accommodated and stored in programable hand held calculators or portable computers for on site monitoring of effluent quality.

Users are cautioned that this model is imprecise and is intended as a tool that will allow users to quickly identify which constituents are likely to have biological effects and whether the overall biological quality of the river water is potentially impaired. The model is best calibrated for individual waters so that after frequent comparison with observed impact interpretation of the calculated Cumulative Toxic Units will improve the predictive capability of the model. For example some managers may find with experience that when the cumulative toxic units exceeds 0.75, samples are likely to be lethal to fish while others may find that a value of 1.5 is required to predict lethality. Such a range of calculated toxicity is well with the range of model uncertainty. A probabilistic simulation exercise would more clearly define thresholds for interpreting the calculations of the model.

3.6 Conclusions

A toxicity model for compounds relevant to management of urban runoff, STP and industrial discharges, and the waters of the Don River was developed in this chapter. Based upon its evaluation, the following conclusions are drawn.

1. Acute and chronic values for the contaminants discussed have been computed for the Don River under a specific set of temperature, pH, hardness and dissolved oxygen conditions and appear in Table 3.1. For the specific conditions selected which are representative of the lower river, the calculations suggest that the water is toxic to aquatic biota, both at an acute and chronic level.
2. Measurements of ambient water constituents to predict ambient water toxicity will improve the management of watershed utilization and assist in the bracketing of distinctly different stretches of river water quality.

3. Frequent comparison of measured sample toxicity with chemical analysis will allow calibration of this model for particular water quality and development of the capability to predict immediate and projected mixing zone toxicity based on chemistry alone.

3.7 Recommendations

Toxicity testing of various influents into the Don River (e.g., North Toronto STP, CSOs, separated storms sewer discharges, rural runoff) and of the river itself could be carried out to calibrate the interpretation of the toxicity model developed above.

The toxicity tests should be made at various dilutions until a non acute response is achieved, if the various waters indicate an acute response. Chemical characterization of the waters should also be made.

Toxicity tests upon synthetic water samples (i.e., solutions prepared in the laboratory) would assist in the the interpretation. Characterization of the role of particulate matter in toxicity measurement should also be made in the assessment.

Special attention to selection of the proper chemical parameters is required. These include pH, hardness, filtered metal concentrations, and total ammonia.

TABLE 3.1: ILLUSTRATION OF CALCULATIONS OF TOXICITY OF DON RIVER WATER

Toxicant		Toxic Unit: Acute		Toxic Unit: Chronic	
Copper (filtered)	= 0.019 mg/L	$\frac{0.0190}{0.0195}$	= 0.974	$\frac{0.019}{0.004}$	= 4.75
Nickel (acid-filtered)	= 0.013 mg/L	$\frac{0.013}{2.33}$	= 0.006	$\frac{0.013}{0.42}$	= 0.003
Zinc (filtered)	= 0.056 mg/L	$\frac{0.056}{0.9}$	= 0.062	$\frac{0.056}{0.03}$	= 1.87
TRC	= 0.25 mg/L	$\frac{0.25}{0.04}$	= 6.25	$\frac{0.25}{0.01}$	= 25
Ammonia - Total N un-ionized NH_3	= 4 mg/L = 0.053	$\frac{0.053}{0.045}$	= 1.19	$\frac{0.053}{0.007}$	= 2.5
Phenol - Total	= 0.0005	$\frac{0.0005}{1}$	= 0.0005	$\frac{0.0005}{0.02}$	= 0.0005
Pentachlorophenol	= 0.072 ug/L	$\frac{0.072}{18.75}$	= 0.004	$\frac{0.072}{12}$	= 0.001
Cumulative Toxic Unit			8.49		34
Adjustment for Dissolved Oxygen			None	Factor = $\frac{1}{5/6}$ = 1.2	
Final Value			8.49		41

4.0 FRAMEWORK FOR EVALUATION OF THE DON RIVER FISHERIES

4.1 Framework for Fish Habitat Management and Assessment of Urban Impacts

There are a number of alternative approaches to setting environmental criteria against which future changes can be assessed or measured and accepted or rejected. The one most commonly used is to establish individual criteria for a number of physical or chemical parameters of water quality or flow regulation at levels which are arbitrarily felt to be "environmentally acceptable". A more contemporary approach has been to adopt the ecosystem concept for natural systems in which plant or animal communities or individual species are identified as being representative of a set of environmental criteria to be maintained or established. This has the advantage of integrating physical, chemical and biological elements of the environment toward a measurable and desirable endpoint, that of supporting a biological community or species. Physical or chemical criteria are not set arbitrarily, but rather relate to the habitat needs of the representative species selected.

This approach is consistent with the recommendations of the Beanlands and Duinker (1983) study for the Environmental Assessment Review Office of Environment Canada. This three-year study, entitled "An Ecological Framework for Environmental Impact Assessment in Canada", represents the most intensive examination of impact assessment concepts and methodologies to be carried out in Canada to date.

In the fisheries management field, a set of Habitat Suitability Index (HSI) models have been developed for major North American fish species which incorporate virtually all habitat information available in the scientific literature. The purpose of the HSI model is to identify important habitat variables for each species which can be used for impact assessment.

4.1.1 Habitat Suitability Index (HSI) Models

The HSI model provides habitat information for evaluating impacts on fish habitat resulting from water or landuse changes. The impetus for the development of these models was the Habitat Evaluation Procedures (U.S. Fish and Wildlife Service, 1980), a planning and evaluation technique that focuses on the habitat requirements of important fish species.

HSI models are analogous to other sources of information that address, in general terms, the habitat requirements of fish and wildlife species. For example, several compilations of species databases have been initiated in recent years (e.g., Mason et al., 1979; U.S. Fish and Wildlife Service, 1980). These databases contain an array of habitat and population information. But these databases are descriptive in content. The HSI models are unique in that they are constrained to habitat information only, with an emphasis on quantitative relationships between key environmental variables and habitat suitability. In addition, the HSI series synthesizes habitat information into explicit habitat models useful in quantitative assessment.

The series of HSI models reference numerous literature sources in an effort to consolidate scientific information on species-habitat relationships. The models provide a numerical index of habitat suitability on a 0.0 to 1.0 scale, based on the assumption that there is a positive relationship between the index and habitat carrying capacity. The models vary in generality and precision, due in part to the amount of available quantitative habitat information and the frequent qualitative nature of existing information. When possible, models are included that are derived from site-specific population and habitat data.

Habitat variables in the HSI series fall into one of two general categories - physical habitat features (substrates, cover, depth, flow velocity, riffle/pool ratio, etc.) and water quality conditions (dissolved oxygen levels, temperature, turbidity, pH, etc.).

The HSI models are usually presented in three basic formats:

- o graphic,
- o word, and
- o mathematical.

The graphic format is a representation of the structure of the model and displays the sequential aggregation of variables into an HSI. Following this, the model relationships are discussed and the assumed relationships between variables, components and HSI's documented. This discussion of model relationships provides a working version of the model and is, in effect, a word model. Finally, the model relationships are described in mathematical language, mimicking as closely and as simply as possible the preceding word descriptions.

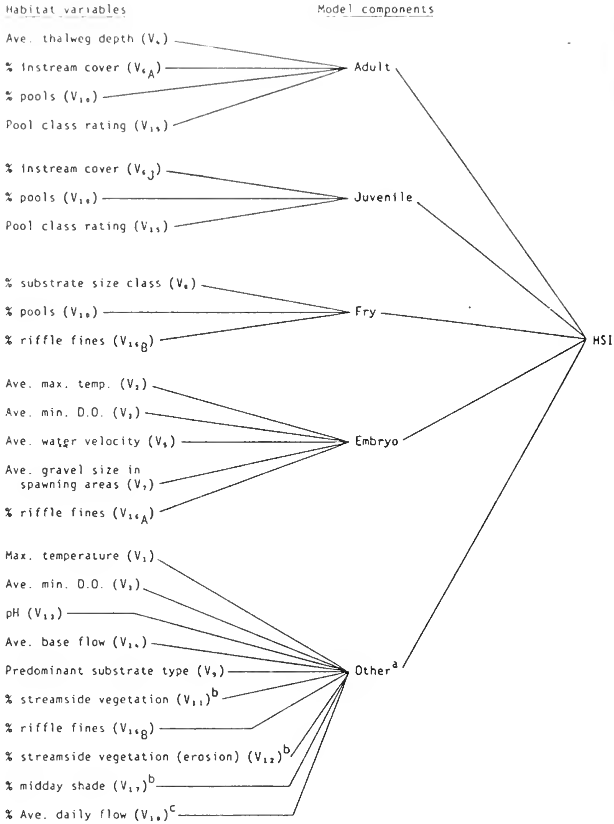
The models present hypotheses of species-habitat relationships, which vary from one geographical area to another, and must be adapted to the specific environmental conditions being considered. As well, the models consider habitat needs for different life stages or functions, such as spawning, juvenile rearing or migration. This is illustrated in Figure 4.1.

4.1.2 HSI Model Application

One of the most effective methods for broadening the ecological perspective of an HSI assessment is to use species that represent groups (guilds) of species that utilize a common environmental resource. Classification of all study areas species into guilds is often a useful step prior to the selection of evaluation species. Figure 4.2 is an example of a guild descriptor matrix that summarizes habitat use information for selected specis. Use of the matrix in Figure 4.2 shows that bluegill, for example, could be selected as representative of a group of fishes that utilize both warm-water temperatures and back-waters. The guilds developed from this matrix can be based on two or more column descriptors (e.g., cold-water and rocky substrate), rather than a single major category, such as temperature. The guilds selected will depend on the descriptors necessary to meet the objectives of the HSI application. Guild descriptors can be based on tolerances of, or responses to, a particular habitat alteration (e.g., turbidity) or on specific requirements for completing the life cycle.

Some typical habitat variables are listed in Figures 4.3 and 4.4 for largemouth bass. Using river velocity (V_{21}) as a typical example variable (Figure 4.3), habitat suitability ranges from 1.0 (completely suitable) for velocities of 0 to 0.6 cm/s to complete unsuitable (SI = 0.0) at velocities greater than 2.6 cm/sec. Similarly, in Figure 4.4, habitat suitability is shown as increasing from marginal (SI = 0.1) for dissolved oxygen of less than 2 up to completely suitable (SI = 1.0) for DO of greater than 8 mg/L. In this case, the curve is shown in step functions as available data do not provide information for a continuous function.

The final result is a composite set of habitat SI curves with quantifiable ranges of values within which the river environment will suit the needs of rainbow trout, or any other target species selected. If the species selected is representative of the habitat needs of the species community or guild which it represents, the river environment should be



[a]Variables that affect all life stages.

[b]Optional variables.

[c]Steelhead variable.

FIGURE 4.1: DIAGRAM ILLUSTRATING THE RELATIONSHIP AMONG MODEL VARIABLES, COMPONENTS, AND HSI

	Riverine						Lacustrine																						
	Habitat			Stream size			Habitat					Cover					Temperature[a]			Spawning[b]							Turbidity tolerance		
							Near-shore		Open-water																				
Species[c]	Riffles, runs	Pools, eddies	Backwaters, bayous, oxbow lakes	Small (< 5 m); order: 1-3	Medium (5-30 m); order: 2-6	Large (> 30 m); order: 5+	Shallow (≤ 5 m)	Deep (> 5 m)	Surface (< 5 m)	Mid-water (5-15 m)	Deep (> 15 m)	Rocky substrate	Aquatic vegetation	Cut-banks	Logs, brush, debris piles	No special cover needs	Cold (< 20°C)	Cool (20-28°C)	Warm (> 28°C)	Free-drifting eggs, no substrate req.	Eggs deposited in or on rocky substrates; current required	Eggs deposited in or on rocky substrates; no current required	Eggs deposited on plants	Eggs deposited in holes, cavities	Eggs deposited in nests of mud, sand, or plant debris	Eggs deposited over a variety of substrates	Low (< 25 JTU)	Moderate (25-100 JTU)	High (> 100 JTU)
Largemouth bass			x		x	x	x						x		x				x						x			x	
Spotted bass		x			x	x		x		x		x			x				x						x			x	
Black crappie		x	x		x	x	x		x				x		x				x						x			x	
White crappie		x	x		x	x	x		x				x		x				x						x				x
Bluegill		x	x		x	x	x			x			x						x						x			x	
Warmouth			x		x	x	x	x					x		x				x						x				x
Slough darter			x		x	x							x						x				x					x	
Common carp		x	x			x	x	x			x		x						x				x						x
Smallmouth buffalo	x	x	x		x	x		x		x	x		x		x				x				x					x	
Channel catfish	x	x	x		x	x		x			x	x		x	x				x					x					x
White sucker		x	x	x	x			x			x	x	x	x				x			x							x	
Northern hogsucker	x	x		x	x							x						x			x						x		
Striped bass	x					x			x	x	x					x		x		x								x	x
Rainbow trout	x	x		x	x		x		x	x		x	x	x	x		x				x						x		

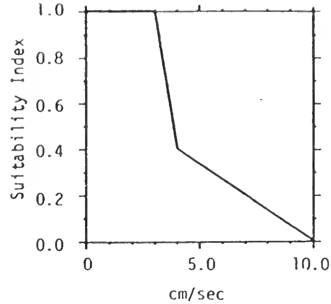
[a]Categories from Hokanson (1977)

[b]Categories from Balon (1975)

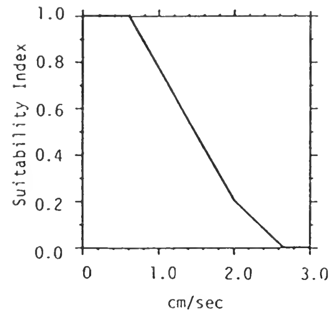
[c]Common names from Robbins et al. (1980)

FIGURE 4.2: SAMPLE SPECIES CLASSIFICATION USING GUILDING CRITERIA

R V_{20} Maximum current velocity at 0.6 depth within pools or backwaters during spawning (May-June). (Embryo)



R V_{21} Average current velocity at 0.6 depth during summer. (Fry)



R V_{22} Stream gradient within representative reach.

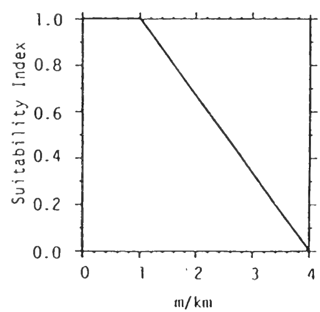


FIGURE 4.3: EXAMPLE OF PHYSICAL COMPONENT OF HSI FOR LARGE MOUTH BASS

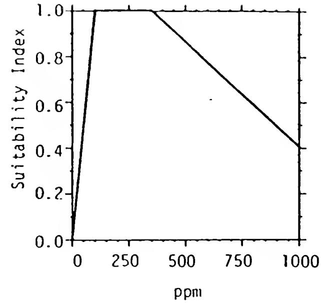
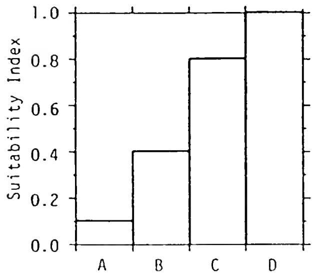
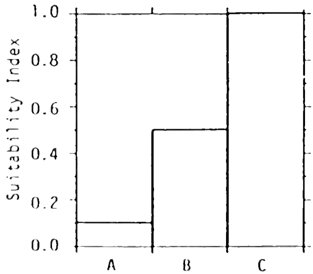
L	V_5	Average TDS concentration during growing season when carbonate-bicarbonate > sulfate-chloride ionic concentration. If sulfate-chloride concentration exceeds carbonate-bicarbonate, reduce SI rating for TDS by 0.2.	
R,L	V_6	Minimum disssolved oxygen levels during midsummer within pools or littoral areas. A) Frequently < 2 mg/l B) Usually ≥ 2 and < 5 mg/l C) Usually ≥ 5 and < 8 mg/l D) Often > 8 mg/l	
R,L	V_7	pH range during growing season. A) < 5.0 or > 10.0 B) ≥ 5 and < 6.5 or > 8.5 and ≤ 10.0 C) 6.5-8.5	

FIGURE 4.4: EXAMPLE OF CHEMICAL COMPONENT OF HSI FOR LARGEMOUTH BASS

generally suited to support all or the majority of these species and their respective food chains. The SI (Suitability Index) curves provide criteria against which habitat changes related to urban developments or other watershed changes can be assessed or modelled to determine whether such changes are within acceptable ranges. They also can help guide the nature and type of preventative or remedial actions to be taken to protect or enhance aquatic environments for the representative species. In this regard, this approach can support the related objectives of assessing and controlling impacts of future watershed developments and providing a solid scientific basis for managing the fish resource.

4.1.3 Priority Habitat Variables

Considering the potential for urbanization impacts on the upper Don River, and the present urban and industrial impacts in the middle and Lower Don River, the most important aquatic habitat variables include:

- changes in base and peak flow regimes,
- water temperatures, particularly in mid-summer,
- turbidity levels,
- water quality changes related to urban industrial and agricultural runoff, and
- quality of fish spawning habitat.

The selection of priority habitat variables will, of necessity, depend on the fishery management priorities for a section of river. If, for example, the lower Don River is managed for a self-sustaining smallmouth bass stock, habitat criteria for all life stages during all seasons of the year must be considered in the HSI model. However, if management is concerned only with a hatchery-maintained adult fishery, in the river for sport fishing purposes, habitat criteria need only relate to those seasonal needs of the adult fish (water temperature, flow and quality). It is for this reason that a fish resource management plan is required for the Don River (see Section 5).

4.1.4 Potential Limitations

One of the potential limitations of an HSI model approach on the Don River relates to the limited water quality database available to describe episodic events (e.g., spills, other transiant phenomena) for inclusion in suitability index (SI) evaluation. A second limitation is inclusion of toxic effects in the HSI model. A third limitation is adequate documentation of habitat variables.

Physical habitat conditions have been inventoried in sections of the Don River. This allows for an adequate SI evaluation of physical factors for purposes of this "framework" study. The inventory is inadequate for detailed fisheries management puproses. Long-term, multi-season water quality data, however, appear less well-suited.

In the absence of similar water quality database, the HSI model could be used to establish minimum criteria for important water quality variables. For instance, a suitability index value of 0.8 for each important variable can be assigned as the minimum level acceptable for a particular species. This might apply to criteria such as water flow, temperature, turbidity, etc. The achievement of this value for each variable can then be tested or modelled to determine its achievability under different development or change scenarios. The effectiveness of alternative approaches or remedial activities to achieve the desired level can also be assessed.

The limitations related to aquatic toxicity and spills were removed in this study by including them in the HSI model (see Chapter 5).

4.2 Selection of Target Fish Species for Don River

4.2.1 Approaches to Assessing Target Species

In the field of fisheries management, the need for using more than one fish species for management of a tributary is of concern. The approach used in other local studies of selecting a target species as an indicator of a guild of species for a subwatershed unit and applying an HSI model is a substantial improvement over present and past practice. In developing the District Fisheries Management Plan (DFMP), the approach of target species and HSI application has not been used. Rather, experience, knowledge of local linkages and creel surveys and general public perceptions are used to establish the plan. This results in the DFMP being generic, rather than watershed specific.

In attempting to assess particular tributaries of the Don River, ground truthing has generally not been carried out except for efforts associated with academic work (e.g., Steedman with the IBI data; Morris with the influence of hydraulics upon channel morphology and fish populations). In manipulating fisheries (e.g., picking up fish and transporting above the Milne Dam), immediate practical measures are used; conducting the work more scientifically would produce a longer term benefit.

A process to more rigorously define fish species for management is required. It would include:

- an expansion of fish species selected from strictly a cold water/warm water basis to at least include the transition zone between cold water regimes and warm water regimes;
- further evaluation of the scientific process required to come to a decision on species selection (e.g., one species; or more than one species to reflect a mixture of fishery community attributes);
- how to evaluate appropriate species for transition zones in the watershed (e.g., between Brook Trout habitat and bass habitat);
- what size of area, length of reach is required for a particular target species;
- data required to check and to modify the HSI to Ontario conditions;
- opportunities provided through two or more species to control and manage different fisheries uses, and an opportunity to estimate the costs of management for different fisheries use; and
- use of one species as a target species, and other species as qualitative factors in management.

These considerations should be evaluated in the future. For purposes of this study, the target species approach was used.

4.2.2 Criteria for Selecting Target Species

A target or key fish species provides the basis for establishing desirable áquatic habitat criteria for specific reaches of the Don River. A target fish species should have the following attributes:

1. its habitat requirements should be reasonably well suited to the actual conditions which exist in the river reach being considered;

2. sufficient qualitative and quantitative information should be available on its habitat requirements to determine suitability levels for key habitat criteria (i.e., calculation of Habitat Suitability Index (HSI) for a given set of habitat parameters);

3. the species should, in most instances, represent a higher trophic level (i.e., predator) since these species' habitat needs tend to integrate a broader range of habitat parameters (i.e., more complex food chain requirements);

4. its habitat requirements should be considered generally representative of the needs of associated species in the resident fish community (species guild). If it is one of the more sensitive species in the fish community, protecting its habitat needs should ensure that the needs of associated species are also met; and

5. it should, in most instances, be a sport fish species which will be recognized as having some value and, thus, a priority in resource management decisions.

The present distribution and general status of various fish species in the Don River was discussed above in Section 2. As well, the delineations of upper, middle and lower reaches of the Don River was provided above. A very brief and general synopsis of possible species is now provided.

4.2.3 Possible Target Species

A variety of possible target species were identified in Chapter 2, based upon existing species. Additional species are possible over the long term (50 years), based upon an improved quality fishery. The fish species include the following:

- o Creek chub, because it is one of the four species consistently found in the River, particularly the lower river, and has an HSI model.

- o Redside dace for the upper reaches, because it is one of the most sensitive species recognized in the area and because it has been assigned a "rare" status by the Committee on Endangered Wildlife in Canada. However, there is not an HSI model available for it.

- o Other members of the four dominant species found in the river system (white sucker, blacknose dace, longnose dace).

- o Smallmouth bass or largemouth bass which occur naturally, for which HSI models are available, which are piscivores, which are indicative of a guild of fish species and which represent a quality fish to the public.

- o Brook trout which are a native quality cold water fishery resident in isolated cold water tributaries of the upper watershed such as MNR lands, and for which there is an HSI model.

- o Rainbow Trout which is an indicator of a guild of quality, cold water species and which would provide a target for managing a significantly restored quality fishery in the Don River.

Of these species, brook trout, smallmouth bass/largemouth bass and rainbow trout were considered further in this study. Other species given above should be reviewed in the future and possibly included in a fisheries management plan for the Don River.

4.2.3.1 Brook Trout

The brook trout is a cold waterfish species. It was endemic to the Don River watershed. Its distribution has been severely reduced because of habitat and water quality changes associated with agricultural, residential, industrial and urban development activities in the watershed over the past century. It is currently restricted to isolated headwater tributaries such as the Maple hatchery where habitat conditions, particularly cold spring water, remain suitable.

Because the presence and survival of a natural brook trout population is one of the best indicators of the maintenance, or restoration, of a natural and high quality stream environment, this species would be an appropriate target species for habitat management in selected reaches of the upper watershed. Major habitat criteria for this species include cool water temperatures (controlled by groundwater sources and canopy), low turbidity levels, adequate instream cover, extensive streambank vegetation to provide shading and prevent erosion, stream morphology providing abundance of riffles and pool habitats, and gravel spawning beds free of siltation.

4.2.3.2 Smallmouth and/or Largemouth Bass

The smallmouth bass is a warmwater fish species. It occurs naturally throughout the Don River watershed. It is one of the species which likely benefited from habitat changes which eliminated the brook trout from sections of river, where higher water temperatures are now found. This species is generally better adapted to the types of stream habitat found in areas of agricultural and extensive residential and industrial land use, typical of the present situation in most of the Don River.

Smallmouth bass is an indicator of a relatively high quality, warm-water stream environment. Its presence and survival will ensure that the associated warm-water fish community comprising several additional species will also have suitable habitat conditions. From a recreational fishing perspective, the smallmouth bass and its close relative, the largemouth bass, reach their greatest population and size potential in larger pools, ponds and reservoirs on the stream, as is the case at the G. Lord Ross Reservoir.

Its primary habitat requirements include moderate to warm water temperatures during the spring spawning period, good cover in pools and backwaters, relatively low turbidity levels and a high percentage of rock substrates.

4.2.3.3 Rainbow Trout

The rainbow trout is a cold-water, migratory fish species. It is a potential indicator of a guild of fish which includes brown trout and chinook salmon. It is an introduced species which has become naturalized in all of the Great Lakes and many of their tributary streams. It is stocked into Lake Ontario in large numbers, along with brown trout, coho salmon and chinook salmon. Like these other migratory salmonid species, the rainbow trout could migrate into the lower Don River during the spring and fall of each year, if the physical habitat could be restored. Such restoration is a long-term (50-100 a) activity. If this occurred, it could provide an important and growing sport fishery to a large number of anglers.

If the rainbow trout was selected as a target species, the two primary reasons would be:

1. the migratory adult rainbow trout's habitat needs are relatively similar to those of the brown trout, coho salmon and chinook salmon, all of which are desirable sport fish species for the lower river reaches; and

2. the rainbow trout has the potential to establish a self-sustaining population if it reproduces successfully. This condition exists in other Lake Ontario tributaries not far from the Don River, such as Duffins Creek, Wilmot Creek, and the Credit River.

Primary habitat requirements for migrant adult trout include adequate flow levels and cool water temperatures during the period of migration and sufficiently large pools to hold adult fish. When considering habitat requirements for a self-sustaining trout population, additional criteria are added, including cool mid-summer maximum water temperatures, rocky and silt-free riffles for spawning, adequate base flows, good instream cover for juvenile trout and ample river shading from streambank vegetation.

If rainbow trout were to be introduced into the Don River, the first major restorative action would be to ensure that temperature conditions are suitable. The second action would be to ensure that habitat is suitable to migratory adult rainbow trout in the lower river, particularly the Keating Channel.

4.2.4 Species Selected

Bass was designated as best meeting the above criteria for the various sections or reaches of the Don River. It exists in the Don River. In most of the Don River watershed, the present habitat, especially temperature, is condusive only to bass, of the three species outlined above.

Smallmouth bass is a more appropriate target fish species for riverine systems, than largemouth bass. Largemouth bass is appropriate for reservoirs such as the G. Lord Ross Reservoir, although smallmouth bass also inhabits reservoirs. Accordingly, smallmouth bass was designated as the target species for this study.

The two cold water species, brooke trout and rainbow trout and other warm water species outlined in Chapter 2 (e.g., creek chub) should be investigated in future fisheries - related, management studies. Brooke trout would be an appropriate target species for cold-water, headwater, tributary streams. Rainbow trout would be useful for the examining the long-term (e.g., a 50 year) planning horizon.

4.3 Application of Habitat Suitability Index (HSI) Model for Smallmouth Bass to the Don River System

Habitat Suitability Index models provide a very useful format for examining and describing the quantitative relationships between key environmental variables and habitat suitability for a particular species. In this section, the HSI model for smallmouth bass is applied to existing habitat conditions in the upper, middle and lower reaches, of the Don River, and to Massey Creek. A summary of these different reaches determined by BEAK fisheries professionals, is given in Table 4.1.

The Don River habitat database available for determining values which can be assigned to each habitat variable in the HSI model ranges from good to poor. For instance,

TABLE 4.1: AQUATIC ECOSYSTEM AND HABITAT FEATURES OF THE DON RIVER WATERSHED

	Headwater Tributaries	Middle Reaches	Lower Reaches*	Tributaries e.g. Massey Creek
Stream Order	1, 2 and 3	1, 2, 3, 4, and 5	5	1, 2, and 3
Mean Gradient (m/km)	2-6	2-6	0-2	2-6
General Physiographic Features	relatively flat agricultural plain,	flat table lands, adjacent to rolling hills and incised valley lands	deeply incised bare valleys; heavy urban uses	gently rolling, residential
Adjacent Land Uses	urbanizing fringe, stagnant lands, agriculture, conservation lands, recreation	urban development light industrial, conservation lands	urban development heavy industrial future conservation lands	urban development few industrial areas, adjacent parkland
Aquatic Habitat Features:				
1. River Morphology:				
- % riffles	30-40	30-40	10-30	30-40
- % pools	5-15	10-20	0-5	5-10
- % runs	20-40	30-50	10-20	20-50
- % flats	10-20	0-10	40-80	0-10
- % concrete	0-5	1-15	0-5	0-2
2. Vegetation Canopy: - % openness	90-100	80-100	80-100	90-100
3. Instream Cover (%)	0-10	10-20	10-20	0-20
4. Substrate	predominantly sand, gravel, cobble, and some organic material	predominantly boulder, rubble, cobble, and gravel in most reaches some organic matter in sediments, substantial concrete lined reaches	predominantly sand, and silt. Concrete lined sides,	predominantly rubble, cobble, silt; little organic material or benthic life below boulders
Fish Communities	warm-water species; cold, clear-water resident species in Maple hatchery area	warm-water resident species	warm-water resident species seasonal anadromous cold-water species possible if adequate canopy is restored	warm-water resident species
Major Fish Species	White sucker, Redbelly dace, Pumpkin seed, Yellow perch, Mottled sculpin, Common shiner, Bluntnose minnow, Fathead minnow, Rainbow darter, Johnny darter, Largemouth bass, Blacknose dace, Longnose dace, Creek chub, Brook stickleback	White sucker, Goldfish, Redbelly dace, Fathead minnow, Blacknose dace, Longnose dace, Creek chub, Pumpkin seed, Johnny darter	White sucker, Emerald shiner (lake species), Spottailed shiner (lake species), Fathead, Blacknose dace, Longnose dace, Creek chub, Brooke stickleback, Pumpkin seed, Carp (migratory)	generally devoid of fish. Species found: White sucker, Blacknose dace, Longnose dace, Cheek chub, Goldfish, Pumpkin seeds
Recommended Key Species for Habitat Preservation or Rehabilitation	Smallmouth bass, Brook trout in Maple Hatchery area	Smallmouth bass	Smallmouth or Largemouth bass, Rainbow trout upon restoration	Smallmouth bass

* Lower reaches from confluence of East and West Don change from having substantial gradient to being essentially in backwater of the Lake. The backwaters of the lake are evaluated in the HSI analysis, as the upper reaches of the Lower Don are similar in physical habitat to the middle reaches.

quantitative information on some physical characteristics of stream habitats (stream morphology, instream cover, substrate types) is good. This is due to the intensive habitat surveys which have been carried out on this river over the past decade by MTRCA and MNR, and in academic work. Other habitat data, however, are of poorer quality, including information on episodic water chemistry (e.g., spills) and some hydrological parameters. Derived data for some hydrological parameters are available from previous modelling studies and monitoring data, but need to be synthesized. The synthesis was not carried out in this study. For some parameters, values have been derived largely from first-hand inspection of the Don River without benefit of an empirical database.

The data source for each assigned value for a habitat variable is identified on the HSI tables (Tables 4.2, to 4.5). As well, the potential significance or sensitivity of each habitat variable for stormwater management activities on the Don River are assessed on each table. Physical characteristics of the river were established from an inspection of MTRCA data and the thesis of Morris (1988) and Steedman (1987). Stream chemistry were summarized from MOE monitoring data; the impacts of stormwater runoff upon dissolved oxygen were forecast using QUAL2E. Flow related variables were established from generic QUALHYMO simulations (BEAK, 1988) and site reconnaissance. Water temperatures were assessed based upon MOE/MTRCA monitoring data and QUAL2E simulations.

Tables 4.2, 4.3, 4.4, and 4.5 list the habitat variables and their assigned values for smallmouth bass in upper, middle, and lower reaches of the Don River and in Massey Creek respectively. The resulting HSI value ranges from 0.78, stream habitats of the upper Don River to 0.42 for the lower river. That is, river habitat is physically well suited to the needs of this species. Important habitat variables to achieve a higher HSI value in the Don River would appear to include the abundance of cover, the degree of water level fluctuations, dominant substrate types and turbidity levels.

A number of habitat variables have been identified as being potentially sensitive to stormwater management activities in the middle reaches of the river. These include water turbidity, water temperatures and water level fluctuations (Tables 4.2 to 4.5).

Stormwater discharges will have an impact upon the dominant substrate in pools and backwater. Good stormwater management will minimize the silt load of the river.

TABLE 4.2: HABITAT SUITABILITY CRITERIA FOR SMALLMOUTH BASS IN THE UPPER REACHES OF THE DON RIVER

Habitat Variable	Assigned Value	Data Source	Potential Significance of Habitat Variable for Stormwater Management
% River Cover in Pools and Backwaters	10	MTRCA data, site reconnaissance assigned value	Low
Minimum DO for Year (mg/L)	7	MOE data - assessed value	Low/Moderate
Minimum DO in Pools Backwaters	7	MOE data - assessed value	Low/Moderate
Stream Gradient (m/km)	4	MTRCA hydraulic profile	Nil
Mean pH for Year	7.8	MOE data analysis	Low
Maximum Mean Monthly Turbidity (JTU)	10	MOE data analysis	Moderate/High
Dominant Substrate in Pools/Backwaters (1,2,3,4)	3	Site reconnaissance - assessed value	Moderate
Water Temperature in Select Habitat (adult)	22	Assessed value	Moderate
Water Temperature in Select Habitat (spawning)	20	Assessed value	Moderate
Water Temperature in Select Habitat (fry)	22	Assessed value	Moderate
Water Temperature in Select Habitat (juvenile)	22	Assessed value	Moderate
Water Level Fluctuations (m) Spawning (1,2,3)	3	QUALHYMO simulation - assessed value	Moderate
% Cover (boulder, stump, tree, vegetation, rock)	20	MTRCA data; assessed value	Moderate

HSI VALUE = 0.78

TABLE 4.3: HABITAT SUITABILITY CRITERIA FOR SMALLMOUTH BASS IN THE MIDDLE REACHES OF THE DON RIVER

Habitat Variable	Assigned Value	Data Source	Potential Significance of Habitat Variable for Stormwater Management
% River Cover in Pools and Backwaters	20	MTRCA data, site reconnaissance assigned value	Low
Minimum DO for Year (mg/L)	7	MOE data - assessed value	Low/Moderate
Minimum DO in Pools Backwaters	7	MOE data - assessed value	Low/Moderate
Stream Gradient (m/km)	3	MTRCA hydraulic profile	Nil
Mean pH for Year	7.8	MOE data analysis	Low
Maximum Mean Monthly Turbidity (JTU)	20	MOE data analysis	Moderate/High
Dominant Substrate in Pools/Backwaters (1,2,3,4)	2	Site reconnaissance - assessed value	Moderate
Water Temperature in Select Habitat (adult)	22	Assessed value	Moderate
Water Temperature in Select Habitat (spawning)	20	Assessed value	Moderate
Water Temperature in Select Habitat (fry)	22	Assessed value	Moderate
Water Temperature in Select Habitat (juvenile)	22	Assessed value	Moderate
Water Level Fluctuations (m) Spawning (1,2,3)	3	QUALHYMO simulation - assessed value	Moderate/High
% Cover (boulder, stump, tree, vegetation, rock)	5	MTRCA data; assessed value	Moderate

HSI VALUE = 0.60

TABLE 4.4: HABITAT SUITABILITY CRITERIA FOR SMALLMOUTH BASS IN THE LOWER REACHES OF THE DON RIVER

Habitat Variable	Assigned Value	Data Source	Potential Significance of Habitat Variable for Stormwater Management
% River Cover in Pools and Backwaters	40	MTRCA data, site reconnaissance assigned value	Low
Minimum DO for Year (mg/L)	6	MOE data - assessed value	Low/Moderate
Minimum DO in Pools Backwaters	6	MOE data - assessed value	Low/Moderate
Stream Gradient (m/km)	5	MTRCA hydraulic profile	Nil
Mean pH for Year	7.8	MOE data analysis	Low
Maximum Mean Monthly Turbidity (JTU)	40	MOE data analysis	Moderate/High
Dominant Substrate in Pools/Backwaters (1,2,3,4)	1	Site reconnaissance - assessed value	Moderate
Water Temperature in Select Habitat (adult)	22	Assessed value	Moderate
Water Temperature in Select Habitat (spawning)	20	Assessed value	Moderate
Water Temperature in Select Habitat (fry)	22	Assessed value	Moderate
Water Temperature in Select Habitat (juvenile)	22	Assessed value	Moderate
Water Level Fluctuations (m) Spawning (1,2,3)	3	QUALHYMO simulation - assessed value	Moderate/High
% Cover (boulder, stump, tree, vegetation, rock)	1	MTRCA data; assessed value	Moderate

HSI VALUE = 0.42

TABLE 4.5: HABITAT SUITABILITY CRITERIA FOR SMALLMOUTH BASS IN REPRESENTATIVE TRIBUTARY OF DON RIVER: MASSEY CREEK

Habitat Variable	Assigned Value	Data Source	Potential Significance of Habitat Variable for Stormwater Management
% River Cover in Pools and Backwaters	20	MTRCA data, site reconnaissance assigned value	Low
Minimum DO for Year (mg/L)	7	MOE data - assessed value	Low/Moderate
Minimum DO in Pools Backwaters	7	MOE data - assessed value	Low/Moderate
Stream Gradient (m/km)	3	MTRCA hydraulic profile	Nil
Mean pH for Year	7.8	MOE data analysis	Low
Maximum Mean Monthly Turbidity (JTU)	20	MOE data analysis	Moderate/High
Dominant Substrate in Pools/Backwaters (1,2,3,4)	2	Site reconnaissance - assessed value	Moderate
Water Temperature in Select Habitat (adult)	22	Assessed value	Moderate
Water Temperature in Select Habitat (spawning)	20	Assessed value	Moderate
Water Temperature in Select Habitat (fry)	22	Assessed value	Moderate
Water Temperature in Select Habitat (juvenile)	22	Assessed value	Moderate
Water Level Fluctuations (m) Spawning (1,2,3)	3	QUALHYMO simulation - assessed value	Moderate/High
% Cover (boulder, stump, tree, vegetation, rock)	5	MTRCA data; assessed value	Moderate

HSI VALUE = 0.78

However, due to the moderately high hydraulic gradient in the upper and middle reaches, water scour will remove most silt. Hence, the effects of stormwater management will not be as directly observed.

Stormwater management will also have some impact upon the oxygen resources of the river through controlling BOD. A limited number of numerical simulations of the effect of water quality control of stormwater discharges upon the Don River was undertaken. The calculations suggest that control of stormwater discharges from separated sewer systems (e.g., wet ponds) will have a small effect upon DO because the organics are composed of humic substances with low decay rates. More rigorous analysis of DO regimes is, however, required to confirm the magnitude of riverine response and to include effects of riverine eutrophication. The effect of controlling stormwater and CSO discharges should be evaluated in the future.

Additional data, including diurnal DO (and diurnal temperature) measurements at critical spots in the river and levels of DO in a plug of water as the water flows from stormwater outfalls would assist in confirming that DO is not presently a significant problem. The existing monitoring data (see Supporting Document 5) indicate that present oxygen levels are not a major limitation upon fish habitat.

Of the three variables turbidity, temperature, and water level variations, water quality control of stormwater discharges may have the largest impact upon turbidity. This would occur if wet ponds were designed to achieve a 80-90% removal of suspended solids. Stormwater management using wet ponds may have a substantial effect upon water level variations over small spatial scales in small watersheds (e.g., order 1, order 2 streams), but a smaller effect upon water level variations in the more main stem of the river.

Flow control, provided by wet ponds or infiltration devices, will also have a beneficial effect upon stream erosion. The ability to decrease the frequency of bank full flow, a surrogate for erosion, in natural channels, will decrease erosion and hence siltation. The main effect of such control will be in small tributary streams; the effect upon the main stem river in the middle and lower reaches (no back water areas) may be minor because the relatively large stream gradient assists in preventing significant siltation in many areas of the river.

Stormwater management using wet ponds will have a small impact upon riverine temperatures of the Don river (see next section) because it is an open system with high temperatures controlled by solar radiation and atmosphere temperatures. The main impact would be in ponds and reservoirs where temperatures would be more constant and at high values, but have a lower diurnal fluctuation then found in a river system due to the thermal inertia of the pond.

Evaluation of the HSI factors indicates that riparian vegetation (i.e., stream canopy) will have the largest effect upon stream temperature. Overhanging canopy for over 3 to 5 km (Barton et al., 1985) may be sufficient to maintain a cold water fishery in tributary streams (see also Steedman, 1987 re importance of riparian zones). However, once the water has heated up, the extent of canopy required is not as clear because in such tributary streams, cold springs in groundwater assist in cooling the streamwater, in addition to the effects of stream canopy.

4.4 Significance of Water Temperature Limitations for Target Fish Species

In the simplest terms, riverine temperature determines whether a cold water fishery can be maintained for its whole life cycle, whether only as a migratory species during spring and fall, or whether only a warm water species is a practical target. Even for warm water species, it is necessary to minimize temperature increases above natural levels.

Excessively high summer water temperatures impose a limiting factor on habitat suitability for coldwater fish species throughout most of the Don River. These high summer water temperatures are directly related to the extensive removal of riparian forests and the beneficial shading effect of riparian forests along the river. Unless this habitat parameter can be improved to the level required for cold-water fish species, rainbow trout or any other salmonid species will not be capable of maintaining a self-sustaining population.

For example, Table 4.6 lists the habitat variables and their assigned values for a self-sustaining rainbow trout population for a river system typical of the lower Rouge River or the lower Credit River. The resulting HSI value is 0.00, indicating that present habitat conditions are unsuited to a self-sustaining rainbow trout population. However, if one examines the HSI habitat variables individually, almost all habitat criteria are at the

TABLE 4.6: HABITAT SUITABILITY CRITERIA FOR RAINBOW TROUT IN RIVERS TYPICAL OF THE LOWER REACHES OF THE ROUGE RIVER AND THE CREDIT RIVER

Habitat Variable	Assigned Value	Data Source	Potential Significance of Habitat Variable for Stormwater Management
% Stable Streambank (vegetation, rocky)	82	MTRCA habitat assessment	Low/Moderate
% River Area in Pools (low water0	15	MTRCA habitat assessment	Nil/Low
% Water Area Shaded (10-2:30)	5	MTRCA habitat assessment	Nil
Mean Stream Width (m) (low water)	3	QUALHYMO simulation	Low/Moderate
% Tree Cover on Bank (flooded MHW)	20	Site reconnaissance - assessed value	Nil
% Shrub Cover on Bank (flooded MHW)	10	Site reconnaissance - assessed value	Nil
% Herb Cover on Bank (flooded MHW)	10	Site reconnaissance - assessed value	Nil
Mean Thalweg Depth (m) (low water)	0.3	Assessed value	Low/Moderate
Dominant Pool Class (A1, B2, C3)	2	Assessed value	Low/Moderate
Maximum Water Temperature for Year (^{o}C)	28	Site reconnaissance - assessed value	Low/Moderate
Mean Maximum Water Temperature in Warm Period	26	MOE data analysis	Low/Moderate
Annual Maximum pH	8.2	MOE data analysis	Low
Annual Minimum pH	7.2	MOE data analysis	Low
Mean Annual Base Flow (% of daily)	25	QUALHYMO simulation	Low/Moderate
% Fines in Riffle Run (L 3 mm)	15	Assessed value	Moderate
% Fines in Spawn Area (L 3 mm)	15	Assessed value	Moderate
Mean Maximum Water Temperature for Embryo (^{o}C)	10	MOE data analysis	Low
Mean Minimum DO for Embryo (mg/L)	6	MOE data analysis	Low
Mean Velocity Over Spawn (cm/s)	15	QUALHYMO simulation	Low/Moderate
% Instream Cover (low water)	22	MTRCA habitat assessment	Low
Mean Substrate Size (cm)	5	Assessed value	Low/Moderate
Mean Length of Spawners (cm)	30	Assessed value	Nil
% Substrate (10 to 40 cm) (juvenile cover)	10	MTRCA habitat assessment	Low
Dominant Substrate in Riffle Run (1,2,3)	1	Site reconnaissance	Low

high range of suitability for rainbow trout, with one major exception. The maximum water temperature for the year (28°C) and the mean maximum water temperature in the warm period (26°C) exceed the upper limits for habitat suitability. This factor alone drops the overall HSI value to 0.00. In fact, these cold water species use the river but in a migratory sense in the fall. They avoid the warm water conditions by living in Lake Ontario during the summer.

One of the more useful features of the HSI model is its ability to do a sensitivity analysis for individual habitat variables. Table 4.7 examines the sensitivity of the rainbow trout HSI model to changes in the two water temperature criteria outlined above. As can be seen, if maximum water temperatures can be held at 26° and mean maximum temperature at 24°C, the HSI value increases to 0.72 with all other habitat variables remaining unchanged. In this situation, the lower Rouge River or Credit River would be rated as having a high suitability for a self-sustaining rainbow trout population.

The potential temperatures of the Don River on a diurnal basis over the spring-summer-fall period should be measured to validate that the values used in Table 4.6 are representative of the Don River. Measurements were made in an extremely hot summer (June 1988) on the lower Don, the lower Rouge and the lower Credit River. Diurnal measurements were made on the Rouge with a continuous recorder while spot measurements were made over a 24-hour period on the Credit River and Don River. Modelling analysis of the diurnal temperatures fluctuations were also made for the lower Rouge River. For the hottest period in June 1988 when diurnal air temperatures ranged from 32°C during the day time to 20°C at night time, the riverine temperatures varied diurnally from 28°C to 19-21°C in the main stem of the river. This portion of both the Credit and Rouge River had substantially more tree cover than the Don River which essentially had no canopy. The measurements on the Don River were similar to those of the Credit River and Rouge River. Accordingly for the lower Don, the diurnal temperature levels are expected to be equal to, or higher than these obtained during field monitoring data on other adjacent rivers and modelling simulations upon the same systems.

This dramatic influence of maximum water temperatures on HSI is in strong agreement with the findings of Barton, Taylor and Biette (1985). Their study of 40 streams in southern Ontario, including the Credit, Humber, Bronte and other Lake Ontario

TABLE 4.7: SENSITIVITY ANALYSIS OF HSI VALUE FOR RAINBOW TROUT IN LOWER REACHES OF THE ROUGE RIVER OR CREDIT RIVER TO CHANGES IN MAXIMUM AND MEAN MAXIMUM WATER TEMPERATURES

	Maximum Water Temperature (°C)	Mean Maximum Water Temperature (°C)	HSI Value
Base Condition	28	26	0.00
Scenario 1	27	25	0.00
Scenario 2	26	24	0.72
Scenario 3	24	22	0.74

tributaries, determined that the only environmental variable which clearly distinguished between trout and non-trout streams was weekly maximum water temperature. Streams with three week, average maxima less than 22,C had trout, while warmer streams had, at best, only marginal trout populations.

The variation in weekly maximum water temperatures in the 40 streams studied was most strongly correlated with percentage of forested stream banks within 2.5 km upstream of a site (Barton et al., 1985). Table 4.6 shows that the percent of tree cover on the banks of the lower Credit River and Rouge River averages approximately 20%. The more critical variable, the percent of water area shaded during mid-day, is only 5% in rivers typical of the Lower Rouge and Lower Credit Rivers. This variable is the primary cause of elevated maximum water temperatures in the lower Rouge and Credit Rivers. The subject of water temperatures is further addressed (measured, modelled) in BEAK (1988) and by Barton et al. (1985).

Another area of concern to fisheries managers is the major influence on water temperature on habitat within the impoundment area and of its discharge on the habitat in the river downstream. Candidate reservoirs for consideration in the Toronto area include the Milne Reservoir in the Rouge River, and the G. Lord Reservoir in the Don River. The increased water retention time in the reservoir combined with the shallowness of the basin and lack of any shading results in high mid-summer water temperatures in the surface water of the reservoir. This provides habitat suitable for smallmouth and largemouth bass but not for rainbow or brook trout. This is a major factor in selecting the smallmouth bass as the target species for HSI determination in reaches of the Don River downstream of a reservoir. If summer water temperatures branches of the Don River below the G. Lord Ross Reservoir could be maintained at suitable levels, it may be possible that both the middle and lower reaches of the Lower Don would be suited for cool or cold water fish management (rainbow trout).

The impact of impoundment temperatures upon riverine temperatures were measured in the same detailed temperature monitoring program in the Rouge River and Credit River described above. Water temperature measurements along the Rouge River during a hot spell in June of 1988 confirmed that not only do water temperatures in the reservoir become elevated, but also water temperatures in the lower Rouge River below the dam continue to increase above the impoundment level during the late afternoon period until a "riverine equilibrium" condition was attained. This appears to be the result of increased exposure to high air temperatures and direct sunlight along the exposed river channel. However, the transition zone from reservoir temperatures to "equilibrium river" temperature was only 200 m. Irrespective, the end result is a riverine water temperature level which exceeds the maximum limit for rainbow trout.

Barton, et al (1985) in their study of 40 Southern Ontario streams concluded the following: "our results confirm that temperature is the most significant factor determining the presence or absence of resident trout in small southern Ontario streams. Control of temperature, and to a lesser extent turbidity and stability of discharge, can be achieved through establishment or maintenance of forested riparian buffer strips." They further suggest that an unbroken buffer extending 3 km upstream of a site need only be 10 m wide to produce a maximum weekly temperature of less than 22^{o}C. At this maximum water temperature, the HSI for rainbow trout in the lower Don River would be good to very good. The fact that a rainbow trout population may be attainable on the Don River is supported by the self-sustaining trout population on the nearby Duffins Creek where riparian vegetation appears to be more extensive.

The watershed management implication is obvious; forested buffer strips along the watercourse of the Don River should be protected where they exist and reestablished where they have been removed. Factors to be included in establishing canopy/riparian habitat requirements include stream width, riparian buffer width and valley width.

5.0 ADAPTATION OF THE HSI MODEL TO INCLUDE TOXICITY COMPONENTS

5.1 Original Smallmouth Bass Model

The original HSI model for smallmouth bass was developed by Edwards et al. (1983). Details are provided by Edwards in his Fish and Wildlife Service (FWS) report. The model was developed for riverine populations, but is based primarily on FWS information pertaining to U.S. populations in large, wide rivers.

An outline of the model structure is shown as a tree diagram in Figure 5.1. Values for the input variables were presented in Tables 4.2 to 4.5. The input variables and functions generating and linking the intermediate HSI values are fully described by Edwards et al. (1983). Some additional factors such as pool size may be relevant in Canadian riverine populations in order 1 and order 2 streams. In such streams, the pool size has small dimensions and may limit the size of the bass.

As indicated in Section 4, the HSI assessment based upon existing physical habitat in the Don River and water quality variables included in the HSI model (pH, DO, turbidity) is forecast to vary between 0.4 to 0.6. This agrees, in general terms, with site reconnaissance of the Don. But it neither agrees with public perceptions of the fishery nor with species caught (see Section 2).

It is the hypothesis of this work that additional water quality impacts due to "toxic" components of the chemical matrix of the aquatic system of the Don River are an additional limitation to the warm water fishery. This hypothesis is now explored by incorporating components of the toxicity model developed in Section 3 into the HSI model applied in Section 4.

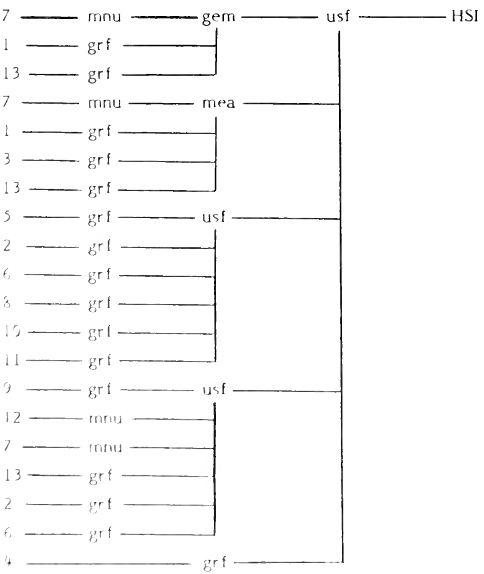
5.2 Addition of Toxicity Components

5.2.1 Components Selected

Four additional factors were considered for incorporation into the HSI model to evaluate toxic and other effects:

FIGURE 5.1: TREE STRUCTURE OF HSI MODEL FOR SMALLMOUTH BASS (Edwards et al., 1983)

Function Type		Variable Number and Name
mnu = menu function	1.	% River Cover in Pools Backwaters
gem = geometric mean	2.	Minimum DO for Year (mg/L)
usf = user function	3.	Minimum DO in Pools Backwaters
grf = graph	4.	Stream Gradient (m/km)
mea = mean	5.	Mean pH for Year
	6.	Maximum Mean Monthly Turbidity (JTU)
	7.	Dominant Substrate Pools Backwaters (1,2,3,4)
	8.	Water Temperature in Select Habitat (adult)
	9.	Water Temperature in Select Habitat (spawn)
	10.	Water Temperature in Select Habitat (fry)
	11.	Water Temperature in Select Habitat (juvenile)
	12.	Water Level Fluctuations (m) Spawning (1,2,3)
	13.	% Cover (boulder, stump, tree, vegetation, rock)



- acute toxicity;
- chronic toxicity of ambient waters;
- frequency of toxic spills (including CSO overflows); and
- barrier (or avoidance) effects.

Of these four components, three were incorporated directly into the HSI model. These are:

- chronic toxicity of ambient waters;
- frequency of toxic spills; and
- barrier effects.

Acute toxicity components were not included explicitly because they occur at higher concentrations than chronic toxicity components. If a chemical contaminant impairs the habitat at low concentrations via chronic effects, the impairment will also occur at higher concentrations where acute effects occur.

Chronic toxicity and the effects of spills were incorporated into the HSI model as one additional factor. Spills were included with chronic effects because they may affect fish through acute toxicity effects. Chronic toxicity includes such adverse effects as long-term mortality or curtailment of reproduction. Critical concentration levels for elicitation of chronic toxicity effects were developed in Section 3.0 for copper, nickel, zinc, total ammonia, phenol, pentachlorophenol (PCP) and total residual chlorine (TRC). Comparison of ambient levels to critical levels in each reach of the Don River provides a "toxic unit" contribution for each contaminant in each reach.

The effect of a barrier was incorporated into the HSI model as a second factor. A barrier to fish migration can involve either a "toxic" type "avoidance" reaction in a fish species or be a physical barrier. A chemical barrier (such as an STP effluent plume) limits the migration of warm-water species through a particular section of the river.

For the target species considered herein (smallmouth bass), neither type of barrier (toxic avoidance; physical) is directly relevant as they can maintain their whole life cycle within a reach of the river, once stocked, without migrating upstream. The barrier factor would need to be considered in more depth, only as an indicator of such warm water species as carp who must migrate to lay eggs and rear their young, or as a factor for completing a complete ecosystem analysis.

5.2.2 Addition of Components to the HSI

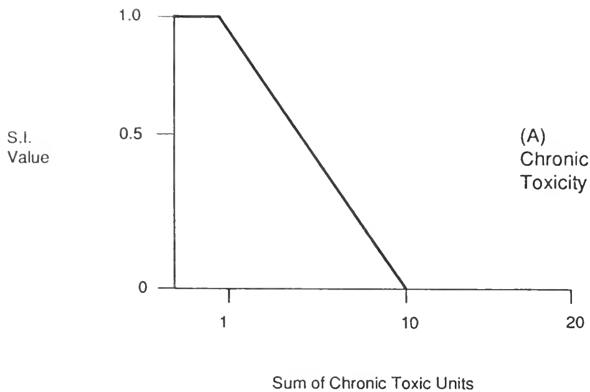
The HSI model can be summarized in the form of a tree diagram (Figure 5.1), with input variables on the right, the final HSI on the left, and functions which determine intermediate HSIs, and their interactions in between. The original HSI model for riverine smallmouth bass (Edwards et al., 1983) incorporates habitat variables listed in Tables 4.2 to 4.4. The additional toxicity variables are diagrammed in Figure 5.2; the barrier effect is given in Figure 5.2. Modifications to the model are illustrated in tree diagram form in Figure 5.3. As described above, the effects of chronic toxicity and/or spills was added as one factor while the effects of barrier was added as a second factor in the HSI model (Figure 5.3).

In inserting the chronic toxicity component of ambient water and the effect of spills (assumed as a toxic threshold effect), the component with the largest effect upon the suitability index is assumed to be the limiting component (see Figure 5.3). The sum of toxic units (CTUSUM) is a new input variable in the modified smallmouth bass HSI model to include the effects of chronic toxicity. The calculation of total toxic units for each reach is illustrated in Table 5.1. The sum can range from 0 to 20. Any sum greater than 20 takes the maximum value, indicating that a resident population cannot be sustained (Figure 5.2).

It is hypothesized that the frequency of toxic spills (FTSPILS), rather than the average ambient contaminant levels, may limit the success of the population. The annual spill frequency is input as an integer variable. Only toxic spills (likely to kill fish) should be counted. Ten such spills per year are hypothesized to be sufficient to reduce the HSI to zero (Figure 5.2).

Barrier effects may be important to some local populations which depend for success on migration from outside the area (e.g. a spawning migration or recruitment of juveniles from more productive areas). Barriers may be either physical (e.g. a dam; a weir) or chemical (e.g. a toxic discharge at a river mouth) and may permit some passage through the barrier. The impact on the population is expected only if a barrier is in place and the

FIGURE 5.2
Toxicity Fuctions Added to the Small Mouth Bass HSI Model



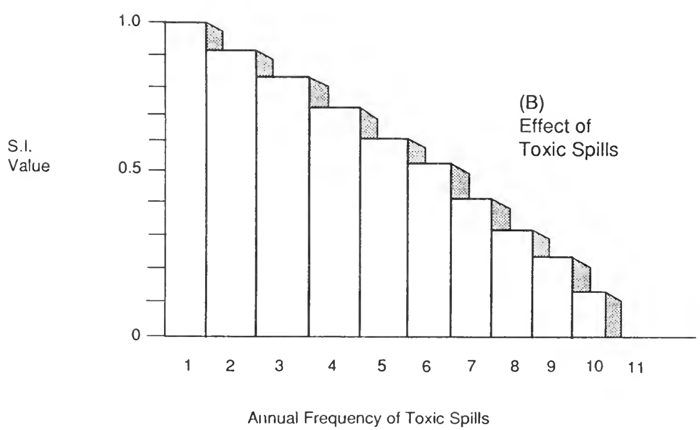
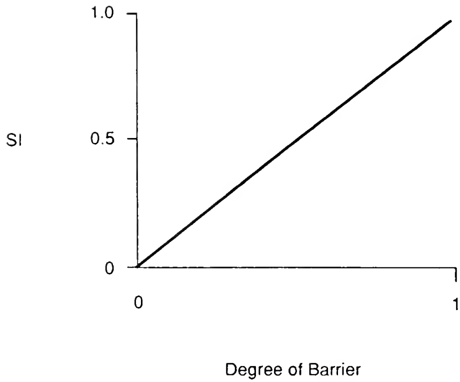


FIGURE 5.2(C)
Barrier Functions Added to the Smallmouth Bass HSI Model



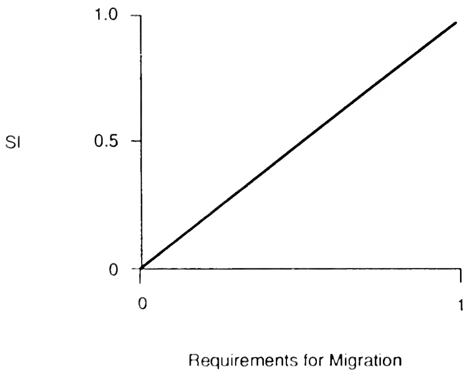
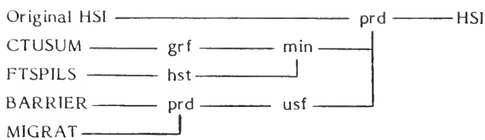


FIGURE 5.3: TREE STRUCTURE OF THE MODIFIED HSI MODEL FOR SMALL MOUTH BASS



usf: 1-X = intermediate HSI

min = minimum of two inputs

prd = product of two inputs

grf = graph (Figure 6.1A)

hst = histogram (Figure 6.1B)

population depends on migration across the barrier. The impact is therefore expressed as a function of two variables, BARRIER and MIGRAT, both of which may range from 0 to 1. The HSI is reduced by a factor equal to one minus their product.

The barrier effect due to a large dam or weir which prevents upward migration of a species which does not require migration for their life cycle would be assigned the value of one for the barrier but a value of zero for its migration requirements. This ensures that the barrier component is not a limitation. The barrier due to a chlorinated STP plume or chlorinated stormwater discharge can be handled similarly. The acute toxicity model (chapter 3) and an empirical SI curve can be used to evaluate the impact of the discharge plume as a "barrier" to adults, if one consciously chooses to neglect the chronic effects upon the whole life cycle. The acute toxicity model can be used to estimate a barrier effect (e.g. 0.5). If the smallmouth bass (as an indicator of a migratory warm-water fishery) should be in the zone of the STP plume or chlorinated stormwater discharge, the migratory factor is set at one, resulting in an over SI for the barrier component of 0.5.

5.3 Impact of Toxicity, Spills and Barriers Upon the HSI

The effect of the different chemicals in the river on toxicity and the frequency of spills assumed for each zone of the Don River is given in Table 5.1. The contribution of toxicity from the different chemicals are based upon concentrations given in Table 5.2. The impact of these components upon the unmodified HSI values are given in Table 5.3.

The chemical concentrations (Table 5.2) for the Middle and Lower Don represent a frequency of being exceeded of approximately 10%, based upon PWQMN (Provincial Water Quality Monitoring Network) and EMP (Enhanced Monitoring Program) measurements. The concentrations in the Upper Don have been assumed to be similar to in magnitude, but smaller than those of the middle Don, in the absence of monitoring data in the upper reaches. Metals estimates are taken as dissolved at these levels.

The HSI in the upper and middle reaches is reduced by the same amount due to the inclusion of toxicity (Table 5.3). The main contributors to this toxicity are the effects of copper, zinc and ammonia upon chronic toxicity. Spills have a larger potential impact in the middle reaches than in the lower reaches but due to the assumption of a limiting

TABLE 5.1: ESTIMATED CHRONIC TOXIC UNIT CONTRIBUTIONS AND SPILL FREQUENCIES IN THREE REACHES OF THE DON RIVER

Toxicant	Critical Concentration	Toxic Units Without Management		
		Upper	Middle	Lower
Copper	0.006	1.67	2.50	3.17
Nickel	0.42	0.028	0.028	0.031
Zinc	0.03	1.33	1.50	1.87
Ammonia	0.007	0.714	0.714	7.57
Phenol	0.02	0.03	0.03	0.03
PCP	12	0.001	0.001	0.006
TRC	0.001	1.0	1.0	250
Total	-	4.8	5.8	260
Spills/Year	-	1	2	10

TABLE 5.2: CHEMICAL CONCENTRATIONS OF ELEMENTS USED IN TOXICITY EVALUATION

Copper (dissolved)	0.019	mg/L
Nickel (dissolved)	0.013	mg/L
Zinc (dissolved)	0.056	mg/L
Ammonia	0.053	mg/L as N
Phenol	0.0005*	mg/L
PCP	0.072	mg/L
TRC	0.25	mg/L in lower river;
	0.0	in remainder of river

* Based upon one-half detection limit of 0.001 mg/L.

TABLE 5.3: HABITAT SUITABILITY INDEX (HSI) FOR SMALL MOUTH BASS IN THREE REACHES OF THE DON RIVER

HSI Model and Scenario	HSI in Reach		
	Upper	Middle	Lower
Original HSI Model			
o no toxicity component in model	0.78	0.60	0.42
Modified Model[1]			
o (includes toxicity and spills improvements)	0.45	0.28	0

[1] Toxic units and spill frequencies as per Table 5.1.

"toxic component", chronic toxicity has the largest effect in both reaches. The contribution of ammonia to sublethal (chronic) toxicity requires further research as the values assessed are found in many urban rivers and even rural ecosystems. The ammonia values measured as representative of rural ecosystems may have resulted from hydrolysis of organic nitrogen in the sample bottle during sample transport and storage in the laboratory before analysis. Accordingly, such ammonia values may be high. Measurements of copper and zinc levels in the upper watershed are required to confirm the toxicity evaluations given in Table 5.1 for the upper watershed.

The HSI in the lower river decreases to completely unsuitable levels due to sub-lethal toxicity (Table 5.3) in comparison to the upper and middle reaches of the Don River. Spills also have a significant effect (SI = 0.1 for spills of 10 per year) but the limiting component is chronic toxicity. Total residual chlorine in the STP effluent contributes over 90% of the toxicity in the lower river.

6.0 PREDICTED IMPACTS OF FURTHER DEVELOPMENT AND REMEDIATION ON STREAM HABITATS (HSI)

6.1 Variables Evaluated

Habitat variables used in HSI models for the target species, smallmouth bass in the Don River are listed in Tables 4.2 to 4.5. Of the variables listed, six are considered as being of primary importance with regard to the potential effects of further urbanization in the headwaters, stormwater management throughout the watershed and management of the STP and CSO's in the lower watershed. These are:

- o changes in base and peak flow regimes,
- o water temperature,
- o turbidity levels,
- o bottom habitat,
- o chronic toxicity, and
- o spills.

Each of these is considered in the context of existing conditions and the effect of control measures.

6.2 Predicted Effects for Non-Toxicity Components

6.2.1 Flow Regime

In general, urban development within a watershed is expected to influence both the peak and base flows more than the average stream flow. From a fisheries habitat perspective, it is the mid-summer and mid-winter base flows which are often critical to fish populations inhabiting streams.

In order to provide a suitable database for HSI analysis of the potential effects of urban development in the upper watershed, a continuous simulation method for hydrologic modelling was required. Calculations made by QUALHYMO in its application in the Rouge River, were extracted generically and used here to generate data required for HSI analysis.

Model calculations for the complete urbanization of a rural catchment, were available for the following hydrologic parameters:

- average daily flows for wet, dry and average years (for whole year and summer season);
- flow, water depth and velocity-duration curves (for annual, April to 15 May, April to September and June to August periods);
- three-week high flows for various return periods (for summer and fall periods); and
- seven-day low flows for various return periods (for summer and winter periods).

Salient results pertinent to the HSI analyses as follows:

- average daily flows are increased in areas downstream of urban development. This applies in wet, dry and average years for either the whole year or for the critical summer period. The largest increases occur in dry years when urban water uses, such as watering of lawns, washing cars, etc., would appear to augment low natural base flows;
- a similar situation exists for the three-week high flow, where urban development scenarios substantially increase peak flows. This would appear to relate to a more rapid run-off in urbanized areas; and
- seven-day low flows are also increased after urban development. This would appear to result from augmentation of base flows by urban water uses.

All of the above simulations assume that no special stormwater management facilities have been incorporated into the development scenarios. Use of small stormwater ponds would have an effect on these results, mainly related to an alternation of values for short-term peak flow rates, an effect upon the frequency of bank-full flow and a small effect upon seven-day low flows.

From the perspective of fisheries habitat, the broad conclusion would appear to be that critical base flows during the summer and winter periods would not decline with the urban development scenarios being examined. On average, low base flows may even be increased somewhat with urban land use in the main stem of the river system. The increase in base flow rates over the past two decades is observed in water flow measurement records of the Water Survey of Canada.

This conclusion, however, must be significantly modified for small tributary streams. Low flow may not change in the Don River tributaries due to canopy removal because little canopy remains in most streams. However, low flow is expected to decrease in small tributaries due to the decrease of perviousness associated with urbanization.

The effect of the above alterations on HSI values outlined in Section 4.0 is negligible for smallmouth bass. These alterations would be more important for rainbow trout or brooke trout, if they were the target species because they would be more adversely affected if flow regimes were altered. However, potential increases in base flow are, on average, too minor to increase significantly the HSI value.

6.2.2 Water Temperatures

Water temperatures in the Don River are already too high for cool or cold water fish species during the summer period. This is the direct result of removal of the riparian forest canopy along much of the middle and lower river.

From a fisheries habitat perspective, urban development or redevelopment should not further affect water temperatures negatively, unless further removal of tree canopy along the river banks also occurred. The rationale for this statement is as follows. The G. Lord Ross Reservoir has a significant effect on water temperatures in the West Don River through summer heating of surface waters in the reservoir. Urban activities in areas above this reservoir would not cause significantly higher water temperatures in the reservoirs than already occur provided that no industrial discharges of heated water are permitted. Thus temperature regimes in the river below G. Lord Ross Dam would be essentially unaffected by urban activities above it. On the East Don River, this reservoir effect does not exist.

Mitigating and restorative efforts should be directed at enhancing the riparian forest canopy in order to reduce water temperature and stabilize stream banks. Headwater tributaries (e.g., Maple District Office Area), where forest cover remains adequate to keep summer water temperatures low enough for brook trout, should be particularly safeguarded in this respect when development plans encroach on these areas.

The impact of further urbanization or urban redevelopment upon temperature components of the HSI for smallmouth bass will be small because the previous land uses (agriculture in the upper reach; urban land uses in the lower river) have the same temperature impacts. This is principally because this habitat variable (temperature) has already been degraded and should be the focus of rehabilitative measures. Remediation involving restoration of canopy will be the principle means for improving water temperatures. Stormwater control by wet ponds will have a significant impact upon cold water streams; they will have a minimal impact under present conditions in the Don River due to the ambient warm summertime temperatures.

With substantial improvement (over the long-term) in summer water temperatures, the lower Don River may attain a relatively high HSI value suitable for a cold-water target species such as a hatchery-maintained, rainbow trout. Attainment of such temperature conditions are the minimum requirement if a resident cold-water species is adopted in the future by agencies such as MNR or MTRCA as a target species. Only modest improvements may be required for temperature, if a migratory cold water species is adopted, as their requirements for cool temperatures are more frequently met during their normal periods of migration in the spring and fall.

6.2.3 Turbidity

Increases in turbidity are often associated with changes in land use, particularly where agricultural or construction activities and bank scour occur. Pertinent conclusions put forward in other studies or developed in the above HSI analysis include the following:

1. turbidity in stormwater from urban land uses likely would not exceed that presently occurring from agricultural land uses in the Upper Don River watershed, at least not in mature, steady-state urban systems;

2. the potential exists for major short-term increases in erosion and turbidity during construction periods if effective preventative measures are not employed;

3. wet ponds and other control options will decrease turbidity levels. This will not have a marked effect upon the bottom habitat of much of the middle and lower reaches of the Don River due to scour resulting from the moderate hydraulic gradient; and

4. present turbidity levels do not have a substantive effect upon the HSI values of smallmouth bass.

On the West Don River, the G. Lord Ross Reservoir tends to function as a sediment trap, with the result that higher turbidity events above the reservoir tend to be moderated before release of this water to the lower river. This would tend to provide some factor of safety for turbidity levels in the lower Don River, and help to protect habitats against siltation.

On the provisions that construction activity would not occur within the floodplain of the river and that suitable erosion prevention measures were employed (wet ponds, sediment traps, etc.), turbidity-related effects should have a minimal influence on the HSI for smallmouth bass in the remainder of the Don River, particularly in the main stem of the river.

Significant improvement in fish habitat will, however, be observed in small tributaries with low stream gradient if water quality control is practiced by wet ponds. This will occur by controlling the discharge of suspended solids to the tributary. Some effects upon the frequency of bank-full flow and hence upon stream erosion may be observed, but the magnitude of this reponse was not calculated in this study.

6.2.4 Bottom Habitat

Urban activities and water quality control will have an indirect impact upon bottom habitat. The potential effects include:

1. Siltation;
2. Change in the size distribution of rubble, cobbles, and stones; and
3. presence of suitable organic matter as food for the food webs and hence fish.

Urban activities have a direct effect through construction of concrete lined channels to provide hydraulic capacity for flood flows, and of weirs or dams which prevent fish migration.

Of all these activities, the impact upon organic matter in the bottom habitat and channelization are the most severe. As noted above, loadings of suspended solids, erosion of banks and their control will not have a substantial effect upon much of the river due to scour associated with the river gradient. Similarly, the size distributionof rubble/cobble will be affected less by flood flows and more by geological factors which control their source and quantity in an urban environment.

The presence of organic matter is not assessed in the HSI model. Rather it is an essential biological factor which is included in a second index, the index of biological integrity (IBI), discussed in Chapter 8.

Concrete lined channels and other channelization projects in the Don River (riprap in small tributaries; terrifix brick, gabben baskets) are one of the major limitations of the HSI, particularly in such reaches as the West Don. Their replacement over the long term with bottom designs which provide for bank stability and hydraulic capacity during flood flows but which allow cobble sand rubble to accumulate and vegetation to grow through the bed material, will significantly enhance bottom habitat.

6.3 Predicted Effects of Control of Chronic Toxicity and Spills

Tables 6.1, 6.2 and 6.3 show the effects upon aquatic toxicity and HSI values for each reach of the Don River, of management scenarios, based on the overall modified smallmouth bass model. Barrier effects were not considered important since this population does not depend on migration. However, toxicity factors are very important.

TABLE 6.1: EFFECT OF MANAGEMENT OF DISINFECTION PRACTICE UPON ESTIMATED CHRONIC TOXIC UNIT CONTRIBUTIONS IN THREE REACHES OF THE DON RIVER

Toxicant	Toxic Units for Present Conditions			Toxic Units for Chlorination Control Measures		
	Upper River	Middle River	Lower River	Lower River[1] (STP Dechlorination)	Lower River[2] (No Chlorination)	Middle River[3] (Stormwater Chlorination)
Copper	1.67	2.50	3.17	3.17	3.17	2.5
Nickel	0.028	0.028	0.031	0.031	0.031	0.028
Zinc	1.33	1.50	1.87	0.83	0.83	1.50
Ammonia	0.714	0.714	7.57	2.86	2.86	0.714
Phenol	0.10	0.10	0.25	0.10	0.10	0.10
PCP	0.001	0.001	0.006	0.004	0.004	0.001
TRC	1.0	1.0	250	10	1.0	250
Total	4.8	5.8	260	17.	8.0	260
Spills/Year	1	2	10	10	10	2

1 Control Measure 1: Treatment of STP chlorine discharge by dechlorination to 0.02 mg/L TRC
2 Control Measure 2: Cessation of chlorination at North Toronto STP
3 Control Measure 3: Chlorination of storm water discharge

TABLE 6.2: HABITAT SUITABILITY INDEX (HSI) FOR SMALLMOUTH BASS IN THREE REACHES OF THE DON RIVER FOR DIFFERENT CHLORINATION ALTERNATIVES

HSI Model and Scenario	HSI in Reach		
	Upper	Middle	Lower
Present Conditions (includes toxicity and spills components)	0.45	0.28	0
Control Measure 1: Treatment of STP discharge to 0.02 mg/L TRC	-	-	0
Control Measure 2: Removal of chlorination in STP effluent	-	-	0.04
Control Measure 3: Chlorination of stormwater to achieve swimming standards in River	-	0	-

TABLE 6.3: PREDICTED EFFECTS OF CONTROL OF OTHER COMPONENTS OF AQUATIC TOXICITY UPON TOXICITY UNITS

	Condition	Toxicity Units for Upper River	Toxicity Units for Middle River	Toxicity Units for Lower River
1.	Toxic Units Without Management (Table 5.1) Except that the STP Effluent is dechlorinated to 0.02 mg/L TRC	4.8	5.8	13
2.	Nitrification of STP effluent (80% removal of ammonia) *	4.8	5.8	7.9
3.	50% removal of heavy metals *	3.3	3.8	10
4.	Nitrificiation of 50% of STP effluent and 50% removal of metals *	3.3	3.8	5.4

* Control of North Toronto STP effluent to give TRC of 0.02 mg/L levels is assumed.

6.3.1 Control of TRC Components of Aquatic Toxicity

The control of chronic toxicity was first evaluated by targetting the key component of chronic toxicity in the lower river - total residual chlorine from the STP; and examining the impact of disinfection of stormwater by chlorination. Three schemes were evaluated. The effect of these schemes upon toxicity units are summarized in Table 6.1 (Columns 5, 6, and 7, respectively). The effect of these schemes upon the HSI is summarized in Table 6.2.

The three schemes are:

1. Reduction of TRC in the North Toronto Plant effluent by dechlorination to an effluent discharge of 0.02 mg/L TRC (see Column 5, Table 6.1).

2. Cessation of chlorination at the North Toronto Wastewater Treatment Plant (see Column 6, Table 6.1).

3. Disinfection of stormwater by chlorination to achieve swimming standards. This is assumed to result in a TRC level of 0.25 mg/L throughout the middle and lower reaches of the Don River basin (see Column 7, Table 6.1).

The assessment of this third scheme is used to assist in establishing the potential impact of this disinfection alternative. Disinfection of stormwater by chlorination without subsequent dechlorination is not under active consideration due to the impact upon fisheries; rather ultraviolet irradation is the main method evaluated in the Summary Report.

A management scenario involving dechlorination of the STP discharge to 0.02 mg/L TRC as outlined in Table 6.1 would probably not be quite sufficient to permit long-term maintenance of a resident small mouth bass population (Table 6.3). The remaining residual chlorine, and two other toxicants, ammonia and copper, are primarily responsible.

The removal of any chlorine residual from the STP effluent by cessation of effluent chlorination may provide a habitat which is marginally suitable (HSI = 0.04). With total removal of chlorine residual, the frequency of spills limits the index to the value of 0.04. The value could approach 0.1 with reduction of spill frequency to 8 spills or less per year.

Chlorination of stormwater discharges in the middle reach of the Don River would clearly have an adverse impact on smallmouth bass populations (Column 7 of Table 6.1). If residual chlorine levels comparable to those in the lower Don occurred in the middle river, resident smallmouth bass would probably be eliminated in the middle reach of the river.

6.3.2 Control of Other Components of Chronic Toxicity

It is useful to note, as well, the potential impact of other management options upon the aquatic toxicity of the river. The effects of nitrification of the STP effluent and removal of heavy metals in stormwater runoff is given in Table 6.3 and compared to present conditions, assuming that the North Toronto STP is chlorinated to 0.02 mg/L residual chlorine levels.

Nitrification of the STP effluent (80% removal of ammonia) will have a substantial impact upon the toxicity, if TRC control were achieved (see Table 6.3). However, it would appear from Table 6.3 that control of toxic heavy metals are equally important to control of ammonia in the upper and middle zones of the river.

Wet ponds or their equivalent have been concluded to be a key method in the "Don River Strategy" for improving water quality in the river system due to stormwater discharges. Removal of 50% or more heavy metals (see Table 6.3) should bring the habitat as expressed by the toxicity modified HSI model to a level where chronic toxicity is less of a limitation to the suitability of the river for maintaining a healthy fishery.

6.4 Summary of Modelling Calculations

The potential effects of further development in the headwater areas of the Don River on flows, water temperature and turbidity in lower river sections suggest that HSI values for the target fish species would not be significantly affected in the lower river by such urban developments. In the case of water temperature, and to a lesser extent turbidities, this is due to the fact that conditions already range from being somewhat degraded to severely degraded in comparison to natural background conditions.

This is not to suggest that further urban development in general would have no effects on habitat suitability for smallmouth bass. In fact, urban development if properly controlled, and redevelopment create opportunities for enhancing present habitat.

Urban development in headwater areas will degrade present streams significantly, but it also provides possibilities for improved habitat if properly designed. The improvements are associated with reduction of suspended solids and nutrient inputs from present open fields associated with plowing and the resultant overland erosion. Degradation will occur due to increased stream erosion associated with flow indicators such as the frequency of bank-full flow, stream channelization projects, removal of existing sparse canopy, increased frequency of spills, and an increased loading of toxicants such as heavy metals.

Several issues related to fish habitat management and toxicant management from the impacts of urbanization and the potential opportunities for environmental enhancement. Following are a number of issues or concerns which should be addressed:

1. The Habitat Suitability Index model is a resource management and planning tool which holds considerable promise. However, rather than only apply it to the average of a broad range of habitat variables over extended sections of the watershed (i.e., upper reaches, middle reaches), it would be a far more effective tool applied to individual tributaries where the specific effects of proposed development and restoration projects could be assessed against stated and quantified habitat objectives.

2. Urbanization imposes other environmental risks which are difficult to quantify or predict and which are not presently incorporated into HSI models. Two particular risks include spills, and urban chemicals. The incidence of accidental spills on roadways, at service stations, or at industrial sites increase markedly with urbanization. The use of many herbicides, pesticides, fertilizers and other chemical agents is more intensive in urban areas. This imposes water quality stresses on receiving streams.

   The effect of spills and toxic discharges was incorporated into the HSI model in this study. The results indicate that these components decrease the habitat suitability particularly in the lower reaches of the Don River from the fair range to essentially non-existant. A toxic material entering the river whether from normal stormwater runoff, STP discharges or spills, rapidly reduces the HSI value to 0.00 for any sensitive fish species.

Further work is required to validate the relative significance of physical habitat and toxic factors predicted by the modified HSI for smallmouth bass.

3. Intensively urbanized watersheds, such as the Don River and Highland Creek, do not support habitats suited to target fish species such as smallmouth bass. While individual urban development projects do not appear to be responsible for major habitat deterioration, the incremental and cumulative effects of all urbanization activities likely have a profound effect on many facets of the stream ecosystem. If there are natural limits to urbanization beyond which river systems can no longer be managed as useful and productive resources, these should be taken into account in developing a total watershed land use management plan.

   In the case of the Don River watershed, particularly the Lower Don, the evidence appears qualitatively to be sufficient to indicate that these natural limits have already been exceeded.

7.0 FUTURE DIRECTIONS IN MODELLING THE RESPONSE OF AQUATIC TOXICITY AND FISH HABITAT TO WATER QUALITY CONTROL

Background

The response of fish habitat to water quality control requires that models be available to predict the response of water flow, water depth, suspended solids concentration, water temperature, dissolved oxygen and aquatic toxicity to control efforts. Models are available to predict, in a reasonable way, the above-noted response variables and the chemical concentrations which cause aquatic toxicity. When applied as indicated previously in Chapters 5 and 6, the response of fish habitat to water quality control efforts can be evaluated quantitatively.

One major link which to date has been missing is the quantitative tools necessary to calculate the response of aquatic toxicity and its effect upon fish habitat. This link has been established in this study. This link is now compared to mechanistic models for fish uptake of contaminants to show where future research and modelling directions may improve the link of aquatic toxicity to fish habitat.

Scope of Chapter

This chapter places existing models for contaminant uptake by fish into a pathways perspective. It then uses this perspective to show a few of the potential shortcomings of the Toxic Unit model approach but also to show why it is a useful tool for the forseeable future.

7.1 Environmental Pathways

An environmental pathways approach to contaminant transport is a method increasingly used by academic, scientific and regulatory agencies to assess the impact of contaminant releases to the environment upon fish and biota. Basically, it is a steady-state, mass balance approach to calculating environmental concentrations, concentrations, or body burdens in fish and biota, and levels in human beings, given release rates from various natural and cultural sources.

An environmental pathways block diagram is given in Figure 7.1 relating the flow rate of water discharged, and the mass discharge rate of contaminants from various sources (households; hospitals, universities and other institutions; watersheds e.g., stormwater runoff; atmospheric; leachate) to concentrations in surface water (including rivers) and aquatic sediments, concentrations in fish and other terrestrial biota, and the resultant concentration in human beings.

In the case of cancer and other human impacts, the accumulation rate of contaminants in humans can be related to the potential risk to developing cancer from carcinogens (such as arsenic, PAH's, PCB's, dioxin) or from ionizing radiation (e.g., radionuclides such as I-129, Cs-137, Ra-226, etc.).

An overview of the mathematical model which uses the steady-state mass balance approach to predict the chemical contaminant burden of elements in fish or humans due to contaminant releases to the environment, is given in the appendix. Relevant aspects of the model are summarized herein for the following purposes:

1. to show how the Toxicity Unit Index approach used in this study is based upon mass balance principles and toxicity concepts; and

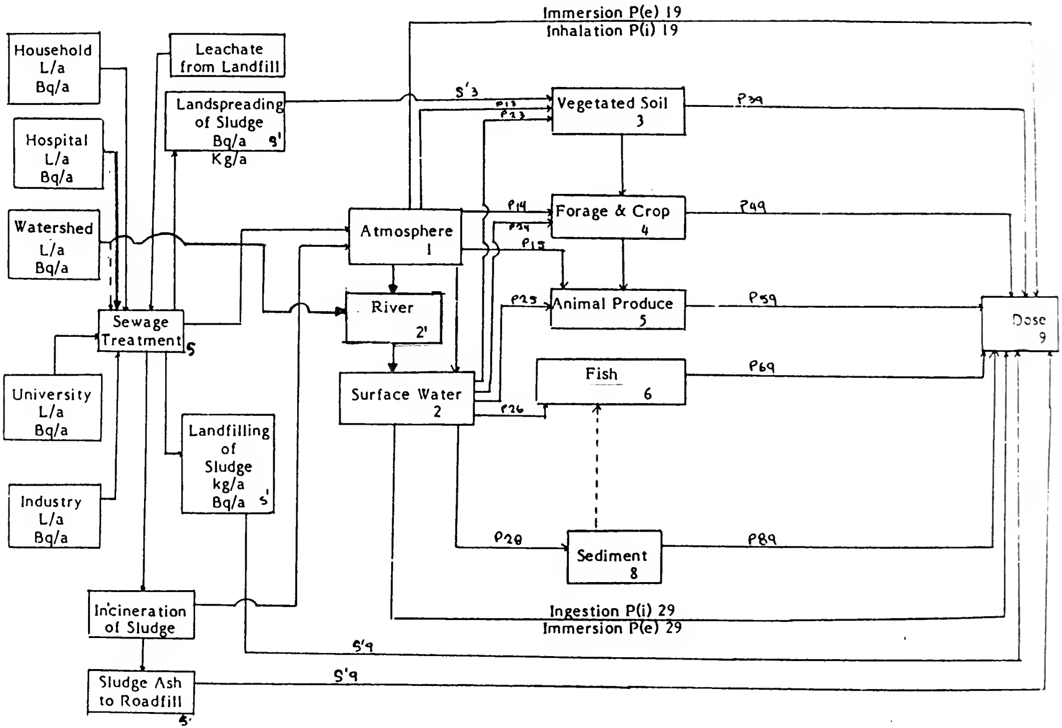
2. to detail corrections necessary to total metal concentrations measured in the environment for use in the toxicity model.

7.2 Models for Fish Uptake

7.2.1 Bioconcentration Factor Approach

The chemical burden of these elements in fish can be assessed from measurements of fish tissue and checked using the bioconcentration factor (BCF) approach. The BCF approach is based upon empirical relationships between waterborne concentrations (or sediment concentrations) and fish tissue concentrations obtained in other aquatic systems.

FIGURE 7.1: PATHWAYS FROM CONTAMINANT SOURCES TO FISH AND HUMANS



The bioconcentration factor (BCF) is defined as:

$$BCF = \frac{\text{mg/kg in edible parts of fish}}{\text{mg/kg in water or sediments}} \qquad (7.1)$$

$$= \frac{X_6}{X_2} \qquad \text{(see Figure 7.1)}$$

Values for BCF's are tabulated in standard references in the scientific literature.

Use of the BCF provides an order of magnitude estimate of the chemical burden in fish, as there are various factors causing variation in the estimates including bioavailability of metals in the water or sediments. Monitoring data narrow the uncertainty but must be carefully assessed where the fish's life cycle is spent in different water bodies (e.g., the Don River, Toronto Harbour, Lake Ontario).

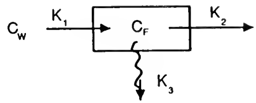
The BCF approach is an equilibrium approach in which the concentration in the fish is assumed to be instantaneously at equilibrium with the water concentration. This implies that the fish concentration responds to the typical half order of magnitude concentration variations observed during and after storm events. Clearly, this does not occur; rather the fish reaches a dynamic steady-state with the environment dependent upon the time scale of ambient concentration variations and the kinetics of uptake.

7.2.2 Kinetic Approach

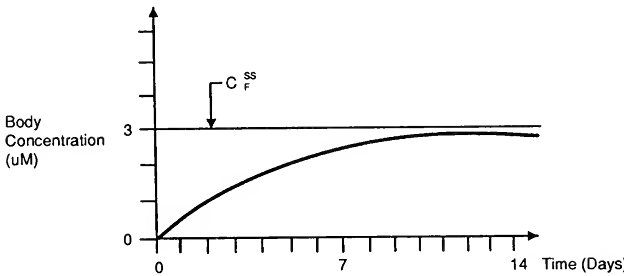
A pathways diagram for movement of contaminants into and out of fish is given in Figure 7.2. The basic mass balance on the uptake and release pathway is

$$\frac{dC_F}{dt} = k_1 C_w - k_2 C_F - k_3 C_F \qquad (7.2)$$

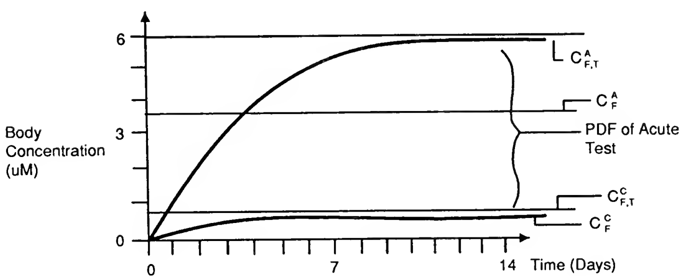
FIGURE 7.2
Fish Pathway Kinetics



(a) Pathways

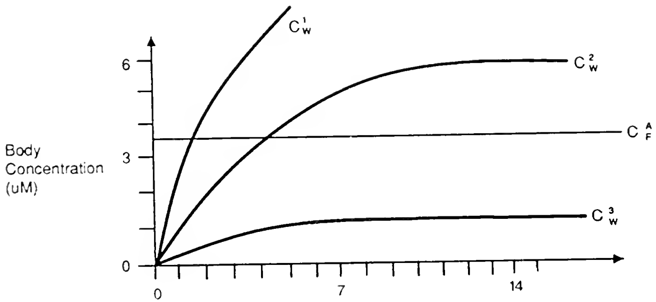


(b) Determination of BCF Value

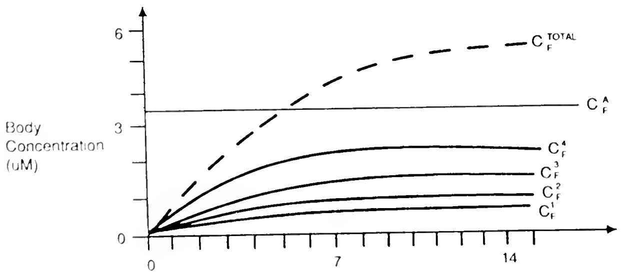


(c) Relationship of "Chronic Body Burden With Acute Body Burden"

FIGURE 7.2 (Cont'd)



(d) Uptake Curve for a Variety of Water Concentrations



(e) Uptake Curve for Several Narcotic Organic Chemicals

where: C_F = fish concentration (molar, i.e., moles/L)
C_w = the water concentration (molar)
k_1 = uptake rate constant (d^{-1})
k_2 = elimination rate constant (d^{-1})
k_3 = decay rate constant (d^{-1})

If decay is negligible, as it is for most inorganic chemicals and many organic chemicals, the general kinetic equation is:

$$C_F = C_w \cdot BCF\,(1 - \exp(-k_2 t)) \quad (7.3)$$

where: $BCF = k_1/k_2$

This is called the general, one-compartment open model operating under first order kinetics (McCarty, 1987). Its assumptions are often not stated in the literature. They are as follows. It assumes that water concentration is constant. It assumes that the fish concentration is zero, initially.

7.2.3 Relationships Between Bioconcentration and Toxicity

Bioconcentration

A curve predicted by the model for accumulation of a substance in fish is given in Figure 7.2(b). Under the given test conditions, the steady-state concentration in the fish is 3uM (micromolar). The time to approach equilibrium is approximately 7-10 days, which, as indicated in Equation 7.2, is determined by the elimination rate constant, k_2. The actual magnitude of bioconcentration is given by the ratio of the two kinetic constants, k_1/k_2.

Toxicity

A curve for the uptake of organic chemicals such as narcotics in a toxicity test is given in Figure 7.2(c). The graph indicates that for the particular narcotic applied to rainbow trout, the body burden at which an acute response (C_F^A) in fish is observed, is approximately 3.5 mM (millimolar) and that the body burden at which a chronic response (C_F^C) is observed, is approximately 0.6 mM.

Two test waters and the resultant body burdens predicted by the contaminant uptake model (Equation 7.2) are also indicated in Figure 7.2(c). For one water sample whose steady-state body burden ($C^{A}_{F,T}$) is approximately 6 mM, the fish attains the acute body burden within 4 days and hence would fail the acute toxicity test (i.e., it would die in the standard 96-hour LC50 test for rainbow trout). For the second water sample whose steady-state body burden ($C^{C}_{F,T}$) is approximately 0.5 mM, the fish would pass the acute toxicity test, but start developing chronic toxicity effects between 7 and 14 days. Such chronic effects include:

- change of skin colour;
- swimming in a disorientated manner; and
- other physically observable stresses.

Sketched also upon Figure 7.2(c) is a postulated set of limits for the 95% confidence interval for the tolerance distribution curve (a type of probability distribution function (PDF)) of fish to the acute toxicity test. These limits suggest that the lower limit of the "acute" response of fish in the terms of mortality are within the same range of chronic toxicity. An alternative interpretation is that errors in the estimates of the short-term acute test fall, at longer time frames, within the same range as the upper limit of the chronic test, a level where other effects such as disorientation of fish can also act to magnify the effects of low levels of contaminants.

The lower threshold curve, $C^{C}_{F,T}$, also indicates that if sufficient time passes, the integration of low levels of contaminants in water can still cause stress to fish, even though "explicit" acute body burdens are not attained. This whole technical area is, at present, contentious and requires further research to validate/challenge the research given in Figure 7.2(c).

Effects of Different Water Concentrations

The effects of three different water concentrations upon body burdens are given in Figure 7.2(d). The highest concentration, C^{1}_{W} , causes acute toxicity within 1-2 days while the second level, C^{2}_{W} , causes an acute response within 4 days. The third concentration level, C^{3}_{W} , does not cause an acute response within 4 days but may cause an acute response in 7-14 days, given the range of the tolerance curve indicated in

Figure 7.2(c). The third curve, C_w^3 , would cause a chronic response because its body burden at 10-14 days, 1.2 mM, is above the "chronic body burden" indicated in Figure 7.2(c).

7.2.4 Recent Advances in Toxicity Testing

Substantial investigations into the theory and science of toxicity testing have been attempted in the past few years (McCarty, 1986, 1987a,b; McCarty et al., 1989; Abernethy et al., 1988). However, most of the recent work in the field has advanced the protocols for testing, without relating the test results to water concentrations or to body burdens. The above section outlined some of the theory of effects of toxicity and bioaccumulation. This section presents the recent advances and their relationships to typical test results.

The following statements outline the recent advances and the interrelationships:

1. Toxicity and bioaccumulation (bioconcentration) are related through the model given above (Equation 7.1). The best predictor of toxicity is body burden; however, this response variable is rarely measured. Water concentration is usually measured. Only when the BCF and the kinetic constant k_2 are known, or when body burden is measured over time in the toxicity test, can the concept of body burden be used to assess toxicity.

2. There is a need to homogenize toxicity testing and bioaccumulation measurements, as both give similar information (based upon the next point, and the kinetic model).

3. Experimental evidence is evolving that body burdens, which cause acute responses, have the same value for similar modes of action. This evidence is limited, at the moment, to narcotics, as they are the only ones tested so far. The evidence suggests that for narcotics, acute toxicity is observed in the range of 3-6 mM and that chronic toxicity is observed in the range of 0.1 to 1% of these levels.

4. The following typical ranges of acute toxicity (McCarty, 1987) have been observed for body burdens for the following compounds.

Compound	Organism	Body Concentration (in M/kg)
Chlorobenzene	Fish	5-12
Chlorobenzene	Fish	2
PCB	Fish	GT 0.7
PCB	Crustacea	1.4-1.9
PCB	Fish	Approximately 1
Chlorobenzene	Macroinvertebrate	3-13
PAH	Crustacea	4-21
Aminocarb	Fish	1.4-2.3

5. When a group of compounds which have the same mode of toxic action (e.g., a narcotic) achieved a cumulative body burden in 4 days which is greater than the acute body burden, an acute response is seen in the fish.

Cumulative Effects of Toxicity

The latter point above is illustrated in Figure 7.2(e) for narcotics. The body burden curves for four compounds (C_F^1, C_F^2, C_F^3, C_F^4) are given. The individual body burdens (at t = 14 d) are 0.5, 1.0, 1.5 and 2.1 mM, respectively. Individually, they would not cause an acute response in 4 days; it is possible however that they individually might cause a chronic response, and even an acute response in 1-2 weeks.

The total body burden curve, C_F^{total}, is also given in Figure 7.2(e). It indicates that the "toxic" body burden, C_F^A, 3.5 mM, is attained in 5 days. This indicates that an acute response may be attained within 4 days, dependent upon the acute toxicity tolerance distribution function.

7.2.5 Overview of State-of-the-Art

A variety of responses are attained in organisms dependent upon whether a mutagenic, a carcinogenic, a teratogenetic, a toxic or other response is being observed. All have different modes of action and induce different responses in cells or a whole body response.

The main chemicals of concern in toxicity testing can be classified into the following:

- metals (e.g., copper, aluminum);
- organometallics (e.g., methyl mercury, organo tin, alkyl lead); and
- organics (e.g., pesticide residues).

A wide variety of organics cause a "physical toxicity" (e.g. gill effects). Other cause "narcosis" (e.g., a chemical effect). At a molecular level, it is not known how narcotic organics act, although several reasonable models exist.

Regardless, the accumulating evidence indicates the following for narcotics (McCarty, 1987a,b):

1. Body residual concentrations are the key variable for predicting the chemical potency of chemicals in the biota.

2. The body concentration at which a toxic effect is observed is essentially constant for similar organisms and narcotic mode of toxic action (3-6 mM acute toxicity).

By extension, additional points result, including the following:

1. The body burden at which toxic effects are observed for other classes of organic chemicals (e.g., phenols) with the same organism may be within the same order of magnitude, but at different levels.

Complicating this relatively simple picture is the rather heterogeneous set of test results documented in the literature. This includes difficulties in explaining test results for the same chemical on a variety of different fish of different sizes. Some of these test results can be explained by the following points:

1. Kinetics can explain many apparent differences. For example:
   - o goldfish reach the critical body burden quickest of many fish species;
   - o the time to equilibrium for large-sized fish of the same species is larger than for small-sized fish of the same species due to a number of factors including:

     i) the larger circulation time within the fish tissue.
     ii) the fish surface area/volume ratio
     iii) the gill surface area/volume ratio
     iv) the diffusional path lengths, and
     v) the effects of lipid tissue.

2. The lipid content of fish can explain some differences particular kinetic differences. Recent evidence indicates that correlations exist between the elimination rate constant (which controls the time to achieve a critical body burden) and the octanol-water coefficient (K_{ow}) for the fish species. The K_{ow}, which measures the tendency of the chemical to partition between octanol and water provides a good explanation for the ability of a chemical to partition between the fatty tissue of fish flesh and the water phase in which they swim.

3. The ionization constant of the chemical in water affects uptake, because uptake through diffusion across the gill is affected by change. For example, ammonia ionizes according to the reaction

   $$NH_4^+ \quad = \quad NH_3 \; + \; H^+$$

   Above pH 9.3, NH_3 (ammonia) is the dominant form, while below pH 9.3, NH_4^+ (ammonium) is the dominant form. The most toxic form of total ammonia is NH_3.

7.2.6 Cumulative Effects of Different Chemicals Upon Toxicity

The site of action within an organism is known with reasonable precision for only a few chemicals when a solution contains an individual chemical. The effects of multiple chemicals in solution is not well-known, although as indicated above, evidence is accumulating that a variety of chemicals can act in a cumulative and probably linear fashion when the same mode of action is involved.

Organic chemical groups such as simple alcohols (methanol, ethanol, 1-propanol, 1-butanol, 1-hexanol, n-octanol, 1-nonanol, 1-decanol) and ketones (acetone, 2-butanone, etc.) cause narcotic effects upon fish such as fathead minnows, a typical species used in aquatic toxicity tests.

The toxic effect of other organic chemicals such as phenols is complicated by ionization in the water and in the organism's body. Phenols have an "acute" body burden which is about an order of magnitude lower than that for narcotics such as alcohols and ketones. Metals, ammonia, and chlorine complicate the picture further because of the significantly different modes of action.

The different sites involved include the following. Metals such as copper and zinc affect gas transfer and to a lesser extent, salt regulation of the gill. Ammonia affects the oxygen carrying capability of the blood and is directly toxic to liver cells. Aluminum may affect gill transport of gases and salts by chemically precipitating at the gill.

The addition of the effects of these multiple chemicals can be synergistic or antagonistic or might be strictly addictive. For example, the Toxic Unit model (Chapter 3) indicates that higher hardness values decreases the effect of metal ion toxicity. Multiple sites of toxicity action from the different chemicals can, theoretically, cause a much greater effect then each chemical acting at a different specific site. The human example equivalent to the synergistic effect upon fish is someone who has a poor heart, who gets a bad cold or pneumonia and who hence is much more susceptible to a potentially "acute" response.

7.2.7 Theoretical Construct for Toxic Unit Model

The theoretical basis for the toxicity unit model is reviewed in this section for two cases:

- a single chemical; and
- a mixture of narcotic chemicals.

Its basis for a mixture of narcotic and non-narcotic chemicals is reviewed in Section 7.2.8.

Single Chemical

For a single chemical, analysis of the kinetic models indicate that the toxicity unit model is the appropriate model. This is based upon the following reasoning. For a single chemical with a fish concentration response C_F to ambient water concentration C_w, and the corresponding fish concentration response curve which causes a toxic response (a "toxicity body residue") in 96 hours, C_F^T, the kinetic curves are respectively:

$$C_F = C_w \, BCF \, (1\text{-}\exp(-k_2 t))$$

$$C_F^T = C_w^T \, BCF \, (1\text{-}\exp(-k_2 t))$$

where: t = time (days)

k_2 = elimination rate constant (days^{-1})

C_w^T = water concentration which causes a toxic body burden in 96 hours (mole)

C_w = ambient water concentration being tested.

The Toxic Unit model defines TU as:

$$TU = \frac{C_w}{C_w^T} = \frac{C_F}{C_F^T}$$

Hence, for a toxic unit of 1.0,

$$C_F = C_F^T$$

That is, the toxic body residue concentration C_F^T will be reached in 96 hours, meaning that the ambient water concentration being tested is the threshold value for the acute response as measured previously.

A Mixture of Narcotic Chemicals

For multiple chemicals causing narcotic actions, the toxicity unit model may result in predicting the same toxic response as the kinetic models, but it does not give the same mathematical result in all cases. For the same modes of action, different chemicals result (see Figure 7.2(e)) in the following relationship for the "acute" body burden:

$$C_{F,1} + C_{F,2} + C_{F,3} + C_{F,4} = C_{F,total}$$

where:
- $C_{F,1}$ = concentration in fish species from chemical 1.
- $C_{F,2}$ = concentration in fish species from chemical 2.
- $C_{F,3}$ = concentration in fish species from chemical 3.
- $C_{F,4}$ = concentration in fish species from chemical 4.
- $C_{F,total}$ = total concentrations in fish species from chemicals 1 to 4.

In terms of the kinetics, the summation results in:

$$C_{w,1}\, BCF_1\, (1 - \exp(-k2_1 t)) + C_{w,1}\, BCF_2\, (1 - \exp(-k2_2 t)) + \ldots = C_{F,toxic}$$

where: $C_{w,1}$ = concentration of chemical 1 in water (molar);
$C_{w,2}$ = concentration of chemical 2 in water (molar);
BCF_1 = BCF for chemical 1
BCF_2 = BCF for chemical 2
$K2_1$ = elimination rate constant for chemical 1 (d^{-1});
$K2_2$ = elimination rate constant for chemical 2 (d^{-1});

The kinetic model then indicates that the appropriate Toxic Unit model (TU^1) is:

$$TU^1 = \frac{C_{F,1} + C_{F,2} + \ldots}{C_{F,A}}$$

The numerator has time varying exponentials for each chemical while the bottom is the cumulative sum of the numerator.

If the narcotic chemicals all have the same elimination rate constant and the same value for BCF, the expression simplifies to a form similar to the linear addition hypothesis used for TU in Chapter 3. It is,

$$TU = \frac{C_{w,1}}{C_w^A} + \frac{C_{w,2}}{C_w^A} + \ldots$$

where: C_w^A = the total water concentration of these chemicals at which a toxic response is observed.

Accordingly, the linear addition hypothesis for the toxicity unit model is a special case of the more general mathematical form.

7.2.8 Practical Application of Toxic Unit Model

Irrespective of the limitations of the TU model based upon kinetic considerations, it will continue to be a practical tool for assessing toxicity for the forseeable future. As noted above in Section 3.3 (EIFAC, 1987; deMarch, 1987a,b), the linear addition hypothesis (based upon a strict addition approach) has no satisfactory alternative because none of the theories of toxicity provide a precise or reliable estimate of toxicity for mixtures.

The toxicity unit model has been checked previously in only a limited number of cases. Solutions tested have included gold mill effluents; data for applying it to rivers and stormwater have not been found. A few solutions have recently been tested by BEAK (internal data).

The results of the test work on gold mill effluents (Flock, 1980) were as follows:

Mine	Predicted LC50	Observed LC50
Schumacher Mine	0.8%	LT 20%
Dome Mine	0.9%	4%
Kerr Addison Mine	2.2%	29%
Campbell Red Lake Mine	0.2%	LT 2%

LT = Less than.

The results indicated as percent are the degree of dilution of the water required to just obtain an acute response in 96 hours. The major components of toxicity were due to copper and free cyanide with minor contributions from un-ionized ammonia and zinc. Where individual chemicals had TU values of less than 0.1, the authors chose to disregard these chemicals in the calculations, assuming that such low values did not contribute significantly to toxic effects.

These data indicate that the predicted LC50's are well below the observed toxicites, often by an order of magnitude. Hence, for these solutions, the calculations are conservative (i.e., overestimating toxicity), since solutions were less toxic than predicted

The use of the model stipulated above in Section 3 continually needs to be emphasized:

1. The results of the TU model should be treated qualitatively.

2. Adjustments to the "linear addition hypothesis", where known, should be made.

3. Chemical test work and toxicity test work upon synthetic solutions and actual solution mixtures will improve use of the TU model.

Another way to use the results of the test work is for calibrating the interpretation of the toxicity unit model. In this context, the phrase "calibrate the interpretation" means

(a) obtaining data which indicates the uncertainty associated with numerical values for TU; and

(b) defining whether an acute response will be observed at particular TU values such as 0.5, 1.0, 2.0, or 5.0, for a specific mixture of chemicals. The more complex the mixture, the more difficult it is to directly interpret the numerical values of the TU model due to synergistic and antagonistic effects in the mixture.

7.3 Influence of Total Metal Concentrations Upon Toxicity Model

Another major influence upon toxicity prediction is the type of metal data available. The toxicity model uses dissolved metal concentration as the measurement required, rather than total metal concentrations.

This requires a correction factor to monitoring data, because much available monitoring data are based upon total concentrations, rather than dissolved concentrations.

In fact, the dissolved metal concentration is not the proper surrogate for several metals because toxicity test work indicates that the ionic concentration is the cause of toxicity. One of the classical pieces of work in environmental science involves examining the effect of organic matter upon copper toxicity to algae. The qualitative observations indicated that two dissolved copper concentrations (for example 10^{-6} M and 10^{-8} M) had the same toxic effect to algae. However, when the concentration of cupric ion (Cu^{2+}) was calculated by correcting for complexation of copper with the different types and amounts of organic matter present, the concentration of Cu^{2+} was the same in each solution (e.g., 10^{-9} M).

These influences can be properly accounted for, at least in a preliminary way, using the following concept. The mass balance for copper in solution where it has a sorbed phase and is complexed with two solution ions (hydroxyl ion, carbonate ion) results in a correction for copper. It must be calculated numerically from the following relationship:

$$(Cu)_T = b\,(Cu^{2+}) + a\,(Cu^{2+})^{1/2}$$

where: $b = 1 + (CO_3^{2-})\,10^{+6.73} + (CO_3^{2-})^2\,10^{+9.83} + K_D\,(SS)\,10^{-6}$

$$(CO_3^{2-}) = (\text{Alkalinity})\,(10^{-10.3})\,10^{pH}$$

$$a = 0.5\,10^{-10.4}\,10^{2pH}$$

Here:

- Alkalinity is the total alkalinity assuming that the pH of the water is between 6.5 and 8.5;
- pH is the pH of the water;
- SS is suspended solids concentration (gm^{-3}); and
- K_D is the linear sorption constant for copper (cc/g).

The chemical data for dominant species and for complexation constants are derived from Baes and Mesmer (1986).

Similar correction factors can be derived for other metals such as zinc, aluminum, etc. The key to using the data is having reasonable estimates of the linear sorption constant K_D. Compilations are available to provide order of magnitude estimates. The validity of the K_D approach for predicting particulate metal speciation requires further analysis because solid phases of metals will also form. The K_D approach is more applicable for concentrations in the ug/L range; its applicability in the mg/L to 10's of mg/L range particularly requires careful assessment.

7.4 Other Considerations

This chapter has concentrated on narcotic-acting organics, summarizing the current understanding, and relating it to the constrict of the Toxic Unit Model. In considering other chemicals, two additional points should be borne in mind. Firstly, specific-acting chemicals will have a critical residue below that found for general narcotic organics. Secondly, it remains to be demonstrated how well the narcotic model predicts toxicity for asphyxiants, irritants, surfactants, etc.

Suspended solids will also have some impact upon the fishery. It is plausible, but unproven, the extent to which sorbed metals can impact toxicity, whether directly or indirectly through desorption into solution and subsequent uptake. They also have a potential impact upon migrating fish, although sketchy literature evidence indicates that migrating fish have the ability to move through riverine waters containing 200-400 mg/L. The largest impact of suspended solids is upon siltation of spawning beds etc. Such a factor is accounted for in the HSI model.

This work has also concentrated upon using rainbow trout as the test species. Different species have different responses. Most of the toxicity data are for trout and possibly fathead minnow, when other (possibly less sensitive) species are actually present. This is especially true for modifying factors such as oxygen and pH. Hence more robust species may be expected to survive conditions which stress trout.

Finally, there is the question of future directions for implementing the model, for the use of, the models and futher development of the Toxic Unit Model. These questions of course depend upon the objective of using the Toxic Unit Model. Relevant objectives include:

- Will it be used to ameliorate water quality in the Don River?
- Will it be used to monitor actions taken by Wastewater Treatment Plant Operators?
- Will it be used for control strategies?
- Will it be used as an improvement in fisheries assessment tools?

Also, there are questions concerning its use, reflecting

- o whether it is useful now;
- o whether it needs further development before implementation;
- o the credibility and feasibility of trying to model toxicity.

In an absolute sense, one can say that if you cannot model it, you do not fully understand it. But, a model is still quite useful as an abstraction of reality as we understand it, since it assists in defining the critical areas of lack of knowledge.

Perhaps the feasibility of predicting toxicity is the key area to be addressed. For a single toxicant, the answer to the question of feasibility is probably "Yes" in varying degrees. EPA-Duluth seems to have done it for acute Cu toxicity as a function of hardness, pH, temperature, DOC and suspended inorganics. For narcotic-acting organics, the workers such as McCarty, and collegues, and some of the Europeans indicates critical residue concentrations for acute lethality and to a lesser extent for sublethal effects.

Predicting toxicity of complex mixtures however is a much more difficult task. This is acknowledged in this work where it is said that it will be most useful in a qualitative way - p3.9, that estimates cannot replace actual toxicity tests - p3.11, that it must be calibrated - p3.13, that there are few toxicity data to parameterize and/or validate the model - p3.12, that managers must rely on past experience when interpreting predicted toxicity - p3.13.

The key use of the toxic unit model in this work and in the analysis of the effects of spills, is thus directed to improving the tools available for examining the relative importance of canopy (temperature), bottom habitat; flow related variables and water quality. Its utility requires further testing; its application to water systems where toxicity is dominated by a few contaminants would appear to be first major step to further evaluating its credibility, its performance, its feasibility.

7.5 Validation of Toxicity Model

Future efforts will be directed to testing toxicity model proposed in this report and its incorporation into the Habitat Suitability Toxicity model. Results from four recent tests (BEAK, 1990) are now presented.

7.5.1 Methods

Samples were collected on May 4, 1990 from Undercliffe and Cecil CSO overflows, as well as from the Don River below the North Toronto WPCP and the creek passing through the Taylor Creek Park. The latter two samples were used as an indicator of characteristic river or creek conditions after a small storm. They were tested for acute toxicity using the 96-hour static acute toxicity test, and their chemical composition was measured. The test was performed according to the procedures outlined in the Ministry of the Environment (1983), and Environment Canada (1980). Samples were aerated prior to commencing the test to increase oxygen levels in the two storm sewer samples. This resulted in no measureable TRC in any of the samples.

The samples were characterized for both dissolved forms and total concentrations of the following substances (Zn, Cd, Mn, Co, Cu, Fe, Pb, Cr, Ni, Be, Ca, V, Al, Na, K, Sr, Na). As well, Chlorophenols, Specific Conductance, Ammonia-Nitrogen, pH, Total Dissolved Solids, Total Kjeldahl Nitrogen, Total Suspended Solids, and Dissolved Oxygen were measured.

The toxicity model described in Chapter 3 was then applied to the data to evaluate its calibration.

7.5.2 Toxicity Results

The two stormwater discharges were toxic to rainbow trout but the two surface water samples were not. The test data results are as follows.

Sample	Initial pH	LC_{50} (% by Volume)	95% Confidence Limits
Don River	7.94	*	--
Taylor Creek Park Creek	7.88	*	--
Cecil Crescent	6.93	73	66-80%
Undercliffe Crescent	7.13	73	63-87%

* no toxicity observed over 4 day test period.

The LC_{50} (% by volume) is interpreted to mean that the sample would have to be diluted to 73% for the sample to just toxic (i.e., for 50% of the test rainbow trout to die after a 4 day test period.

There was no fish mortality or sublethal impairment observed in undiluted effluent in Treatment Plant and Taylor Creek Park samples during the exposure time. Most of the mortality in two other tested samples (Cecil Crescent and Undercliff Cresent) occurred gradually over the 96 hours of exposure. Temperature and dissolved oxygen levels remained stable throughout the exposure time at $15 \pm 1^{\circ}C$ and above 8 mg/L.

7.5.3 Toxicity Modelling

The toxicity model described in Chapter 3 was applied to the measured chemical data and the toxicity of the samples forecast. The detailed results are given in Table 7.1 and are summarized here in the text. The following comparison of toxicity results with model calculations were obtained.

TABLE 7.1: CALCULATION OF ACUTE TOXICITY BASED UPON MEASURED COMPONENTS

Parameter	Undercliffe		Cecil Crescent CSO		Taylor Creek Park		Don River below North Toronto STP	
(mg/L unless noted)	Concentration	TU	Concentration	TU	Concentration	TU	Concenteration	TU
Total Ammonia	1.55	0.06	0.10	.01	0.24	0.05	0.25	.05
Copper (Total ug/L)	72	-	40	-	L3	-	L3	-
Copper (Dissolved, ug/L)	36	1.8	48	2.2	L3	L.08	L3	L.08
Zinc (Total)	.38	-	.34	-	.05	-	.09	-
Zinc (Dissolved)	.28	.17	.25	.13	.015	0.01	.025	0.02
Nickel (Total)	L.01	-	L0.01	-	L.005	-	L.005	-
Nickel (Dissolved)	.005	.002	0.02	.01	L.005	L.002	L.005	L.002
Phenols (Total)	0.021	.02	0.013	.01	L.001	L.001	L.001	L.001
pH	7.1	-	6.9	-	7.9	-	7.9	-
Calculated TU	-	2.0	-	2.3	-	L0.1	-	L0.1

L = less than

Sample	Observed TU	Calculated TU	Percentage of TU due to the following Chemical Components: Ammonia	Copper	Zinc
Don River	NDT*	NDT*	--	--	--
Taylor Creek Park Creek	NDT*	NDT*	--	--	--
Cecil Crescent CSO	1.4 (1.3-1.5)	2.3	0	94	6
Undercliffe Crescent	1.4 (1.2-1.6)	2.0	3	87	10

NDT * = no detected toxicity

The unit TU, is defined as toxic units. A threshold of 1 indicates that the sample would be toxic (i.e., that 50% of the rainbow trout would die over the 4 day test period). It is equal to 100 divided by the LC_{50} (% by volume) given above.

Of all the possible components contributing to the toxicity described above, ammonia, copper and zinc are the principal ones which could potentially cause toxicity. Their contribution to the calculated TU values calculated by the model indicate that copper makes the largest contribution to toxicity with a minor possible contribution by zinc and ammonia. Due to their small contributions, it is concluded that the toxicity is mainly caused by dissolved copper.

The models' calculated toxicity compares favourably to the observed toxicity. This provides some confidence in the use of the model as a screening tool for establishing toxicity. The model overestimates toxicity to some degree. This is within the uncertainties in the model. The model, does not consider possible complexation of copper with organic anions such as fulvic substances, which would tend to lower the predicted TU value, if considered.

It is concluded that the model can be usefully used to forecast the potential toxicity for such samples when the chemical composition of key components are known.

Based upon low oxygen values in the actual samples, the model of Chapter 3 was used to evaluate the effects of low dissolved oxygen. The dissolved oxygen effects, accordingly, result in the following increment in acute toxicity.

	Observed In situ DO	Increase in Toxicity
Cecil CSO	2.5 mg/L	20%
Undercliff	3.0 mg/L	0%

8.0 INTEGRATION OF A FISH RESOURCE MANAGEMENT PLAN WITH A WATER QUALITY MANAGEMENT PLAN AND RISK ASSESSMENT

8.1 General Considerations Re Don River Habitat

Based on the many conflicting resource use demands being placed on the Don River watershed at the present time, the need for a comprehensive fish resource management plan or strategy becomes apparent if effective restoration and management of fish resources is to be achieved. Present urban and industrial development throughout the watershed and changing land uses in the upper watershed have already significantly altered the aquatic environment of the Don River. At the same time, increasing demands are being made throughout Ontario for increased recreational fishing opportunities.

In the case of anadromous salmonid fisheries using Lake Ontario and suitable tributary rivers, recreational fishing can create or stimulate significant economic activity in the region. A study by the City of Scarborough has estimated that over 143,000 anglers live in that city, and that close to $1,000,000 of economic benefit could be realized with a "properly managed and stocked Rouge River fishery". It has been estimated that this type of fishery management program on the Credit River is responsible for between $10,000,000 and $15,000,000 of annual economic benefit to Mississauga. Similar benefits could be realizable in the Don River, if a quality fishery is restored.

Unless there is a clearly stated management plan for this fish resource, restoration of aquatic habitats, water quality and fish fauna can only be measured or judged against a previous condition rather than against a future plan or strategy which is being implemented.

To be effective, a fish management plan must relate to the habitat constraints and opportunities which exist in various sections of the river. Whether it involves habitat restoration or water quality improvement, the capabilities and potential of river habitats to produce the results being sought must be clearly and realistically assessed.

The need for this type of management plan becomes most apparent when one considers the evolution of the fishery in the Don River. Previously, the river supported a resident warm-weather fish fauna, and possibly a self-sustaining cold-water fish fauna. Each of these has significantly different habitat and water quality requirements. In the absence of an active management program, it can be expected that future environmental changes will continue to favour warm-water species over cold-water species, as has occurred in most of the watershed over the past half century. Since much of the lower river provides only poor habitat for warm-weather game species, such as the smallmouth or largemouth bass, these species will not support a significant sport fishery.

The anadromous cold-water species are hatchery-supported, use Lake Ontario for feeding and growth, and move into tributary rivers in large numbers during the spawning periods. These species provide the potential for large and highly-sought recreational fisheries. This type of fishery presently exists on the lower Rouge River and Credit River even through stocking programs in these rivers have been limited. In order to facilitate a management strategy, aquatic habitats and water quality conditions would be managed and protected to meet the seasonal needs of these species.

Finally, if the objective is to support natural reproduction of cold-water species in the lower river, a whole new set of environmental criteria relating to water quality, mid-summer flow levels, temperature and habitat conditions must be considered.

The practicality of any of these options should be assessed based on habitat capability, following which a realistic resource management plan can be developed and an implementation program organized. Only when this has been done can environmental criteria or standards be set to ensure that habitat quality will be maintained or improved to meet the plan's objectives. This is clearly beyond the scope of the current study.

To this date, the only habitat capability assessment carried out on the Don River system is that by MNR involving a general analysis, and two academic theses.

At this stage, it is recommended that habitat conditions at least suitable for smallmouth bass be established as the minimum acceptable environmental criteria for the lower Don River.

8.2 Use of the Index of Biotic Integrity (IBI) to Measure and Monitor HSI Effectiveness and Significance

The Index of Biotic Integrity (IBI) was developed to serve as an integrated measure of the health of stream ecosystems. The term "biological integrity" generally refers to an accepted standard set by ecosystems that have not changed structurally or functionally as a consequence of human activity, and can thus be used as a basis of comparison for ecosystems which have been altered to varying degrees.

The IBI uses the fish community as a measurement parameter for biotic integrity. It consists of a number of ecological measurements or metrics in categories of species richness and composition, trophic composition, species abundance and physiological condition. Originally developed in the U.S. midwest, it has been adapted to suit southern Ontario streams and applied over a range of stream habitats by R.J. Steedman (1987) in a doctoral thesis. This included several sampling stations on the Don River distributed from the headwater tributaries to the lower main stem.

The IBI results for the Don River system were as follows (from Steedman, 1987):

River Section	IBI Rating
Upper Reaches (Headwater Tributaries)	fair to good
Middle Reaches	poor to fair
Lower Reaches	poor

These results, which provide a measure of the fish community and, thus, the biological environment, are in general agreement with HSI results if these were applied for the same target species throughout the watershed. For instance, the HSI for small mouth bass would be rated fair to good in the upper and middle reaches, and fair to poor for the lower reaches.

The HSI provides a measure of the habitat suitability for a target fish species, while the IBI provides a measure of the ecological health of the fish community, including the target species, utilizing these habitats. The IBI is of limited value as a direct planning or management tool for watersheds since, unlike the HSI, it does not provide quantifiable habitat criteria which can be used as management objectives. It is these quantitative physical and chemical criteria which are required for planning and management of land use activities affecting the watershed, including stormwater management. However, the IBI is a useful tool for measuring and monitoring the success of achieving the HSI objectives as this is ultimately reflected in the fish community. If the HSI parameter values are appropriately set and if the HSI objectives are achieved, the target fish species should prosper along with associated fish species in that aquatic ecommunity. Thus, the IBI score should be high to reflect this. Conversely, if the target fish species does not survive and the IBI score is low, the habitat suitability criteria are either set at inappropriate levels or are not being achieved. The IBI is a very useful monitoring tool in this regard, since it is a healthy fish community which is the ultimate objective. Habitat (HSI) management is the means for achieving this objective.

8.3 Recommendations

8.3.1 Specific Recommendations

The following specific recommendations result from this study.

1. To effectively manage aquatic resources of the Don River and achieve fisheries management objectives, a comprehensive and integrated land use management plan for the total watershed is required.

2. The land use plan must examine the limits of watershed urbanization beyond which it loses its capacity to function as a stream ecosystem and becomes little more than a network of urban drainage channels.

3. The HSI approach to determining acceptable habitat criteria for a target fish species should be applied on individual tributaries or specific river reaches which could be affected by a proposed development. In this report, HSI's for the target species have been applied to the average conditions found in large subsections of the watershed.

4. Fisheries objectives specific to the Don River and its various tributaries should be established. The District Fisheries Management Plan is generic for the Don River since it considers the region as a whole, rather than being shaped specifically to the Don River.

5. Key habitat parameters and the resident fish community (IBI) should be monitored on a regular basis to ensure that the fisheries objectives are being achieved. This will also provide useful data to refine and better adapt the HSI model to a Don River application.

6. Toxicity testing and chemical characterization of different waters from the Don River (various tributaries; various main stem sections; various sources including CSOs, storm sewer discharges, treatment plant effluents) should be carried out to check the predictions of the toxicity unit model and the calibration used to include it in the HSI model.

7. Protocols for combining: (1) bioconcentration measurements; (2) bioassays (acute toxicity tests); and (3) residual effects on fish need to be formulated to obtain data for all three phenomena (BCF, acute tests, residues) since the kinetic models indicate that they are all interrelated.

8.3.2 General Recommendation for Further Work in Fisheries - Water Quality Area

A need for flood plain mapping, land use assessment and classification of stream bank and riparian vegetation condition was identified, in order to permit establishment of baseline conditions, and required buffer strips within the Plan. This recommendation arose from the meeting on setting fisheries objectives attended by various people from MOE, MNR, MTRCA, BEAK and Theil. It is made because the streams need to be classified as to their degree of cover and its influence on stream temperature and whether there is a likelihood of developing a fishery.

An other major requirement is to amplify the modelling approaches used in this study, to establish the magnitude of fisheries benefits associated with water quality control.

These general recomendations are based upon the following points.

1. A Fish Management Plan has not been established specifically for the Don River system.

2. Little time has been spent in general by MNR upon degraded streams in relation to non-degraded streams (Martin-Downs, personal communication).

3. Rehabilitation work by MNR has concentrated upon cold water streams where the largest return upon money spent, is achieved.

4. Limited data have been gathered upon the Don River.

5. The Don River has only recently been screened in terms of planning controls in the later 1980's.

8.4 Recommended Approach

Based on the foregoing, the following approaches are recommended:

1. classification of aquatic habitats in various sections of the Don River for fish communities and species, including a ranking of habitat suitability for each;

2. development of a fish resource management plan which optimizes habitat opportunities in each section of river for primary species of importance or interest;

3. examination and amplification of representative, key species (guilds) for HSI model application; and

4. development of habitat variable criteria which will maintain habitat suitability at the desired, specified level for the representative species.

It is strongly recommended that the fish species assemblage/habitat requirement classifications be completed for the Don River as a logical information prerequisite to the development of a fish resource management plan for the watershed and a basis for establishment of habitat protection guidelines or criteria related to watershed development. The theses written by R. Steedman and R.J. Morris provide some further information or analyses in this regard.

These habitat criteria can be tested and modelled to ensure that changing land uses do not further reduce habitat suitability and to ensure that source water quality control attains the improvement needed to allow for restoration of the fishery in the Don.

The effectiveness of remedial or mitigative measures to protect habitat quality was tentatively modelled in this work. It requires further testing. It could then be used as part of the planning and approvals process.

The Don River appears to be an excellent candidate for this type of proactive and innovative watershed management approach. The river retains excellent habitat conditions in a few headwater reaches. There is a good habitat inventory and assessment database for use in suitability classification. The river currently has the potential for supporting an important recreational fishery and even perhaps an anadromous fishery. The watershed is experiencing a rapid rate of urbanization in the headwaters, and other land use changes in existing developed areas (e.g., the St. Lawrence Square Area). Results of this program on the Don River should have direct application to other tributaries of Lake Ontario experiencing urban land use changes in their watersheds.

9.0 REFERENCES

Abernethy, S.G., D. MacKay and L.S. McCarty. 1988. "Volume Fraction". Correlation for Narcosis in Aquatic Organisms: The Key Role of Partitioning.

Anderson, P.D. and L.J. Weber. 1975. The toxicity to aquatic populations of mixtures containing certain heavy metals. In: Proceedings of the International Conference on Heavy Metals in the Environment. Institute of Environmental Studies, University of Toronto, Toronto, Ontario, Canada.

Arthur, J.W. and L.G. Eaton. 1971. Chloramine toxicity to the amphipod, Gammarus pseudolimnaeus, and the fathead minnow, Pimephales promelas. Jour. Fish. Res. Bd. Can. 28: 1841.

Baes, C.F. and R.E. Mesmer. 1986. The Hydrolysis of Cations. McGraw-Hill.

BEAK. 1988. Rouge River Environmental Studies. Report for Metropolitan Toronto Region Conservation Authority.

BEAK. 1990. Chemical Characteristics to be Treated by a Flow Balancing System. Supporting Document 3 for 'Feasibility Study for Flow Balancing System'. Report for City of Scarborough.

Barton, Taylor and Biette. 1985. Dimensions of riparian buffer strips required to maintain trout habitat in Southern Ontario streams. North. Am. J. of Fisheries Management. 5: 364-378.

Bradley, R.W. and J.B. Sprague. 1985. The influence of pH, water hardness and alkalinity on the acute lethality of zinc to rainbow trout (Salmo gairdneri). Can. J. Fish. Aquat. Sci. 42: 731-736.

Brungs, W.A. 1973. Effects of residual chlorine on aquatic life. Jour. Water Poll. Cnot. Fed. 45: 2180.

Callahan, M. and 12 other other authors. 1979. Water Related Environmental Fate of 129 Priority Pollutants. Volume 1 Introduction and Technical Background, Metals and Inorganics, Pesticides and PCB's. Report No. EPA-44014-79-029a. Report for U.S. EPA Available From N.T.I.S. as PB80-204373.

Canadian Council of Resource and Environment Ministers (CCREM). Canadian Water Quality Guidelines. Environment Canada, Inland Waters Directorate, Ottawa, Ontario.

Canviro Consultants Ltd. 1985. Personal communication.

Cohen, B.L. (1985). Transport of Elements from Soil to Human Diet: An Alternative Approach to Pathway Analysis. Health Physics 49(2), 239-245.

Craig, G.R. 1987. Development of Provincial Water Quality Objectives: Substituted Phenols. Beak Consultants Limited, Mississauga, Ontario, prepared for the Ontario Ministry of the Environment, Toronto, Ontario, Canada.

deMarch, B.G.E. 1987a. Mixture toxicity indices in acute lethal toxicity tests. Arch. Environ. Contam. Toxicol. 16: 33-37.

deMarch, B.G.E. 1987b. Simple similar action and independent joint action - two similar models for the joint effects of toxicants applied as mixtures. Aquat. Toxicol. 9: 291-304.

EIFAC (European Inland Fisheries Advisory Commission). 1987. Report on combined effects on freshwater fish and other aquatic life of mixtures of toxicants in water. EIFAC Tech. Pap. 37. 49 p.

Edwards et al. 1983. Habitat Suitability Index Model for Smallmouth Bass. United States Fish and Wildlife Service Publication.

Emerson, K., R.C. Russo, R.E. Lund and R.V. Thurston. 1975. Aqueous ammonia equilibrium calculations: effect of pH and temperature. J. Fish. Res. Board Can. 32: 2379-2383.

Environment Canada. 1980. Standard Procedures for Testing the Acute Lethality of Liquid Effluents. Report No. EPS-WP-80-1.

Flock, B.K. 1980. The Toxicity of Gold Mining Effluents in Ontario. Report for Environment Canada.

Great Lakes Science Advisory Board. 1985. 1985 Annual Report. Report of the Aquatic Ecosystem Objectives Committee to the International Joint Commission.

Heming, T.A., R.V. Thurston, E.L. Meyn and R.K. Zajdel. 1985. Acute toxicity of thiocyanate to trout. Transactions of the American Fisheries Society 114.

Howarth, R.S. and J.B. Sprague. 1978. Copper lethality to rainbow trout in waters of various hardness and pH. Water Res. 12: 455-462.

IJC (International Joint Commission). 1985. Report of the Aquatic Ecosystem Objectives Committee. Ammonia. p 26. I.J.C. Windsor, Ontario, Canada.

Indian and Northern Affairs Canada. 1984. The acute toxicity of thiocyanate and cyanate to rainbow trout. Environmental Studies No. 47.

Ingles, J. and J.S. Scott. 1985. State-of-the-art of processes for the treatment of gold mill effluents. Mining, Mineral and Metallurgical Processes Division, Industrial Programs Branch, Environmental Protection Programs Directorate.

Kovacs, T.G. and G. Leduc. 1982. Acute toxicity of cyanide to rainbow trout (Salmo gairdneri) acclimated at different temperatures. Can. J. Aquat. Sci. 39: 1426-1429.

Larson, G.L., C.E. Warren, F.E. Hutchins, L.P. Lamperti, D.A. Schlesinger and W.K. Seim. 1978. Toxicity of Residual Chlorine Compounds to Aquatic Organisms. U.S. Environmental Protection Agency, Duluth, Minnesota. EPA-600/3-89-023.

Martin-Downs, D. 1988. Don River Biological Inventory Past, Present and Future Evaluation. TAWMS #16.

Mason et al. 1979. Compilation of Database for Several Fish Species. U.S. F.W.S. Publication.

McCarty, L.S. 1986. The Relationship Between Aquatic Toxicity QSARS and Bioconcentration for Some Organic Chemicals. Environmental Toxicology and Chemistry. 5: 1071-1080.

McCarty, L.S. 1987a. Relationship Between Toxicity and Bioconcentration for Some Organic Chemicals: I. Examination of the Relationship. In: QSAR in Environmental Toxicology (K.L.E. Kaiser, Ed.). pp. 207-220.

McCarty, L.S. 1987b. Relationship Between Toxicity and Bioconcentration for Some Organic Chemicals: II. Application of the Relationship. In: QSAR in Environmental Toxicology (K.L.E. Kaiser, Ed.). pp. 221-229.

McCarty, L.S., G.W. Osburn, A.D. Smith, A. Bharath, D. Orr and D.G. Dixon. 1989. "Hypothesis Formulation and Testing in Aquatic Bioassays: A Deterministic Model Approach". Hydrobiologia 80: 01-15 (In Press).

McKee, P. and B. Parker. 1986. The distribution, biology and status of the fishes Campostoma anomalum, Clinostomus elongatus, Notropis photogenis (Cyprinidae), and Fundulus notatus (Cyprinodontidae) in Canada. Canadian Journal of Zoology, 60 (6): 1347-1358.

Meisner, J.D. and W.Q. Hum. 1987. Acute toxicity of zinc to juvenile and subadult rainbow trout, Salmo gairdneri. Bull. Environ. Contam. Toxicol. 39: 898-902.

Ministry of the Environment. 1983. Protocol to Determine the Actue Lethality of Liquid Effluents on Fish.

Morris, R.J. 1988. Urban Influences on Flavial Features and Fish Communities of the Don River, Toronto, Canada. Masters Thesis, Trent University.

Osborne, R.V. 1982. "Optimizing radiation protection in the management of uranium mill tailings" in Management of Wastes From Uranium Mining and Milling. Internat. Atomic Energy Agency Report. (AEA-SM-262/30. Vienna, Austria, pp. 471-482.

Parker, W.R. 1983. The acute lethality of potassium thiocyanate to rainbow trout as influenced by pH and hardness. Environmental Protection Service, Environment Canada.

Smith, L.L., Jr., S.J. Broderius, D.M. Oseid, G.L. Kimball, W.M. Koenst and D.T. Lind. 1979. Acute and chronic toxicity of HCN to fish and invertebrates. U.S. Environmental Protection Agency, EPA-600/3-79-009.

Snodgrass, W.J., D.L. Lush, R.R. Walker and W. Bell. 1986. "Particle-Based Lake Model for Calculating Dose Commitment" in Sediments and Water Interaction (P.G. Sly et. al.). Springer-Verlag (ISBN0-387-96293-X) pp. 229-241.

Spear, P.A. 1981. Zinc in the aquatic environment: Chemistry, distribution and toxicology. National Research Council of Canada, NRCC No. 17589.

Steedman, R.J. 1987. Comparative Analysis of Stream Degradation and Rehabilitation in the Toronto Area. Ph.D. Dissertation, University of Toronto.

U.S. EPA (United States Environmental Protection Agency). 1984. Water Quality Criteria for the Protection of Aquatic Life and its Uses: Ammonia. U.S. EPA Washington, D.C., U.S.A.

U.S. EPA. 1980. Federal Registrar: Environmental Protection Agency: Water Quality Criteria Documents; Availability pp. 79318-79380.

U.S. EPA. 1986. Quality Criteria for Water: Copper. United States Environmental Protection Agency. EPA 440/5-86-001. Washington, D.C., U.S.A.

U.S. EPA. 1986. Quality Criteria for Water: Nickel. United States Environmental Protection Agency. EPA 440/5-86-001. Washington, D.C., U.S.A.

U.S. EPA. 1986. Quality Criteria for Water: Pentachlorophenol. United States Environmental Protection Agency. EPA 440/5-86-001. Washington, D.C., U.S.A.

U.S. EPA. 1985. Ambient Water Quality Criteria Document for Dissolved Oxygen. Federal Register. 50(76): 15634.

U.S. FWS. 1980. Series of Publications Documenting Habitat Suitability Index Models and their Development. United States Fish and Wildlife Service Publication.

Vaughan, J.D.A., W.R. Parker and K.G. Doe. 1985. The effect of pH and hardness on the acute lethality of cyanate to fingerling rainbow trout. Environmental Protection Service, Environment Canada.

Watson, S.J. and E.J. Maly. 1987. Thiocyanate toxicity to Daphnia magna: modified by pH and temperature. Aquat. Toxic. 10: 1-8.

APPENDIX I

Use of Ecosystem Approach to Development of Levels of Protection Criteria

DISCLAIMER

This appendix provides background documentation for developing the Levels of Protection Approach for the following water quality benefits:

- o Contact and Non-Contact Recreation;
- o Fisheries Enduse; and
- o Aesthetics.

This appendix was developed by study personnel after a series of meetings of MTRCA, MOE, MNR and study team representatives. The meetings involved evaluating factors limiting the Don River fishery and other goals required to attain a quality of water which may be desired by the General Public.

The meetings lead to the development of parts of this supporting document (particularly Chapters 2 and 4) and assisted in developing the Levels of Protection Table given in Chapter 1 and the main summary document. This appendix was also materially assisted by the participation of various agency and study personnel in the Rouge River Water Management Study, and draws in part from the results of that study.

The material detailed in this appendix is intended solely to provide an overview of all factors necessary to obtain an understanding of the complexities of watershed planning from an Ecosystem approach. Substantially more refinement of this material is required before it can be effectively used.

As such, the information presented in this appendix do not represent the policy or position of the MTRCA, MOE or the MNR.

APPENDIX 1: USE OF ECOSYSTEM APPROACH TO DEVELOPMENT OF LEVELS OF PROTECTION CRITERIA

A1.1 INTRODUCTION

Preamble

The majority of the Don River is an urban water course subject to degradation from a mixture of point and non-point source discharges. The upper reaches are a non-sewered, rural water course which formerly was dominated by agricultural sources but which is rapidly undergoing urbanization and the impacts of construction.

In the near future, the watershed will essentially be completely urbanized. The water quality will further deteriorate unless new development is sufficiently controlled.

Redevelopment within present urban areas and further densification may also promote deterioration unless controls are implemented on such development. Controls on existing sources to achieve improvements in water quality may require extensive retrofitting.

This, at first glance, appears to be a bleak picture. In fact, substantial opportunities for improvement in water quality control will occur over the next 50 years as redevelopment occurs and urban infrastructure improvements are made. These opportunities must be captured in order to make a water quality management plan successful.

Present Water Quality

Monitoring data are available from six stations in the Provincial Monitoring Network and from specialized water quality monitoring programs established for TAWMS (e.g., for pesticides, dry weather flow estimates, etc.), and the Enhanced Monitoring Program. Its analysis indicate that the upper undeveloped reaches are impacted mainly by agricultural activities and construction associated with development of the urbanizing fringe. The middle reaches are further impacted while the downstream main stream below the confluence of the East and West Don has the worst water quality. Special tributary streams (Wilkett Creek, Massey Creek) suffer from CSO and/or industrial discharges/spills effects.

The water quality data for the 1980's indicate that the river is often turbid, and eutrophic. It has high bacterial counts and high temperatures in the summer. The river has plentiful oxygen resources with few observations below 6 mg/L. This indicates that treatment and control of oxygen demanding substances has achieved the objectives of water quality control programs implemented previously in the form of wastewater treatment plants and construction of separate sewer systems. The river is likely toxic in the lower reaches downstream of the North Toronto WWTP to Lakeshore Blvd. due to ammonia discharges. Toxicity due to metals or synthetic organic chemicals (SOC's) are plausible but uncertain due to sorption onto suspended solids and a paucity of data. Inplace pollutants may be problematic in the Keating Channel where they may pose an effect on salmonoid fish migration. The fishery quality is poor, but this may be primarily due to habitat/hydrologic factors.

The long term trend analysis of water quality in different reaches shows a gradual improvement for certain parameters (e.g., BOD, ammonia) and occasional "step" type improvements for particular parameters (e.g., BOD). These "steps" are generally associated with removal of certain STP discharges from the system (e.g., Richmond Hill in 1979). The gradual improvements appear to be associated with refinements in treatment. Trends are apparent over a twenty year period for two organic compounds (PCB's, reactive phenolics) but no trends are apparent for trace metals or other organic compounds because the monitoring data strings are too short.

Seasonal effects are also evident in the data set. They are caused by temperature variations (e.g., dissolved oxygen saturation) and flow effects and the effects of flow upon suspended solids. The suspended solids effects are observed for metals and trace organics which sorb to, or are associated with the solid phase. In many instances, the highest exceedances of PWQO's are observed during periods of high suspended solids concentration. Whether such concentrations represent toxic conditions need to be evaluated because many toxicity tests are conducted in the presence of only small quantities of particulate matter.

Objectives of this Appendix

The objectives of this appendix are:

(i) to provide a framework for managing water resources in the Don River which cover societal objectives related to a balanced ecosystem, public health, public safety, fisheries and terrestrial attributes;

(ii) to enunciate the meaning of ecosystem orientated principles;

(iii) to develop long-term (approximately 50 year) goals for this framework based upon ecosystem orientated principles;

(iv) to develop short-term and long-term objectives to fulfil these goals; and

(v) to provide the background to the development of the levels of protection approach to measuring improvements in Don River Water Quality.

Other activities are necessary for implementing measures to improve water quality. These include:

(i) review the goals and objectives suggested herein and modify as required;

(ii) enunciate criteria and policies for a 5-10 year-frames which can lead to attaining these goals;

(iii) suggest a plan for implementing these policies;

(iv) suggest procedures for auditing the implementation of a plan; and

(v) suggest agencies/municipalities which should be responsible for implementing a plan.

These activities would need to be carried out in the future with a set of procedures yet to be defined by the appropriate agencies.

A1.2 DEFINITION OF ECOSYSTEM BASED APPROACH TO WATERSHED PLANNING

The water of the Don River is degraded due to urban and industrial impacts. Linkages with other watersheds through atmosphere cycles and impacts from agriculture are of secondary importance. A return to the pristine condition of pre-European settlement is not realistic in our lifetime, or perhaps ever. However as human society attempts to come to grips with the carrying capacity of the planet, any tendancy towards restoring a small riverine ecosystem to a more balanced condition will result in a small contribution to a larger scale ecosystem. Only by the step-by-step approach of restoring various small ecosystems does the sum of many small effects result in a large effect for the overall ecosystem.

Perspective on Environmental Degradation on Don River

Degradation of Water Quality has occurred in the Great Lakes basin since European settlement. In order of effects, the following events have had the greatest impact upon the Great Lakes and associated riverine systems.

(i) glaciation;
(ii) post glaciation including revegetation and isotatic rebound;
(iii) deforestation by European settlement and development of agriculture;
(iv) sanitary sewage and partial treatment;
(v) urban stormwater runoff through sewers; Late Twentieth Century agricultural runoff;
(vi) atmospheric transport of contaminants;
(vii) rural or estate developments with ditches and septic tanks; and
(viii) groundwater seepage.

Humans are a part of the ecosystem. Each influences the other. Many of the present and future urban, industrial, and commercial uses of these ecosystems have a degrading effect on them. As long as the Don River watershed remains urbanized, many of the past ecological changes are irreversible. Only with the next glaciation age and the subsequent post glaciation period is it probable that an ecosystem similar to pre 1800 may develop.

Ecosystems and nature have many unpleasant, even dangerous characteristics which impact humans. Atmospheric conditions include violent storms and excessive heat or cold. Aquatic conditions impacting human health include poisonous plants, standing water that breed mosquitos, streams from which swarms of black files originate, waters that contain piranha, and leaches, and contacted diseases such as swimmer's itch. Aquatic conditions which impact aesthetics, include fish mortality resulting from natural causes, decaying algal mats on shorelines, and marsh gases (methane, sulphide) from decaying vegetation.

Degradation of water and ecosystems is unacceptable to many people. But complete restoration is impossible due to the probability that settlement induced ecological changes are irreversible. Some changes occur due to nature. For example the sand spit which protected Toronto Harbour prior to European settlement was severely breached by storms in 1852-54 and 1858 (Whillans, 1977). But many changes occur due to man. For example, the shift in direction of the Don River outlet, degradation of the wetlands and the virtual elimination of the delta and associated marshes has resulted from development in the watershed after European settlement and in the Harbour.

Rehabilitation, enhancement, wise use (conservation) and mitigation (see Figure 2.1) are midway courses between degradation and restoration which can be used to stop and reverse the long-term trend of continual ecological degradation. But their implementation through management policies, engineered source controls, and mitigating measures can only be conducted in a pragmatic way since we have no tested theory of ecological rehabilitation (Francis et al., 1979). Neither is a tested theory nor much evidence available for the economic and institutional aspects of rehabilitation and mitigation.

Ecosystem Approach to Planning

An ecosystem is composed of various biological niches within the watershed and the interacting elements of water, air, land and living organisms, including man. An "Ecosystem Approach" is based upon using these various biological/physical niches as the fundamental building blocks for the plan. It necessitates explicit recognition of the exchange of materials between these building blocks. The exchange of material which has conventionally been recognized in Water Resources Planning is the transport of water through the atmosphere, and subsequent rainfall. The material exchange explicitly recognized in water quality management is the discharge of fecal material, nutrients, suspended solids, trace metals and toxic organics to the receiving water after partial or incomplete treatment. Implicitly recognized is food production, mining, paper production etc. in other watersheds and the transport of these "raw materials" into an urban basin to form building blocks for the wastes subsequently discharged.

An ecosystem approach to planning "necessitates explicit recognition of the transport of materials such as atmospheric pollutants into and out of the Basin, in biosphereic perspective. The ecosystem approach provides the philosophic basis for a view of man as part of nature. It directs the efforts of 'different human institutions, industries and government agencies' toward treatment of the patient (the Ecosystem) rather than the symptoms of the disease. It relates the biological and technological activities of man to the carrying capacity of the Ecosystem" (GLRAB, 1977).

Past Applications of the Ecosystem Approach to Planning

The Governments of Canada and the U.S.A. adopted the "Ecosystem Approach", under the 1978 Great Lakes Water Quality Agreement, as the basis for future Water Quality Management within the Great Lakes. Attempts have been made and are still being made to incorporate this approach into the advisory and management structure of the International Joint Commission on Canada-America Boundary Waters (IJC).

Management of various components of the environment were attempted in the 1970's (GLRAB, 1978) including:

(i) new environmental legislation;
(ii) dialogue on the mutual benefit to water quality and fisheries programs of coordinated efforts on Great Lakes surveillance;
(iii) research relating environmental quality to human health; and
(iv) assessment of the implications of land use activities in relation to other parts of the Great Lakes Basin Ecosystem.

"These steps, however, remain separate in that they lack the integrative framework linking these and other human activities with those of non-human parts of the Ecosystem and biosphere. This necessary integrative framework is an ecosystem approach." (GLRAB, 1977).

The ecosystem approach was also mandated in the Great Lakes Charter signed by the Premier of Ontario and the American Governors of Great Lakes States in 1985. The charter notes the following:

"The planning and management of the water resources of the Great Lakes Basin should recognize and be founded upon the integrity of the natural resources and ecosystem of the Great Lakes basin. The water resources of the basin transcend political boundaries within the basin, and should be recognized and treated as a single hydrologic system. In managing the Great Lakes basin waters, the natural resources and ecosystem of the basin should be considered as a unified whole."

Definition of Ecosystem Approach to Planning

An ecosystem approach to water resources planning is difficult to define adequately. The above statements do not present a definition of the "Ecosystem Approach to Planning". Rather, they describe the elements of an ecosystem approach; the social, philosophical and ecological basis for the approach; and its advantages.

An ecosystem approach may be defined as the following:

(i) the plan uses the various biological niches of the watershed as the basic building blocks of the plan;
(ii) the plan uses natural rates of cycling of material between water, air and land as one basis for defining unpolluted conditions;
(iii) the plan views various living organisms including man as the basic biological building blocks of the plan;
(iv) the plan defines pollution as an unbalanced ecosystem resulting from accelerated rates of cycling of matter or from the entry of toxic substances into these cycles which cannot be tolerated by particular plants or living organisms including man; and
(v) the ecosystem provides the integrative framework for relating various human activities to the non-human parts of the ecosystem.

Application of Ecosystem Approach to Don River Water Management

The application of an Ecosystem Approach to the management of water quality in the Don River requires that a holistic Ecosystem based plan first be adopted. An ecosystem based plan would take the perspective of perhaps a 50 year planning horizon. Then from this plan, a short term plan (with perhaps a 5-10 year planning horizon) and a long-term plan (with a 20 year planning; and/or a 50 year planning horizon) would be developed for Water Quality Management.

An Ecosystem Approach to planning is difficult to do within the original mandate of the Terms of Reference of this Water Quality Management Study. With the inclusion of this fishery related component, it becomes somewhat more feasible. However, the basis for the formulation within this study is incomplete. A complete plan is based upon fisheries, water quality, terrestrial habitat, human values (such as human health, human safety economic development and recreation), and erosion and flood control and sets priorities where there are conflicts.

In this study, a first cut is made at presenting an ecosystem approach to developing water management goals. A comprehensive framework is developed in which ecosystem values are placed within the human context. If such ecosystem values cannot be placed in human terms, they are left out for the present. Human terms are used as the basis for expressing ecosystem values because this forms a framework to which various political, social and economic human systems can relate. Aspects of the ecosystem most directly related to water quality are fleshed out in the plan. Other aspects (terrestrial habitats, an indepth fisheries habitat plan, flood control, etc.) will need to be fleshed out in other studies.

A statement of water quality goals and objectives for the short term in the Don River has been the subject of some debate over the past decade. In the synopsis of opinions of the various institution stakeholders (Cumming Cockburn, 1987), goals ranged from status quo to attaining Provincial Water Quality Objectives and instream wading. It was generally agreed that "pristine" water quality objectives were not realistic, since the Don River is an urban water course. It was also generally agreed that some improvement in environmental quality is desirable. Accordingly, objectives were stated as a general narrative. They (Cumming Cockburn, 1987) advocated that the objectives be further defined as the development of the management plan proceeds.

This study has attempted to establish long term goals and short-term objectives which have the following characteristics:

(i) they are ecosystem-based;
(ii) they are ambitious in the long term, but realistic in the short term;
(iii) they find the status quo to be unacceptable and hence require improvement in order to just maintain the status quo;
(iv) they require the setting of bench mark criteria for auditing;
(v) they recognize that the predictive science for assessing the response to various remedial measures and restorative works is presently imprecise but will improve in the future;
(vi) they recognize that improved management; retrofitting and rehabilitation; and redevelopment are 3 tools available for obtaining improved environmental quality; and
(vii) they allow for redefinition of the objectives in the future as public demands for environmental quality change.

The approach detailed in the remainder of this appendix is to formulate goals which are long-term in perspective and which are ecosystem based. For these goals, short-term and long-term objectives are then established. The water quality objectives are established mainly for the short-term (implementation period of 5-10 years). Long term objectives (e.g., 50 years) are considered but their attainment is less precise because they are much more dependent upon opportunities such as redevelopment. The timing of redevelopment is known much less precisely.

The next step in development and implementation of a strategy for water quality improvement is to examine management options, remedial and mitigating measures and control options in addition to human factors for achieving short-term objectives. Their potential effectiveness, costs, ecological implications and other factors are then examined and an implementation strategy developed. This step is summarized in the Summary Report. Other steps will need to be carried out in the future. A detailed implementation plan will be required. Milestones for plan implementation and criteria for auditing plan implementation and the success of the plan are then established. The plan is then audited during implementation, because it is doubtful that implementation will be complete before the original short-term objectives are changed.

This however allows for the dynamic process which will occur in water quality management given in Figure XX (diagram of this process). It however is based upon long-term goals can are ecosystem-based and which will be a benchmark against which all future short-term objectives, implementation measures, redevelopment proposals and economic forces can be assessed.

Scope of the Remainder of this Appendix

The long term goals and associated short-term and long-term objectives are described.

A1.3 LONG-TERM ECOSYSTEM-BASED GOALS FOR THE DON RIVER

A1.3.1 Statement of Goals

General: Quality of Life Within Great Lakes Ecosystem

1. **Linkage to Great Lakes Ecosystem:** Recognize that the Don River watershed is a component of the larger Great Lakes ecosystem and that appropriate watershed management efforts will benefit the Great Lakes, particularly Toronto Harbour and the nearshore area of Lake Ontario adjacent to Toronto Harbour.

2. **Pride in Restored Don River Ecosystem:** Take pride in a restored Don River Ecosystem - its system of interconnected waterways and valleys; its head waters, its source and its estuary; a balanced ecosystem unit within the most heavily populated metropolitan area in Canada.

3. **Balance of Economic and Environmental Values:** Balance the mutual benefits of sustained economic growth, development and redevelopment; and ecological health and environmental quality within the Don River watershed.

4. **Quality of Life and Land Ownership:** Take pride in the quality of life opportunities provided through public and private ownership and collective management of the valley system.

Public Health and Aesthetics

5. **Swimming:** Swim in the Don River without becoming infected by disease or soiled by waste films on the water surface.

6. **Drinking Water:** Drink through incidental ingestion, surface and groundwater supplies within the watershed that are free of harmful viruses, protozoa and poison.

7. **Fish Consumption:** Eat fish from resident Don River populations knowing they are uncontaminated by dangerous chemicals.

8. **Aesthetics:** Delight in the enjoyment of clear stream waters (in the seasons when waters should normally be clear) that have no unpleasant odours, abnormal algal growths or unsightly industrial and domestic waste.

Public Safety

9. **Erosion and Flood Control:** Maintain dwellings adjacent to the river valleys secure in the knowledge that they will not suffer damages from erosion and flooding.

10. **Risk to Life in Valley Lands:** Enjoy open space opportunities in the valley streams of the Don River secure in the knowledge that users are not exposed to undue risks to life.

Fisheries and Riparian Habitats

11. **River Beds as Fish Habitat:** Enjoy the beauty of natural aquatic habitats and river beds that are uncontaminated by abnormal algal growth and unsoiled by industrial and domestic wastes.

12. **Angling:** Angle in the Don River with some expectation of encountering various preferred species of fish.

13. **Enjoyment of Plants and Wildlife:** Enjoy with pleasure a healthy riverine/valley environment, watching birds, plants, mammals and fish in their natural environment doing what they have always done.

14. **Wildlife and Waterfowl:** Delight in the enjoyment of terrestrial habitats that support populations of wildlife and waterfowl.

A1.3.2 General Rationale for Long-Term Goals

The long term goals are expressed in a manner consistent with introducing statements to the Great Lakes Water Quality Agreement of 1976. They are consistent with terminology in the 1976 agreement of:

- "restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin ecosystem;

- "the waters of the Great Lakes Basin system should be free from deterious materials resulting from human activity; and

- "the virtual elimination and zero discharge of persistent toxic substances".

and in the recent 1986 Great Lakes Water Quality Agreement of:

- "to restore and protect the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem as a multi-use resource whose base provides the settling and foundation for social development and economic investment.

The direct linkage of the Don River to the nearshore ecosystem of Lake Ontario and perception of the public for riverine water quality require goals consistent with these agreements.

The language of the Goals has been based upon the images of a restored environmental quality for the Great Lakes developed by George et al. (1979). The language was adapted into human terms (as noted above) for the Don River. The imagery of the goals are similar to those being considered by MTRCA for the Rouge River Watershed Management Plan.

The goals are not as idealistic as some publics may desire due to the extremely complex nature of urban linkages and associated environment quality. The language is consistent with the statement of the IJC that "the complete restoration of the chemical, physical and biological integrity of the water of the Great Lakes Basin Ecosystem will not occur in our life times". But such ideals "are a necessary part of such a serious, complex, and fundamental enterprise as the 1978 Agreement".

A1.3.3 Description of Individual Goals

The background of the individual goal statements are now discussed.

1. Linkage to Great Lakes Ecosystem

The goal re-emphasizes that the Don River is one part of the Great Lakes Ecosystem and the linkage of the River to the Lake through the effects of Don River loadings on water quality and ecological balance of the nearshore of Lake Ontario.

2. Pride in Restored Don River Ecosystem

This goal expresses the general feeling of people that "restored" or "good" is a significant benefit even though they may not actively participate in using the resource. This feeling is often based upon general knowledge and perceptions rather than direct knowledge or contact with the resource. This goal is the goal which various economists attempt to quantify under the category "indirect benefits", "intrinsic values", or "non-use values".

This goal statement recognizes that a balanced riverine ecosystem, in which all biological, hydrological and chemical processes interact in a balanced fashion with human society, is a key indicator of the health of the river and of a "restored" Don River. The difficult part of examining this goal is to define quantitatively what constitutes a "balanced ecosystem" and the associated interactions and linkages. This definition will require considerable work in the future. In this study, the presence of key biological niches which are integrators of a balanced food web, is chosen as the appropriate approach at this time.

3. Balance of Economic and Environmental Values

This goal recognizes that our political system oscillates between economic growth and restoration of ecological health and environmental quality. It suggests that a balance between "economy" and "environment" is most desirable. It acknowledges that much more work is needed to define sustainable development within the context of the carrying capacity of the ecosystem of the Don River, the Great Lakes, and the planet. An indication of similar goals in other political jurisdictions is the possible new federal agency, the "Centre for Sustainable Economic Development" to be based in Winnipeg. As noted in recent (January 1989) press articles, the objective of the centre is to promote advice and technology to businesses and governments for economic growth with minimal ecological damage.

In examining the concept of carrying capacity, a differentiation needs to be made between various types of substances in the water. Some substances such as particulate and dissolved organic carbon, phenols, etc. degrade through microbiological processes while others do not degrade. Of those which do not degrade, some such as chloride are relatively innocuous while others such as PCB's are carcinogenic to humans (and possibly to biota) at elevated concentrations. Degradation of such "toxic substances" does not occur because microorganisms have not yet evolved appropriate enzyme systems. This results in a split of substances with respect to using the concept of carrying capacity in environmental management. For substances such as BOD and TP, the ecosystem has an assimilative capacity for such substances at a low flux to permit a balanced ecosystem. For substances such as "non-degradable" toxics, their eliminations from discharges is mandated because the human health impacts are highly uncertain.

4. Quality of Life and Land Ownership

This goal recognizes that public ownership has, historically, been a prime vehicle for ensuring environmental management of critical land areas, especially as related to maintaining riparian vegetation etc. It recognizes that valley lands are a crucial portion of the watershed for attaining goals related to fisheries, terrestrial, riparian and instream habitat and a necessary component for water quality management. But substantial portions of the Don River Valley lands are a private ownership. It may not be possible, practical, economic nor desirable to bring all privately-owned lands into public ownership. Collective management provides a tool for attaining quality of life and environmental objectives for both privately owned lands and publicly owned lands.

European approaches in which constraints on how privately-owned historical buildings can be modified and used, may provide a useful model, for involving private land owners in "collective management".

5. Swimming

This goal assumes that contact recreation (swimming) may be feasible over the long-term. However, in the short-term, non-contact recreation is the only feasible goal without complete control of all STP, CSO and stormwater discharges. Occasional, incidental contact with the river water presently occurs by people who are wading etc. A minimal goal for the short-term is that they be free from diseases caused by pathogenic bacteria of human origin after incidental contact with Don River water.

The swimming goal is viewed as independent of other environmental health goals since fecal organisms represent a small portion of the total bacterial to biomass in an unbalanced ecosystem.

There are several points about assessing the suitability of water for swimmers and the impact of control which will affect these objectives over the short-term and long-term. The water quality parameter used to assess possibilities of swimming (fecal coliforms) may change in the future. This may fundamentally change present assessments of swimmability of the water. The degree of control necessary to achieve the long-term goal is assessed elsewhere in this plan. The predictive tools used for establishing the effectiveness of control require refinement.

6. Drinking Water

This goal assumes it is not probable that Don River surface water will be of a potable water quality for direct ingestion within the forseeable future due to the impact of stormwater systems. The protection of drinking water from pathogenic bacteria can only be assured after disinfection or boiling of the water. Typical disinfection techniques are those employed in water treatment plants. Similarly, an assurance that groundwater supplies from an urban area meet potable water standards for various water quality parameters (fecal bacteria; nitrates) cannot be made without more research on loadings to groundwater, groundwater dynamics, and evaluation of appropriate remedial measures.

The resultant goal, thus, is quite realistic. It recognizes that incidental ingestion of watershed water will occur.

Its implications include the following. Short-term water quality must be appropriate to prevent harmful effects to humans, or management sytems must be in place within the health care system to remediate health impacts of incidental ingestion during wading and other incidental body contact with Don River water. Public liability for such ingestion needs also to be examined.

7. Fish Consumption

This goal uses resident fish populations (complete life cycle) as an integrator of chemical contaminant burden (heavy metals; and industrial, agricultural, and horticultural organic chemicals) to various ecological niches and to humans. It expresses the human desire that fish consumed from the Don River be acceptable for human consumption.

8. Aesthetics

This goal recognizes that many human perceptions of water quality are associated with aesthetics. Two of the prime face human senses of aesthetics are sight (with the image of "clear") and smell (with the image of "free from unpleasant odours). It specifically implies nutrient conditions (as the control of abnormal algal growths) and specific sources of unsightly wastes (spills, accidental discharges of industrial (dyes, etc.) and domestic wastes (CSO's, STP bypasses' cross-connection of sanitary wastes to storm sewer) as crucial elements required to maintain the aesthetics of flowing riverine water.

9. Erosion and Flood Control

This is a goal statement for the historical human safety and property value basis for the management of water quantity (peak flow rates and its mitigation). Alteration of natural flows have resulted from the removal of forests associated with European settlement. Attempts to control the flows include flood control reservoirs (storage for peak water volume), channelization (increased hydraulic capacity), and stormwater management ponds (storage for maintaining peak runoff rates the same in newly urbanized lands as previously in agricultural lands).

10. Risk to Life in Valley Lands

This goal is a more explicit statement of the safety of an individual human enjoying valley lands which may be subject to flooding. The previous goal (#9) is more general in its orientation.

11. River Beds as Fish Habitat

This goal statement overlaps with aesthetics. It is placed here because uncontaminated and unsoiled river beds are the key habitat for a balanced food web and for a self-sustaining fishery.

12. Angling

This goal recognizes that angling is highly valued by various members of society. But this goal has a larger importance than this solely. Preferred species of fish are an indicator of a diverse population of fish, a balance of ecosystem, and the supporting food web. Society's knowledge that angling is successful, ever though everyone does not participate, is an important component of the second goal.

13. Enjoyment of Plants and Wildlife

This goal reflects the ideal that a natural assemblage of birds, plants, mammals and fish are an indicator of an overall healthy ecosystem. It recognizes that many humans get enjoyment from visually observing these assemblages without physically intruding into the ecosystem.

14. Wildlife and Waterfowl

This goal statement acknowledges that humans obtain enjoyment both from terrestrial ecosystems and from wildlife and waterfowl. It acknowledges that terrestrial habitats are essential for wildlife and waterfowl. Whether the populations can be (i) self-sustaining within the watershed, (ii) self-sustaining by migrating to other watersheds; or (iii) human maintained (zoos, etc.) is species specific. It is information which requires further research before it can be stated in this type of a plan. This goal statement assumes that the Don River watershed will be urban for the 50 year period and that neither hunting of mammals nor trapping are permitted activities.

A1.4 SHORT-TERM AND LONG-TERM OBJECTIVES FOR THE DON RIVER

The following section outlines a set of objectives which will assist in attaining the long-term, ecosystem based goals outlined in the previous section.

The objectives are outlined as short-term objectives and long-term objectives. As noted previously, it is the intent of this Appendix that the goal statement would not change over time but that the statement of objectives would change as the plan is implemented or as new information becomes available. That is, the statement of objectives are relatively dynamic in their statement.

The short-term objectives outlined below represent a mixture of measures for implementation and a statement of other information required to define the nature of the problem to be addressed. This mixture is required, as present knowledge available to this study team was not adequate to define short-term objectives which could be implemented.

From this list of measures for implementation, the most effective ones were evaluated quantitatively in the Summary Report while many of the remainder were evaluated qualitatively. This listing was also used to assist in developing the implementation measures given in the Summary Report under the headings:

- o Immediate Actions (1989-1990);
- o Phase I (5-10 Year Time Frame); and
- o Phase II (Long-term; 10-50 Year Time Frame).

General: Quality of Life Within Great Lakes Ecosystem

1. Linkage to Great Lakes Ecosystem

Short-Term Objectives	Long-Term Objectives
a) Define the linkages to Great Lakes	a) Implement requirements of ecosystem based plan.

Short-Term Objectives	Long-Term Objectives
b) Define requirements of an ecosystem based plan.	b) Complete reduction of loads
c) Augment definition of river water quality objectives from a RAP and whole lake point of view.	
d) Achieve partial reduction of loads for . nutrients (80% of NH_3 and 50% of TP from STP) . fecal coliforms (CSO's, stormwater) . Metals/organics . Suspended solids	
e) Improve fish/marsh habitat at mouth of Don River.	
2. Pride in Restored Don Valley Ecosystem	
a) Assess public perceptions and demands	a) Assess changing attitudes and demands of the public
b) Establish diversity parameter or similar social survey instrument for assessing public "pride".	b) Update ecosystem based plan and other plans described below, as required
3. Balance of Economic and Environmental Values	
a) Establish environmental quality goals	a) Implement program to achieve goals
b) Establish carrying capacity of Don River watershed for human populations	

Short-Term Objectives	Long-Term Objectives
c) Establish economic goals and impacts on Don River Watershed	
d) Establish economic constraints	
e) Establish necessary plans to meet goals	
4. Quality of Life and Land Ownership	
a) Complete attainment of public lands	a) Obtain acceptance by private and public land-owners of tools necessary to manage the lands
b) Establish the type of ownership and collective management tools necessary to manage the valley system	b) Implement the tools
Public Health and Aesthetics	
5. Contact Non-Contact Recreation	
a) Assess achievability of swimming goal over the long-term	a) Achieve objective for incidental contact
b) Assess achievement of a goal for incidental contact over the short-term	b) Achieve objectives for swimming in selected ponds and reservoirs
c) Establish technical objectives for a goal of incidental contact with water	c) Possibly achieve swimming objective in all river waters, most of the time
d) Implement necessary controls for "no lumps/waste flows" etc.	

Short-Term Objectives	Long-Term Objectives
e) Reduce bacterial loadings from priority sources	
f) Achieve contact recreation water quality objective (200 FC/100 mL) in prime swimming areas (e.g., a few ponds/ reservoirs) some of the time	
6. Drinking Water	
a) Survey all present well water supplies to individual homes to ensure that they achieve drinking water objectives	a) Evaluate need for changing objectives for incidental ingestion of surface water
b) Establish water quality objectives for incidental ingestion of surface waters in the Don River Watershed	b) Achieve water quality objectives for incidental ingestion, most of the time
c) Achieve water quality objective for incidental ingestion in areas prone to such occurrences	c) Evaluate need and/or feasibility of drinking water objective for water from reservoirs, in light of achievement of objectives related to bacterial control
7. Fish Consumption	
a) Assess transmittable diseases; control all sources	a) Complete the assessment and determination of appropriate objectives, initiated for the short-term
b) Assess chemical burden in fish from metals, radionuclides and SOC's	

Short-Term Objectives	Long-Term Objectives
	b) Change chemical and biological parameters for assessing long-term objectives as new chemical data, new contaminants and/or new concerns are identified
c) Differentiale fish burdens as to source of origin (implace pollutants, stormwater, sewage, agricultural runoff, other human activities in the watershed, and atmospheric inputs)	
d) Assess contaminant burden in sediments of depositional environment and determine the geochemical	c) Attain long-term objectives by appropriate means
e) Establish criteria for long term objectives	
f) Clean up (by dredging or other techniques), hot spots which cause significant contaminant bioaccumulation in fish or in the food chain	

8.0 Aesthetics

Short-Term Objectives	Long-Term Objectives
a) Reduce total P loads to reduce periphyton and other abnormal algal growths	a) Attain a balanced ecosystem which generates natural odours even though they are unpleasant as a result of decay processes
b) Assess causes of unpleasant odours; realize that decay processes are the causes of some unpleasant odours but are an essential part of the ecosystem	b) Return the river to a meso-trophic state rather than the present hypereutrohpic state
c) Reduce inputs of vegetation to river where organic matter is beyond the requirements of fish and a balanced ecosystem	c) Eliminate all sources of CSO's and industrial wastes

Short-Term Objectives

d) Reduce suspended solids/turbidity inputs by vegetating banks and achieving some reduction in suspended solids

e) Control some CSO discharges (either on frequency or volume basis) and separate contaminated industrial discharges from storm sewer system

f) Control turbidity discharges from all new developments and redeveloped areas

Long-Term Objectives

d) Control all spills

e) Control all stormwater discharges

Public Safety

9. Erosion and Flood Control

Short-Term Objectives

a) Vegetate lands, obtain setbacks and conduct other passive measures to minimize erosion at active sites

b) Continue to assess which erosion scars are natural and hence those for which human intervention will not be overly successful

c) Establish that redevelopment sites such as the St. Lawrence Square will be subject to flooding at some point in the future. Floodproof buildings to maintain their stability. Implement appropriate evacuation plans

Long-Term Objectives

a) Minimize erosion

b) Change erosion control policies, as scientific/ geomorphological understanding of the causes of erosion increases

c) Remove dwellings from areas which are too close to natural erosional areas

Short-Term Objectives	Long-Term Objectives
d) Change channelization construction designs to take account of fisheries objectives	
e) Establish policies to increase infiltration of rain water where soils conditions permit, as redevelopment occurs	
f) Implement erosion control measures in small catchments	
10. Risk to Life in Valley Lands	
a) Assess risk to life due to use and enjoyment of valley lands	a) Implement long-term objectives
b) Establish long-term objectives	
Fisheries and Riparian Habitats	
11. River Beds as Fish Habitat	
a) Replace concrete lined channels as opportunities arise	a) Replace all past concrete-lined, channelized river beds with stable structures which provide fish habitat, bottom vegetation, and hydraulic transport capabilities
b) Reduce algal growth using objectives laid out above	
c) Implement CSO/industrial/stormwater controls to improve habitat	b) Achieve nutrient control objectives
d) Improve canopy cover	

Short-Term Objectives	Long-Term Objectives
	c) Complete control of CSO, industrial and stormwater discharge

12. Angling

Short-Term Objectives	Long-Term Objectives
a) Establish smallmouth bass and other appropriate species as an indicator of a quality guild of warmwater species of fish	a) Develop balanced food web for fish
	b) Carry out necessary habitat improvements
b) Assess long-term cold-water objective	
c) Complete indepth HSI evaluation initiated in this study	c) Control all contaminant inputs to level necessary
d) Establish fish management plan	d) Develop the balanced ecosystem required for a smallmouth bass guild, and possibly for a cold-water fish build
e) Maintain food sources transported from upper watershed to lower watershed for fish	
f) Reduce frequency of spills	e) Manage human fishing pressure
g) Reduce toxicity of river water	
h) Audit performance of plan using IBI	
h) Establish fishing pressure limits to sustain a fishery	

13. Enjoyment of Plants and Wildlife

Short-Term Objectives

a) Assess public perception of requirements for enjoyment of a healthy riverine/ valley environment

b) Establish a parameter for assessing enjoyment of the public

c) Initiate revegetation

Long-Term Objectives

a) Assess changing attitudes and needs of the public

b) Audit the success of established plans

14. Wildlife and Waterfowl

Short-Term Objectives

a) Develop requirements for a balanced wildlife regime in an urban dominated valley system, taking account of existing core areas (e.g., Maple MNR lands, Science Centre, conservation lands)

b) Develop a plan

c) Initiate revegetation

d) Augment habitat in existing areas

e) Develop policing necessary to preserve and protect existing areas against vandalism etc.

Long-Term Objectives

a) Implement complete plan

b) Protection of habitat and wildlife/waterfowl against vandalism, illegal hunting and trapping

APPENDIX 2

Environmental Pathways Modelling as a Tool for Assessing the Response of Fisheries Resources and of Human Health to Water Quality Control in the Don River Watershed

APPENDIX 2: Environmental Pathways Modelling as a Tool for Assessing the Response of Fisheries Resources and of Human Health to Water Quality Control in the Don River Watershed

A2.1 Approaches to Assessment

Water quality criteria have been established for the protection of aquatic life and drinking water sources. Values established in Canadian and American jurisdictions are summarized in Table A2.1.

Other approaches for assessing salient features of water quality include chemical impact on humans and chemical burdens in fish. Chemical burdens in fish result from their consumption of water and food from river waters and sediments containing heavy metals and organic compounds. These substances may only bioaccumulate in fish or may be toxic to both humans and/or the fish. Chemical impacts to humans can be assessed using a health assessment approach, or a comparative approach in which ingestion of the river water is compared to normal consumption. The health assessment approach evaluates the possibility of cancer development and other human health effects due to humans drinking the water and consuming fish from the river. The comparative approach compares the mass of contaminant in ingested water to the mass consumed from all dietary sources.

The use of both approaches (fish impact; human health) were initiated in this study. The mathematics of the approaches are summarized in project files as a position paper. An overview of the approach are now described to show the quantitative linkage between water quality control and fisheries/human health.

A2.2 Environmental Pathways

Environmental pathways modelling is the master tool used for both approaches. It is a steady-state, mass balance approach for predicting the release rate of chemicals to the environment, the resultant concentrations in various biota and environmental compartments, and the rate of uptake by, and the impact on humans from carcinogens, radionuclides and other substances.

TABLE [illegible] WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE

[illegible]	PWQO[5]	CWQG[6,7] (old)	CWQG[8] (new)	EPA[9,10]
Suspended Solids	Suspended matter should not be added to surface water in concentrations that will change the natural Secchi disc reading by more than 10%	Natural season maximum	Increase of 10 mg/L when background is less or equal to 100 mg/L, or increase of 10% above background when background is greater than 100 mg/L	Reduction of more than 10% of depth of compensation point for photosynthetic activity
Phosphorus (total)	10 to 30 ug/L[1]	25 to 100 ug/L[1]	-	25 to 100 ug/L[1]
Ammonia	20 ug/L as un-ionized form	20 ug/L as un-ionized form	80 to 2,500 ug/L as total ammonia depending on pH and temperature (equals 0.7 to 35 ug/L un-ionized; e.g., 25 ug/L at pH 8 and 10°C)	0.7 to 370 ug/L (un-ionized) depending on pH, temperature, species sensitivity and is based on 1-hour and 4-day averages (e.g., max. 4-day average at pH 8 and 10°C for salmonids is 25 ug/L)
Nitrite	1 mg/L[2]	1 mg/L[2]	0.06 mg/L	
Nitrate	10 mg/L[2]	-	Concentrations which cause excessive weed growth	10 mg/L[2]
Nitrite + Nitrate	10 mg/L[2]	10 mg/L[2]	-	-
Fecal Coliforms	Geometric mean density of 100 per 100 mL for a series of water samples[2]	Geometric mean density of at least 5 samples over a 30-day period should be less than 200 per 100 mL[2]	Geometric mean density of at least 5 samples over a 30-day period should be less than 200 per 100 mL[2]	Geometric mean density of at least 5 samples over a 30-day period should be less than 126 per 100 mL for *E. coli* and 33 per 100 mL for enterococci
Copper	5 ug/L (unfiltered)	2 ug/L	6 ug/L[3]	21 ug/L[3] as 4-day average 34 ug/L[3] as 1-hour average
Lead	25 ug/L[3] (unfiltered)	10 ug/L[3]	7 ug/L[3]	7.7 ug/L[3] as 4-day average 200 ug/L[3] as 1-hour average
Zinc	30ug/L (unfiltered)	200 ug/L[3]	30 ug/L	190 ug/L[3] as 4-day average 210 ug/L[3] as 1-hour average
Aluminum	-	100 ug/L[4]	5 ug/L (pH L 6.5) 100 ug/L (pH GE 6.5)	150 ug/L (pH between 6.5 and 9.0) as 4-day average 950 ug/L (pH between 6.5 and 9.0) as 1-hour average
Mercury	0.2 ug/L (filtered)	0.1 ug/L (unfiltered)	0.1 ug/L	0.012 ug/L as 4-day average 2.4 ug/L as 1-hour average
Oil and Grease	Should be visually and olfactorily non-detectable	5 mg/L[1]	Should be visually and olfactorily non-detectable	Individual petrochemicals should not exceed 0.01 of 96-hour LC50 of important sensitive species. Surface waters should be virtually free of oils
Pentachlorophenol	0.5 ug/L[12]	None	0.5 ug/L	13.6 ug/L[13] as 4-day average 24.8 ug/L[13] as 1-hour average
2,4,5-T	None	None	None	None
Atrazine	None	None	None	None
BOD_5	None - see dissolved oxygen			
Dissolved Oxygen	47 to 63% of saturation must be maintained dependent on resident biota	47 to 63% of saturation must be maintained dependent on resident biota	5 to 9.5 mg/L dependent on resident biota and life-stage	3 to 9.5 mg/L dependent on resident biota and life-stage
Chlorine	2 ug/L	2 ug/L	2 ug/L	11 ug/L as 4-day average 19 ug/L as 1-hour average
Chloride	None	None	None	None

1 No objective for protection of aquatic life. Guidelines based on nuisance algal growth, aesthetic deterioration and/or excessive plant growth.
2 No objective for protection of aquatic life. Maximum acceptable concentration related to human health.
3 Based on a hardness of 200 mg/L ($CaCO_3$). Criterion is dependent on hardness.
4 Tentative limit proposed by IJC (1977).
5 Provincial Water Quality Objectives; MOE (1984)
6 Canadian Water Quality Guidelines; Environment Canada (1981).
7 McNeely et al. (1979).
8 CCREM (1987)
9 U.S. EPA Water Quality Criteria; U.S. EPA (1976).
10 U.S. EPA (1986); most objectives allow for one exceedence every three years.
11 Draft Objective, proposed 1986.
12 Proposed, Mc[illegible] et al. (1984)
13 Based on pH of 8. [illegible] criterion is dependent on pH

A2.2.1 Information Needed to Develop an Environmental Pathways Model

The block diagram and mass transfers involved in an environmental pathways model relevant to fish in the Don River is given in Figure 7.1 in the main body. Basically, to apply it, the following information is required.

(1) which particular chemicals are to be considered;

(2) where these particular chemicals originate in the community and the quantities that are disposed of from various sources;

(3) the particular pathway followed by each chemical and its fate in passing through particular waste handling and treatment systems;

(4) define which humans are likely to be exposed to the highest dose from these chemicals; and

(5) define a series of environmental transport pathways that will allow the calculation of an impact to the population exposed to the released chemicals.

A2.2.2 Human Health

The general population, members of the general public whose habits expose them to the chemicals through body contact or food consumption or occupational workers are candidates for assessing the effects of water quality on human health.

For various occupational workers in waste handling and treatment facilities, potential human health parameters calculated for various work groups based on their job duties. From these calculations, the maximally exposed group, or critical group can be identified. Similarly, for members of the general public, specific persons whose fishing and incidental ingestion of Don River water result in their exposure to the chemical(s) of concern would be evaluated.

On-site field investigations using structured observational techniques (a sociological approach in which specific behavioural data are collected with minimal knowledge by or influence on the human subject (Whyte, 1977)) can be used together with interviews in the watershed, to identify the most probable highly exposed individuals or occupational critical groups. These are employees whose working habits, occupational environment, proximity to possible chemicals, exposure duration and exposure geometry would place them at greater danger to exposure to the chemicals than other employees.

Members of the general public who should be considered are those who may enter high exposure areas through such activities as recreation, wading, or fish consumption.

A2.2.3 Environmental Pathways for Urban Runoff and Wastewater Treatment

The main pathway associated with thse sources are surface waters. Contaminants of concern in Figure 7.1 are found in urban and rural stormwater runoff. Inputs to the wastewater treatment system shown in Figure 7.1 are derived from hospitals, universities, industries and other institutions. Input of leachate from a landfill site containing chemicals that may have leached from household garbage and incineration ash may also be a source, but may not be significant in the Don River Case. The impact of old dumps upon Don River water quality requires further assessment.

Chemicals released to the environment are dispersed and transported through various environmental pathways. For the purpose of human health relevant to the general population, possible exposure pathways are:

1. External exposure from:
    - o immersion in the airborne plume,
    - o contaminated ground;

2. Inhalation; and

3. Ingestion of aquatic foods.

Other potential pathways include immersion in contaminated water and ingestion of terrestrial foods (crops, livestock).

For occupational workers, exposure occurs through the external and inhalation pathways:

1. External exposure from:
   - immersion in the airborne plume,
   - exposure to gamma radiation from waste at the workplace; and

2. Inhalation, primarily of dust, aerosols and volatile chemical in the working environment.

For carcinogens, external exposure is generally not a concern and hence is disregarded in environmental pathways models. These pathways are only relevant where the substances of concern are radiochemicals handled in municipal treatment plans such as C-14 and H-3. These substances are found in human wastes and were assessed in a previous study (BEAK, 1986). Carcinogens and other substances are mainly of concern herein.

Environmental dispersion pathways from the WWTP may include atmospheric releases from the burning of sludge (if present), the release of chemicals like CO_2 in the sludge digester and the release of volatile organics in aerosols from aeration tanks, as well as the release to surface water of the treated water. The atmospheric release pathway considers human exposure arising from inhalation, and external exposure to both the plume and ground deposited material. The aquatic pathway considers exposure from both the consumption of fish and water.

A2.3 Perspective for Stormwater Management and Water Quality Control in the Don River

A2.3.1 Development of Levels of Protection

A practical question of whether protection of aquatic biota or human health should be used as the basis for evaluating response of water quality developed in this study. It also poses the question of whether a gradient of **fishable-swimmable-drinkable**, or of **drinkable-swimmable-fishable** is a more stringent gradient for purposes of water quality management.

These questions can be illustrated by comparison of (i) PWQO's of MOE or CCREM's for protection of aquatic life to (ii) Water Quality Criteria based upon drinking water limits. The values that result, are as follows:

Element	Typical Don River Conc.	PWQO/CWQG (Protection Aquatic Life, Table 7.1)	PWQO Drinking Water Considerations Guideline
Cu	10 ug/L	2-6 ug/L	1 mg/L
Zn	25-360 ug/L	30 ug/L	5 mg/L
Pb	7 ug/L	7-25 ug/L	50 ug/L
Ni	8-37 ug/L upon hardness	60-180 ug/L dependent	13.4 ug/L
Hg	40 ng/L	100-200 ng/L	140 ng/L
Cr	12 ug/L	20 ug/L (fish) 2 ug/L (zooplankton)	170 mg/L

In establishing approximate target levels, essential element considerations for human health will rarely be the criteria used for elements such as copper, chromium and zinc. Rather, it is expected that humans will get these essential elements from normal diets. Then water quality will be protected for the most sensitive use: protection of aquatic life.

For other elements, however, such as nickel, and mercury, guidelines based upon human health effects may be as strict as, or more strict than, protection of aquatic life. The evolution of the pathways assessment tools approach may assist in proritizing the value system used in evaluating the effectiveness of response.

In this study, the levels of protection approach was developed for specific end uses (swimming, fishing, aesthetics). These questions and an ecosystem perspective were used as the basis for developing these "levels". The overlay of which human benetical end use or ecosystem component (fish) is more important was left for further analyses.

A2.3.2 Impacts of Water Quality Control

The loadings analysis for SS, TP, ammonia, Cu, Zn, and Pb established that the most effective water quality control measures in the Don River are wet ponds or equivalent in urban areas, flow reduction techniques such as infiltration in redeveloping areas, and improved CSO and STP control.

The effectiveness of these control efforts for improvement of human health can be assessed once appropriate loading riverine concentration models are developed. It would be useful to do this, but such activity is beyond the time frame available to this study, since loadings-receiving water models for key contaminants such as arsenic were not developed in this study.