TECHNICAL ANALYSIS AND INTEGRATION PROCESS SUMMARY REPORT

DUFFINS AND CARRUTHERS CREEK WATERSHED PLAN

August, 2003

Prepared by

Toronto and Region Conservation

in cooperation with

Aquafor Beech Ltd.
Clarifica Inc.
Gerber Geosciences Inc.
Stantec Consulting Ltd.

For the Duffins and Carruthers Creek Watershed Task Forces

Preface

This report contains an overview of the individual technical studies carried out in support of the Duffins and Carruthers Creek Watershed Plan. It is intended to serve those readers who wish to understand the general scope of technical work and rationale behind management strategy recommendations, but who do not require full copies of all technical background reports. All supporting documents are listed at the back of the report, and may be obtained from the TRCA.

NOTE: In this report, figures are found at the end of each chapter.

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SUMMARY REPORT FOR THE
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1.0 INTRODUCTION

1.1 Duffins and Carruthers Creek Watershed Planning Process

In 1999, the Toronto and Region Conservation Authority (TRCA) began the process of developing a watershed management plan for the Duffins and Carruthers Creek watersheds. This initiative continued the Authority's commitment, under its 1989 Greenspace Strategy, to prepare a watershed strategy for each of the nine watersheds within its jurisdiction. The Duffins Creek watershed, draining an area of 283 km^2, and Carruthers Creek watershed, draining 38 km^2, form the eastern end of the TRCA jurisdiction **(Figure 1-1)**. This planning initiative represented the sixth and seventh management strategies to be completed out of the nine TRCA watersheds, and as such was designed to build upon the successes and lessons learned from past experience.

The purpose of the Duffins and Carruthers Creek watershed planning process was to: undertake a thorough study of natural features and functions, human heritage, and public use and the interdependencies among these elements; evaluate the potential effects of current and future watershed activities; and identify management actions needed for watershed protection and enhancement.

The planning process was divided into three phases **(Figure 1-2)**. The Characterization phase involved the assessment of current watershed conditions and issues, which were documented in State of the Watershed Reports produced for each watershed (TRCA, 2002). Management goals, objectives, and associated indicators and working targets were also developed in this phase and were used to guide the technical analysis. The Technical Analysis and Integration phase involved an evaluation of the watershed's response to alternative land use and management scenarios. The final phase, Plan Development, focused on preparation of the watershed plan, including management recommendations, implementation strategies, roles and responsibilities. Recognizing the importance of involving watershed residents and other stakeholders, an extensive and broad-based public and stakeholder involvement program was conducted throughout the process.

This report documents the process, methodologies, and key findings associated with the Technical Analysis and Integration phase of the Duffins and Carruthers Watershed Planning Process. As such, it is a background report supporting the Watershed Plan and other associated technical reports and implementation plans.

1.2 Toward an Integrated Analysis

From the 1980s to the present, watershed management practices in Ontario and internationally have evolved significantly toward an integrated approach.

> *"Integration is the study of the complete system (the watershed, its components, and their interrelationships). Integration in watershed planning is both a process and an evolving discipline - a science that is cross-disciplinary in nature. As a discipline, integration is a very young science.*
>
> (Snodgrass *et. al.*, 1996)

Table 1-1 describes several of the trends and characteristics associated with current practice. "State-of-the-art watershed management today not only addresses a broader range of resource and environmental protection issues than previous initiatives, but also considers and evaluates the interrelationships among these issues" (CVC, GRCA, and TRCA, 2002).

Table 1-1: Trends in Watershed Planning and Management Approaches

SHIFT FROM		***TO***
Single media focus (e.g. flood management)	➜	Trans media, cumulative approaches (e.g. hydrology, aquatic and terrestrial natural heritage, human heritage, etc.)
Natural science focus	➜	Ecosystem approaches addressing natural watershed systems and the human communities in them
Single disciplinary led	➜	Interdisciplinary
Government led	➜	Multi-stakeholder involvement and empowerment
Regulated and reactive approaches	➜	Shared responsibilities, proactive approaches

(Heathcote, 1998; Executive Resource Group, 2001; Conservation Ontario, 2001)

In order to take a proactive approach, watershed managers must anticipate future activities that will take place within the watershed and quantitatively predict the watershed response to these activities to the extent possible. The evaluation should be carried out within each technical discipline and address linkages between the disciplines and within the system as a whole. The degree to which the scientific relationships are understood and the availability of predictive models, necessary to quantify these linkages, varies from one science to another.

A 1997 study by a committee of the provincial government identified ten essential scientific components of watershed management: aquatics, terrestrial, hydrology, stream morphology, water quality, groundwater/hydrogeology, economics, social, mapping and data management, and integration. Following a review of current practice, the committee reported that the components of aquatics, hydrology, and water quality generally reflect state-of-the-art science, however applications within the remaining components are generally lagging behind state-of-the-art (WPIPMC, 1997).

Integrated watershed management is still a relatively new concept. Although the management of water on a watershed basis is reasonably well accepted, Heathcote (1998) acknowledges that water management activities are less frequently integrated with other resource management activities affecting or affected by water. Even where practitioners express an interest in analysing the effects of resource management decisions on watershed systems, Snodgrass *et.al.* (1996) have noted *"...the field is at least half a decade away from being able to quantify the 'stress-response' relationships as a predictive tool for impact assessment, and the immediate future will depend upon relationships and synthesis of models and experience".* While predictive models and tools have been widely available in the fields of hydrology, hydrogeology and water quality, similar tools are still being developed in the fields of aquatic and terrestrial ecology, human heritage, and in the overall science of integrated watershed planning.

Given the relatively rich information base existing within the Duffins and Carruthers Creek watersheds and TRCA's extensive experience with broad-based watershed planning, the Watershed Task Forces were in a good position to not only employ, but advance, the state-of-the-art in integrated watershed planning.

1.3 Purpose

The overall goal of the technical work was to provide a defensible, scientific knowledge base that could be used to set management policies and recommendations that will contribute to the long term protection and enhancement of the health of the Duffins and Carruthers Creek watersheds and their communities. A key aspect of the approach to this work was the attempt to advance the state-of-the-art practice in predicting the response of watershed systems to alternative land use and management scenarios and interpreting the interdependencies among watershed systems.

The studies addressed three primary objectives:

1. To develop benchmarks of watershed condition in response to selected alternative land use and management scenarios;

2. To identify key management issues and effective management approaches; and

3. To develop and test an improved integration model for TRCA watershed and subwatershed planning.

Figure 1-1: Location of Duffins and Carruthers Creek Watersheds

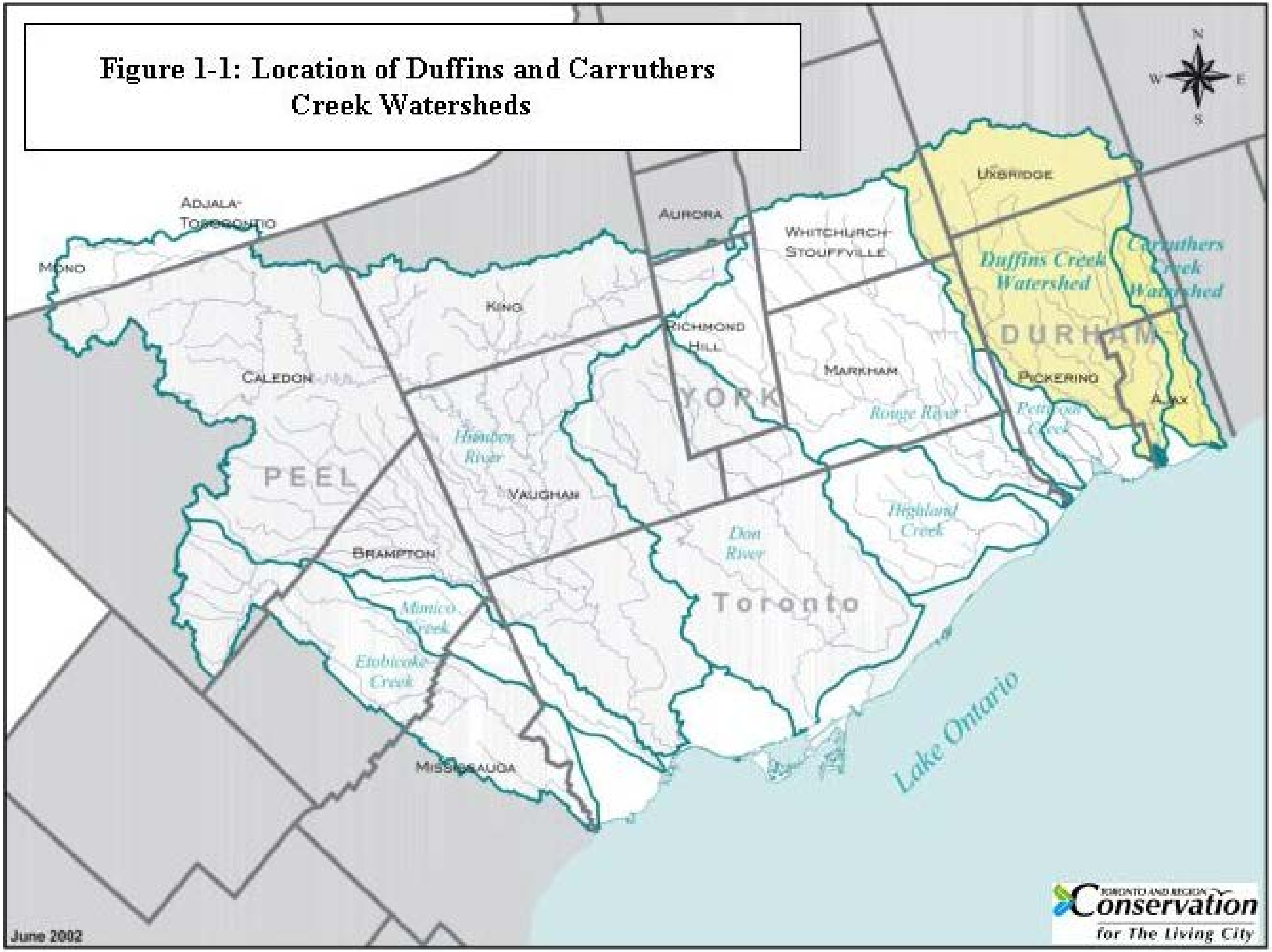
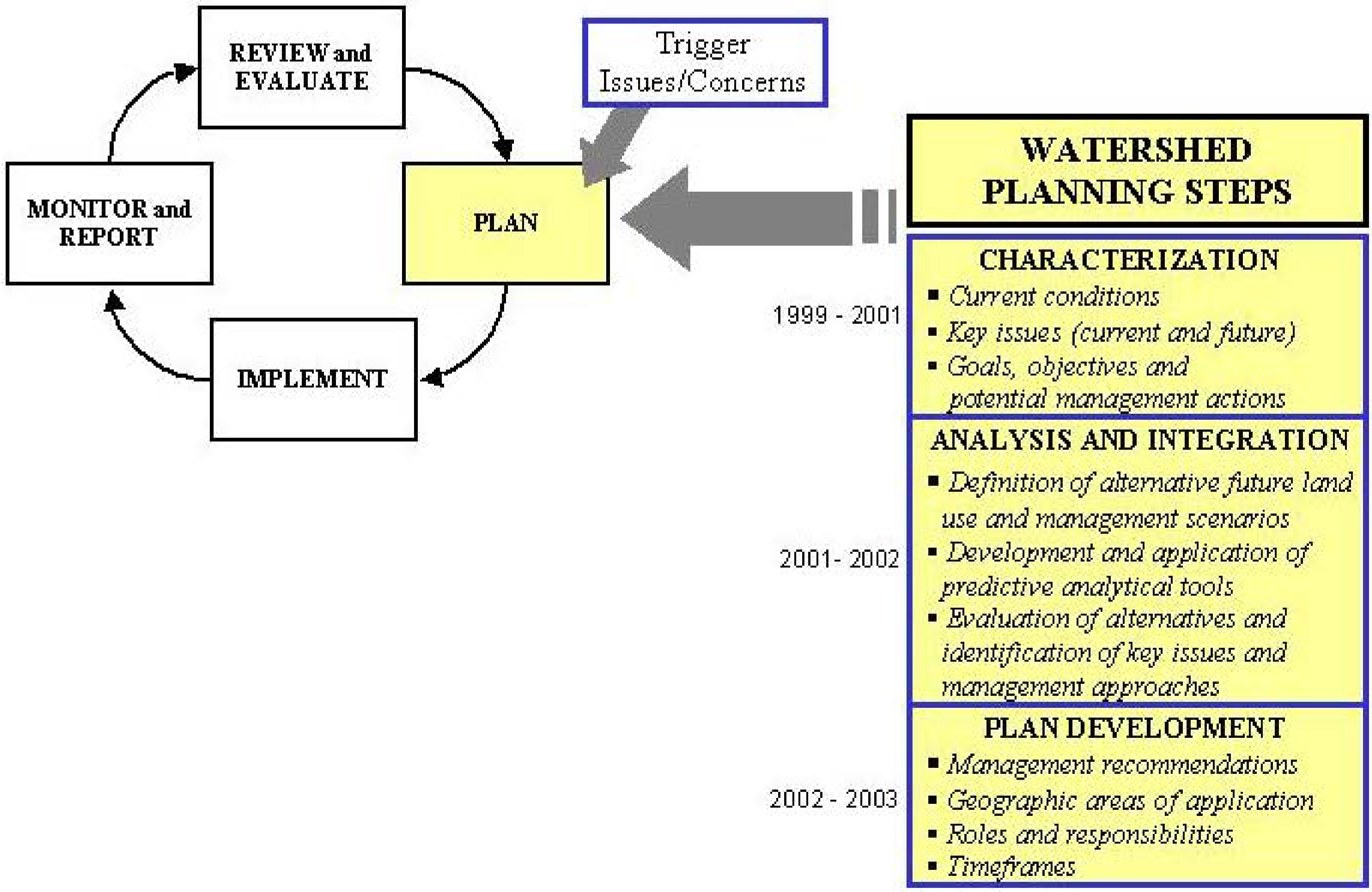


Figure: 1-2 Duffins/Carruthers Watershed Management Process



2.0 AN INTEGRATED APPROACH

2.1 Setting the Stage for Technical Integration

Application of an integrated analysis must be considered at the earliest stages of the technical work, because the foundations for this approach need to be inherent in the design of the work program components, scheduling, and in decisions about the specific parameters and scope of work to be completed. Without this early coordination of work, there may be information gaps or inconsistencies in the presentation of findings from each of the technical components. These problems create weaknesses in understanding watershed function and in the overall strength of the results.

The importance of this coordination was discovered shortly after several of the technical studies had been initiated, such that there was time to modify the workplans and improve consistency. It was also found that coordination among technical teams was necessary throughout the process so that any modifications in workplans could be discussed and understood by other teams that may have been reliant on the information.

Sections 2.2 to 2.7 discuss critical aspects of the integrated approach used in the technical work for the Duffins and Carruthers Creek Watersheds. Due to the lack of certain data and resultant lag in technical studies for the Carruthers Creek watershed, a modified approach was necessary for that watershed (see Section 2.8).

2.2 Technical Study Components

Recognizing that the watershed ecosystem is a complex network of inter-related features and functions, it was necessary to take it apart and reduce it to a set of simpler component systems in order to understand each one and its contribution to the whole.

For the purpose of the Duffins and Carruthers Watershed studies, the following technical components were defined **(Figure 2-1)**:

1. Surface Water Quantity (including surface water budget, hydrology, flooding, stream morphology, base flow, and water taking issues);

2. Groundwater Quantity and Quality (including recharge, water levels, discharge, water taking, and contaminant issues);

3. Surface Water Quality (including pollutant loading issues associated with rural and urban runoff, construction activity, and wastewater discharges);

4. Aquatic Habitat and Species (addressing issues associated with fish and benthic invertebrate species and communities, instream and riparian habitat);

5. Terrestrial Habitat and Species (addressing forest, wetland and meadow habitats, plant and animal communities and species);

6. Human Heritage (archaeological and built heritage); and

7. Recreational Use (primarily trails and other passive use opportunities).

Although not identified as separate components of study, watershed geomorphology (landforms, topography, soils) and land use data were assembled and used as input data to other study components. An integrated analysis of all of these components constitutes an ecosystem approach and provides the foundation for sustainable watershed management.

A complementary study effort looked at state-of-the-art approaches to sustainable development and provided assistance in the formulation of management recommendations for sustainability.

Air quality, climate, and stream geomorphology information for the two watersheds was documented in the State of the Watershed Reports, but no further technical analyses were carried out for these components as part of the initial watershed plan development process. Air quality in the watersheds is relatively good, and therefore the Task Force felt strongly that work should focus on other more critical issues. TRCA was aware that future climate change scenarios were to be defined under a larger Environment Canada study of climate change in the Toronto to Niagara area, although not in the timeframe needed for the local watershed work. This factor, coupled with inadequate funding, led to the decision to postpone work on evaluating climate change implications and possible strategies. Recognizing that the primary threats to natural stream stability were limited to a few subwatersheds expected to undergo urban development, a decision was made to conduct the potential erosion analysis and associated studies at the subwatershed scale. These studies were initiated concurrent with the Task Force's plan development process, but were not intended to be completed within that timeframe.

Identifying and understanding the linkages between technical components was an important aspect of the integrated analysis, and these concepts are addressed at greater length in the following sections.

2.3 Watershed Response Model

Within the Duffins and Carruthers Creek Watersheds, the predominant drivers of future change are associated with urban development pressures, the proposed development of an airport, and the opportunity to protect and enhance an extensive terrestrial natural heritage system afforded by the provincial Oak Ridges Moraine Conservation Act, significant government land holdings, and willing landowners. The potential impacts of urban development on a watershed ecosystem are well-documented (e.g. Ministry of the Environment, 1994; Toronto and Region RAP, 1994) and include such changes as increased runoff to streams, degraded water quality, and loss of habitat.   Likewise, there is a growing renewal of understanding of the benefits of vegetation in not only providing habitat, but also serving hydrological functions, preventing erosion, protecting water quality, and enhancing recreation and quality of life. This concept was recognized by conservationists in the last century, as early as the 1940s (Richardson, 1974).

A set of three alternative land use and management scenarios were defined by the technical team, to foster a consistent analysis within and between each technical discipline. Each land use scenario represented a different proportion of natural, rural and urban land cover characteristics. These alternative scenarios are described in Chapter 3.

In order to analyse the response of the watershed ecosystem to each of the three scenarios, a simplified model/procedure was defined, which identified the relationship between each watershed system and the order in which changes would occur. **Figure 2-2** illustrates the Watershed Response Model used by TRCA in this work. The model describes the sequential order in which changes occur in the condition of each watershed system in response to a given stress, such as a change in land cover. The pathways of change include direct “footprint” effects (such as the loss of forest habitat or destruction of a human heritage site due to resource development); indirect “flow related” effects (such as increased flooding and stream erosion potential due to increased runoff associated with urban development); and cumulative effects (such as changes in aquatic community composition arising from a combination of hydrological, chemical, and physical habitat effects from upstream areas). The procedure guided the integration and exchange of information among separate technical staff teams.

The model was adapted from an initial model developed by Snodgrass *et. al.* (1996), which focussed on impacts on aquatic ecosystems contained within streams and rivers, and on a later adaptation of that work by Credit Valley Conservation in a subwatershed study (CVC, 2001), which also focussed on flow related impacts to the aquatic system. TRCA has expanded the model to address terrestrial natural heritage, human heritage, and recreational use components.

2.4 Predictive Tools

Currently, there is not a comprehensive computer model that is designed to predict all of the effects of a watershed activity on all of the various ecosystem components (i.e. ecological, human heritage and recreation). Therefore, for the purposes of this analysis, a combination of computerized mathematical models, empirical relationships, and professional judgement were used to assess changes within each technical study component. By specifying common standards for the scale of analysis, units, and presentation of results, the input and output data could be shared from one model to another, within the context of the overall watershed response model (after Snodgrass *et. al.*, 1996).

Figure 2-3 identifies the predictive tool or assessment methodology used in each theme area. A more detailed description of each methodology is found in Chapter 3.

2.5 Objectives, Indicators, Measures, and Targets

To analyse and evaluate the results generated by the predictive models, a set of management objectives and an associated set of meaningful indicators and measures of change were specified. Management recommendations for the Duffins and Carruthers Creek Watersheds were defined, with input from the Watershed Task Forces, for each of the eight technical theme areas, using a framework of Goals, Objectives, Indicators, Measures, Targets, and Management Actions.

Goals: identify the desired end points for each component that are necessary to achieve the watershed vision.

Objectives: identify the approaches necessary to address the key issues affecting that component.

Indicators: are facts or devices that provide specific information about the objective.

Measures: are quantitative or qualitative ways to measure the state of the indicator.

Targets: represent a numerical threshold or directional aim, associated with each measure, and were chosen as the minimum (or maximum) state necessary to achieve the desired objective.

Management Actions: are mechanisms recommended to achieve the objective and may include: policy, planning and regulatory tools, stewardship, regeneration, and education/awareness activities, land securement, monitoring, and/or further study needs.

Appendix A presents the goals, objectives, indicators, measures and targets that were established for the Duffins and Carruthers watersheds. Recommended management actions were finalized following the technical studies and are presented in the watershed plan. This overall framework has evolved from and is consistent with frameworks used in TRCA's previous watershed report cards and strategies for the Don (TRCA, 1997 and 2001), Humber (1997 and 2000), and Etobicoke-Mimico (TRCA, 2002) Watersheds and the Regional Watershed Monitoring Network (TRCA, 2000). Indicators provide a useful means of summarizing complex information into understandable, relevant terms, and therefore they have also been widely used in other jurisdictions for state-of-the-environment reporting (eg. UTRCA and RVCA, 2002).

Most of the Duffins and Carruthers watershed management objectives, and subsequently the indicators, describe the desired watershed condition; several indicators provide information about stresses (of human or natural origin) on environmental quality or the status of management actions (response). A condition-stress-response framework of indicators has been widely accepted as a means of monitoring and reporting on watershed health (Environment Canada and US EPA, 1999; Campbell and MacLaren, 1995). Each of the three types of indicators provide different information, but they are linked by causal relationships. For the purposes of this technical analysis, the condition and stress indicators are of particular use.

Figure 2-4 identifies the specific indicators and measures that were the focus of the integrated analysis. These were chosen due to their ability to be quantitatively modelled and their established relationships with other indicators and measures of interest.

2.6 Watershed Study Area and Subwatershed Units

The State of the Watershed Reports provided a good understanding of key issues associated with the Duffins and Carruthers Creek Watersheds, and facilitated the development of technical work programs. An important management consideration within the Duffins Creek watershed is the degree to which the well-forested headwaters and the Oak Ridges Moraine geology contribute to the maintenance of a high quality river system. Significant areas of the Duffins Creek headwaters are already in public ownership or are protected under conservation easements and the remaining lands are afforded a level of protection under the Oak Ridges Moraine Act. Significant land areas off the Moraine are owned by the federal government, and are being held for a future airport development. Other lands, known as "Seaton", are owned by the provincial government, and are intended for future urban development. Less than one-third of the Carruthers Creek watershed is currently urbanized, although urban expansion is projected and will need to be managed in order to maintain and restore environmental conditions within this somewhat degraded system. The technical analyses were designed to provide guidance for the management of these and other issues.

In order to facilitate interpretation, the Duffins Creek Watershed was divided into six smaller subwatershed units, including the West Duffins Creek, East Duffins Creek, Ganatsekiagon Creek, Urfe Creek, Miller Creek, and the Lower Duffins Creek Subwatersheds **(Figure 2-5)**. Subwatershed units were defined with consideration for common physical characteristics and land use issues present within each and the desire for a manageable number of study units.

These subwatersheds, together with the Carruthers Creek watershed, provided a common basis for communication among the technical teams when presenting and interpreting study findings. This coordination was necessary, because individual technical studies discretized the watersheds into smaller or larger units, depending on the specific level of resolution needed for their work. For example, the hydrology and water budget exercises divided the Duffins Creek watershed into 31 sub-basins. The terrestrial natural heritage modelling and public recreational use studies were conducted on a watershed-wide scale, but results were qualitatively described for each subwatershed.

These subwatershed units also provided the basis for a more detailed assessment of management priorities and implementation requirements, that were identified in the watershed strategy.

2.7 Presentation and Interpretation of Findings

The preceding sections have described a number of steps taken to facilitate an integrated approach to studying the watersheds, including: definition of a common set of alternative land use and management scenarios for analysis by all disciplines; definition of the environmental pathways that describe the relationships between disciplines; identification of key indicators and associated standardized measures; and agreement on a common geographic scale for analysis. This groundwork provided for a level of integration that was embedded in the technical studies and assisted in ensuring that the findings were presented, discussed and interpreted in a consistent, integrated way.

Modelling results from individual studies were presented in a variety of ways, including tables and thematic maps. Overlay methods, using either a crude system of overhead transparencies or a more sophisticated Geographic Information System (GIS) on-line, were used to assist staff in identifying common patterns and interdependencies within the results. These techniques were used to identify areas within the watersheds that required special management considerations. Section 4.3.2 describes in more detail how a GIS-approach was used to integrate the key management recommendations and illustrate the multiple watershed management benefits of natural heritage cover.

A series of four technical team workshops were held at different stages throughout the study. At each workshop, each technical disciplinary group presented findings from their studies and received input and a broader base of interpretation from the overall team.

2.8 Carruthers Creek Watershed - Modified Integration Approach

Adequate stream flow data for the Carruthers Creek were not available at the outset of this study. These data are needed to calibrate a watershed hydrology, water budget, and groundwater flow models. Therefore, a decision was made to proceed with the installation of a stream gauge and, once adequate data are collected, undertake the modelling studies. Interim approaches were used to facilitate a similar technical evaluation of the alternative land use and management scenarios, as was carried out for the Duffins Creek watershed where information was unavailable. For example, in some cases the results of previous, simplified studies were used (e.g. hydrology and floodplain mapping) or surrogate information was applied (e.g. estimates of pollutant loads from similar neighbouring watersheds were pro-rated for the Carruthers watershed). These modified methods are noted with the technical study approaches and findings.

Figure 2-1 : Technical Study Components of the Duffins and Carruthers Watersheds Planning Process

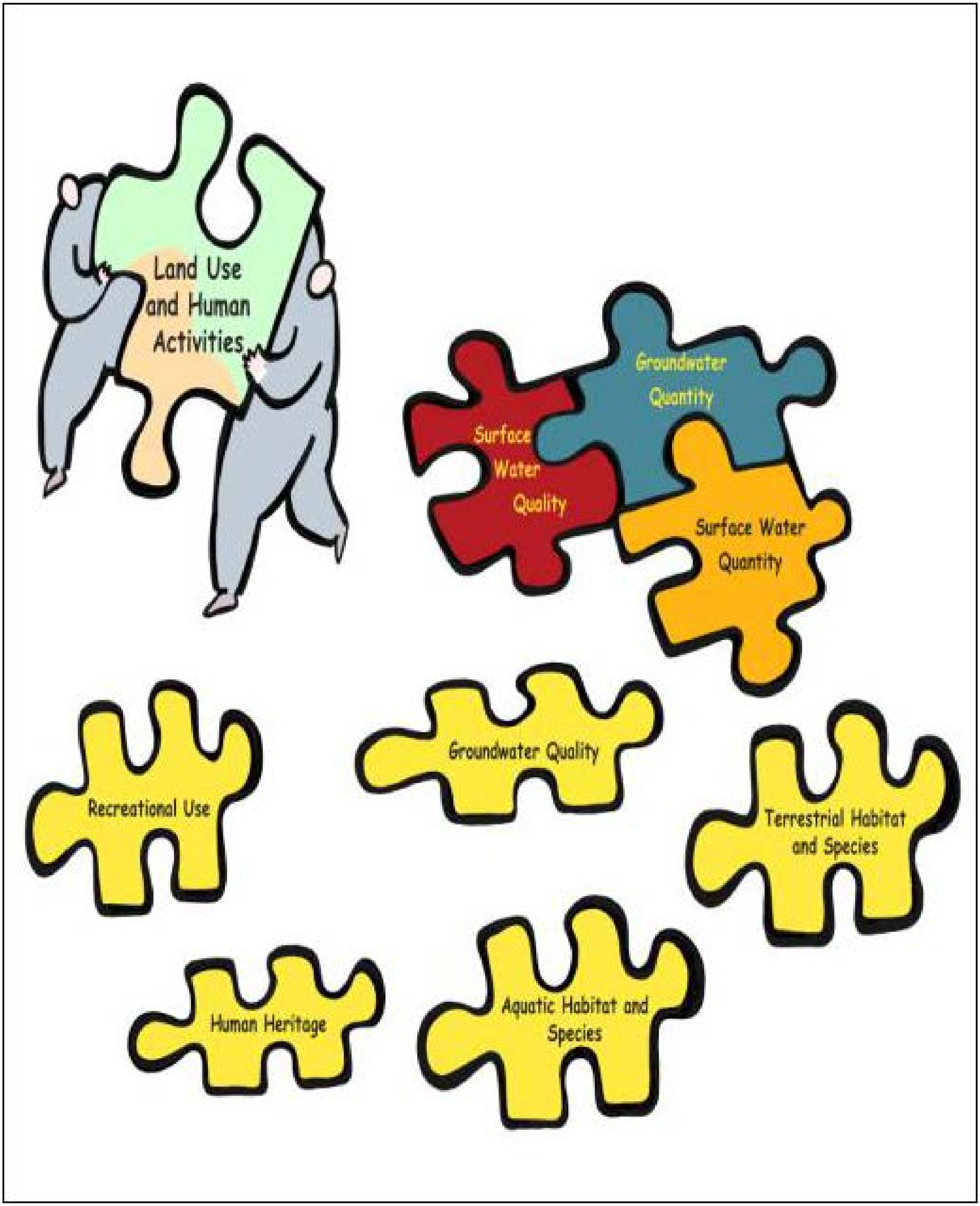


Figure 2-2: Watershed Response Model – Hierarchy of Change

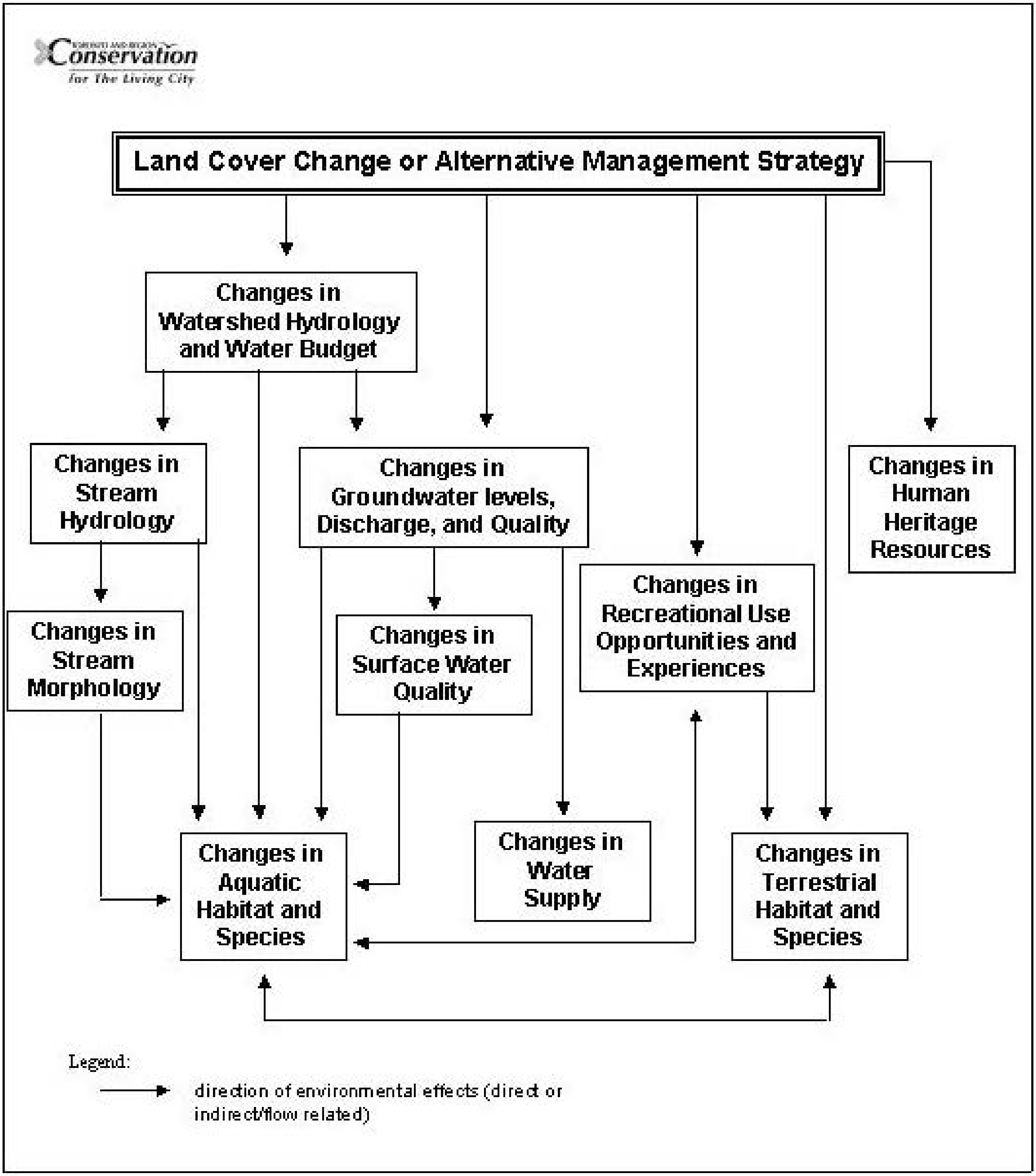
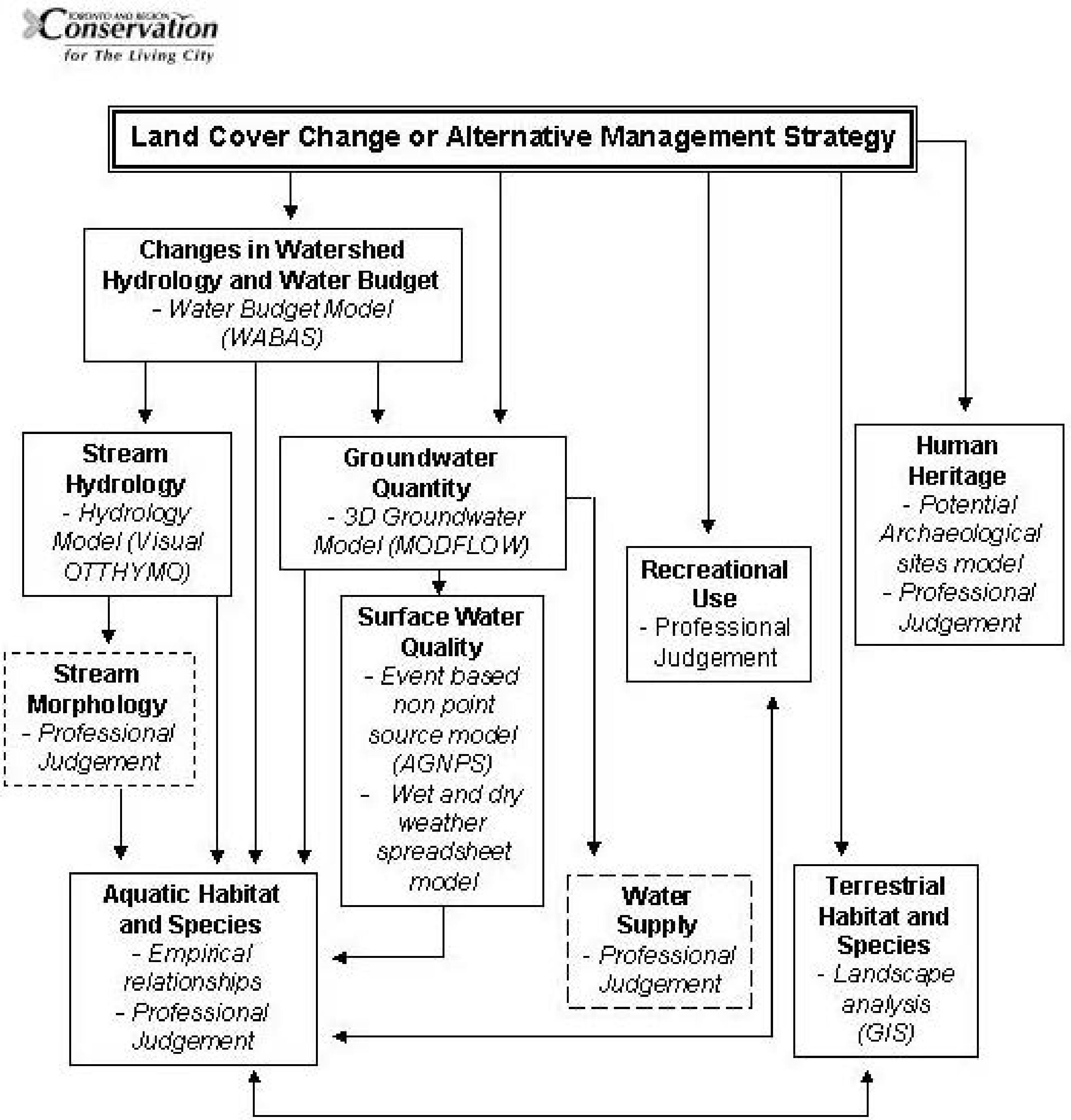


Figure 2-3: Predictive Tools Employed in the Duffins and Carruthers Watershed Planning Process



Legend:

→ Direction of environmental effects (direct or direct flow related)

--------- Subject not modeled at watershed scale

Figure 2-4: Primary Indicators of Change

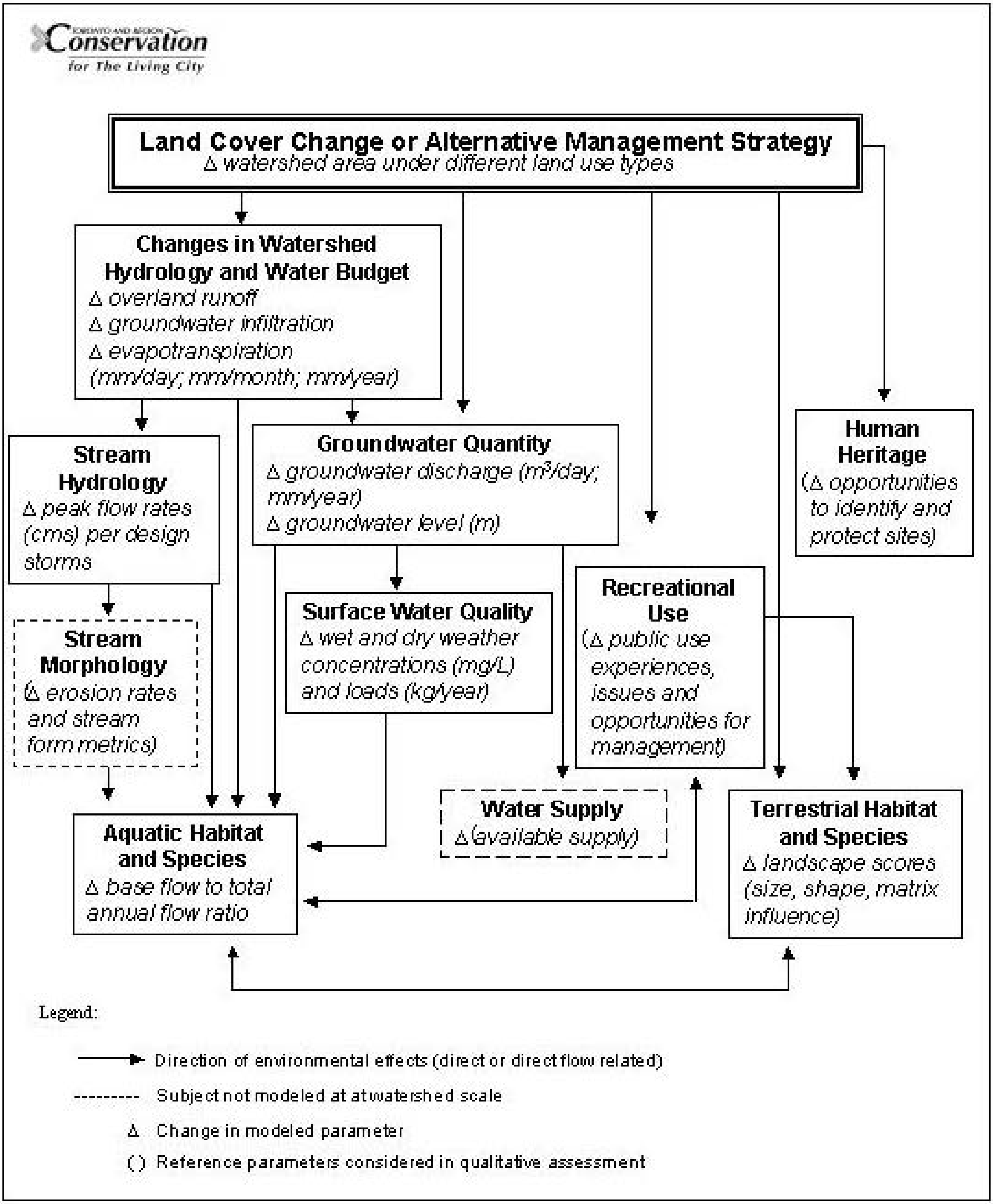
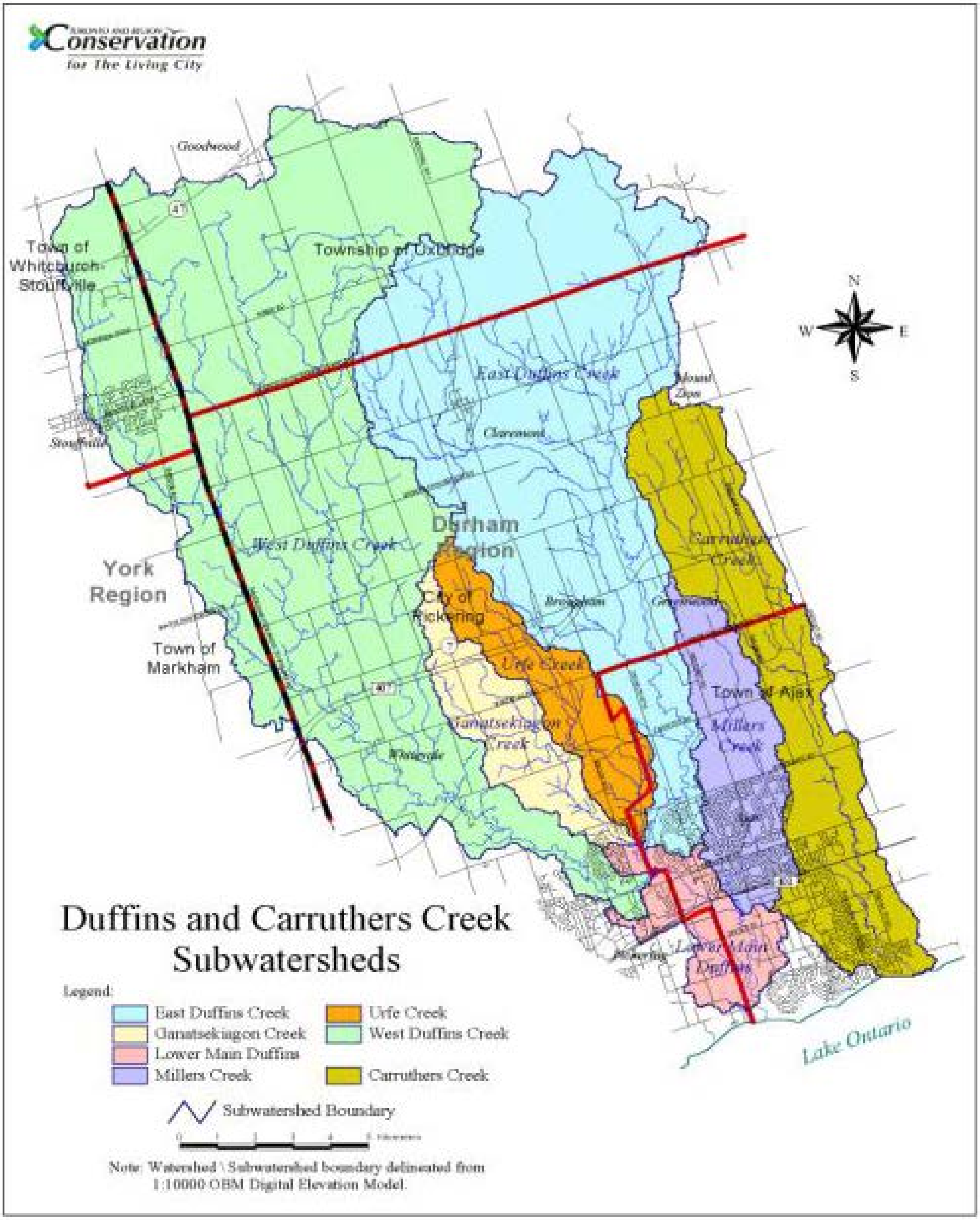


Figure 2-5: Watershed and Subwatershed Study Units



3.0 ANALYSIS OF ALTERNATIVE LAND USE AND MANAGEMENT SCENARIOS

3.1 Land Use and Management Scenarios

While the Duffins and Carruthers Creek Watersheds are in relatively good condition today, they are not static systems. Future pressures from urban growth, road widenings and construction (e.g. Hwy. 401 and 407), proposed airport development, and associated impacts are anticipated in these watersheds over the next 20 years. Although an infinite number of land use and management combinations could have been defined, it was felt that by identifying a few discrete future watershed states, the technical team would be able to generally benchmark the watershed's response along a continuum and use these alternative states as guidance in formulating a management strategy.

Considering the anticipated pressures and opportunities, three primary alternative land use and management scenarios were defined for common analysis by all technical disciplines:

1) Existing Land Use;
2) Future Land Use;
3) Future Land Use With Enhanced Natural Heritage Cover.

Additional land use and management approaches, tailored to individual technical issues, were also reviewed. The following sections describe the methods used to develop and depict the alternative scenarios.

Municipal land use maps were used as a primary basis for the scenario development, along with 1999 Digital Ortho Aerial Photography (1:4000) in the case of the Existing Land Use Scenario. Municipal ***land use*** classifications were interpreted and digitized in terms of their associated ***land cover*** characteristics. **Appendix B** presents the municipal land use maps used in this work and identifies the assumptions made in their interpretation. **Figures 3-1 (a,b,c) and 3-2 (a,b,c)** illustrate the three scenarios. **Table 3-1** summarizes the area of land under each land cover type within each subwatershed for the three scenarios. It should be noted that more detailed land cover classifications and mapping were tailored to the needs of individual technical studies. For example, golf courses were assigned runoff values similar to natural areas for surface and groundwater studies, while natural areas were further subdivided into areas of forest, wetland, meadow, and successional habitat for terrestrial natural heritage studies.

Table 3-1: The total area and percent land cover in the Duffins and Carruthers Creek watersheds and subwatersheds for three alternative land cover scenarios

	Size (ha.)	Existing Conditions (%)				Future Land Use -Official Plan (%)				Future Land Use (OP) + Natural Heritage (%)			
		Golf Course	Agri-culture	Natural Areas	Urban	Golf Course	Agri-culture	Natural Areas	Urban	Golf Course	Agri-culture	Natural Areas	Urban
West Duffins	13538	2	63	32	3	2	58	31	9	2	43	46	9
East Duffins	9202	1	50	45	4	2	48	45	5	1	30	64	5
Ganatsekiagon	1305	0	58	40	2	0	24	33	43	0	23	34	43
Urfe	1436	3	52	44	1	3	31	36	30	3	30	37	30
Millers	1698	0	38	24	38	0	16	23	61	0	16	23	61
Lower Main	1124	6	0	49	45	6	0	36	58	6	0	36	58
Whole Duffins	28303	2	54	37	7	2	47	36	15	2	34	49	15
Whole Carruthers	3812	5	49	29	17	4	34	25	37	5	28	30	37

3.1.1 Existing Land Use

The "Existing Land Use" scenario (**Figures 3-1a and 3-2a**)assumed maintenance of existing land use conditions and associated land cover characteristics (i.e. areas of imperviousness, vegetation, etc.). Mapping was developed by interpreting 1999 Digital Ortho Aerial Photography at a scale of 1:4000. Analysis of this scenario would essentially provide a benchmark for current watershed conditions and identify healthy elements to be protected and existing problems to be remedied.

As shown in **Table 3-1**, the Duffins Creek watershed supports predominantly agricultural/rural (54%) and natural (37%) land cover. Forests make up a significant proportion of the natural area. There is about three times as much of the natural area in forest cover as compared to meadow. Wetlands make up only 2% of the watershed area. About 49% of the Carruthers Creek watershed is under agricultural/rural land cover. The area in natural cover represents about 29%. In the case of the Carruthers Creek watershed, this natural area is made up of roughly half meadow and half forest cover. Wetlands form a small percentage of the watershed area.

3.1.2 Future Land Use

The "Future Land Use" scenario assumed full build out of the approved Regional and Local Municipal Official Plans, which projected watershed land use up to the year 2020. Under this scenario, urban land cover in the Duffins watershed would increase from 7% (existing) to 15% of the watershed area. In the Carruthers Creek watershed, the urban area would expand from 17% (existing) to 37%. Mapping was developed by digitizing municipal official planning schedules. When applying the land cover classifications, associated with future designated urban growth areas, it was assumed that the TRCA's Valley and Stream Corridor Policies would be implemented, and therefore vegetated land cover was applied to all valley and stream corridors, as defined under the TRCA program. Modelling exercises assumed no best management practices would be incorporated with the urban development, in order to demonstrate the response of watershed systems under a "worst case" scenario.

The Durham Region Official Plan assumes urban development within the provincially-owned Seaton lands, so results of the modelling exercises provided some indication of the potential impacts associated with the development of "Seaton", although the exact density and type of the future urban land cover is not known. This information is especially timely, in consideration of an April 2002 provincial government decision to facilitate a "land swap" in the Seaton area with private land owners in Richmond Hill and Uxbridge, in order to remove sensitive Oak Ridges Moraine lands from development in that area (MMAH, 2002). Under the agreement, these lands will be brought into public ownership for the creation of a park and the landowners will be compensated with land more suitable for development in Seaton.

Durham Region's Official Plan identified a future regional airport, but did not show any details with respect to an airport on the federal lands. Even the future prospect of an airport was questionable when this watershed study began. Therefore, the federal lands were classified as rural and assigned the same land cover classifications as in the Existing scenario.

3.1.3 Future Land Use with Enhanced Natural Heritage Cover

The "Future Land Use with Enhanced Natural Heritage Cover" scenario assumed full build out of the approved Regional and Local Official Plans, as in the previous scenario, but also assumed revegetation of lands, where such opportunities were expected to exist and where other watershed management objectives were likely to be realized. The resulting scenario represented an increase in area of natural cover from 37% (existing) to 49% in the Duffins Watershed and from 29% (existing) to 30% natural cover in the Carruthers Creek Watershed.

This land use scenario inherently incorporates the Task Forces' "environment first" and "net gain" management approaches, which are premised on the understanding that natural systems provide a long term, sustainable first step in an integrated management strategy. It also recognizes that any management benefits derived from the protection/enhancement of natural systems would still need to be augmented by mitigative measures and best management practices associated with land use activities. However, for the purposes of the modelling, no BMPs were assumed in order to demonstrate the watershed response associated with the enhanced natural cover. The management philosophies represented by this scenario are consistent with trends in water management approaches from the early 1980s to late 1990s, as identified by Heathcote, 1998 and summarized in **Table 3-2.**

Table 3-2: Trends in Water Management Approaches

SHIFT FROM	***TO***
End of pipe	➜ Control at source
Remediation	➜ Prevention
Point source focus	➜ Point and Non Point source focus
Site focussed solutions	➜ Regional and watershed approaches
Trust of technology	➜ Understanding the limits of technology

Adapted from Heathcote, 1998

The formulation of this scenario preceded detailed terrestrial natural heritage modelling conducted by TRCA as part of its Terrestrial Natural Heritage Program, and thus applied a similar but alternative approach. The lands targeted for enhanced natural cover were delineated manually, according to the following considerations:

- opportunities to improve size, shape, and connectivity of existing habitat patches
- opportunities to rehabilitate riparian vegetation
- likelihood of benefitting other watershed management objectives (i.e. groundwater infiltration, floodwaters detention, recreational use enhancement, etc.)
- compatibility of adjacent land use and likelihood of implementing enhanced natural cover
- assumption that aggregate operations would be naturalized
- land ownership and expected willingness to implement enhanced natural cover (emphasis on public lands, areas of known private landowner interest in conservation

easements, Transport Canada's Greenspace Lands, Minister's Airport Zoning Control Order)

- provincially-owned Seaton lands were assumed to be urbanized according to the provisions of existing legislation and policies for natural heritage, and therefore, typical of privately developed lands, no revegetation opportunities were assumed beyond the protection of existing natural heritage features. It is expected that there will be opportunities for enhancing natural heritage cover as planning for these lands proceeds.

It should be emphasized that these considerations went beyond those factors that might solely be associated with terrestrial habitat management objectives, in recognition of the other benefits of natural cover, such as hydrological benefits and enhanced public recreational use experiences. Most of the opportunities for enhanced natural cover were concentrated in the headwater areas, particularly in the East Duffins Creek subwatershed.

The development of this scenario preceded the release of the Oak Ridges Moraine Conservation Plan (ORMCP) and its protective land use designations. When compared, the TRCA enhanced natural heritage cover scenario would address all of the lands protected under the ORMCP, and go further in a few areas.

The resulting scenario, representing 49% natural cover in the Duffins Watershed and 30% natural cover in the Carruthers Watershed, was intended for study purposes and was not intended to limit revegetation to these specific geographic areas.

3.1.4 Other Land Use and Management Alternatives

Additional land use and management scenarios were defined and evaluated for several of the individual technical components, in order to provide more direction to the management of specific issues.

<u>Watershed Hydrology, Water Balance, Groundwater, and Aquatic Resources</u>

In an effort to define an ultimate benchmark of water quantity response in the Duffins Creek watershed, a land use scenario was analysed involving build out of the approved Official Plans plus an additional 50% impervious cover on the remaining non-urbanized lands. Results of this analysis are published in the component technical reports. Results were used to help demonstrate the watershed's sensitivity to change.

<u>Flooding Concerns</u>

In addition to modelling the watershed's hydrological response to the three land use scenarios, the hydrological modelling exercise evaluated alternative stormwater management strategies for peak flow control for each land use scenario. The alternative stormwater management strategies included: no control; control of flows from the 2 year to 100 year return period storms; and control of flows from the Regional Storm.

<u>Surface Water Quality</u>

The modelling exercises that were undertaken to identify the primary source areas of rural pollution, specifically sediments and nutrients, incorporated one additional management scenario. The "Priority Management Areas Revegetation" scenario was based on the "Existing" land use scenario, but simulated the effects that increased forest cover would have on pollutant loads, if selectively applied to areas identified as predominant sources of sediment load. Predominant source areas were defined as those 1 km^2 grid cells, which together contribute over 65% of the total sediment load. Percent forest cover within each cell was increased to a total of 60% of the grid area to form the “Priority Management Area Revegetation” scenario. This cover would equate to a forested area of 300 x 500 m across the grid cell and might be achieved through such best management practices as riparian plantings, vegetated buffer strips, and reforestation.

3.1.5 Existing Water Use

Data regarding existing surface and ground water takings, as recorded in the Ministry of the Environment’s Permit to Take Water database, were obtained and reviewed in the context of the groundwater management and low flow management issues.

3.2 Predictive Tools and Methodologies

A combination of computerized mathematical models, empirical relationships, and professional judgement were used to assess the watersheds’ response to the alternative land use scenarios. The following sections identify the methods used within each technical theme.

3.2.1 Surface Water Quantity

3.2.1.1 Water Balance

A water balance analysis has increasingly been recognized as one of the most integral indicators of change in many watershed functions. The Oak Ridges Moraine Conservation Plan (Government of Ontario, 2002) has in fact made the development of a water balance a requirement, prior to consideration of major development approvals. Based on the components of the hydrologic cycle, the purpose of the water balance analysis in this study was to estimate changes in overland runoff, infiltration, and evapotranspiration values due to land cover changes associated with the three land use scenarios. Typically, urbanization causes an increased volume of runoff and reduced infiltration, due to the hardening of surfaces, removal of depression storage, and reduced evapotranspiration associated with the loss of vegetation.

A water balance analysis tool was developed for the Duffins Creek Watershed to quantify the current and future water balance according to the alternative scenarios. A similar study was not possible for the Carruthers Creek Watershed due to the lack of stream flow data needed for calibration. Monitoring is underway to address this deficiency. For the purposes of the technical analysis, qualitative estimates of water balance changes were made for the Carruthers Creek Watershed.

Details of the water balance study are included in the technical report *Water Budget in Urbanizing Watersheds: Duffins Creek Watershed* (Clarifica Inc., May 2002)

The water balance analysis methodology calculates the water balance component of the basin using the “WABAS” system. WABAS (Water Balance Analysis System) was developed by Clarifica Inc. to analyze the hydrologic water balance of rural and urbanizing watersheds. WABAS was designed to use the data from other surface hydrology analysis techniques including SCS CN runoff method, snowmelt methodology (GAWSER), unsaturated groundwater infiltration and evaporation techniques. The model operates from an ‘EXCEL’ worksheet platform. It requires a time series input of daily precipitation, average or maximum-minimum temperature, and measured evaporation. It outputs a time series of runoff, infiltration, evaporation, and storage conditions within each water balance reservoir (pervious and impervious interception storage, surficial soil storage, snowpack storage).

Input includes climate, hydrometric (measured flows), and physical basin parameters. Local climate data and measured flows are used for surface runoff calibration. Physical basin parameters define the surface and surficial properties of each basin affecting the storage and movement of water from one stage to another including imperviousness, interception abstractions, vegetation, and surficial soil characteristics. These parameters are collected directly or indirectly based on typical land-use or surrogate soil and vegetation parameters. Because the model outputs daily time step volumetric results, it does not require routing coefficients. However, for the Duffins watershed, a three-day unit hydrograph lag was found suitable for calibrating observed daily average in-stream flows following rainfall events and this was incorporated as part of the surface runoff response.

This water balance tool provides advantages over other existing hydrologic modelling tools because it:

- Explicitly calculates evapotranspiration as a function of vegetation cover and soil moisture availability. Therefore, it can be used to assess impacts of urbanization as well as natural heritage (reforestation) strategies.
- Utilizes daily time step to account for consecutive rainfall events and antecedent soil moisture conditions and tracks available storage such as in stormwater management infiltration facilities.
- It links evaporation and groundwater infiltration with surficial soil moisture when accounting for antecedent soil moisture conditions.
- Has been adapted from accepted and practised SCS CN surface approach in use in Southern Ontario.
- Determines urbanization effects such as directly and indirectly connected impervious areas.
- Incorporates winter snow and snowmelt processes.
- Can be utilized at the site plan and sub-division level to size stormwater management infiltration practices to mitigate potential reductions in groundwater infiltration.
- Can be readily used to conduct sensitivity analysis such as short or long-term precipitation changes (ie. climate changes).
- It can be made user-friendly and adapted for wide spread distribution.

Model Calibration

Model calibration is the process by which modelled and measured runoff flows are matched by varying ‘calibration’ parameters. The calibration process involves collection, screening and analysis of measured flows and climate data, as well as the systematic evaluation of the response of runoff to variations of calibration parameters. Specifically, the following steps were taken during calibration:

1. Collection and evaluation of measured flow data at several locations in the watershed.
2. Baseflow separation. The process requires the analysis and quantification of low flow patterns and separation from the total observed stream flow. The difference between total stream flow and baseflow is assumed to be the wet-weather response.
3. Isolate and quantify the physical watershed parameters upstream of each flow gauge.
4. Set-up basin model with the physical watershed information at each gauging station and with climate data corresponding to the measured flow period. Include additional years of climate data prior to calibration to provide a 'warm-up' period to estimate 'initial' conditions.
5. Execute model while varying calibration parameters within physical limits to best match wet-weather hydrograph obtained in Step 2.
6. Adjust individual basin calibration parameter to match gauge calibration results.

The water balance analysis has been calibrated using measured flows from 1997 to 2000 from six stream gauges located throughout the watershed. The long term water balance analysis was completed using 15 years of climate data and the alternative land use scenarios for each of 30 sub basins in the Duffins watershed.

The findings from the water balance study are presented in section 3.3.1.1.

3.2.1.2 Watershed Hydrology and Hydraulics

The primary purpose of watershed based hydrological modelling is to estimate peak flow rates arising from differently sized storm events, as an indication of where changes in flooding risk may occur under the various land use scenarios, and to evaluate the effectiveness of alternative stormwater management approaches. Typically, urban development causes an increase in the magnitude and frequency of severe flood events. Flood control strategies from the 1940s have demonstrated the moderating effects of headwaters reforestation programs.

Duffins Creek Watershed

Aquafor Beech Limited was retained by the Toronto and Region Conservation Authority to complete an update of the hydrologic model for Duffins Creek. The existing watershed model was created in 1991, also by Aquafor Beech Limited.

The software selected for the Duffins hydrology update was VISUAL OTTHYMO, Version 1.06. This model is a HYMO-based model and was selected for this application given that it has essentially the same operating characteristics as the model used for the original, 1991 model with some additional interface upgrades. VISUAL OTTHYMO is a mathematical model that uses the unit hydrograph theory to simulate a watershed response to simulated or actual rainfall events.

In order to carry out the hydrologic analysis, the Duffins Creek Watershed was discretized into 31 subcatchments based on physical characteristics. A number of parameters were then calculated for each of the subcatchments for input into the model. The model output identified peak flow estimates for specified locations in the watershed for three land use scenarios. A comparison of the results was carried out to determine the hydrologic impact of proposed future land use, to identify the effectiveness of runoff controls and to quantify the benefit assuming an expanded natural heritage system.

The hydrologic model was calibrated using local hydrometric data (i.e. stream flow) collected at six locations throughout the watershed. In addition, precipitation data, collected and archived by the Region of York was also used for calibration purposes. In total, six events, occurring between 1999 and 2000 were selected for the calibration exercise. Details of this work are described in *Duffins Creek Hydrology Update* (Aquafor Beech Limited, May 2002).

For the purposes of the watershed planning process, a qualitative assessment was carried out to summarize the anticipated changes to the existing hydraulic conditions throughout the watershed given the results of the hydrology update. An update to the existing hydraulic model and associated floodplain mapping for the Duffins Watershed is underway and will continue over the next 2 years. This update will be carried out to define the limits of the Regional Floodplain given the updated flow information. Corresponding updates to the Flood Vulnerable Areas (FVA) and Flood Vulnerable Roads (FVR) database will be carried out as required.

The results of the hydrology study are summarized in section 3.3.1.2.

Carruthers Creek Watershed

The Carruthers Creek hydrology model was last updated in 1999 by Totten Simms Hubicki Limited and further updated by Cosburn Patterson Mather Limited in 2000 through the A8 Secondary Plan process. The watershed model was developed using the OTTHYMO 89 computer model. OTTHYMO 89 is a mathematical model that uses the unit hydrograph theory to simulate watershed response to simulated or actual rainfall events.

In order to carry out the hydrologic analysis, the consultants discretized the watershed into 3 subcatchments based on physical characteristics. A number of parameters were then calculated for each of the subcatchments for input into the model. The model output identified peak flow estimates for specified locations in the watershed for three land use scenarios, including existing conditions, approved future land use and future forseeable land use.

For the purposes of the watershed planning process, results from the earlier modelling work were used for assessment purposes. TRCA plans to recalibrate and update the Carruthers Creek hydrology model in 2003, once adequate streamflow data have been collected from the gauge installed in 2002.

3.2.1.3 Stream Morphology/Erosion Assessment

Stream channel form is a function of the hydrologic flow regime and the erodibility of the channel sediments. The typical impacts of urbanization on the flow regime and stream morphology have been well documented and include: increased frequency of erosive flow events, increased stream cross-sectional area by widening or down-cutting, increased sediment loads and altered riffle-pool-run sequences and a shift toward finer grain sizes in streambed sediments (MOE, 1999; MacRae and Rowney, 1992). To predict the location and severity of adjustments in the stream channel, in response to altered flow regimes, it is necessary to determine the erosion potential of stream banks and bed sediments, based on field measurements. This level of effort was not possible throughout the watershed during the planning timeframe so, for the purposes of watershed plan development, it was assumed that erosion rates will increase downstream of urbanized areas under the Future Land Use scenario (assuming no erosion control) given the extent of proposed development. Erosion rates are also expected to increase downstream of urbanized areas, under the Enhanced Natural Heritage scenario (assuming no erosion control); however, the rate of increase will be smaller than experienced under the Future Land Use scenario, due to the moderating effects of vegetative cover on runoff and streamflows.

Further work in Duffins Watershed

An erosion assessment for portions of the Duffins Creek watershed was carried out in 2002 and will be finalized in 2003. The assessment was carried out for those subwatersheds where future development is proposed, and included: field work to determine baseline conditions and erosion thresholds. Results of the erosion analysis will be used by development proponents and their consultants to determine criteria for future development in terms of release rates (L/s/ha) and storage volumes (m^3/imp.ha).

Available Erosion Criteria in Carruthers Watershed

In 1997 an erosion and fluvial geomorphology assessment was carried out as part of the Secondary Planning process for the A8 area in the Town of Ajax. The A8 area is bounded by Taunton Road in the north, Audley Road in the east, and Kingston Road in the South. The western boundary, south of Rossland Road is approximately half way between Harwood Ave. and Audley Rd. North of Rossland Road, the western boundary varies from east and west of Salem Road. The A8 area encompasses the majority of the remaining future development area, within the existing Official Plan, in the Carruthers Creek Watershed. As part of the A8 study, erosion thresholds were determined and the corresponding stormwater pond volumes and release rates were also calculated.

In addition to the criteria set for the A8 area, erosion thresholds have also been determined for Carruthers Creek from Kingston Road, south to Bayly Street. These thresholds will be used to calculate the appropriate erosion control volumes and release rates for new stormwater ponds associated with new development applications in this area.

3.2.1.4 Baseflow Measurements and Modelling

Baseflow monitoring and mapping was undertaken to provide an indication of stream reaches receiving groundwater discharge or flow losses, through either natural processes (i.e. recharge) or human induced water withdrawals. This observed baseline data, under existing land use conditions, was used as a reference in interpreting the predicted changes from future land use scenarios and evaluating the impacts of water withdrawals.

Baseflow Measurements

Baseflow measurements were undertaken by Authority staff on the Carruthers Creek watershed in 2000, based upon Water Survey of Canada flow measurement standards and a sampling protocol originally developed by the Geologic Survey of Canada (GSC) during its sampling program on the Duffins Creek watershed in 1995 and 1996. The GSC sampling protocol was used by TRCA, to ensure that a baseflow condition existed following any precipitation event.

Given the hydrologic response of the TRCA watersheds, a 72 hour period was established as the minimum time to wait following any rainfall event, prior to beginning any sampling.

Sampling sites were chosen from headwaters to mouth on topographic maps prior to field reconnaisance at major and minor road crossings. Locations were chosen with consideration for accessibility to field staff and opportunity to develop a stage-discharge relationship (eg. at road crossings). Once a transect location was chosen, the channel was broken into 20 panels. These panels were measured for depth, width, and water velocity. The collected measurements were recorded and calculated to give a total discharge of the stream segment sampled. The final discharge figure was then referenced with the closest upstream discharge and compared for accuracy and continuity.

Using TRCA's baseflow measurements at a total of 19 sites on Carruthers Creek (2000 data) and GSC's 1995-96 data for 93 sites on Duffins Creek, a set of maps were developed to show the existing baseflow distribution within the two watersheds. An assessment of the distribution, at watershed and subwatershed scales was undertaken to better understand the existing system in terms of significant discharge areas and potential recharge areas. The maps also provided an understanding of the relative local subwatershed inputs on a reach basis. An understanding was also developed of the stressors that exist, including natural processes, such as losses or gains due to geologic features (i.e. Lake Iroquois shoreline) and water takings (i.e. known withdrawals as per the Ministry of the Environment's Permit to Take Water (PTTW) data base.

Results of the baseflow monitoring work are presented in section 3.3.1.3.

Modelling of Future Scenarios

Predicted impacts to the groundwater discharge components of the stream baseflow, in response to the projected land use changes within these watersheds, were also estimated. This assessment was undertaken by reviewing the relative changes in ground water infiltration (GWI; i.e. recharge) predicted by the water budget model under various land use scenarios. The relative changes in recharge amounts were used as input data to run the groundwater flow model, which in turn was used to predict changes in the volume of groundwater discharge to watercourses. The distribution of measured baseflow was evaluated at reach, subwatershed and watershed scales, and used in verifying the groundwater model outputs. Impact assessments of changes in groundwater discharge from the modelling exercise were analysed at subwatershed and watershed scales. Results are found in section 3.3.1.3.

3.2.1.5 Surface Water Use

The significance of existing surface water withdrawals was evaluated with reference to the existing PTTW data base and an online database of permit applications produced under the Environmental Bill of Rights (http://204.40.253.254/samples/search/Ebrquery_REG.htm). Data records from these sources include days of pumping per year, maximum daily taking amounts, and hours of pumping per day. With this information and the measured baseflow data, approximate water budgets could be calculated. As the PTTW data base had several records with missing data, several assumptions had to be made. Estimates of these missing data were based on a review of other similar use permits and the minimum pumping amount at which a PTTW is required (ie: >50,000 litres/day). Expired permits were, for the most part, included in all calculations. It was noted many permits were issued in the 1960s and '70s, and upon expiry the client had not re-applied. It was assumed that the water is still being actively pumped if the land use had not changed. The only permits omitted from all calculations were those listed as temporary (ie. road construction), or permits cancelled by the user.

The assessment of surface water withdrawals is discussed in section 3.3.1.4.

3.2.2 Groundwater Quantity and Quality

The groundwater quantity assessment was designed to establish an understanding of groundwater flow directions, water levels, and discharge areas, and to predict the changes that would occur in these parameters in response to an altered water balance (specifically infiltration rates) associated with future land use scenarios. Typically, urbanization is expected to reduce infiltration volumes, lower the water table elevation, and reduce discharge volumes, however these impacts depend on scale, location in the watershed, and local geology. Groundwater chemistry under the existing land use scenario was considered.

3.2.2.1 Groundwater Flow Model

The scope of work for the groundwater component of the study included:

- Review of existing data regarding the regional and local geology and hydrogeology of the Duffins Creek watershed;
- Update of the conceptual geological model of the Duffins Creek watershed;
- Update of the three dimensional groundwater flow model using MODFLOW;
- Updated calibration of the groundwater flow model to the observed conditions in the flow system and baseflow in the various reaches of Duffins Creek
- Comparison of the modelled groundwater infiltration to infiltration calculated by Clarifica Inc.; and
- Assessment of potential effects of land use change with the calibrated model.

There is an extensive existing knowledge base of the geology and hydrogeology of the Duffins Creek watershed. This information includes water well records, intensive subsurface investigations for the Durham component of the Interim Waste Authority landfill search (IWA, 1994-c), regional geologic data compiled by the Geological Survey of Canada (Sharpe *et. al.*, 1997) and the Ontario Geological Survey (Barnett *et. al.*, 1998), and a three dimensional flow model of the watershed (Gerber and Howard, 2000). To maximize the benefit of this existing data, TRCA assessed the documentation and used the information to update the conceptual hydrogeological model of the watershed.

The calibrated numerical flow model for the study area (Duffins, Petticoat and Frenchman's Bay watersheds) is described in detail in Gerber and Howard (2000). The model was constructed using Visual MODFLOW (Waterloo Hydrogeologic Inc. 1996) which provides a graphical user interface for the three-dimensional finite-difference code MODFLOW (MacDonald and Harbaugh 1988). The model encapsulates the three-dimensional framework of the geologic deposits using nine model layers with a grid discretization of 200 x 200 m cells (110 columns and 150 rows).

The configuration of the geologic layers in the model was prepared using borehole data extracted from approximately 7000 Ontario Ministry of the Environment (MOE) water well records, supplemented by borehole data collected from landfill (M.M. Dillon Limited 1990; IWA 1994a-e), regional water resource (Sibul et al. 1977) and aquitard investigations (Gerber and Howard 1996; Boyce 1997; Gerber 1999).

Other inputs to the steady-state model include recharge and hydraulic conductivity estimates for the various hydrogeologic units. Recharge estimates used were obtained from streamflow separation and soil moisture balance methods (Gerber 1994; IWA 1994e; Gerber and Howard 1997), and regional groundwater flow modeling (M.M.Dillon Limited 1990; Smart 1994; IWA 1994e), and more recently from Clarifica Inc (May, 2002) who estimate recharge for various land use scenarios. Hydraulic conductivity (K) estimates for all hydrogeologic units were obtained from slug tests, pump tests and specific capacity analysis. Hydraulic conductivity anisotropy for all layers was set as $K_x = K_y$ and K_h (K_{xy}) = 10 times K_v (K_z), consistent with values for similar deposits to the west of the study area near Waterloo (Martin and Frind 1998).

The model was calibrated to observed hydraulic heads (112 monitoring wells at 38 locations) and estimates of groundwater discharge to streams at seventeen locations. Model calculated hydraulic head distributions were also calibrated to hydraulic head distributions produced from MOE water well records in areas where monitoring wells were not available. The calibration was achieved by trial and error and involved varying recharge and hydraulic conductivity values independently within the range of estimated values, until the observed heads and groundwater discharge to streams were reproduced. The root mean square (RMS) error for the calibrated heads within all three aquifers is 3.5 m. Although not calibration targets, the model spatial distribution of groundwater discharge to streams proved to be consistent with field observations of low streamflow in the summer (Hinton 1996; Kenney et al. 1996); also model estimates of spring and aquifer discharge to Lake Ontario (700 m^3/d) compared favourably with estimates from Haefeli (1972) and Ostry (1979)(600 m^3/d).

Although the model was calibrated at steady state to the estimated annual average groundwater discharge to streams and the average annual values of hydraulic head for the period of record, it is recognized that both groundwater recharge and groundwater discharge to streams vary seasonally and from year to year depending on climatic and antecedent conditions. For the study area, groundwater recharge occurs mainly in the spring during snow melt and in the late fall when soil moisture deficits are satisfied and evapotranspiration rates are low. It is during these seasons that the water table and aquifer hydraulic head values are highest, hydraulic gradients are greatest and groundwater discharge to streams reaches a maximum. Groundwater discharge to streams is at a minimum when the water table and hydraulic head configuration are at their lowest. The calibration for the Duffins model is to an “average” groundwater flow system condition, or to an average basin saturated state of mean water levels in aquifers and long-term mean groundwater discharge to streams.

Hydrogeologic Modelling of Land Use Scenarios

The groundwater infiltration values (GWI) from the water balance analysis (Clarifica Inc., 2002), described in section 3.2.1.1, were incorporated into the numerical groundwater flow model (MODFLOW) which exists for the Duffins basin, as a means of estimating the effects of future land use scenarios on recharge and the groundwater system.

As previously described, the groundwater model was calibrated to an average watershed saturation condition and discretized the study area into 200 m cell sizes. The Clarifica water balance estimates provide an average groundwater infiltration rate for each of the 30 subcatchments within the Duffins watershed (Figure 3-4). The different characteristics relating to soil conditions and land use have been averaged or lumped for each subcatchment area. The groundwater flow model was not re-calibrated to the Clarifica GWI values because these estimates represent an average value for the subcatchment. For example, for a sub-catchment containing both surficial sand and till deposits, calibrating to an average GWI will lead to a model calculated water table that is too low for the sand area and too high for the till area because the actual recharge value over the sand will be higher than the till.

The emphasis of this exercise was to estimate the potential changes to the groundwater flow system based on the estimated changes in recharge due to land use change. The Existing calibration scenario of Gerber and Howard (2000) was compared to the GWI values for the Existing land use conditions as estimated by Clarifica for the 30 subcatchments shown on Figure 3-4. Results from Clarifica's evaluation of the other land use scenarios were then compared to the Existing land use scenario to address the estimated changes to the groundwater flow system due to land use changes.

It should be noted that river cells within the groundwater flow model were given a recharge value of zero to reflect the fact that they are potential discharge, or 100% runoff zones. The remaining land not covered by river cells within the subcatchment was given the GWI value of Clarifica. In other words the GWI values of Clarifica were used but just over a smaller area within the model. Therefore, the recharge area in the Duffins basin within the model is 24,720 ha as compared to the total basin area used in the Clarifica water balance of 28,301 ha. This has the effect of reducing the total recharge in the model to 139,000 m^3/d compared to the total recharge (GWI) of 159,500 m^3/d reported in the Clarifica water balance. In general, the water table configuration using the Clarifica GWI estimates is lower on the Oak Ridges Moraine and higher over some parts of the South Slope and Glacial Lake Iroquois areas, than the model calculated water table of Gerber and Howard (2000) and the observed water table.

The calculation methodology of the Clarifica water balance assumed that all runoff (RO) and recharge (GWI) calculated for each subcatchment was received by the stream by the outlet of each of the subcatchments. In reality, some recharge which occurs over the northern parts of the flow system moves to the deeper aquifer system and is not realized as groundwater discharge until areas within the southern parts of the flow system where the river valleys intersect these deposits. Most of the groundwater recharge within the basin has been realized as groundwater discharge to streams prior to the mouth of the river at Lake Ontario. Total streamflow measured at gauging station 02HC006/049 can then be considered to be representative of all of the groundwater runoff and recharge components for the basin. The RO and GWI estimates for 28 of the 30 (#1 to 26) subcatchments can then be compared to the observations at 02HC006/049 (subcatchment locations are shown on **Figure 3-4**). Subcatchments #27 and #28 do not contribute to Duffins Creek upstream of this gauge and were not included. A comparison of the Clarifica RO plus GWI estimates for the 28 subcatchments was compared to total streamflow at this gauge for the period 1986 to 1997. This showed that the water balance estimates for some years were much higher than observed total streamflow. This could be due to a number of factors relating to meteorological data, streamflow observations, and/or calculation procedures that do not incorporate all of the physical processes that are occurring within the basin. The Clarifica water balance numbers for the existing scenario are considered to represent a slightly higher than average saturation state for the watershed.

Findings of the groundwater flow modelling are summarized in section 3.3.2.1.

3.2.2.2 Groundwater Use

Gerber Geosciences, on behalf of TRCA, reviewed the active permits to take water (PTTW) on file with the MOE (Gerber, 2003) as well as pumping data provided by the Regional Municipality of York. The study team's assessment of these data is provided in section 3.3.2.2.

3.2.2.3 Groundwater Quality

Gerber Geosciences, on behalf of the TRCA reviewed the available chemical data for groundwater within the Duffins Creek and Carruthers Creek Watersheds. These data included:

- 44 groundwater samples collected by the MOE from the Duffins and Rouge River watersheds in 1970 and 1974 (Sibul et al., 1977);
- 260 groundwater samples collected in the Duffins and Rouge watersheds between 1982 and 1984 (Howard and Beck, 1986);
- 79 groundwater samples collected on behalf of The Regional Municipality of Durham for a regional landfill site search (M.M. Dillon Limited, 1990); and
- 205 groundwater samples collected on behalf of the Interim Waste Authority for the Metro Toronto/York and Durham landfill site searches (IWA, 1994a-e).
- 9 samples from research projects at the University of Toronto.

The study team's assessment of these data is provided in Section 3.3.2.3.

3.2.3 Surface Water Quality

The surface water quality assessment evaluated the changes in in-stream water chemistry and the relative predominance of pollutant sources in response to predicted changes in watershed hydrology (i.e. overland runoff, groundwater discharge to streams) and pollutant availability associated with the various land use scenarios. Several methods were used in this analysis, and they are described in sections 3.2.3.1 to 3.2.3.5.

3.2.3.1 Agricultural Non Point Source (AGNPS) Model

The AGNPS model is a distributed water quality model, designed to predict water quality and hydrologic response conditions in agricultural watersheds for the purpose of evaluating different land cover scenarios and Best Management Practices (BMPs). Developed by the U.S. Department of Agriculture, the AGNPS model is an event-based model, simulating conditions based on a single precipitation event, uniformly distributed across the catchment (Young *et. al*. 1988.). The model is widely used in the United States and is considered by practitioners to be a robust, practical model for decision support purposes (Leon *et. al.*, 2002).

The model considers a wide range of factors affecting water quality, including local hydrology, soils, nutrient and sediment loading, land use practices, land slope, precipitation, drainage, erosion and existing water quality. Hydrology outputs in the model are calculated using the Soil

Conservation Service (SCS) curve number approach. According to this method, runoff is calculated simply by subtracting the infiltration volume from the amount of precipitation. The AGNPS model simulates soil loss and sediment yield in a two step process. The Universal Soil Loss Equation (USLE) is used to predict soil erosion for five particle sizes (silts, clays, sand small and large aggregates). Eroded sediments are then transported in the receiving channel using a steady state continuity equation. The pollutant transport part of the model estimates chemical oxygen demand, soluble and sediment bound nitrogen, phosphorous concentrations and loads.

Model set-up and calibration

For the purposes of this study, the AGNPS model runs for the Duffins Creek watershed and East and West Branches employed a 1.2 x 1.2 km grid size. For smaller subwatersheds in the Duffins Creek, grid sizes of 600 x 600 m (Urfe, Millers) and 900 x 900 m (Ganatsekiagon, Reesor) were used. The grid size for the Carruthers Creek watershed was 900 x 900 m. For each grid cell, inputs from GIS mapping of soils, land cover and topography (DEM) are automatically extracted using an interface developed by Leon (1997). All user defined inputs to the model followed procedures established in the calibration study (Leon, 1997; Leon, 2002).

The hydrological response of the watershed was calibrated from eight events monitored in 1995 and, at the subwatershed scale, from 17 events monitored between 1997 and 1999. Peak flows calculated by the model matched the measured peak flows reasonably well for both data sets. The coefficient of efficiency (CE) - a dimensionless number from less than 0 to 1 - was used to indicate the goodness of fit between calculated and measured values. The CE for peak flows ranged from 0.75 to 0.92 among modelled events.

As noted above, the model computes deposition based on sediment transport of five particle size classes: clay, silt, sand, small and large aggregates. The size class or classes of particles permitted to scour within a particular cell was the only option selected during the calibration process. For each event, the model was run twice; the first allowing all particle size classes to be scoured, and the second allowing none of them to be scoured. The model produced a relatively small difference between values for full or no scouring and both produced a satisfactory match with measured sediment yield (CE range from 0.86 to 0.87).

Fertilizer applications rates and suggested availability factors were based on the results of a survey conducted for the Duffins Creek watershed in 1997 (JDE Ventures, 1998). Rates were propogated as a function of landuse coverage. Decay factors were the only parameters modified in the calibration of nutrient concentrations. These values were obtained by trial and error until the model produced a good match with field data. The ranges used in the model for nitrogen decay were between 5 and 12%, and for phosphorus, between 20 and 30%. These decay ranges produced a satisfactory fit between calculated and measured concentrations and loads for both nitrogen and phosphorus (CE values ranging from 0.58 to 0.64 for nitrogen, and from 0.96 to 0.99 for phosphorus).

Results of the AGNPS Modelling are shown in section 3.3.3.1.

3.2.3.2 Spreadsheet Model

A simple spreadsheet model was developed to estimate annual dry and wet weather loads and pollutant concentrations under the following three alternative land use scenarios:

1) existing land cover;
2) future land cover under the Official Plan; and
3) future land cover under the Official Plan with enhanced natural heritage cover.

This work, together with the Agricultural Non-point Source (AGNPS) modelling, serves as a tool for evaluating the water quality impacts associated with different land use scenarios. A full analysis of available stream water chemistry data from the Provincial Water Quality Monitoring Network (PWQMN) and other sources in the Duffins and Carruthers Creek Watersheds was dcoumented in the State of the Watershed Reports (TRCA, 2002). This assessment provided a broader basis for discussing water quality under the existing land use scenario.

The following data were used in the spreadsheet calculation of annual loads for TSS, Phosphorous, and Chloride under the three alternative land use scenarios discussed above:

(i) percent area in rural, wooded, and urban land use;
(ii) total wet / dry weather flow (runoff / baseflow) volumes for each study area;
(iii) mean concentrations for three pollutants under each of the three land use categories (rural, wooded, and urban) during wet and dry weather.

The mean wet weather concentrations for rural, wooded, and urban land uses in the Duffins Creek watershed represent an average of annual land use specific event mean concentration (EMC) data from several studies of stormwater quality, most of which were conducted in the City of Toronto (Aquafor Beech, 2001). Dry weather concentrations were derived from observed baseflow concentrations for monitoring stations with similar upstream land cover types in the Duffins Creek watershed and other Southern Ontario watersheds (Hinton, 1996; Beak, 1993). The wet and dry weather concentrations used in this study for each land use category were as follows:

Table 3-3: **Phosphorus, TSS, and chloride concentrations under three land use scenarios during wet and dry weather.**

	Rural	Wooded	Urban
Wet weather			
Phosphorus (mg/L)	0.20	0.12	0.30
TSS (mg/L)	100	70	170
Chloride (mg/L)	30	5	98
Dry weather			
Phosphorus (mg/L)	0.020	0.016	0.015
TSS (mg/L)	6	6	6
Chloride (mg/L)	17	5	32

Note: Rural land use includes both open space and agricultural land, and wooded areas include wetlands, meadows and forests. Wet weather event mean concentrations represent an average concentration from several studies for specific land uses. (Aquafor Beech, 2001).

Estimates of annual loads for TSS, Phosphorus, and Chloride were calculated as:

$$\text{Annual load}_i = \text{runoff}\,[LU^r * C^r_i + LU^w * C^w_i + LU^u * C^u_i]$$

where: LU = percent land use
C= wet or dry weather event mean concentrations
runoff = total runoff volume or total baseflow for the sub-watershed
subscript i represents the individual pollutant listed above; and
superscripts r,w and u represent rural, wooded, and urban land uses, respectively.

A detailed description of how the land use percentages were determined is provided in Chapter 3. Wet weather runoff was determined from water budget model outputs for each watershed / sub-watershed and each scenario (Clarifica Inc., 2002). Dry weather runoff was determined for the same watershed / sub-watershed and scenarios from discharge rates generated by a groundwater model, MODFLOW (Gerber, 2003).

Annual runoff and baseflow volumes were not available for the Carruthers Creek watershed. Hence, Carruthers Creek runoff volumes were calculated from Millers Creek sub-watershed runoff volumes, as follows:

$$\text{Carruthers Creek runoff } (m^3) = C * \text{Millers Creek runoff } (m^3)$$

where: C = Carruthers Creek area (3810 ha)/Millers Creek area (1698 ha)

Millers Creek was chosen for this purpose because it is immediately adjacent to Carruthers Creek and has similar physical characteristics (e.g. slope, soils, land use).

Calculations were completed for each of the 31 subbasins, defined in the hydrologic and water balance models. Results were consolidated and presented for watershed and subwatershed units.

Findings from the spreadsheet modelling are shown in section 3.3.3.2.

3.2.3.3 Wastewater Discharge Assessment

An assessment of discharges from the Stouffville Water Pollution Control Plant (WPCP) was undertaken in 2001 to estimate downstream phosphorus concentrations in the Reesor and West Duffins Creeks attributed to discharges from the plant. These estimates, together with measurements of WPCP discharge volumes, help to characterize existing conditions and generally indicate the magnitude of water quality improvement that may be expected following decommissioning of the plant, which is scheduled to occur in 2003.

The influence of the WPCP on phosphorus concentrations in the creeks was determined from the average phosphorus concentration in the WPCP effluent from 1993 to 2001 (0.17 mg/L) and dilution ratios at various points within the creeks, where the dilution ratio is:

$$\frac{\text{Average monthly streamflow volume}}{\text{Average monthly WPCP effluent volume}}$$

Average monthly streamflow volumes were calculated over the period of record for each stream gauging station. The data were ranked and dilution ratios were calculated for observations that fall at or below a range of percentiles. Where possible, the dilution ratio was also calculated for the minimum 7 day flow over a 20 year recurrence interval (the 7Q20 flow), which is the most frequently used criterion for assimilative capacity assessments.

The phosphorus concentration in the creek attributable to the WPCP at a given location and for a range of dilution ratios was subsequently calculated as:

$$\frac{\text{Average WPCP effluent phosphorus concentration (0.17 mg/L)}}{\text{Dilution ratio}}$$

Section 3.3.3.3 presents the findings from the wastewater discharge assessment.

3.2.3.4 Stormwater Management Assessment

The water quality impacts associated with urban stormwater runoff were recognized in the 1980s, and since 1990 all new developments have been required to install stormwater quality control measures. The quality of stormwater runoff is controlled through the provision of best management practices at the lot level, along the conveyance route and at the end of pipe. Currently, TRCA requires Level 1 water quality control (i.e. 80 % total suspended solids removal) for all new development areas. A review of the existing status of stormwater control within the watershed was carried out to identify areas where improvement was needed. Three levels of control were quantified: percent of developed area with quality and quantity control, percent of developed area with quantity control only (i.e. areas developed in the 1980s), and percent of developed area with no control (i.e. areas developed prior to the 1980s).

In an effort to improve the level of stormwater control within the Duffins, TRCA and area municipalities are undertaking stormwater retrofit studies for the watershed. The studies will identify opportunities to upgrade existing facilities (i.e. quantity facilities upgraded to incorporate quality and erosion control as well) and will also identify opportunities for new facilities (i.e. in areas where there currently is no control).

3.2.3.5 Erosion and Sediment Control for Urban Construction

For the purposes of the watershed plan development, it was assumed that in-stream, total suspended solid (TSS) concentrations would increase and that the duration of these elevated levels would also increase, under future development, without effective erosion and sediment control measures in place.

Recently, TRCA completed two important initiatives designed to improve the quality and effectiveness of erosion and sediment control measures being implemented on urban construction sites. The first initiative involved the development of a “model” by-law for control of erosion and sediment, mud tracking, litter, debris, and dust. This model by-law will assist in implementing the recommendations of the watershed plan.
The second initiative was to carry out a background study which included a literature review

relating to in-stream sediment and the effects on aquatic ecosystems. The study also included the development of a modelling framework to simulate erosion and sediment transport on construction sites and to effectively evaluate treatment facility performance. Over the next two to three years, TRCA will be monitoring a sediment and erosion control facility in the Town of Richmond Hill. Data collected from this exercise will be used to calibrate the modelling component. It is anticipated that a new sizing criteria will be developed using this information. In the interim, TRCA has adopted a revised, more stringent criteria that requires both a permanent pool and an active storage component. The revised criteria will be a requirement for new development applications until the new criteria has been established.

3.2.4 Aquatic Habitat and Species

The analysis of aquatic data has been an important component of assessing the health of watercourses within the TRCA's jurisdiction for many years. Previous watershed strategies for the Don and Humber Rivers and the Etobicoke and Mimico Creeks provide background information and rationale for many of the measures and indicators used in this document. These strategies relied on analysis done as part of the Fisheries Management Plans (FMP) prepared for each of these watersheds. Similarly, the information contained in the aquatic habitat sections of the Duffins and Carruthers Watershed Plan is presented in more detail in the Fisheries Management Plan (TRCA, 2003) prepared for the watersheds under present day or "existing land use" conditions.

Tools for assessing aquatic habitat and species are identified in the following discussion. Of these tools, the only one available at this time that could provide a basis for predicting aquatic habitat impacts from future land use scenarios is an empirical relationship between fish community type and the baseflow to total annual flow ratio. This empirical relationship and its use in predictive modelling is described under "Instream Habitat".

A summary of results from the aquatic system analyses is shown in section 3.3.4.

Tools for Assessing Aquatic Habitat and Species

Starting with the Don River Fisheries Management Plan in 1997, a similar approach has been used to characterize the aquatic system and to set future management direction for TRCA's watersheds. Using physical and biological information, an assessment of how the watershed would have functioned historically is prepared. Human factors such as barriers, land use change, and user input is applied as an additional level of analysis to help set management direction.

The process used in the Duffins and Carruthers watersheds, however, was slightly different. Analysis of the watershed response to future land use scenarios, particularly through the completion a water budget and groundwater flow modelling allowed for the assessment of potential impacts on the aquatic system, and the formulation of recommendations for reducing potential impacts.
A total of six indicators and associated measures and targets were developed to assess the health of the aquatic community. These are summarized in **Table 3-4.**

Table 3-4: Indicators of Aquatic Community Health

INDICATOR	MEASURES	TARGETS
Fish and Invertebrate Community Makeup	• invertebrate indices • IBI • indicator species and abundance	• To be determined • minimum IBI of good • maintain/achieve historical distribution of targeted indicator species as specified in the FMP
Instream habitat	• % instream woody cover • % riffle substrate • baseflow as a per cent of total annual flow	• to be determined • to be determined • as specified in FMP
Water chemistry	• water temperature • TSS • phosphorus • chlorides	• as specified in FMP • as specified in FMP • as specified in FMP • as specified in FMP
Fish passage to critical habitat (breeding, rearing, foraging grounds)	• presence of instream barriers	• only strategic barriers for fisheries management to remain
Riparian zone	• extent of woody vegetation along stream length	• minimum of 75% of stream length
Stream hydrograph	• flow events (timing, duration, frequency, and rate of change) • baseflow to average annual flow ratio • seasonal baseflow ratio	• to be determined with consideration or restoring historical hydrograph as specified in FMP; consideration for timing of low flows with respect to sensitive life cycle requirements of fish community

Fish and Invertebrate Community Makeup

Sampling was done in 2000 at six stations in the Carruthers Creek and 32 in Duffins Creek. At each of these stations, benthic invertebrate, fish, algae, and instream habitat data were collected. It is this information that provides much of the recent information on the status of the aquatic community within both watersheds.

<u>*Invertebrate Indices*</u>
Benthic invertebrates were collected, preserved and identified to the species level in the lab for the 2000 data. However, no detailed analysis was done. Some initial calculations of Hilsenhoff index was done for some of the data. Very little historical benthic invertebrate data was found.

Based on the lack of historical information and level of analysis done on the 2000 data, no targets or ratings have yet been set for the benthic invertebrate community.
<u>*Indicator Species and Abundance*</u>
Historical fish collection information was gathered from many sources including the Ontario Ministry of Natural Resources, Royal Ontario Museum, Highway 407 baseline reports, TRCA, and North Pickering Development Corporation Lands reports. Some of this information dates

back to the early 1950s and provides a detailed picture of the fish community throughout the watershed over a period of more than 50 years.

Recent fish species information was collected in 2000 from six stations in Carruthers Creek and 32 in Duffins Creek. This information allowed a comparison between current and historic fish distribution across both watersheds. It was also one of the components used to determine fisheries potential in the watersheds.

Index of Biotic Integrity

The presence or absence of aquatic communities and/or indicator species are considered to be good indicators of aquatic ecosystem health as they are integrators of a variety of disturbances to their environment. An example of this methodology of evaluating aquatic ecosystem health is seen in the Index of Biotic Integrity (IBI). IBI is a measure of fish community associations that is used to identify the general health of the broader stream ecosystem. It was first developed to assess small to moderate sized warmwater rivers in the United States (Karr, 1981). Steedman's (1987) adaptation of this method for streams in southern Ontario includes two local indicators: *Salvelinus fontinalis* (brook trout) and *Rhynichthys* species (Longnose and blacknose dace). In general terms, the presence of brook trout is an indicator of a healthy coldwater system, while a high abundance of *Rhynichthys* species, generally indicates a degraded system. Steedman uses 10 measures of fish community composition to determine an IBI on a scale from 10 (poor) to 50 (very good) grouped into four general categories: species richness, local indicator species, trophic composition and fish abundance. A detailed explanation of these indices can be found in Steedman, 1987. **Table 3-5** shows the measures used in the Duffins/Carruthers application, as adapted from Steedman.

Table 3-5: Nine sub-indices used in calculation of the Index of Biotic Integrity

SPECIES RICHNESS	
1.	number of native species
2.	number of darter and /or sculpin species
3.	number of sunfish and/or trout species
4.	number of sucker and/or catfish species
LOCAL INDICATOR SPECIES	
5.	presence or absence of brook trout (only in streams designated as coldwater)
6.	percent of sample as *Rhinichthys* species
TROPHIC COMPOSITION	
7.	percent of sample as omnivorous species
8.	percent of sample as piscivorous species
FISH ABUNDANCE	
9.	catch per minute of sampling

Two modifications of Steedman's work were necessary for the application of IBI using the data for the Duffins Creek data set. The presence/absence of blackspot (a parasite of fish) was eliminated from the IBI because the information was not available for all surveys. The second modification related to the brook trout indicator. Steedman assumed that brook trout should be present in all streams and their absence was, therefore, a sign of degradation. However, there are numerous streams in the Greater Toronto Area that due to low groundwater input, would not have historically supported brook trout. For this reason, IBI scores in streams where it is felt brook trout would not have been found historically (ie. warmwater streams) were calculated using eight sub-indices, rather than nine. These scores out of 40 were then transformed to a score out of 45 to allow comparison with the remaining stations (ie. coldwater streams).

The modified IBI scores ranges from a low of nine (scoring one for each index) to a high of 45 (scoring five for each index). Four ranges of IBI scores have been designated to reflect stream quality.

Instream Habitat

Percent Instream Woody Cover
Only data for 2000 were available and it was felt they did not provide enough of a basis for setting targets and establishing ratings of current condition. It is anticipated that this will be done in a future update.

Percent Riffle Substrate
Only data for 2000 were available and it was felt they did not provide enough of a basis for setting targets and establishing ratings of current condition. It is anticipated that this will be done in a future update.

Baseflow As A Percent of Total Annual Flow
Due to their interconnectedness, surficial geology, baseflow and the water budget are described together in this section.

One of the roles surficial geology plays in stream morphology is determining infiltration of precipitation. The type and percentage of soils within a subwatershed will control the amount and rate of run-off to the streams versus infiltration to the ground. Since groundwater discharge is critical to maintaining baseflows, determining the type and extent of surficial materials is key to understanding areas of potential groundwater recharge and discharge.

Digital surficial geology data for the both watersheds was used in this assessment. Surficial geology types with similar infiltration characteristics, were grouped together. The resulting map provided a general assessment of potential areas of high and low infiltration and discharge rates. This information was used as one component of establishing habitat potential. An infiltration map was also produce by Gerber (2000) which provided an additional layer of analysis.

Groundwater is defined as subsurface flow that occurs in fully saturated soils and geologic formations (Freeze and Cherry, 1979). Where these saturated soils or geologic formations intersect the surface, groundwater discharge occurs. Groundwater discharge to a stream forms baseflow and is critical for maintaining water flows, especially during the drier, summer months. In the Greater Toronto Area, groundwater temperatures are in the range of 8-10^{0}C. The more groundwater discharge to a stream the lower and more stable are the water temperatures, which is important to temperature sensitive species like brook trout. Groundwater is also relatively sediment free as it discharges into a stream. This is very important for brook trout spawning since they often spawn upon locations of groundwater discharge. Decreases in the amount of groundwater entering a watercourse may result in increased water temperatures or even cause a stream to dry up completely. This is particularly harmful in coldwater streams. Bowlby and Roff (1986) indicate that groundwater discharge is one of the major characteristics that determines the presence of a cold or warmwater fish community. Understanding the influence of baseflow on aquatic habitat is, therefore, of critical importance in protecting and rehabilitating aquatic communities.

Habitat Suitability Indices developed in the United States utilize annual baseflow as a percent of average annual daily flow to determine habitat suitability for certain trout species (Raleigh, 1982, Raleigh et al., 1984; Raleigh et al. 1986). This ratio is useful in determining flow fluctuations, providing an indication of flow stability. This research suggests that ratios greater than 50% are excellent for trout production, between 25-50% are good for trout production, and less than 25% is poor for trout production. The higher the ratio, the more stable the flow and the more likely the habitat is suitable for sensitive coldwater species.

The water budget and groundwater flow modelling evaluations of the future land use scenarios enabled the calculation of baseflow as a percent of total annual and total monthly flows.

Water Chemistry

A target setting approach developed as part of the Toronto Wet Weather Flow Management Master Plan (WWFMMP) provided the basis for assessing the aquatic habitat and species targets and ratings for this indicator. Current water quality conditions are as reported in the Duffins and Carruthers State of the Watershed Reports (TRCA, 2002). Refer to the water quality section (3.2.3.2) for more information on how water quality was analysed in response to the future land use scenarios.

Water Temperature

Some water temperature information was collected in 2001. This information provides some insight into a few locations of both watersheds and, therefore, does not allow for a full assessment of current conditions.

Total Suspended Solids

A literature review used in the WWFMMP suggests that for most fish communities, except the most tolerant, a maximum TSS concentration should not be more than 100mg/L.

Phosphorus

A literature review used in the WWFMMP suggests that for the least tolerant fish communities, a phosphorus concentrations should not exceed 0.03 mg/l under dry conditions and 0.1 mg/l under wet conditions 80% of the time.

Chlorides

The Government of Canada has recently published a report on the toxicity of road salt (Environment Canada and Health Canada, 2001). They establish a maximum concentration of approximately 250 mg/l.

Fish Passage

Some previous work had already identified instream barriers in the headwater areas of Duffins Creek. Using 1999 air photos, additional instream barriers were identified. Beaver dams and log jams were not included since they tend to be relatively short term in nature. Initially, road and rail crossings were not identified but were added later. Due to limitations in resolution of the air photos and tree cover, additional barriers may exist that were not identified.

Concern over competition between stream resident trout (native brook trout and naturalized brown trout) and migratory trout (rainbow trout and chinook salmon) necessitated that maintenance of a partition between these two fish communities. The existing barriers on the West Duffins at Whitevale and north of Highway 7 on the East Duffins were felt to fulfill this role and should be maintained as fisheries management structures.

While many barriers were identified in both watersheds, they did not limit fish movement as much as many of the other watersheds in TRCA's jurisdiction.

Riparian Zone

The riparian vegetation within these watersheds was mapped, measured, and categorized from interpretation of 1999 ortho photography. Riparian communities were divided into five categories: forest, wetland, meadow, successional, and bare. Although the targeted riparian zone would be delineated as being within 30 m of the digital watercourse, due to limitations of the GIS analysis, only the vegetation type found immediately adjacent to the watercourse was used for the purposes of classification and measurement. This evaluation also looked at the percent of total stream length having woody riparian vegetation. It should be recognized that the total riparian zone length was calculated by doubling the total stream length, because every stream has a left and right bank.

Stream Hydrograph

Flow Events
More detailed analysis will need to be done before an asessment of current conditions is undertaken with respect to the aquatic community.

Baseflow to Total Annual Flow Ratio
Refer to previous discussion, under "Instream Habitat".

Seasonal Baseflow Ratio
Some initial analysis from the three modelling scenarios shows that the potential increases in run-off and decreases in infiltration are also reflected monthly, as well as overall in the annual water budget. However, more detailed analysis will need to be done before and assessment of current conditions is completed.

3.2.5 Terrestrial Habitat and Species

Although natural cover has been increasing in the upper Duffins and Carruthers watersheds over the past 50 years, rapid growth in the Greater Toronto Area has generally led to the incremental loss of remaining forest fragments, local extirpation of sensitive species, and loss of ecosystem health. In an effort to identify the values of all remaining habitat patches, and to determine restoration potential, Toronto and Region Conservation, through its Terrestrial Natural Heritage

Program, has developed a landscape analysis of habitat patches using GIS. Applying landscape ecology principles, the analysis is able to predict the impact that small changes have on the overall terrestrial natural heritage system at a variety of geographic scales and so can direct both restoration and preservation efforts at the local level in order to improve the health of the regional system.

This analysis is built upon common principles from the scientific fields of conservation biology and landscape ecology, and all components of the program have been extensively peer reviewed by scientific experts. The analysis has been used by TRCA and the City of Toronto for a natural heritage study that was used to inform the City of Toronto's new Official Plan (City of Toronto, 2001). A version of the analysis has also been adopted by Lake Simcoe Region Conservation Authority for their study of the Town of Newmarket (LSRCA, 2002).

The landscape analysis goes beyond the short-term, local planning needs of the regional and local municipalities by demonstrating the long term cumulative impacts of local decisions at the regional level. It allows municipalities to develop and monitor their Official Plans in a way that builds in clear and specific biodiversity targets and provides a method for measuring progress against those targets. The program is also able to model results of decisions at the site level and thereby provides a robust planning tool which will be essential for restoring a healthy regional ecosystem.

TRCA, through literature review and consultation with the scientific community, has identified indicators that address six critical aspects of the terrestrial ecosystem. A set of twenty measures are used to report on the status of each of these indicators. Each of these measures covers a different component of the terrestrial ecosystem from landscape level, down to community level, and down again to species level.

The indicators and measures provide a scientifically valid, quantitative, defensible approach for evaluating conditions at a site through landscape scale. The use of these indicators and measures will allow the establishment of quantitative targets for the terrestrial ecosystem.

The indicators and measures used are:

Indicator	Measure	Level of Detail
Quantity	Percent natural cover	Landscape
	Vegetation community proportion	Community
	Species population	Species
Distribution	Distribution of natural cover	Landscape
	Distribution of communities of concern	Community
	Distribution of species of concern	Species
Matrix Influence	Landscape matrix influence	Landscape
	Trail density	Community
	Sensitivity to development index	Species
Size and Shape	Average patch size	Landscape
	Average patch shape	Landscape
	Interior habitat	Landscape
	Area-sensitivity index	Species

Connectivity	Natural cover connectivity	Landscape
	Vegetation type connectivity	Community
	Mobility index	Species
Biodiversity	Vegetation type representation	Community
	Geophysical requirements index	Community
	Species representation	Species
	Habitat dependence index	Species

Except for the matrix influence measure (which is an original measure developed by TRCA) the remaining landscape measures are commonly used in other ecological studies. The use and interpretation of these other measures by the TRCA Terrestrial Natural Heritage Program is consistent with many other studies. Sample studies are documented in Freemark (1988), Forman (1995), and Fahrig (1997). There is scientific support in the literature, the scientific community, and from TRCA field data for how the matrix influence measure has been employed and interpreted by the TRCA; however, beyond TRCA's (City of Toronto, 2001) and LSRCA's (LSCRA, 2002) reports, this exact measure has not yet been utilized in other studies.

The remote sensing to collect the landscape scale data has been completed. Major cover types mapped include forest, successional, wetland, meadow, urban and rural. The vegetation community and species data are more labour intensive to collect, requiring field surveys by biologists. The current health of the terrestrial ecosystem in the Duffins and Carruthers watersheds was assessed primarily using the landscape level measures and aided by the field data where these were collected. These results will be updated as new field-collected or remote-sensed information becomes available.

For each of the three land use scenarios, a map illustrating the resulting land cover was digitized. The Existing and Future Land Use with Enhanced Natural Cover scenario maps were then analysed for five selected measures: percent natural cover, distribution of natural cover, matrix influence, average patch size, and average patch shape. Percent of natural cover was measured by calculating the percent of the total watershed area that is under natural land cover, which includes forest, meadow, wetland and successional land cover types. The measure of "distance-to-centroid" was used to evaluate the distribution of natural cover over the watershed. For this measure, a GIS is used to determine the Cartesian coordinates of the centroid (the theoretical "centre of mass") of the mosaic of patches of natural cover that make-up the terrestrial system, and the Cartesian coordinates of the centroid of the watershed. The measure of "distance-to-centroid" is the distance that separates the two sets of coordinates. The ideal condition for this measure is a distance of zero, which occurs when the patches of natural cover that make up the terrestrial system are distributed evenly across the watershed.

The matrix influence score is a measure of the influence of surrounding land uses on the status of each individual patch as a viable natural habitat area. Scores consider land uses within 2 km of the edge of each natural cover patch and are based on a rating scale of 0 to 5 developed by TRCA. Patches that score high are considered to experience less negative impact from surrounding land uses than patches that score low. Using GIS, matrix influence scores are assigned to each natural land cover patch and an average score is calculated for each watershed.

The patch size and shape indicators were also evaluated using GIS to quantify the area of each patch of natural land cover (size indicator), and to establish the ratio of patch area to perimeter length (shape indicator) which provides a means of quantifying the extent to which each natural land cover patch is being influenced by "edge effects". These values were transformed into patch size and shape scores which are based on a scale of 0 to 5. Patches that score high are considered to be quality habitats capable of supporting a variety of sensitive species, mid-scoring patches are considered to be in fair condition, and low scoring patches support only the most robust species.

In addition, the scores for matrix influence, average patch size, and average patch shape are also summed together to achieve a total patch score. The analysis is taken this extra step as it is at this more localized level where management plans and land use policies will have a visible effect on habitat quality. These total patch scores are used to compare changes at a patch level under each management scenario. Patches that score high are considered to be quality habitats capable of supporting a variety of sensitive species, mid-scoring patches are considered to be in fair condition, and low scoring patches support only the most robust species.

Results are used to compare the status of the terrestrial ecosystem at a landscape level under each scenario. The Future land use scenario was not analysed, because it represented only limited, localized changes in the natural heritage system, which would not likely be reflected in the landscape level analysis.

It should be noted that the Future with Enhanced Natural Heritage Cover land use scenario was developed using principles of the TRCA Terrestrial Natural Heritage Approach with consideration for practicality and feasibility of implementation in these watersheds. Therefore, this scenario represents a targeted terrestrial natural heritage system, from the standpoint of terrestrial habitat and species management objectives.

More details about this methodology, species scoring and ranking, data collection protocol, and landscape analysis can be found in the TRCA Terrestrial Natural Heritage Approach (report in progress, TRCA, 2003).

Results of the terrestrial natural heritage analysis are shown in section 3.3.5.

3.2.6 Public Use and Recreation

The primary indicators associated with recreation objectives relate to public use opportunities and experiences (e.g. area of publically accessible greenspace, recreational facilities, trail networks, etc.). A combination of quantitative and qualitative data were collected for these indicators, based on existing land use conditions. A qualitative assessment of changes in these areas was applied to the future land use scenarios. Particular consideration was given to the change in public use experience and opportunity for implementation provided by change in land ownership, land use, and population growth that may arise in the future.

3.2.7 Human Heritage

Key indicators associated with the human heritage objectives include the number of identified heritage sites, awareness and appreciation, and policy mechanisms for identifying and protecting sites. TRCA's existing database of known heritage (archaeological and built heritage) sites was reviewed.

TRCA's predictive model for identifying potential archaeological site locations was applied using Geographic Information Systems (GIS). The Archaeological Site Predictive Model (ASPM) was developed by TRCA (formerly MTRCA; MTRCA, 1990), based on correlations established within the TRCA jurisdiction, between an extensive database of known archaeological site locations and physical geographic features. The ASPM does not predict precise site locations rather it presents a generalized view of the current understanding of prehistoric settlement patterns in the watershed. In this application of the model, areas of potential archaeological sites were identified as those lands within 250 m of a waterbody and in areas of well-drained soils.

A qualitative assessment of the impacts or opportunities associated with future land use scenarios was carried out. Consideration was based on the opportunity to identify sites during the process of land use change and the relative opportunity for preservation of sites under different land ownership settings.

3.3 Integrated Findings by Technical Component

This section presents results of the analysis of three land use scenarios. A brief summary of the results and evaluation according to the watershed management objectives is included in **Appendix A.**

3.3.1 Surface Water Quantity

3.3.1.1 Water Balance

The details and findings of the water budget modelling can be found in *Water Budget in Urbanizing Watersheds: Duffins Creek Watershed (Clarifica, 2002)*. The following is a brief summary of these findings.

Understanding and quantifying water balance components is of particular interest when planning watershed management strategies. Land use changes during urbanization are known to shift the water balance in a watershed: increasing surface runoff and decreasing the amount of water retained on-site. After urbanization, water will be distributed differently, both temporally and spatially. Therefore, more water will be available in some places at certain times and less in others. There are also changes in the amount of water entering the ground with impacts to the water table levels. This can be significant in shallow, unconfined groundwater aquifer systems where groundwater supplies water to vegetation root zones and is a source of base flow in streams through seepage along stream valleys when there is a hydraulic gradient from water-bearing soil layers.

The objective of the Duffins Creek Water Balance Study was to characterize the surface water balance of the Duffins Creek watershed for existing and future land use conditions. Results from the study will be used to assist watershed managers deal with potential changes associated with future urbanization.

Three land use scenarios were considered in the Water Balance Study.

1. Existing Conditions;
2. Future (Land Use); and
3. Future (Land Use) with enhanced natural heritage cover.

The water balance analysis of the Duffins Creek watershed was completed using the Water Balance Analysis System (WABAS). The WABAS approach achieves multiple objectives such as consistency with existing hydrologic models, availability of data, flexibility for adaptation, simplicity, etc. The surface runoff response was calibrated at six historical stream flow gauging locations. The calibration showed good agreement between the model and the measured flows.

The long-term water balance analysis was completed using 15 years of climate data and future land-use scenarios for each of the 30 basins in the Duffins Creek Watershed. **Table 3-6** summarizes the watershed-weighted water budget components for each scenario. The "IN-OUT" term refers to the overall continuity of the analysis (Water in - Water out = Storage Change).

Table 3-6: Duffins Creek Watershed Water Budget for the Three Land Use Scenarios

Scenario	Precipitation (mm/yr)	Runoff (mm/yr)	GWI (mm/yr)	E (mm/yr)	IN-OUT (mm/yr)
Existing	844	145	206	489	4
Future (OP)	844	170	197	472	5
Future with Natural Heritage	844	162	195	481	6

GWI = Groundwater Infiltration, E = Evapotranspiration

As expected, runoff volume increases with uncontrolled development. This increase is a direct result of higher imperviousness. Imperviousness within the watershed increases from less than 1% to about 22% **(Figures 3-3 a and b)**. Overall, the reductions in groundwater infiltration under future conditions appear small due to the relatively small change in land use over each basin (i.e. small change in overall imperviousness). More significant changes are expected within each development site. The Enhanced Natural Heritage Scenario results in a small reduction in runoff due to the expected decrease in rainfall 'abstractions' associated with reforestation **(Figures 3-4 a and b).**

3.3.1.2 Watershed Hydrology

Design flows for the 2 year to 100 year return period and the Regional Storm were estimated using the VISUAL OTTHYMO model for the three land use scenarios: existing land use, future land use, and future with enhanced natural heritage. In terms of land uses, approximately 7% of the Duffins Creek Watershed is developed with urban land uses under the existing scenario. The future land use scenarios will increase the level of urban development to approximately 15%.

Based on the future scenario, peak flows are expected to be approximately 15% to 120% greater than existing flows for the 100-year event (**Figure 3-5a**). These increases only occur in areas that will be impacted from future development. Therefore, stormwater management measures are essential in these areas to ensure that pre-development peak flows are maintained. The future scenario also results in a number of subcatchments having no change in peak flows and a few having peak flows that are marginally less than existing peak flow rates for the 100-year event.
Based on the future with enhanced Natural Heritage scenario, peak flows are expected to be approximately 10% to 110% greater than existing flows for the 100-year event, which are slightly less than the increases expected with the future scenario (**Figure 3-5b**). As with the future scenario these peak flow increases only occur in future development areas. The future Natural Heritage scenario also results in a number of subcatchments having peak flow decreases that are expected to be approximately 0% to 25% less than existing flows for the 100-year event.

In order to mitigate against the potential for increased flood risk associated with increased peak flows under future scenarios, the implementation of flood plain management and stormwater management programs is essential. Additional analyses of alternative levels of control were carried out to provide guidance as to the most effective stormwater management strategies.

Stormwater Management

"Unit flow rates", expressed as litres per second per hectare (l/s/ha), were defined for catchments within the Duffins Creek watershed, as a means of standardizing the definition of pre-development flow conditions. Unit flow relationships were derived for three individual catchments with varying characteristics, located throughout the watershed. Unit flow equations were developed based on drainage area and location within the watershed, and the results of this analysis were then extrapolated to remaining catchments where future development may be planned. Unit flows are used as management criteria for designing flow control measures as part of new developments.

Based on a comparison of model results for existing and future landuse scenarios, "post-to-pre" flood control (i.e. 2-year to 100-year events) facilities are recommended for developments draining to the following tributaries:

- Reesor Creek;
- Whitevale Creek;
- Urfe Creek;
- Ganatsekiagon Creek;
- Millers Creek (north of Taunton Road);
- Mitchell Creek ;
- Brougham Creek (including Spring Creek);
- West Duffins Creek (north of Hwy. 7); and
- East Duffins Creek (north of Hwy. 7).

In addition, any proposed commercial infill development draining to Millers Creek (south of Taunton Road) will also require 2-year to 100-year “post-to-pre” control.

Based on a comparison of model results for existing and future landuse scenarios, Regional Storm control may be required for the following tributaries:

- Whitevale Creek;
- Urfe Creek; and
- Ganatsekiagon Creek.

A Regional Storm assessment will be required for proposed developments which drain to the above-mentioned tributaries to determine whether Regional control is required.

Should future development be proposed beyond those assumed in the Official Plan scenario, “post-to-pre” runoff controls may be required, regardless of the location within the watershed, and an assessment will also be required to determine whether Regional Storm controls will be necessary for such developments.

In addition, the hydrologic model should be further verified when rainfall and streamflow data becomes available for future storm events which are larger than those used for the calibration. The model should also be updated by development proponents as future development proceeds and future stormwater management facilities are constructed.

Floodplain Management

Existing regulatory floodlines are based on the future scenario peak flows for the regional storm from the 1991 Duffins Creek Hydrology by Aquafor Beech Ltd. These floodlines will be updated in forthcoming hydraulic updates in 2003/2004, using the future scenario peak flows for the regional storm from the 2002 Duffins Creek hydrology update by Aquafor Beech. The future scenario peak flows from the 2002 hydrology update are approximately 9% to 50% lower than the flows from the 1991 hydrology model, for a majority of the subcatchments. Peak flows from a few subcatchments resulted in higher regional flows when compared to the 1991 model, however, these increases are due to drainage boundary changes to the subcatchments that arose from better topographic information. As a result of the changes in future scenario peak flows for the regional storm, it is anticipated that the regulatory floodlines will possibly decrease for a majority of the subcatchments, which would result in a corresponding possible decrease in flood vulnerable areas (FVA) and flood vulnerable roads (FVR).

Under the future Natural Heritage scenario, peak flows for the regional storm are lower than the peak flows for the future scenario, therefore, even further possible reductions in regulatory floodlines would be expected if these flows were used in the floodplain mapping updates. However, using a precautionary approach, floodlines will be set using peak flows under the future scenario. Any further reductions that may arise from the establishment of enhanced natural heritage may not be realized for some years as the vegetation matures.

3.3.1.3 Baseflow Distribution

To illustrate the spatial distribution of baseflow within Duffins Creek, the watershed was broken down into 6 major drainage basins **(Figure 3-6)**. Present conditions show more than half (57%) of the total output of Duffins Creek is contributed by the East Duffins creek, a large portion of this is concentrated within the Oak Ridges Moraine. The West Duffins contributes approximately 38% of the total output, with the largest contributions emerging from the Uxbridge area headwaters and the Oak Ridges Moraine. The more southern basins contribute significantly less baseflow, with 2% contributions from Ganatsekiagon and Millers Creeks, and 1% of total output is contributed from Urfe Creek.

Carruthers Creek was not broken into sub-basins, but linear analysis was done through a percentage breakdown by segments, based on the total output equalling 100% **(Figure 3-7)**. It was found that in the Carruthers the baseflow contributions are more evenly distributed. Increases of approximately 15-25% were shown at most flow points. Baseflow losses were shown throughout the Carruthers watershed in the 4th Concession area. This is attributed to the Lake Iroquois Shoreline, where a hydraulic down gradient is known to exist. A marked increase is noted at Rossland Road at the edge of the Iroquois Shoreline, where sand and gravel deposits are exposed.

An interpretation of impacts on baseflows due to potential land use changes can be defined in the Duffins Creek watershed, based on results from the Water Budget Model and the Groundwater Flow Model. The Groundwater Model was used to predict changes in the amount of water being shown as discharge, in response to changes in groundwater infiltration volumes (GWI) generated from the Water Budget Model.

Under the Future Official Plan scenario, the modelled reductions in baseflows would range from 0 to approximately 26 percent when viewed on an individual drainage basin basis. Baseflow reductions by sub-watershed are modelled as; the Lower Duffins (26%), Ganatsekiagon (17%), Urfe (14%) and Millers Creeks (4%). Little change would be anticipated within the East (1%) or West branches (3%) which generate the bulk of the overall system baseflow. With the majority of the overall watershed's baseflow being from the East and West branches and the most significant baseflow reduction taking place within subwatersheds which contribute only a small percentage of overall baseflow, no significant impacts to overall baseflows would be expected within the lower reaches of the watershed.

Due to limitations within the current state of the art in water budget tools, the inclusion of the Enhanced Natural Heritage scenario also shows a minor effect on groundwater infiltration, that may impact baseflows. This is deemed to be more a reflection of the tool's limitations as opposed to a true reflection of the impacts of additional vegetation. In a report for the Ganaraska watershed, which exhibits similar geology to that of the Duffins, Richardson (1946) noted that springs were more numerous and streams commenced farther up slope when the watershed was more heavily timbered.

3.3.1.4 Surface Water Use Assessment

The impacts of surface water withdrawals, either permitted or un-permitted under the Provincial PTTW are difficult to assess solely through field observations, due to the nature of how the data were collected. If for instance, baseflow measurements were taken upstream and downstream of a permitted taking when the taking was not underway, a second reading downstream when the taking was underway would be required to clearly define the impact. The collection of data originally done by the Geologic Survey of Canada (GSC) in 1995 and 1996 on the Duffins Creek watershed was done as a single collection of data at each point. On the Carruthers Creek, data were collected by TRCA in 2000 in a similar fashion. A second collection of base flows within the Reesor creek sub-watershed in 2001 and the subsequent comparison to the 1995 GSC data did flag an occurrence of a surface water taking. The 2001 set of observations reflect a reduction in upstream to downstream baseflows of close to 80% due to a surface taking, which is a significant reduction in base flows within the Reesor Creek sub-basin.

As an alternative to field observations, a review of the PTTW database was undertaken and the significance of maximum annual permitted water withdrawals was considered in relation to total annual baseflow volume **(Table 3-7)**. It was found that within the Duffins Creek Watershed, known water takings represented a maximum withdrawal amounting to approximately 5% of measured annual baseflow for the overall watershed. When further analysis was completed at the subwatershed scale, it showed that Reesor Creek was one of the most affected with a maximum withdrawal of 16% of the annual measured baseflow, and the West Duffins was subject to removal of approximately 17% of annual measured baseflow. East Duffins Creek, the most significant contributor of baseflow to the overall watershed, with 10 identified surface water takers has a potential reduction of 12 % of annual measured baseflow.

Table 3-7: Estimated Surface Water Withdrawals as a Proportion of Total Annual Baseflow

Watershed/ Subwatershed	#PTTW	Maximum permitted annual water takings (Millions/L/yr)	Total annual Baseflow volume (Millions/L/yr)	Percent of total annual baseflow permitted to be withdrawn (%)
Duffins Creek watershed	29	4721	47400	10
West Duffins Creek	17	3348	19871	16.8
Reesor Creek	9	924	5765	16
East Duffins Creek	10	1258	10784	11.7
Ganatsekiagon Creek	0	n/a	n/a	n/a
Urfe Creek	0	n/a	n/a	n/a
Millers Creek	2	23	729	3.2
Carruthers Creek Watershed	2*	1458	1057	138

*current PTTW applications

While there are no active permits in the Carruthers Creek watershed, a PTTW application, currently under review by the Ministry of the Environment, would represent a potential withdrawal of approximately 138% of total annual baseflow. This withdrawal may represent a large potential for detrimental effects to the watercourse.

Initiatives currently underway in the PTTW program by the Ministry of the Environment will require all permitted surface takers to change the methods of taking in order to protect a significant portion of the baseflow. This change in requirements, if applied to all renewals and for new permits, will significantly reduce impacts to base flows. The availability and maintenance of the baseflow and PTTW databases should provide a basis for assessing both local and cumulative impacts to the baseflows within the watersheds. This knowledge will provide for improved decisions regarding future PTTW applications and renewals.

3.3.2 Groundwater Quantity and Quality

3.3.2.1 Groundwater Flow

The detailed findings of the groundwater flow modelling are found in *Duffins Creek Watershed Hydrogeology and Assessment of Land Use Change on the Groundwater Flow System* (Gerber Geosciences, 2003). The following is a summary of these findings. The initial sections discuss the background geology, flow, and aquifer characteristics. Latter sections present the impacts of the future land use scenario on the groundwater flow system.

Geologic Setting

The Duffins watershed is situated on the south flank of the Oak Ridges Moraine and drains southward towards Lake Ontario. Two landforms greatly influence the groundwater flow system. These are the Oak Ridges Moraine which forms the height of land in the northern part of the basin, and the Lake Iroquois shoreline which forms a topographic break in slope within the southern part of the basin. The regional ground surface gradient is approximately 0.009 toward the south. Both ground and surface water flows from north to south, or from the Oak Ridges Moraine highlands to Lake Ontario.

Hydrostratigraphic Units and Setting

Sibul et al. (1977) mapped fourteen overburden aquifer systems within the Duffins Creek and Rouge River surficial drainage basins and classified them as either upper or lower aquifer systems. These aquifer systems were originally interpreted to exist as discrete lenses of permeable sands and gravels within low permeability tills, silts and clays (Haefeli, 1970; Sibul et al., 1977). However, hydrochemical studies by Howard and Beck (1986) suggest that many of these aquifer systems (shallow and deep) are interconnected regionally and receive a significant component of recharge via the overlying till. This latter conclusion is supported by more recent investigations (Gerber and Howard, 1996; 2000; 2002).

Based on updated stratigraphic information for the basin (Boyce, 1997), the overburden aquifers are classified in this report as Upper, Middle and Lower systems, with Middle and Lower aquifers occurring below the Northern/Newmarket till within deposits of the Thorncliffe and Scarborough Formations, respectively. The Upper aquifer system occurs above the Northern/Newmarket till within Oak Ridges Moraine deposits and sand bodies associated with the Halton Till and Mackinaw Interstadial deposits. The shale bedrock is not considered to be a good aquifer from either a quantity or a quality perspective (Sibul et al., 1977). A schematic of these stratigraphic units is provided in **Figure 3-8.** A conceptual model of the groundwater flow system is shown in **Figure 3-9.**

The three-dimensional arrangement and classification of these geologic deposits into hydrostratigraphic units are illustrated on **Figure 3-10.**

It is important to note that not all hydrostratigraphic units are present throughout the study area. For example, some of the deposits older than the Northern/Newmarket till thin and pinch-out in the southern parts of the basin where the overburden sequence is thin. The Northern/Newmarket till has also been eroded in places south of the Lake Iroquois shoreline. These areas would be classified as Newmarket till breaching channels according to Sharpe et al. (2002).

Groundwater Recharge

Groundwater recharge occurs over most of the study area. Groundwater discharge occurs along stream reaches, and where upward vertical hydraulic gradients are associated with topographic breaks in slope along the flank of the Oak Ridges Moraine (e.g. Stouffville) and the Lake Iroquois shoreline. The Oak Ridges Moraine forms the major recharge area within the northern part of the study area with recharge estimated between 280 and 400 mm/a. Estimates of recharge through the Halton Till plain range from 125 to 200 mm/a.

The glaciolacustrine deposits associated with the Halton Till dramatically reduce recharge with estimates ranging from 35 to 50 mm/year. Beach sand and gravel deposits associated with the Lake Iroquois shoreline have estimated recharge rates of approximately 200 mm/year.

The sand and gravel deposits of the Oak Ridges Moraine are estimated to have higher recharge rates compared to similar deposits associated with the Lake Iroquois shoreline because of the presence of hummocky topography along the moraine. For large portions of the moraine, defined stream channels do not exist and much of the water surplus eventually forms groundwater recharge. The Lake Iroquois silt, clay and till deposits are estimated to have recharge rates less than 100 mm/year due to a combination of relatively low permeability and a high degree of urbanization.

Travel times from recharge to discharge zones can range from weeks/months to thousands of years. Present maximum estimates are up to 3000 years for water particles to travel from the recharge zone at the watershed divide along the crest of the moraine, to eventual groundwater discharge from the Lower aquifer to Duffins Creek south of Taunton Road (Gerber and Howard, 2002).

Groundwater Discharge

There are two main areas of groundwater discharge to streams as measured by Marc Hinton of the Geologic Survey of Canada (Hinton, 1996) and Don Haley of the TRCA (TRCA, 2003). These areas are depicted in the baseflow distribution mapping discussed in section 3.3.1.3. One area is the south flank of the Oak Ridges Moraine where groundwater discharge forms the headwaters for major streams within the Duffins basin and comprises 60% of the entire basin groundwater discharge to streams. Headwater discharge for West Duffins Creek and Duffins Creek headwaters alone account for 16% and 28% respectively of the entire basin groundwater discharge to streams. The second area of significant groundwater discharge occurs to Duffins Creek, Carruthers Creek, and the mouths of the Ganatsekiagon, Urfe and Brougham Creeks along and south of the Lake Iroquois shoreline. This discharge is received from all three aquifers but more significantly from the Middle and Lower aquifers which outcrop in this area. It is estimated that 77% of the entire basin groundwater discharge is received from the Upper aquifer, 21% from the Middle aquifer and 2% from the Lower aquifer (Gerber and Howard, 2002).

There are four general hydrogeologic settings which occur within the Duffins Creek basin. Setting one includes the deposits of the Oak Ridges Moraine and associated areas of hummocky Halton Till along part of the south flank. This area is characterized as a net groundwater recharge area. Setting two includes the areas of the south flank of the ORM, south of the hummocky terrain, which are a net discharge zone where groundwater discharge exceeds groundwater recharge. The third setting is the South Slope or Halton Till Plain situated between the headwaters and the Lake Iroquois shoreline, and is a net recharge zone. The fourth setting occurs south of the Lake Iroquois shoreline and is a net groundwater discharge zone. While recharge does occur over part of this area, the deeper aquifer discharge associated with the Lake Iroquois shoreline is greater than the relatively low recharge estimates for this area. Estimates of the relative groundwater recharge and discharge quantities for the various hydrogeologic settings are summarized in **Table 3-8.**

Table 3-8:Groundwater Recharge and Discharge Quantities by Hydrogeologic Setting

Hydrogeologic Setting Surficial Geology	**IN** Recharge	**OUT** Springs	 River Discharge	**IN-OUT**
1. Headwaters > 275 m amsl				
ORM deposits	36200	0	16600	19900
Hummocky Halton Till	27900	0	7200	20700
Halton Till	4200	0	6200	-2000
Glacial Lake Peel	200	0	0	200
subtotal	**68500**	0	30000	38,500 net recharge
2. Headwaters < 275 m amsl				
ORM deposits	2600	0	9700	-7100
Hummocky Halton Till	3900	0	8900	-5000
Halton Till	6100	100	16100	-10100
Glacial Lake Peel	2100	0	8000	-5900
subtotal	**14700**	100	42700	-28,100 net discharge

Hydrogeologic Setting Surficial Geology	**IN** Recharge	**OUT** Springs	River Discharge	**IN-OUT**
3. South Slope				
Halton Till	24600	5400	15500	3700
Glacial Lake Peel	4500	1000	6200	-2700
subtotal	**29100**	6400	21700	1,000 net recharge
4. Glacial Lake Iroquois				
Lake Iroquois	14700	2500	20100	-7,900 net discharge
	127000	**9000**	**114500**	**3500**

Note: Quantities from Calibrated flow scenario described in Gerber and Howard, 2002. Hydrogeologic settings shown in Figure 12.

Ref.: Gerber Geosciences Inc., 2003

Upper Aquifer

Surface drainage divides coincide with groundwater flow divides for the Upper aquifer system and groundwater flow within this aquifer system is predominantly south to southeast toward Lake Ontario at regional horizontal hydraulic gradients of about 0.01. Local deflections in groundwater flow occur toward creeks and rivers where horizontal hydraulic gradients increase near discharge areas. Groundwater flow within the Upper aquifer system is generally horizontal and unconfined, however, confined conditions exist where Halton Till overlies Oak Ridges Moraine deposits along the southern slope of the moraine (e.g., Stouffville area) and within Mackinaw Interstadial deposits where the overlying Halton Till and glacial Lake Peel deposits are of sufficiently low hydraulic conductivity.

Middle Aquifer

The groundwater divide for the Middle aquifer system corresponds generally with the surface water drainage divides. The Middle aquifer system is recharged mainly by downward vertical leakage through the overlying Northern/Newmarket till from the Upper aquifer system with minor inter-aquifer flows entering the basin. Vertical hydraulic gradients downward through the Northern till range from 0.4 in the northern part of the study area and increase to approximately 0.8 in the southern part of the study area. The increase in downward vertical hydraulic gradient southward is caused by discharge from the Middle aquifer system to creeks where valleys have been eroded through the Northern/Newmarket till. Within the southern part of the study area near the Lake Iroquois shoreline, the Middle aquifer system also receives recharge by vertical leakage upwards through the Sunnybrook diamict from the Lower aquifer system.

The Middle aquifer system is confined by the Newmarket Till, except where the units outcrop adjacent to steep creek valleys within the southern part of the study area. Groundwater flow within this aquifer system is predominantly south to southeast toward Lake Ontario at regional horizontal hydraulic gradients of 0.001 to 0.01 in the southern part of the basin. Local deflections in groundwater flow occur toward creeks and rivers where horizontal hydraulic gradients increase near discharge areas.

Lower Aquifer

Groundwater divides for the Lower Aquifer system correspond generally with surface water drainage divides. Groundwater flow within this aquifer system is predominantly south to southeast toward Lake Ontario at regional horizontal hydraulic gradients of 0.001 to 0.01. Local deflections in groundwater flow occur toward creeks and rivers where horizontal hydraulic gradients increase near discharge areas. The Lower aquifer system is recharged by inter-aquifer regional groundwater flow entering the surficial drainage basin and vertical leakage from the Middle aquifer system in the northern part of the Study Area.

A preliminary discussion of groundwater flow across surficial drainage divides is included in Gerber and Howard (2000). Regional investigations are presently being conducted, as part of the Ontario Ministry of the Environment (MOE) Municipal Groundwater Study program, that aim to quantify the groundwater balance and the presence of groundwater flow across watershed divides in more detail. These investigations are scheduled for completion during June of 2003.

Hydrogeologic Effects of Changing Land Use

This section summarizes the hydrogeologic impacts of changing land use within the Duffins basin for recharge reductions as estimated by Clarifica Inc. (2002) using a water balance model described in section 3.2.1.1 and by Gerber Geosciences (2003) using a MODFLOW groundwater flow model described in section 3.2.2.1. The groundwater infiltration values (GWI) from the water balance analysis were incorporated into the numerical groundwater flow model (MODFLOW) which exists for the Duffins basin, as a means of estimating the effects of future land use scenarios on recharge and the groundwater system.

Under the Future land use (as per municipal Official Plans) scenario, significant GWI reductions occur within subcatchments 2, 12, 21, 23, 24, 25 and 28, which are the areas expected to undergo urbanization. The estimated change to the water table is shown in **Figure 3-11.** Due to the significance of potential changes in the Urfe and Ganatsekiagon Creek subwatersheds (subcatchments 22, 23, 24 and 25), associated with the planned community of Seaton, more detailed hydrogeological assessments were undertaken for the Future land use scenario to understand the local ground-surface water interactions. The details of this assessment are found in Gerber Geosciences (2003).

Under the Future land use with Enhanced Natural Heritage Cover scenario, the estimated changes to groundwater recharge from increasing the tree cover is negligible, therefore this scenario has not been modelled in the numerical groundwater flow model. The impacts of reforestation are difficult to quantify as discussed by Clarifica Inc. (May, 2002), and examples from the literature predict both increases and decreases in recharge following reforestation. In a report for the Ganaraska watershed, Richardson (1946) suggested that replanting should be beneficial to increasing groundwater recharge. Richardson based this opinion on inverse reasoning after observing the differences in streamflow on the Oak Ridges Moraine following extensive deforestation. Richardson argued that when the upper part of the watershed was heavily timbered, springs were more numerous, and the streams commenced farther up the slope compared to stream headwater areas following deforestation. It was felt that with replanting, the summer flow in streams would be increased and there would be more deep seepage through the moraine gravels for water supply to the wells on the area. Other quotes on the topic provided by Richardson, are as follows:

p. 58 “The influence of tree growth on the stream flow is emphasized also by the fact that on old maps of the area, notably Tremaine’s Map of Durham County, 1861, and the Historical Atlas of the Counties published in 1878, the headwater streams extend much farther up the morainic slope, which at that time was well wooded. Many of these dried-up water courses can still be followed, and these probably help to increase the rate of run-off on this part of the watershed at certain seasons of the year.”

p. 65 “But the function of the roots does not end with giving support and nourishment to the tree, since in the act of extending themselves for food they open up the soil and make thousands of small channels into the ground, which greatly increases its porosity.”

p. 66 “This assistance which the forest floor gives to the absorption of moisture by the soil is partly responsible for the feeding of springs and underground storage....... No one, who has lived in wooded areas of Ontario and has watched the forest being cut down over large areas, will gainsay the fact that the water supply in springs has been changed.”

A study conducted by Buttle (1996) compared stream flows in the Duffuns and Ganaraska basins for the period of record (since 1945). The headquarters of the Ganaraska basin have been reforested during the period of record whereas the headquarters of the Duffins basin have not. For the Ganaraska basin, Buttle interpreted a decrease in annual maximum daily runoff and an increase in annual minimum daily runoff following reforestation. These changes result in little change in annual streamflow. Buttle suggests that an increase in forest and ultimately soil cover limits rain-on-snow events which contribute to flood events, and increases interception and snowpack shading which enhances infiltration. The increase in recharge more than compensated for the higher evapotranspiration associated with increasing the forested area. The periods of greater recharge within southern Ontario (spring and fall) occur during lower periods of evapotranspiration. Buttle also cautioned that water management programs “need to be prepared for equivocal results to limited basin restoration”. Any reforestation program also needs to consider long-term climatic trends (figure 16) when analysing stream Hydraulic changes.

The anticipated impacts and benefits to the groundwater flow system from replanting large areas of the Duffins basin, as outlined in the Future land use with Enhanced Natural Cover scenario, remain unresolved with respect to numerical groundwater flow modelling.

3.3.2.2 Groundwater Use

The majority of the water wells within the Duffins and Carruthers Creek watersheds are for private potable supplies, which typically involve less than 175 L/person/day and discharge to the groundwater system via tile beds. These domestic wells are not required to have permits to take water (PTTW). However, larger scale users (>50,000 L/day), including golf courses (irrigation), municipal water supplies, and commercial enterprises are required to have a PTTW. The largest active PTTW on file with the MOE in these two watersheds is the municipal water supply for the Town of Whitchurch-Stouffville. (4,000 m^3/day), which draws water from the upper and middle aquifers (Gerber Geosciences, 2003). The treated wastewater generated by the Town of Whitchurch-Stouffville is currently discharged to Stouffville Creek. In the future, however, the wastewater will be sent via the York-Durham sewer system to a treatment plant on the shore of Lake Ontario.

The groundwater withdrawals by the Town of Whitchurch-Stouffville represent approximately 29% of the total streamflow in Stouffville Creek and 2% of the total streamflow in Duffins Creek (Gerber Geosciences, 2003).

3.3.2.3 Groundwater Quality

Upper Aquifer

The background groundwater quality in the upper aquifer is generally good, with moderate hardness (Gerber, 2003). Chloride, nitrate, and bacteria are elevated in some of the shallow wells in this aquifer, which is attributed to local contamination from road salt application and domestic sewage treatment systems (Gerber, 2003).

Middle Aquifer

The background groundwater quality in the middle aquifer is generally good, with slightly lower hardness and sulphate than in the Upper Aquifer. Some water well records report generation of hydrogen sulphide gas (Gerber, 2002). The TRCA is not aware of any significant impacts from chloride, nitrate, or bacteria in this aquifer.

Lower Aquifer

The background groundwater quality in the lower aquifer is generally good, with slightly higher hardness and suphate than in the Middle Aquifer. Some water well records report generation of hydrogen sulphide gas, likely associated with the underlying pertroliferous shale. TRCA is not aware of any significant anthropogenic impacts from chloride, nitrate, or bacteria in this aquifer.

Bedrock

The background bedrock groundwater is generally hard with high sodium, chloride, and sulphate (Gerber, 2003). TRCA is not aware of any significant anthropogenic impacts from chloride, nitrate, or bacteria in this unit.

3.3.3 Surface Water Quality

3.3.3.1 Agricultural Non Point Source (AGNPS) Modelling

The findings of AGNPS modelling for various storm events under different land cover scenarios are presented in a TRCA report entitled *Agricultural Non-point Source Modelling of the Duffins and Carruthers Creek Watersheds* (2003). The following is a brief summary of these findings.

Tables 3-9 and 3-10 summarize sediment yield and phosphorus results for model runs under existing conditions, the (Future Land Use), the (Future Land Use) and Enhanced Natural Heritage cover, and the “Priority Management Areas Revegetation (PMAS)” scenario, which simulated increased forest cover in priority grid cells. **Figures 3-12 and 3-13** summarize predominant source areas of phosphorus and sediments for the whole Duffins and Carruthers Creek watersheds, respectively.

Sediment yield

Storm events simulated under the official plan scenario (scenario 2) generally result in more sediment load than under existing conditions, particularly in study areas experiencing significant urban expansion, such as Urfe and Ganatsekiagon. Although these latter areas are small relative to other subwatersheds, the large increase in sediment yield represents an increase of 10% and 7% for the whole Duffins watershed yield under the official plan scenario.

For most watershed areas, scenario 3 (official plan plus enhanced natural heritage cover) produces sediment yield levels equal to or lower than existing conditions. Similarly, the BMP exercise of simulating increased forest cover in “priority management areas” (determined from the Trace Source Contribution analysis in scenario 1 for existing conditions) produced sediment yield levels that were approximately equal to or better than existing conditions in all but one study area (Urfe), and in several cases, were as good as the result obtained in scenario 3.

The Reesor and East subwatershed showed the most significant improvement in suspended sediment yield between scenario 3 and existing conditions because, relative to other subwatersheds, application enhanced natural heritage under scenario 3 would result in large conversions of agricultural land to forest cover in these areas. Since the Reesor/Stoufville subwatershed contributes 71% of the total sediment yield to the West Duffins, and the West Duffins contributes 76% of the sediment yield to the total Duffins yield, a large decrease in sediment yield under scenario 3 in the Reesor/Stouffville subwatershed would contribute substantially to sediment yield reductions in the watershed as a whole.

Phosphorus

Four of the eight subwatershed study areas show no change or only a slight change in phosphorus levels across the four scenarios, including the study areas: (1) Reesor, (2) West, (3) East, and (4) Whole Duffins. These four study areas exhibited the least amount of land use change relative to their total areas, and therefore changes in phosphorus sources would be expected to be minimal. Although phosphorus concentrations among scenarios show little change, phosphorus loads in the watershed would likely show greater increases under the OP scenario due to the increased volumes of overland runoff associated with urban expansion.

Of the remaining four study areas that exhibited phosphorus level changes between scenarios 1 and 2, three decreased (Ganatsekiagon, Miller, Whole Carruthers), and one increased (Urfe). The decreases are attributed to the significant conversion from agricultural land to urban land uses, which thereby removes a major source of phosphorus. The increase in Urfe may be partly explained by the predominantly sandy soils in this subwatershed, which are less capable of binding phosphorus compared to clay/loam soils.

Relative to the overall dry weather/wet weather phosphorus Provincial Water Quality Objective (PWQO) of 0.03 mg/l, all modeled storm events that generate runoff fail to meet the objective. However, water quality levels tend to be at their worst under storm conditions, and since phosphorus levels only marginally exceed the objective, it is possible that phosphorus concentrations averaged over dry and wet weather conditions may meet the PWQO.

Summary of AGNPS Model Findings

Overall, sediment loads can generally be expected to increase in the Duffins and Carruthers watersheds as a result of urban growth under the OP scenario. The enhanced natural heritage scenario can compensate for some of the negative impacts of urban growth by at least maintaining existing water quality conditions. A reasonable level of watershed protection could be achieved by incorporating rural and urban stormwater management practices in all new developments. Natural heritage enhancement programs focused on priority management areas have roughly the same benefit as the enhanced natural heritage scenario. Some differences in these overall trends occur in subwatersheds that have one predominant land use.

Table 3-9. Suspended sediment yield at the outlet cell of each study area under the various land use scenarios and rain events.

Watershed or Subwatershed	Storm Event	Sediment Yield (metric tons) *(Percent change compared to sediment yield under scenario 1 shown in parenthesis)*			
		Scenario1 - Existing	Scenario 2 - Official Plan (OP)	Scenario 3 - OP + Natural Heritage	BMP*
Reesor	15mm 9 hr 25mm 12 hr	22.4 45.8	21.6 (↓4%) 52.4 (↑14%)	5.2 (↓77%) 20.8 (↓55%)	- 28.3 (↓38%)
West	15mm 9hr 25mm 12hr	28.7 64.4	31.3 (↑9%) 72.1 (↑12%)	28.4 (↓1%) 63.4 (↓2%)	- 61.8 (↓4%)
East	15mm 9hr 25mm 12 hr 30mm 12 hr 35mm 12 hr 38mm 12 hr	2.3 4.8 38.8 43.0 -	2.6 (↑13%) 4.0 (↓17%) 44.5 (↑15%) 45.3 (↑5%) -	1.1 (↓52%) 1.0 (↓79%) 4.1 (↓89%) 5.7 (↓87%) 23.5	- - 29.7 (↓23%) 37.5 (↓13%) -
Ganatsekiagon	15mm 9hr 25mm 12hr 35mm 12hr 40mm 12hr	no runoff no runoff 1.2 16.0	0.86 11.4 32.6 (↑2617%) 36.9 (↑131%)	1.3 10.3 27.3 (↑2217%) 34.5 (↑116%)	- 12.2 (↓24%)
Urfe	15mm 9hr 25mm 12hr 30mm 12hr 35mm 12hr 38mm 12hr 40mm 12hr	no runoff no runoff no runoff no runoff 7.23 7.26	1.01 7.55 - - 26.4 (↑265%) 29.5 (↑306%)	0.85 5.70 - - 18.1 (↑150%) 22.1 (↑204%)	- - - - 9.8 (↑36%) -
Miller	15mm 9hr 25mm 12hr	2.68 15.1	6.16 (↑130%) 18.7 (↑24%)	3.91 (↑46%) 10.5 (↓30%)	- 10.9 (↓28%)
Whole Duffins	15mm 9hr 25mm 12hr	31.6 84.2	40.5 (↑28%) 110.4 (↑31%)	28.9 (↓9%) 71.9 (↓15%)	- 73.4 (↓13%)
Whole Carruthers	15mm 9hr 25mm 12hr	2.69 12.5	1.80 (↓33%) 8.39 (↓33%)	no runoff 7.8 (↓38%)	- 11.1 (↓11%)

* "BMP" - also referred to as "PMA Revegetation" Scenario simulated increased forest cover in"priority" grid cells determined from the trace source contribution analysis

Table 3-10: **Phosphate concentration results modeled with AGNPS from the outlet cell of each study and the conversion to total phosphorus based on an established relationship between PO_4 and Total P.**

Watershed or Subwatershed	Storm Event	Phosphate (PO_4) Concentration (mg/l)				Converted to Total Phosphorus (mg/l) Using Relationship Between PO_4 and Total P			
		Existing	Offical Plan (OP)	OP + Natural Heritage	BMP	Existing	Offical Plan (OP)	OP +Natural Heritage	BMP
Reesor	15mm 9 hr	0.02	0.03	0.03	-0.02	0.06	0.08	0.08	-0.06
	25mm 12 hr	0.02	0.02	0.02		0.06	0.06	0.06	
West	15mm 9hr	0.00	0.00	0.00	0	0.07	0.07	0.07	-0.07
	25mm 12hr	0.00	0.00	0.01		0.07	0.07	0.08	
East	15mm 9hr	0.15	0.15	0.15	-	0.22	0.22	0.22	-
	25mm 12 hr	0.11	0.12	0.15	-	0.18	0.19	0.22	-
	30mm 12 hr	0.09	0.11	0.10	0.10	0.16	0.18	0.17	0.17
	35mm 12 hr	0.08	0.09	0.09	0.08	0.15	0.16	0.16	0.15
	38mm 12 hr	-	-	0.09	-	-	-	0.16	-
Ganatsekiagon	15mm 9hr	no runoff	0.05	0.05		no runoff	0.22	0.22	
	25mm 12hr	no runoff	0.04	0.04		no runoff	0.17	0.17	
	35mm 12hr	0.11	0.04	0.03	-0.09	0.46	0.17	0.13	-0.38
	40mm 12hr	0.09	0.03	0.03		0.38	0.13	0.13	
Urfe	15mm 9hr	no runoff	0.05	0.05		no runoff	0.22	0.22	
	25mm 12hr	no runoff	0.04	0.04		no runoff	0.17	0.17	
	30mm 12hr	no runoff	-	-		no runoff	-	-	
	35mm 12hr	no runoff	-	-		no runoff	-	-	
	38mm 12hr	0.01	0.03	0.03	0.01	0.05	0.13	0.13	0.05
	40mm 12hr	0.01	0.03	0.03	-	0.05	0.13	0.13	-
Miller	15mm 9hr	0.12	0.02	0.03	-0.08	0.19	0.09	0.10	-0.15
	25mm 12hr	0.10	0.02	0.02		0.17	0.09	0.09	
Whole Duffins	15mm 9hr	0.09	0.07	0.07	-0.07	0.16	0.14	0.14	-0.14
	25mm 12hr	0.07	0.06	0.05		0.14	0.13	0.12	
Whole Carruthers	15mm 9hr	0.10	0.03	no runoff	-0.08	0.17	0.10	no runoff	-0.15
	25mm 12hr	0.08	0.03	0.06		0.15	0.10	0.13	

* BMP tested simulated increased forest cover in “priority” grid cells determined from the trace source contribution analysis

3.3.3.2 Spreadsheet Modelling

The detailed findings of the spreadsheet modelling are found in “Dry and Wet Weather Modelling of Water Quality under Alternative Land Use Scenarios in the Dussins and Carruthers Creek Watersheds - A Simple Spreadsheet Approach”. (Stantec and Aquafor Beech, 2003).

Wet weather

Model results for loads and concentrations under different land use scenarios during wet weather are presented in **Table 3-11.** In general, the change in pollutant concentrations and loads under future land use scenarios was strongly influenced by urbanization. The largest planned increase in urbanization is in Ganetsekiagan, Urfe, Millers and the Lower Main Duffins subwatersheds. Consequently, these areas also had the largest increase in runoff and pollutant concentrations under future scenarios. However, since these areas comprise less than 20% of the Duffins watershed, their overall water quality impact on the Duffins watershed as a whole is relatively small.

Conversion of rural to forested land use under the Future Land Use with Enhanced Natural Cover Scenario results in a small decrease in pollutant concentrations and runoff volumes, and hence, a relatively minor impact on loads. The smallest change occurs in Ganetsekiagan, Urfe, Miillers, Lower Main Duffins and Carruthers Creek areas, where the Enhanced Natural Heritage strategy results in no change or only a very small increase in total wooded area over the Official Plan scenario **(Table 3-11)**.

Table 3-11: **Estimated wet weather loads and concentrations for a) existing land use; b) projected land use under the Official Plan; and c) projected land use under the OP with Enhanced Natural Heritage Cover.**

		Loads (kg/day)			Concentrations (mg/L)			Land use (%)			Runoff (m^3/yr)
		TP	TSS	Cl	TP	TSS	Cl	Rural	Wooded	Urban	
West Duffins (13,539 ha)	a	8.5	4477.2	1174	0.18	92.8	24.3	64.5	32.1	3.5	17609789
	b	9.9	5228	1235.1	0.18	96.4	27.9	59.3	31.9	8.6	19778548
	c	8.8	4716.3	666	0.17	91.9	24	44.2	47.2	8.6	18737994
East Duffins (9,202 ha)	a	5.3	2802.4	666	0.17	89	21.1	51.1	45.3	3.6	11499156
	b	5.4	2920.8	715.6	0.17	89.8	22	49.2	45.7	5.1	11869204
	c	4.6	2495.4	513.9	0.15	84.2	17.4	30.5	64.4	5	10812808
Ganetsekiagan (1,305 ha)	a	0.8	417.9	101.2	0.17	89.8	21.7	57.7	39.8	2.5	1698791
	b	2	1113.3	472.3	0.22	120	51	23.4	33.4	43.1	3380821
	c	2	1107.6	468.9	0.22	119.9	50.8	22.5	34.3	43.1	3371259
Urfe (1,437 ha)	a	1	526.2	118.6	0.17	87.5	19.7	53.8	44.9	1.4	2195203
	b	2.1	1158	440.4	0.2	110.9	42.2	30.6	37.6	31.7	3809847
	c	2.1	1151.2	436.7	0.2	110.7	42	29.9	38.4	31.7	3795484

Millers (1,698 ha)	a	2.6	1145.4	593.2	0.22	119.1	49.5	37.5	24.6	37.8	4369051
	b	3.2	1814.8	879.3	0.24	136	65.9	16	22.8	61.1	4872120
	c	3.2	1811.2	877	0.24	135.8	65.8	15.5	23.2	61.1	4867174
Lower Main Duffins (1,124 ha)	a	2	1140.9	467.6	0.2	115.6	47.3	0	54.5	45.6	3603906
	b	2.7	1571.9	738.6	0.23	130.6	61.4	0	39.4	60.6	4392176
	c	2.7	1571.6	738.5	0.23	130.6	61.4	0	39.4	60.6	4391273
Whole Duffins (28,305 ha)	a	19.9	10509.7	2847.6	0.18	93.6	25.4	55.1	37.8	7.1	40975895
	b	24.5	13159.6	4135	0.19	99.9	31.3	48.1	36.4	15.4	48102717
	c	22.1	12066.9	3526.5	0.18	95.8	28	34.6	50	15.4	45975992
Carruthers (3,810 ha)	a	5.1	2751.3	910.1	0.19	102.6	33.9	47.6	34.1	18.3	9786674
	b	6.2	3388.1	1325.1	0.21	113.3	44.3	27.4	39.6	33	10913549
	c	6	3322.7	1271.7	0.2	111.2	42.5	33.3	33.4	33.3	10902470

Dry weather

Modelled loads and concentrations under different land use scenarios during dry weather are presented in **Table 3-12.** There was little or no change in dry weather concentrations of phosphorus and TSS under the three scenarios modelled because median concentrations were similar among all three land use categories. Chloride median concentrations varied more with land use and hence concentrations increased slightly in areas where urban growth was part of the Official Plan (esp. Ganatsekiagon and Urfe).

Dry weather loads of TSS and phosphorus were similar under the three land use scenarios in all subwatersheds except Ganatsekiagon, Urfe and, to a lesser extent, Millers subwatershed. Future scenarios in these areas increased the impervious cover, resulting in less groundwater recharge and lower baseflows. Increased forest cover under the Official Plan with Enhanced Natural Heritage cover had a relatively minor impact on baseflow generation.

Table 3-12: **Estimated dry weather loads and concentrations for a) existing land use; b) projected land use under the Official Plan; and c) projected land use under the Official Plan overlain with enhanced natural heritage cover.**

		Loads (kg/day)			**Concentrations (mg/L)**			**Land use (%)**			**Base Flow (m^3/yr)**
		TP	TSS	Cl	TP	TSS	Cl	Rural	Wooded	Urban	
West Duffins (13539 ha)	a	1.01	326.7	744.3	0	6	13.7	64.5	32.1	3.5	19870965
	b	0.97	317.6	766.2	0	6	14.5	59.5	31.9	8.6	19324560
	c	0.94	317.6	668.6	0	6	12.6	44.2	47.2	8.6	19324560
East Duffins (9202 ha)	a	1.08	359.5	725.3	0	6	12.1	51.1	45.3	3.6	21867515
	b	1.06	356	728.2	0	6	12.3	49.2	45.7	5.1	21656545
	c	1.02	356	595.3	0	6	10	30.5	64.4	5	21656545

Ganetsekiagan (1305 ha)	a	0.12	39.1	82.1	0	6	12.6	57.7	39.8	2.5	2380530
	b	0.1	32.4	105.4	0	6	19.5	23.4	33.4	43.1	1975380
	c	0.1	32.4	104.8	0	6	19.4	22.5	34.3	43.1	1975380
Urfe (1437 ha)	a	0.1	29.5	58.3	0	6	11.8	53.8	44.9	1.3	1798355
	b	0.1	25.5	73.3	0	6	17.3	30.6	37.6	31.7	1552345
	c	0.1	25.5	73	0	6	17.1	29.9	38.4	31.7	1418390
Millers (1698 ha)	a	0.1	24.3	79.8	0	6	19.7	37.5	24.6	37.8	1478615
	b	0.1	23.3	91.1	0	6	23.4	15.9	22.8	61.1	1418390
	c	0.1	23.3	90.8	0	6	23.3	15.5	23.2	61.1	1418390
Lower Main Duffins (1124 ha)	a	0	13	37.6	0	6	17.3	0	54.5	45.6	793510
	b	0	10.9	38.9	0	6	21.4	0	39.4	60.6	665395
	c	0	10.9	38.9	0	6	21.4	0	39.4	60.6	665395
Whole Duffins (28305 ha)	a	2.39	792.1	1785.6	0	6	13.5	55.1	37.8	7.1	48189490
	b	2.27	765.8	1906.6	0	6	14.9	48.1	36.4	15.4	46592615
	c	2.2	765.8	1699.5	0	6	13.3	34.6	50	15.4	46592615
Carruthers (3810 ha)	a	0.1	54.5	142.1	0	6	15.6	47.6	34.1	18.3	3312098
	b	0.2	52.2	156.6	0	6	18	33.3	33.4	33.4	3177194
	c	0.2	52.2	149.7	0	6	17.2	27.4	39.6	33	3177194

3.3.3.3 Wastewater Discharge Assessment

The dilution ratios and phosphorus concentrations attributed to the Stouffville WPCP under existing conditions for a range of flows at stream gauging stations downstream of the plant are presented in **Table 3-13.** The WPCP was not found to impact water quality during high flow conditions associated with precipitation events. During dry weather, the impact of the plant on phosphorus concentrations immediately downstream of the plant in Stouffville Creek failed to meet the Provincial Water Quality Objective (PWQO) for phosphorus (0.03 mg/L) for at least half of the monthly average flows. At 8th concession on Reesor Creek, the phosphorus concentration was above the PWQO for approximately one quarter of the monthly average flows. During extreme low flow conditions, represented as the minimum observed 7 day flow (7Q20), phosphorus concentrations exceeded the phosphorus PWQO as far downstream as the Green River station on West Duffins Creek.

Table 3-13: Dilution ratios and phosphorus concentrations attributed to the Stouffville WPCP at four locations downstream of the plant.

Location	Average streamflow percentiles	Dilution ratio	P concentration attributed to WPCP (mg/L)
Stouffville Creek	median 25th percentile 10th percentile 7Q20	3.2 2.3 2 n/a	0.05 0.07 0.09 n/a
Reesor Creek @ 8th concession	median 25th percentile 10th percentile 7Q20	7 5 4 n/a	0.02 0.03 0.04 n/a
West Duffins Creek @ Green River	median 25th percentile 10th percentile 7Q20	n/a n/a n/a 2	n/a n/a n/a 0.09
Duffins Creek Mouth @ Kingston Road	median 25th percentile 10th percentile 7Q20	4633259	0.004 0.01 0.01 0.02

Notes: Provincial Water Quality Objective for phosphorus is 0.03 mg/L; 7Q20 represents the minimum 7 day flow over a 20 year recurrence interval.

Table 3-14 shows observed phosphorus concentrations above and below the plant for the 1988 to 1994 period. At least 75% of samples were collected during dry weather. Median concentrations met the PWQO for phosphorus of 0.03 mg/L at the monitoring station above the plant but exceeded it at all stations downstream of the plant. These results are consistent with Table 1 estimates of phosphorus contributions to the stream associated with plant discharges.

Table 3-14: Average phosphorus concentrations (mg/L) and PWQO exceedence frequencies for phosphorus at stations upstream and downstream of the Stouffville WPCP (1988-1994).

	# Obs.	Min	Max	Mean	Median	Frequency of PWQO Exceedance
Stouffville Ck above WPCP	70	0.008	2.09	0.081	0.03	49%
Stouffville Ck below WPCP	70	0.008	0.268	0.1	0.091	89%
Reesor Ck @ 8th Concession	69	0.006	0.348	0.072	0.051	78%
Duffins Ck @ Bayly Street	72	0.002	0.54	0.053	0.024	38%

Under the Official Plan and Natural Heritage/Official Plan scenarios, a reduction in phosphorus concentration associated with decommissioning of the WPCP would be expected. The magnitude of this reduction downstream of the plant would depend on the contribution of other sources of phosphorus to the stream, and the decrease in stream flow that would result from plant decommissioning. Increased natural cover under the Natural Heritage/Official Plan scenario would normally be expected to reduce phosphorus loading to the Creek. Further modelling work is required to quantify the magnitude of expected improvement under future scenarios.

3.3.4 Aquatic Habitat and Species

Fish and Invertebrate Community Makeup

Based on the fisheries potential and resource use/fisheries management issues, fisheries management zones were developed for both watersheds **(Figure 3-14)**. They are shown as follows:

Table 3-15: Fisheries Management Zones

DUFFINS CREEK		CARRUTHERS CREEK	
MANAGEMENT ZONE	TARGET SPECIES PRESENT	MANAGEMENT ZONE	TARGET SPECIES PRESENT
Brook trout, Atlantic salmon	1 of 2	Brook trout	No
Redside dace, darter species	1 of 2	Redside dace, darter species	No
Redside dace, rainbow trout	1 of 2	Redside dace, rainbow trout	1 of 2
Smallmouth bass	No	Smallmouth bass	No

Based on the above status, the ratings of good and fair for Duffins and Carruthers Creeks, respectively, was assigned.

Index of Biotic Integrity

The modified IBI scores ranges from a low of nine (scoring one for each index) to a high of 45 (scoring five for each index). Four ranges of IBI scores have been designated to reflect stream quality and are listed in **Table 3-16.**

Table 3-16: 2000 IBI Ratings and Scores.

IBI RATING	IBI SCORE	NUMBER OF STATIONS	
		DUFFINS CREEK	CARRUTHERS CREEK
Poor	9 - 20	6	0
Fair	21 - 27	13	5
Good	28 - 37	13	1
Very good	38 - 45	0	0

Instream Habitat

Baseflow As A Percent of Total Annual Flow

The empirical relationship between aquatic community type and the ratio of baseflow to total annual flow was used as the basis for predicting the potential impacts of future land uses on the aquatic community (i.e. the higher the ratio, the more stable the baseflow and more likely the habitat is suitable for sensitive coldwater species). Using the annual groundwater discharge estimates from Gerber (2003), as an indicator of baseflow, and annual run-off estimates from the water budget (Clarifica, 2002), a rough approximation of groundwater discharge and total flow was estimated for each of the 30 sub-basins for each scenario. It was felt that an evaluation of the percent difference in the ratio of annual discharge to total annual flow among the three scenarios provided a better gauge of change than using the actual ratio values.

The most significant changes in the ratio of baseflow to total annual flow from the existing to future scenarios were seen in the watersheds where urban landuse is expected to increase. These changes are summarized in **Table 3-17** and shown in **Figures 3-15 a and b**. These findings suggest that, as urban development proceeds, extra care should be taken to ensure the protection of local water balance, including groundwater infiltration, discharge and overland runoff. Otherwise, the future land use change may result in a shift away from the existing coldwater community.

Table 3-17: Change in the ratio of basefow to average annual flow in sub-basins with increased urbanization

Subwatershed	Sub-basin	Change in % urban area	Change in the Ratio of Baseflow to Total Annual Flow From Existing Scenario (%)	
			Future Scenario	Future + Natural Heritage Scenario
West Duffins Creek	2	21.71	-8.79	-7.68
West Duffins Creek	12	32.8	-15.1	-15.11
Ganatsekiagon Creek	24	29.85	-14.94	-14.81
Ganatsekiagon Creek	25	53.74	-27.34	-27.34
Urfe Creek	23	48.65	-24.55	-24.55
East Duffins Creek	21	24.44	-7.82	-7.82
Main Duffins Creek	28	29.11	-9.6	-9.59

It should be noted that in all the sub-basins except for sub-basin 2, natural heritage goals were not aggressively pursued, and therefore the benefits from implementing the natural heritage approach are not seen. It is also important to note that for the purposes of this modelling, stormwater management controls were not incorporated.

However, in sub-basins where the natural heritage approach was aggressively pursued, a positive change in the ratio of baseflow to annual average flow is seen, as shown in **Table 3-18**.

Table 3-18: Change in the ratio of basefow to average annual flow in sub-basins with the Enhanced Natural Heritage Cover

Subwatershed	Sub-basin	Change in % natural area	Change in the Ratio of Baseflow to Total Annual Flow From Existing Scenario (%)	
			Future Scenario	Future + Natural Heritage Scenario
West Duffins Creek	1	20.08	-0.6	1.87
West Duffins Creek	37925	8.43	-0.12	0.6
West Duffins Creek	15	45.01	-0.01	7.55
West Duffins Creek	5	27.76	-0.03	2.59
West Duffins Creek	7	22.41	0	1.97
West Duffins Creek	6	31.87	-0.08	1.99
West Duffins Creek	8	1.94	-0.02	0.1
West Duffins Creek	4	1.46	-0.11	0.05
East Duffins Creek	13	26.72	-0.01	4.36
East Duffins Creek	14	15.9	-0.04	1.73
East Duffins Creek	16	24.02	0	2.37
East Duffins Creek	17	25.73	0	2.14
East Duffins Creek	18	45.15	-0.01	4.62
East Duffins Creek	19	11.15	-0.05	0.92

Water Chemistry

Total Suspended Solids
Both watersheds have data indicating that TSS concentrations do not exceed 30mg/L more than 80% of the time. Based on this information, TSS levels are considered to be good for aquatic communities in both watersheds. The greatest increases in TSS concentrations in the future land use scenarios will be in the sub-basins experiencing urban growth (ie. Urfe, Ganetsekiagon, and West Duffins Creeks) (Stantec and Aquafor Beech, 2003). Although the increase in TSS concentrations is not significant, the loads are expected to double due to increased runoff volume. Increased duration and frequency of elevated TSS concentrations could impact aquatic communities and should be addressed through preventive and mitigative measures.

Phosphorus
Both watersheds have data indicating that phosphorus concentrations exceed 0.03 mg/L more than 50% of the time. Similar to TSS, modelling has indicated that under future land use scenarios phosphorus concentrations will likely increase marginally and loads will increase more significantly, especially in sub-basins with urban growth. This trend will be offset somewhat in the West Duffins Creek by the decommissioning of the Stouffville Sewage Treatment Plant. Elevated phosphorus is a contributor to a change in species composition at lower trophic levels and overall oxygen demand that could effect a change in the aquatic community composition.

Chlorides
Water quality monitoring data indicates that no station exceeds 250 mg/l in either watershed.

This is within acceptable levels for the aquatic community. It should be noted, however, that chlorides are most noxious during spring run-off when eggs and alevins are very vulnerable, and water quality sampling programs may fail to detect event-related elevated chloride incidents. Chloride concentrations were predicted to be approximately 30% higher than current levels in Carruthers Creek and double current levels in the Ganetsekiagon and Urfe Creeks under future land use scenarios (Stantec and Aquafor Beech, 2003). However, according to the model, predicted levels will remain within the 250 mg/L threshold of toxicity to aquatic organisms. It should be noted that the model was unable to predict chloride concentrations during snowmelt events and these peak levels may be of most concern.

Fish Passage

In total, 102 instream barriers (not including road and rail crossings) were located within both watersheds.

Riparian Zone

In the Duffins Creek watershed, 76% of the riparian zone is naturally vegetated with either forest, successional, meadow, or wetland type habitat. This percentage does not include manicured grasses or agricultural crop lands. Fifty percent of the total stream bank length is considered to have a woody vegetation component.

In the Carruthers Creek watershed, 75% of the riparian zone is naturally vegetated with either forest, successional, meadow, or wetland type habitat. This percentage does not include manicured grasses or agricultural crop lands. Forty-two percent of the total stream bank length is considered to have a woody vegetation component.

3.3.5 Terrestrial Habitat and Species

Five measures were used to evaluate the health of the terrestrial natural heritage system under the different land use scenarios: quantity of natural cover; distribution of natural cover; matrix influence, size of natural cover patches; and shape of natural cover patches.

The results of the Duffins Creek Watershed analysis are presented in **Table 3-19.** The scenario involving Future land use with Enhanced Natural Cover represents a net increase in area under natural land cover, in such a way that also improves the average size and shape scores for natural land cover patches as compared to Existing land use conditions. In the "Future with Enhanced Natural Cover" scenario, increases to natural land cover are concentrated in the northern portions of the watershed, which result in a greater distance-to-centroid value, and represents a less desirable condition for the distribution of natural land cover over the watershed. The average matrix influence score improves under this scenario, due to the increased proportion of natural cover relative to urban or rural land uses. The benefits to other scores (i.e., average patch size and shape), and to the connectivity of the natural system as a whole that are associated with this change makes this condition a preferable option.

Overall, the scores for the Existing land use scenario in the Duffins Creek watershed reflect the fact that the existing amount of natural land cover provides a good basis on which to build a healthy and functioning terrestrial system. However, improvements to the size, shape and distribution of natural land cover patches are needed to provide the conditions necessary to achieve biodiversity targets (i.e., support species-of-concern).

Table 3-19: Duffins Creek Watershed Terrestrial Natural Heritage System Analysis

Measure	Scores for Each Land Use Scenario*		
	Existing	Future**	Future with Enhanced Natural Heritage Cover
Percent of watershed under natural cover	37%	36%	≥48%
Distribution of natural cover in relation to total watershed area as measured by distance to centroid (metres)	992 m	Not modelled	≤2351 m
Matrix influence score	2.68		4.16
Average patch size score	2.23		≥3.87
Average patch shape score	1.621		≥2.79

* The technical analyses conducted to develop these scores utilized the Duffins Creek watershed boundary that was derived from 1:50 000 scale topographic mapping data. Subsequent technical studies utilized a new watershed boundary that was derived using higher resolution data (1:10 000 scale digital elevation model). This discrepancy accounts for the difference between the percent natural cover scores indicated here (e.g. 48% for the "Future Enhanced" scenario) and the target indicated in the watershed plan (49% using the higher resolution watershed boundary, in association with the land use scenario descriptions). In this reporting period, the technical analyses required to calculate the terrestrial scores were not repeated using the new watershed boundary.
**Future scenario was not modelled as part of the terrestrial studies, because the difference in natural cover between this scenario and the Existing land use scenario was limited to localized areas, and differences in scores would probably not be detected by the landscape level analysis. Percent natural cover has been provided from subsequent watershed planning studies, noted above.

The results of the terrestrial analysis for the Carruthers Creek Watershed are presented in **Table 3-20.** The Future land use with Enhanced Natural Cover scenario in this watershed results in a net loss in natural land cover associated with the expansion of urban settlement areas, while improving the average size of natural land cover patches. Improvements to the size of existing natural cover patches contribute to a shifting of the centroid of all natural land cover patches further away from the centroid of the watershed, thus improving the distribution of natural cover. Despite increases in the average patch size, the average patch shape scores are somewhat reduced.

It is important to acknowledge that the target for natural land cover (i.e. the Future land use with Enhanced Natural Cover scenario) in the Carruthers Creek watershed was established with consideration of the constraints associated with existing developed areas and lands that are designated for development in the future. Fewer opportunities exist for restoring natural land cover in the Carruthers Creek watershed, than in the Duffins Creek watershed because the proportion of the watershed in public ownership is much less.

It is acknowledged that the target for natural land cover in the Carruthers Creek watershed does not reflect conditions required to achieve biodiversity targets (i.e., support species-of-concern) or to significantly enhance recreational use opportunities to the same extent that the targets for the Duffins Creek watershed do. However, the target does represent a significant improvement from Existing conditions and is believed to be the best condition that could be achieved within the constraints to regeneration that currently exist.

Table 3-20: Carruthers Creek Watershed Terrestrial Natural Heritage System Analysis

Measure	Scores for Each Land Use Scenario*		
	Existing	Future**	Future with Enhanced Natural Heritage Cover
Percent of watershed under natural cover	28%	25%	≥27%
Distribution of natural cover in relation to total watershed area as measured by distance to centroid (metres)	784 m	Not modelled	≤1750 m
Matrix influence score	2.67		3.11
Average patch size score	2.1		≥2.89
Average patch shape score	2.02		≥1.89

* The technical analyses conducted to develop these scores utilized the Duffins Creek watershed boundary that was derived from 1:50 000 scale topographic mapping data. Subsequent technical studies utilized a new watershed boundary that was derived using higher resolution data (1:10 000 scale digital elevation model). This discrepancy accounts for the difference between the percent natural cover scores indicated here (e.g. 48% for the "Future Enhanced" scenario) and the target indicated in the watershed plan (49% using the higher resolution watershed boundary, in association with the land use scenario descriptions). In this reporting period, the technical analyses required to calculate the terrestrial scores were not repeated using the new watershed boundary.
**Future scenario was not modelled as part of the terrestrial studies, because the difference in natural cover between this scenario and the Existing land use scenario was limited to localized areas, and differences in scores would probably not be detected by the landscape level analysis. Percent natural cover has been provided from subsequent watershed planning studies, noted above.

Figures 3-16 a and b illustrate the differences in individual habitat patch size scores, between the Existing land use and Future land use with Enhanced Natural Cover scenarios. The figures show improvements in individual patch size scores under the "future enhanced" scenario, particularly in the northern parts of the watersheds where the majority of the enhancements to the terrestrial system have been targeted. The figures also show how, overall, the average patch size scores are improved under the "future enhanced" scenario.

3.3.6 Public Use and Recreation

A qualitative assessment of challenges and opportunities for public use and recreation under the alternative land use scenarios was completed. Under existing land use conditions, the large amount of publicly owned land in the watersheds is very positive and, coupled with private landowner cooperation, provides very good opportunities for achieving an accessible and integrated greenspace system. If urban development proceeds under the Future Official Plan scenario, without integrated planning for greenspace and recreation, the available public use opportunities will fail to meet the demands of the increased population base. Furthermore, over use of existing greenspace areas will negatively impact the environment, through over use of existing trails, creation of informal trails, and other impacts, and the quality of the user's experience will deteriorate due to crowding and user conflicts. Under the Future Official Plan with Enhanced Natural Heritage scenario, there will be greater opportunity for the creation of integrated, accessible and extensive greenspace system, however, again, without planning for recreational use opportunities, the potential may fail to be realized and negative impacts from informal, unplanned use may result.

3.3.7 Human Heritage

Known archaeological and built heritage sites are shown on maps published in the Duffins and Carruthers Creek State of the Watershed Reports. Application of TRCA's Archaeological Site Predictive Model suggests that many more archaeological sites may exist than those that have been identified to date (Results of a partial application of this model are shown in **Figure 4-1g and 4-2a**). Many more built heritage sites are generally known in the watersheds, that are not yet designated or listed. As urban development proceeds under the Future Official Plan scenario, there will be opportunities through the normal development process to identify archaeological sites and arrange for their protection. Under this scenario there will likely be a reduction in the number of built heritage sites, unless the municipal policies and tools for their protection are strengthened. Under the Future Official Plan with Enhanced Natural Heritage scenario, there will be an increase in the number of archaeological sites identified and protected *in situ* (within natural heritage restoration areas). There may be a reduction in the number of built heritage sites identified, as in the Future Official Plan scenario, but an increase in the level of protection afforded to existing listed sites, where they are located in areas identified for the targeted natural heritage system.

3.4 Summary Evaluation of Findings

The technical study findings were reviewed and evaluated according to the Task Forces' management objectives, indicators and targets, and the results of this analysis has generally been presented in the preceding sections of Chapter 3. **Appendix A** contains a brief summary of the results from the evaluation of each land use scenario for each objective.

Within the Watershed Plan, key management considerations and issues have also been summarized by subwatershed, in order to provide further direction on priorities for local stakeholders.

Results of the assessment of watershed health under existing land use conditions, as compared to the management objectives and targets, were further reviewed and a rating of health was applied to each. A detailed description of the rating methodologies for each objective and set of indicators is documented in *Ratings Report for the 2003 Duffins and Carruthers Creek Watersheds Report Card* (TRCA, 2003). A summary of the final ratings was published in the Watershed Plan, and is intended to serve as the baseline "report card" of conditions, from which progress can be measured in future years.

Figure 3-1: Duffins Creek Watershed Alternative Land Use Scenarios

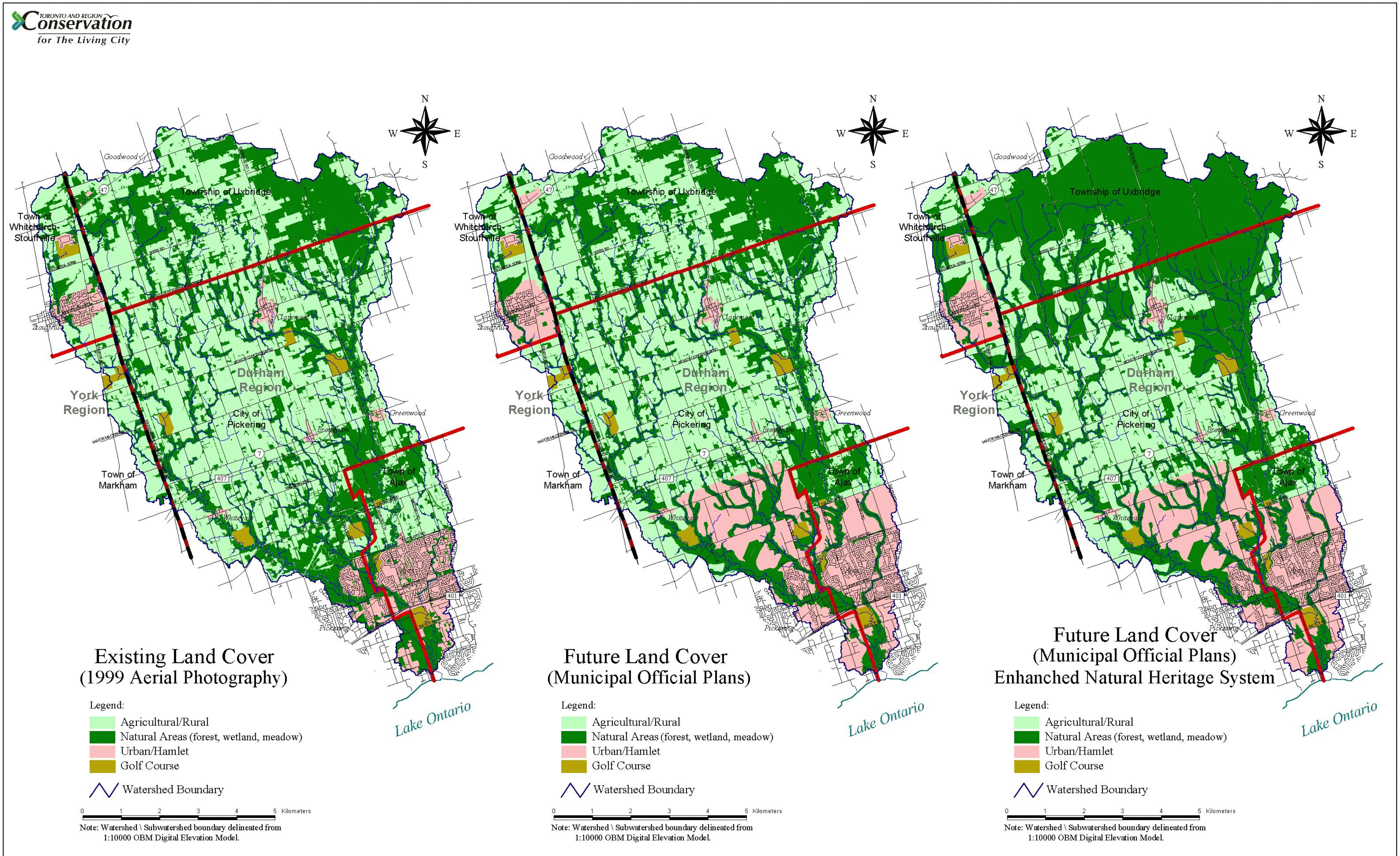


Figure 3-2: Carruthers Creek Watershed Alternative Land Use Scenarios

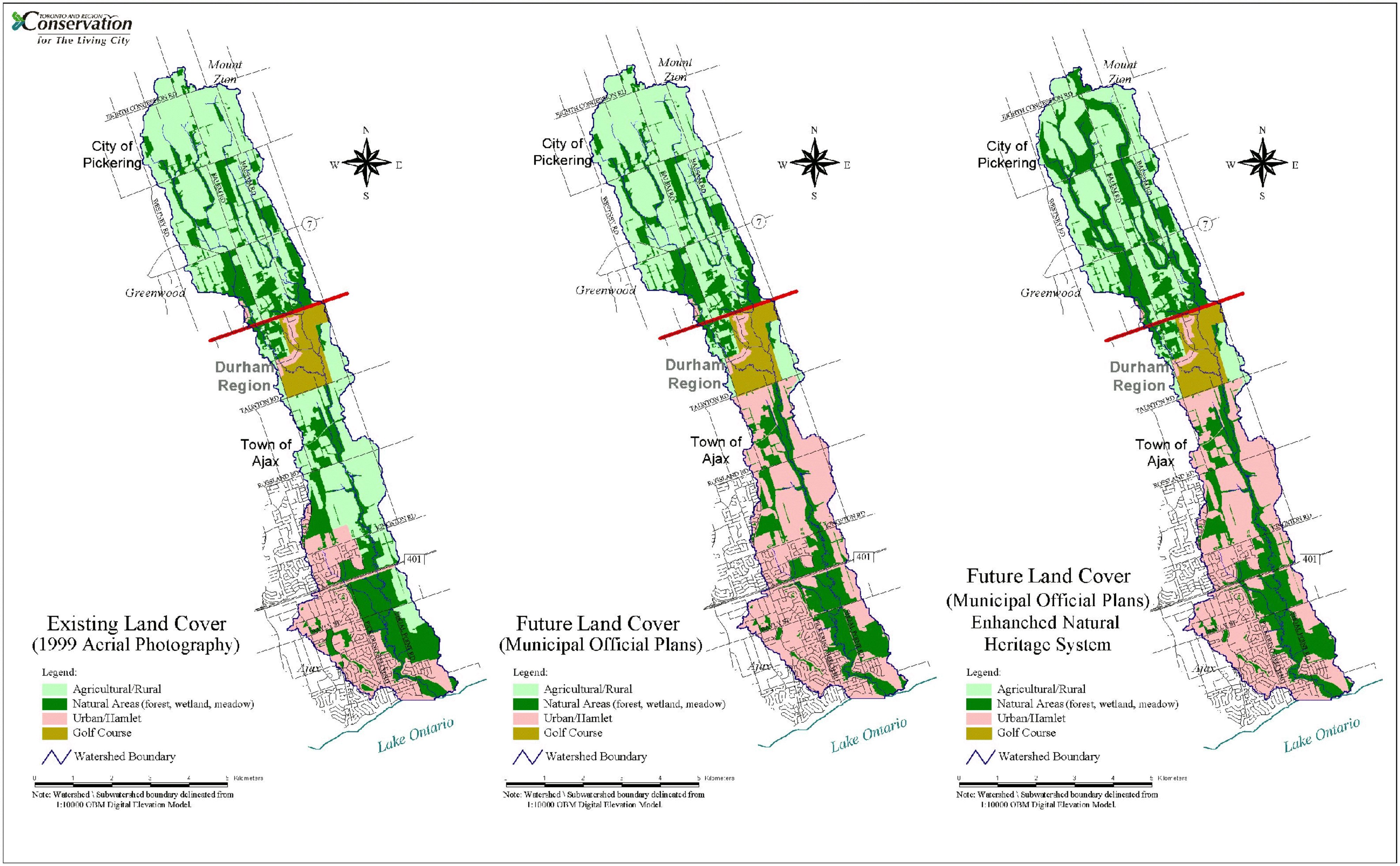


Figure 3-3: Duffins Creek Watershed - Percent Impervious - Existing and Future Land Use Scenarios

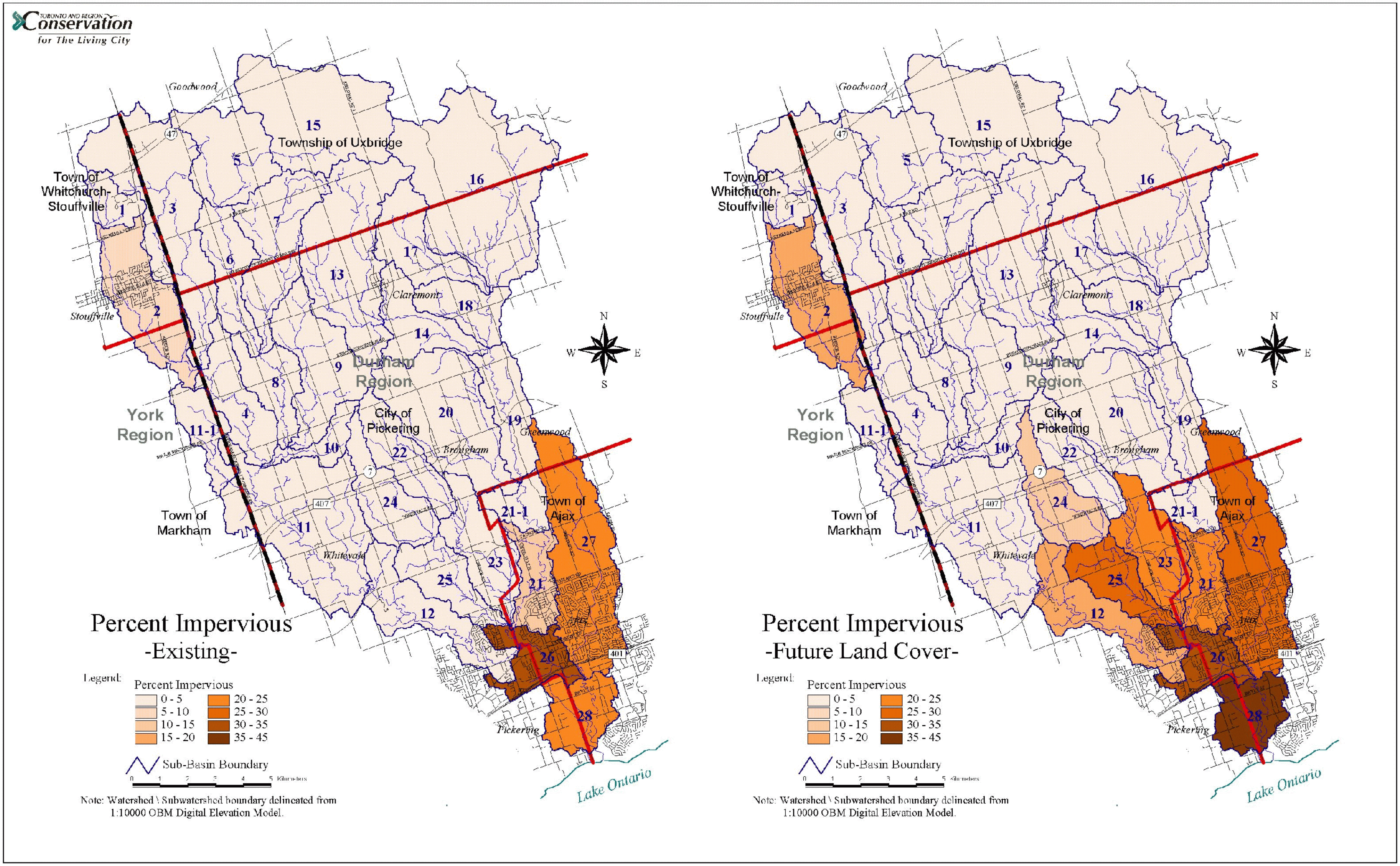


Figure 3-4: Duffins Creek Watershed - Groundwater Infiltration Rates under Existing Land Use Scenario and Groundwater Infiltration Recharge Deficit under Future Land Use Scenarios

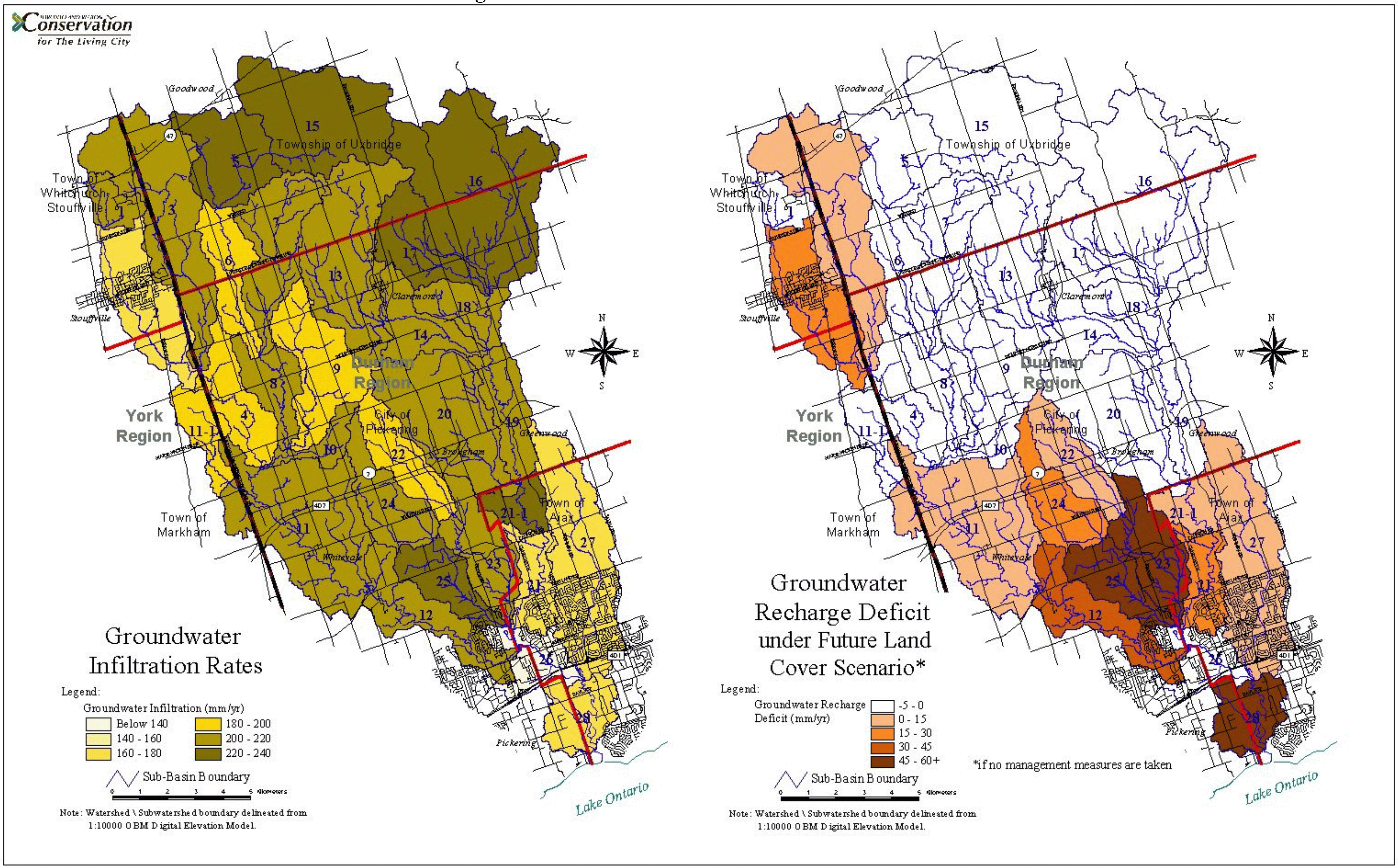


Figure 3-5: Duffins Creek Watershed - Peak Flow Reduction - Future Land Use Enhanced Natural Heritage Cover

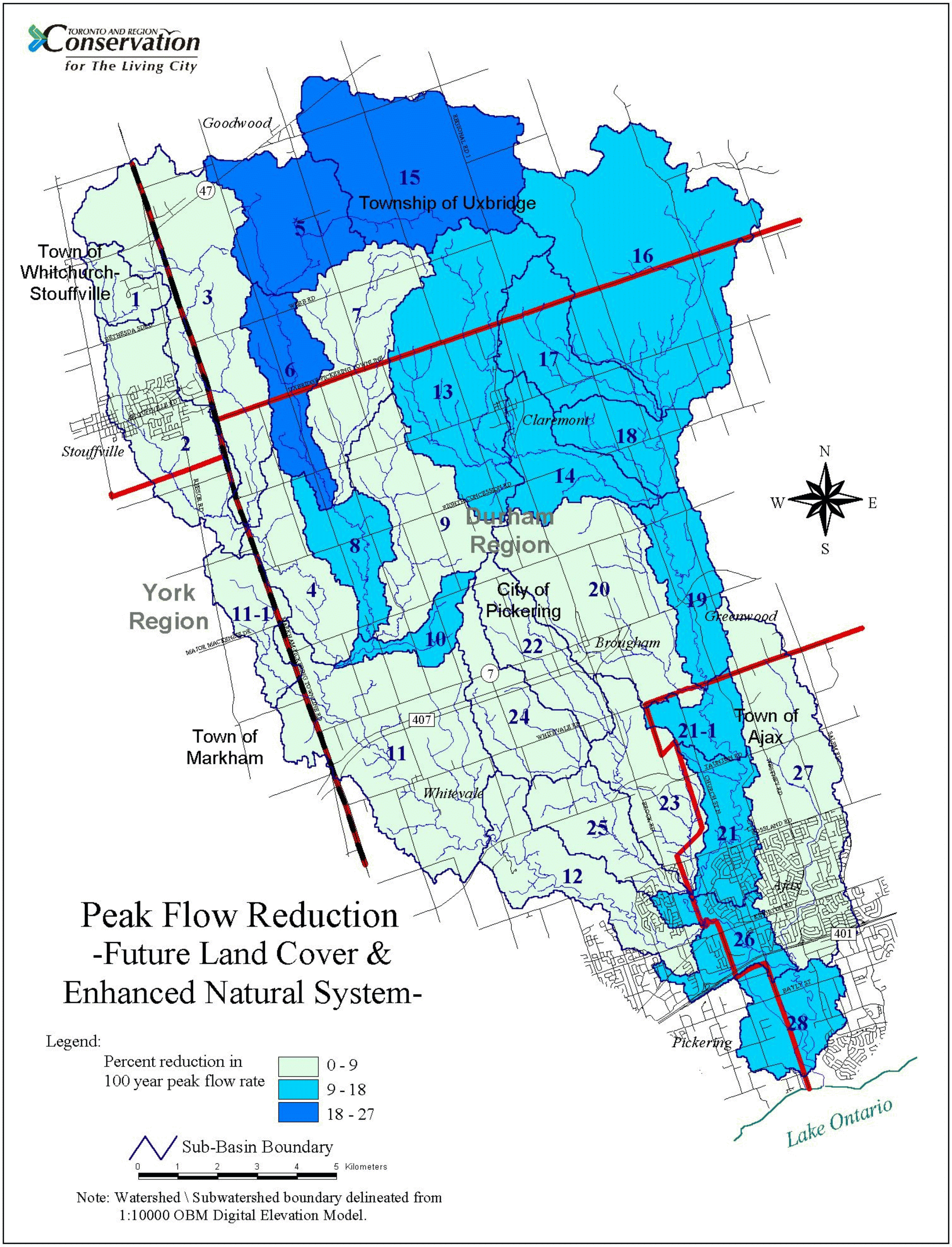


Figure 3-6: Duffins Creek Subwatershed Baseflow Contributions

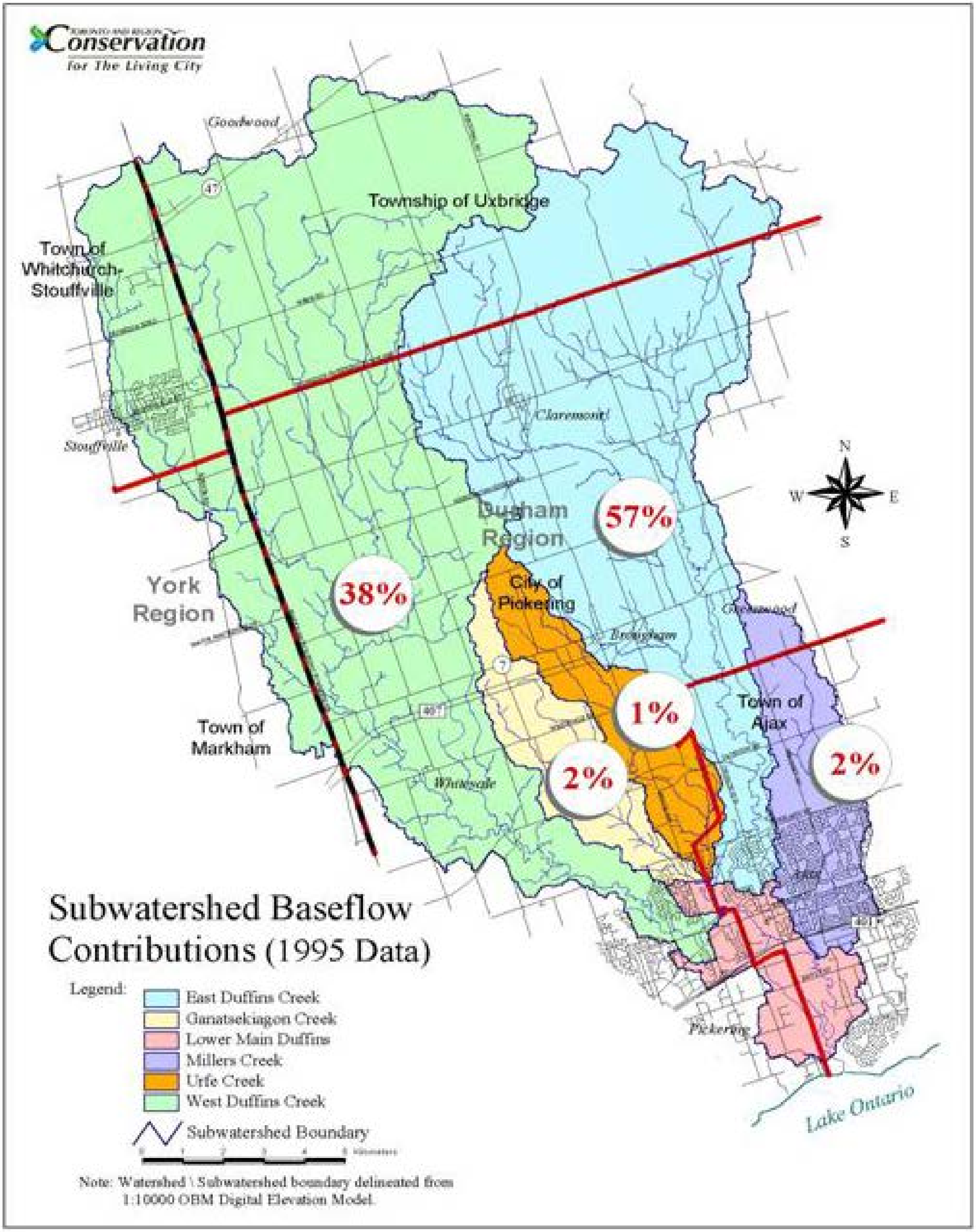


Figure 3-7: Carruthers Creek Baseflow Discharge

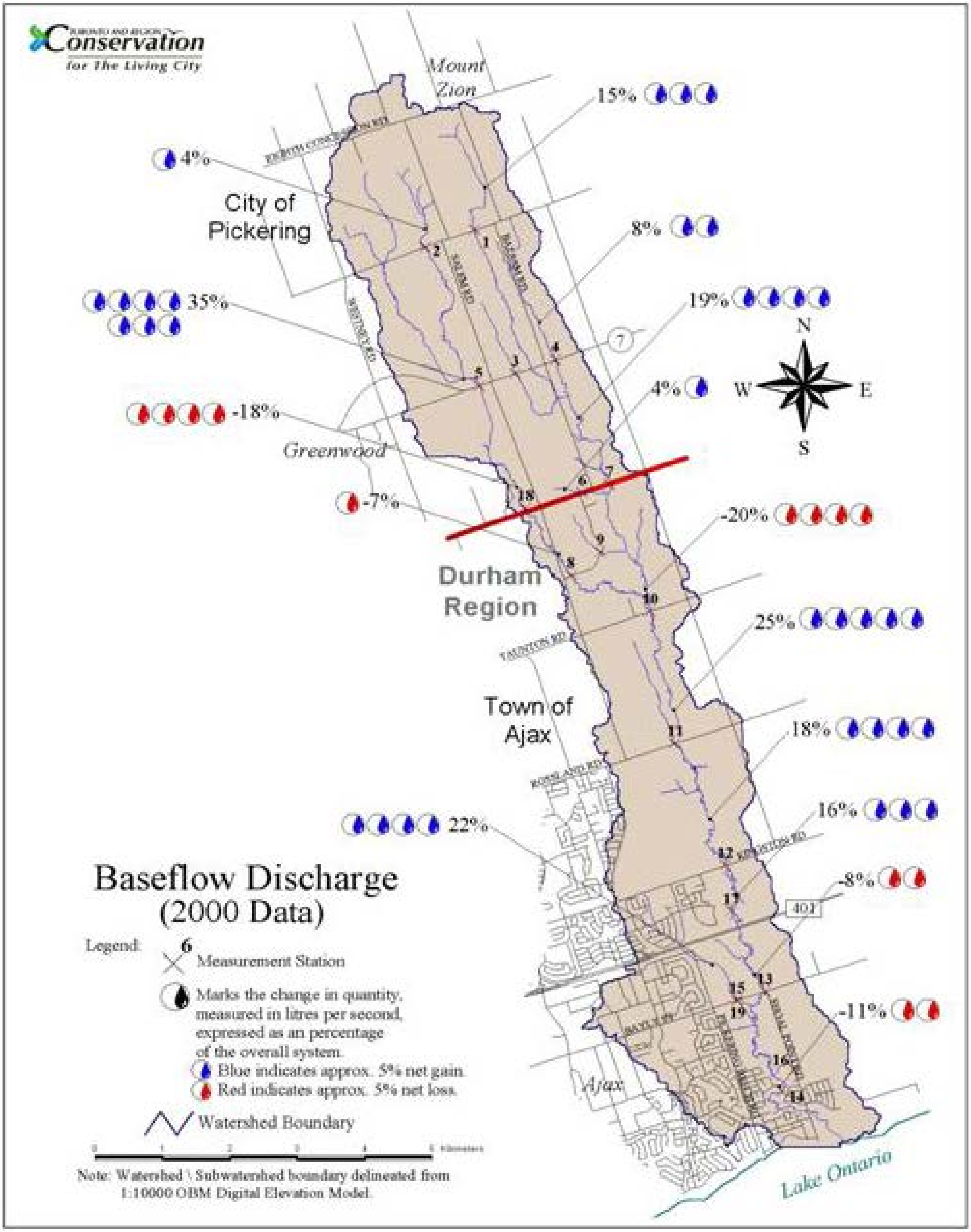


Figure 3-8 Sedimentary Deposits Exposed in the Toronto Area

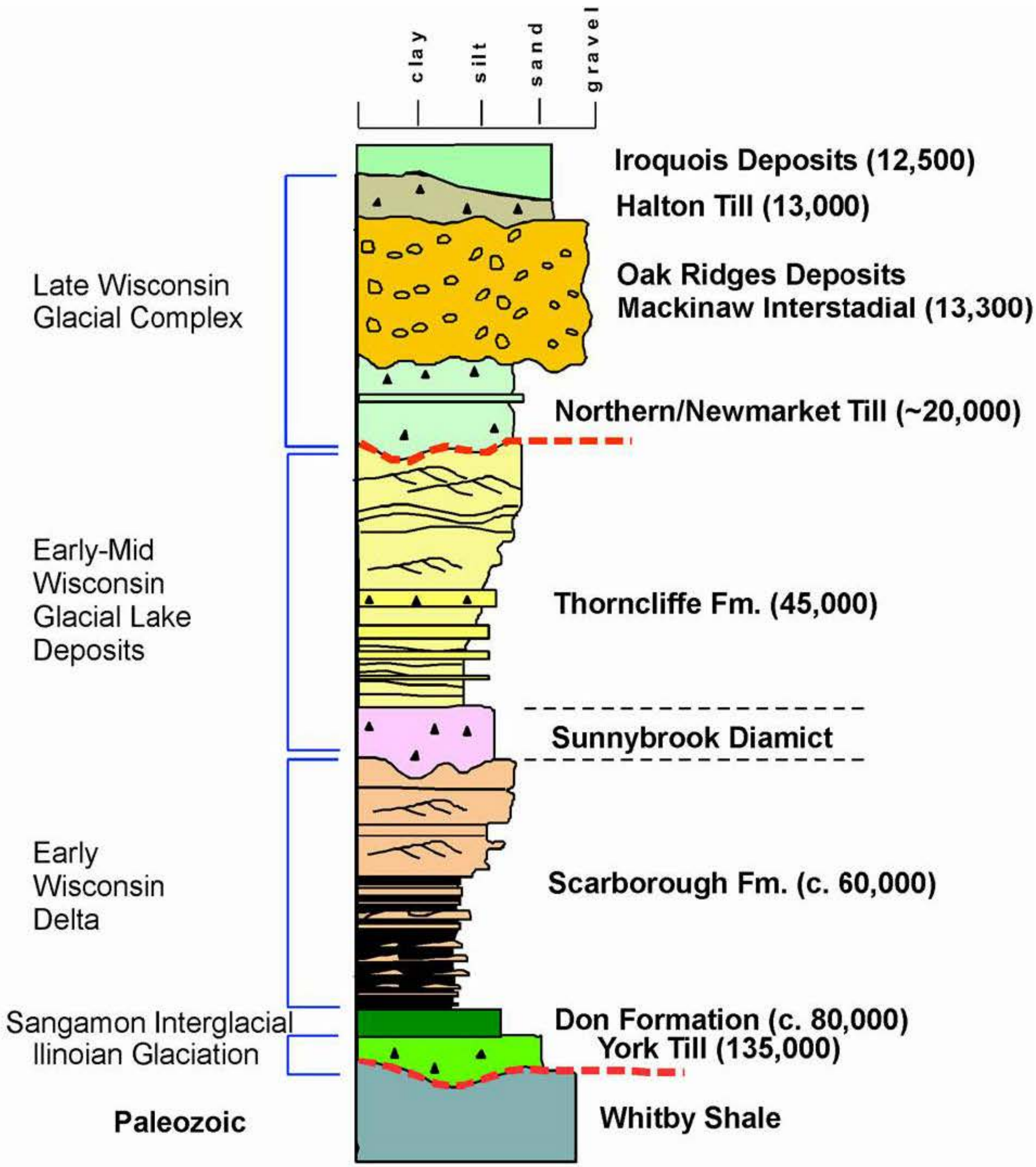


Figure 5: Quaternary deposits found in the Toronto area. Figure from Eyles (2002).

Figure 3-9: North-South Stratigraphic Cross-Section Showing Surface Geologic Deposits of the Duffins Creek Watershed

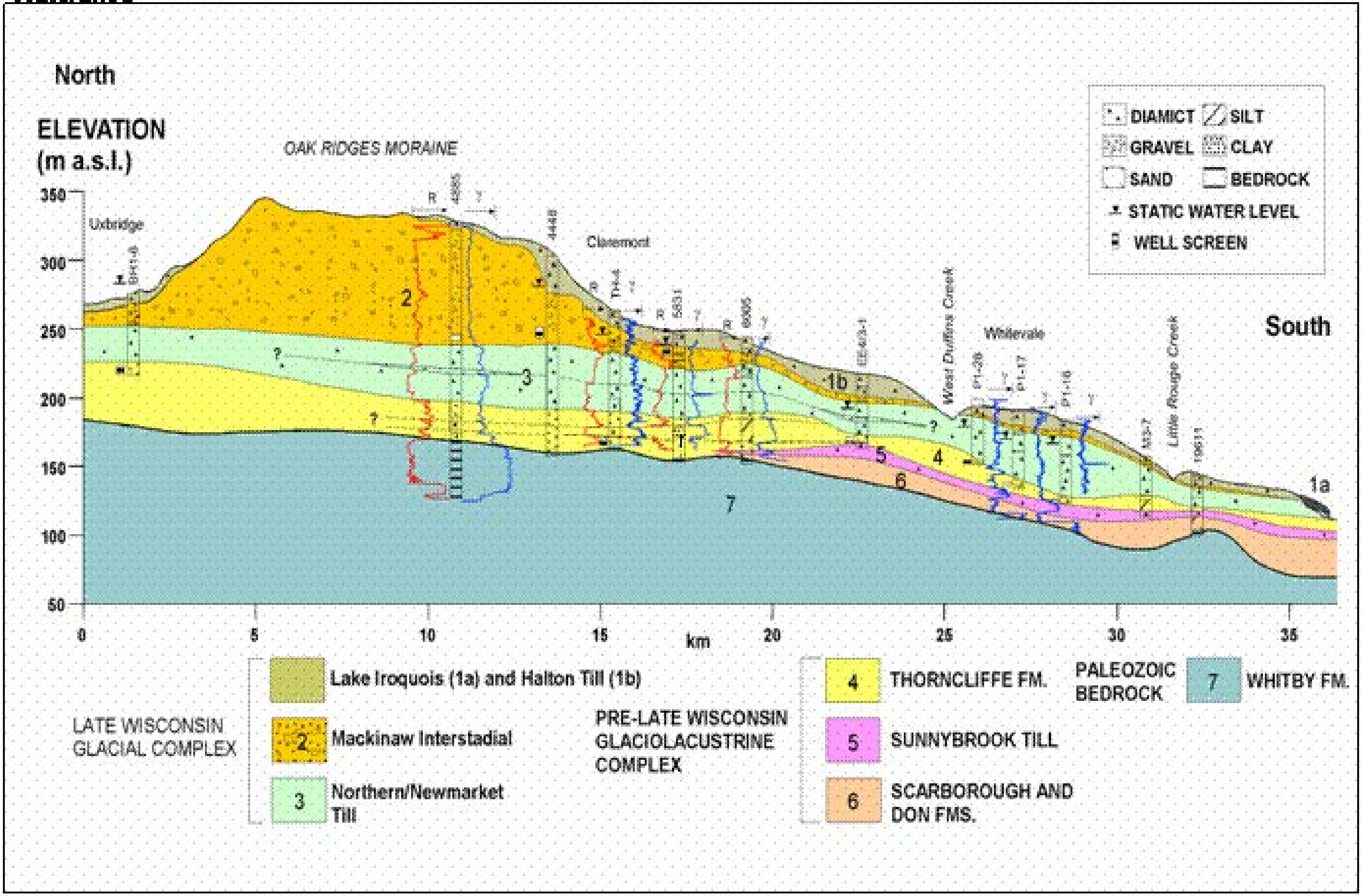
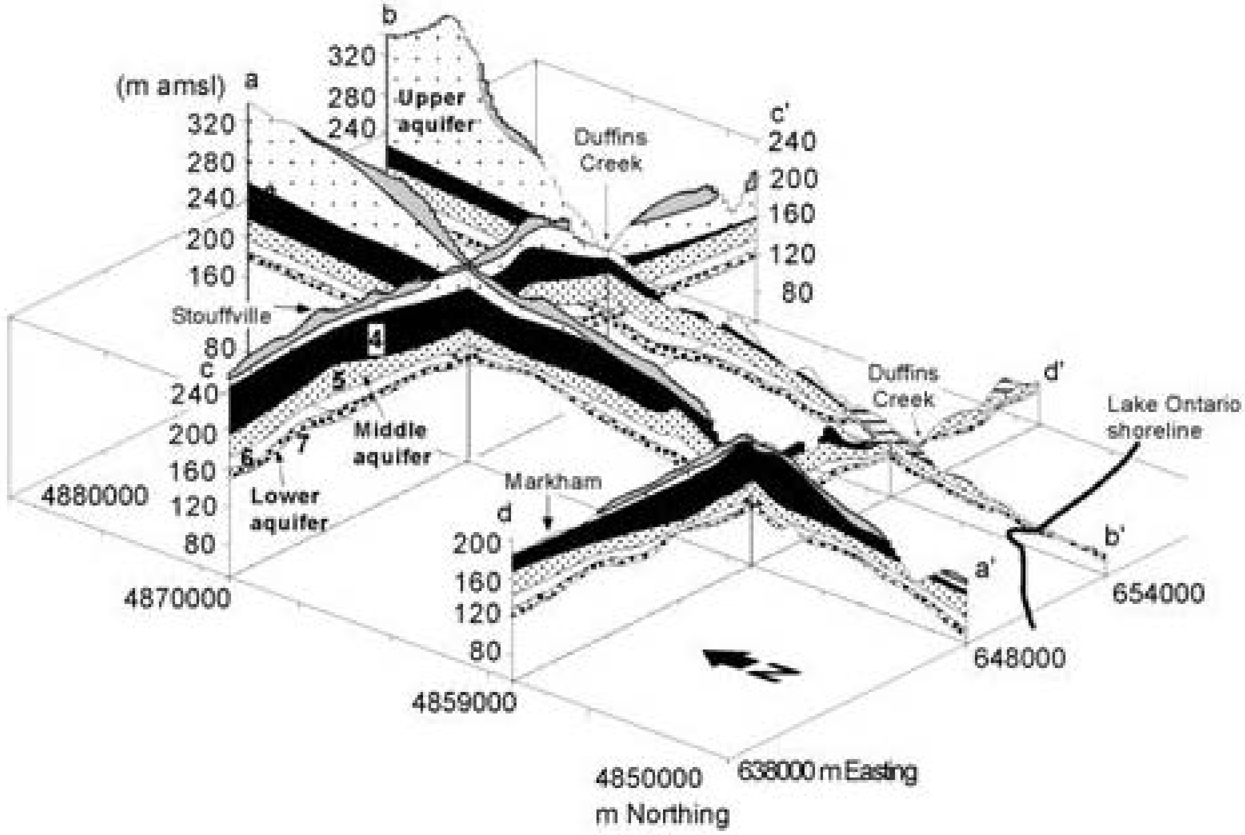


Figure 3-10: Duffins Watershed Fence Diagram



Late Wisconsinan	Model Layer #
Lake Iroquois	1,2
Halton Till	1,2
Mackinaw Interstadial/Oak Ridges Complex (**Upper aquifer**) Glaciofluvial and glaciolacustrine with sand and gravel outwash.	3
Northern/Newmarket till (23-18,000 y BP)	4
Middle Wisconsinan	
Thorncliffe Fm. (**Middle aquifer**) Deltaic sand and lacustrine silt and clay interbedded with diamict (<50,000 y BP)	5
Early Wisconsinan	
Sunnybrook Diamict	6
Scarborough Fm. (**Lower Aquifer**) Deltaic sands and glaciolacustrine silt and clay (~70,000 y BP)	7

Figure 3-11: Duffins Creek Watershed – Decline in Water Table Elevation Under Future Land Cover Scenario

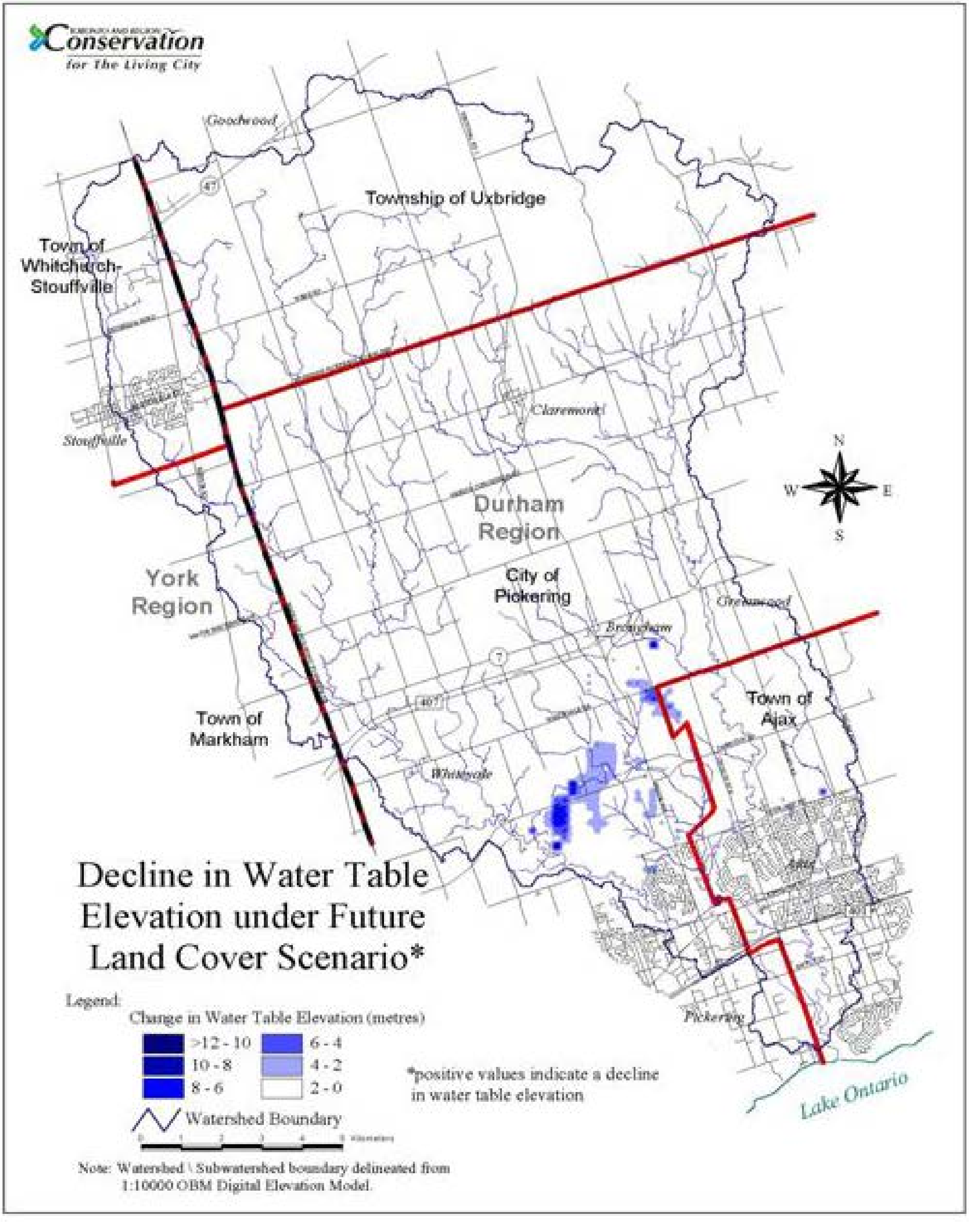


Figure 3-12: Duffins Creek Watershed - Predominant Sources of Sediment Load

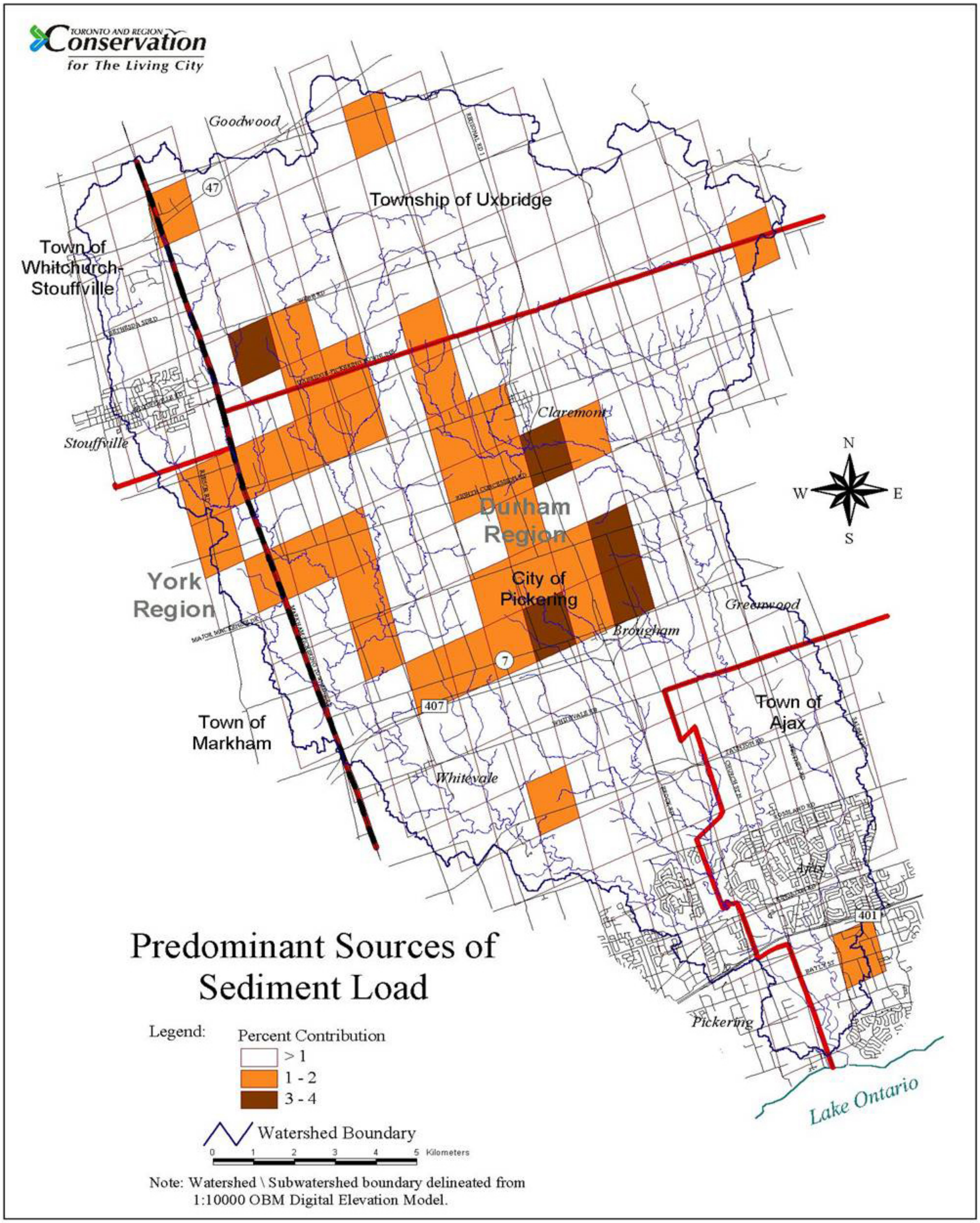


Figure 3-13: Carruthers Creek Watershed - Predominent Areas of Sediment

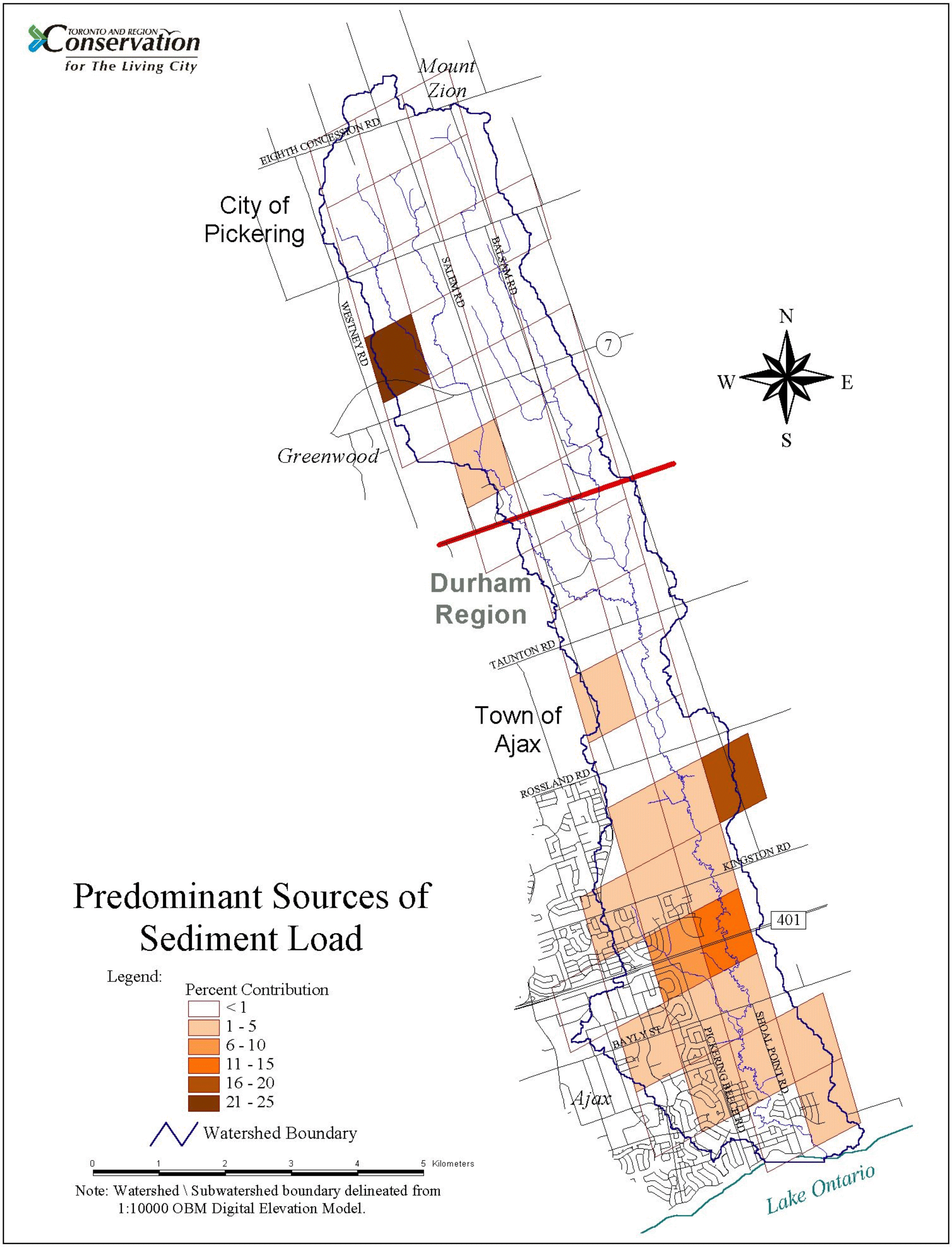


Figure 3-14: Duffins and Carruthers Creek Watersheds Fisheries Management Zones

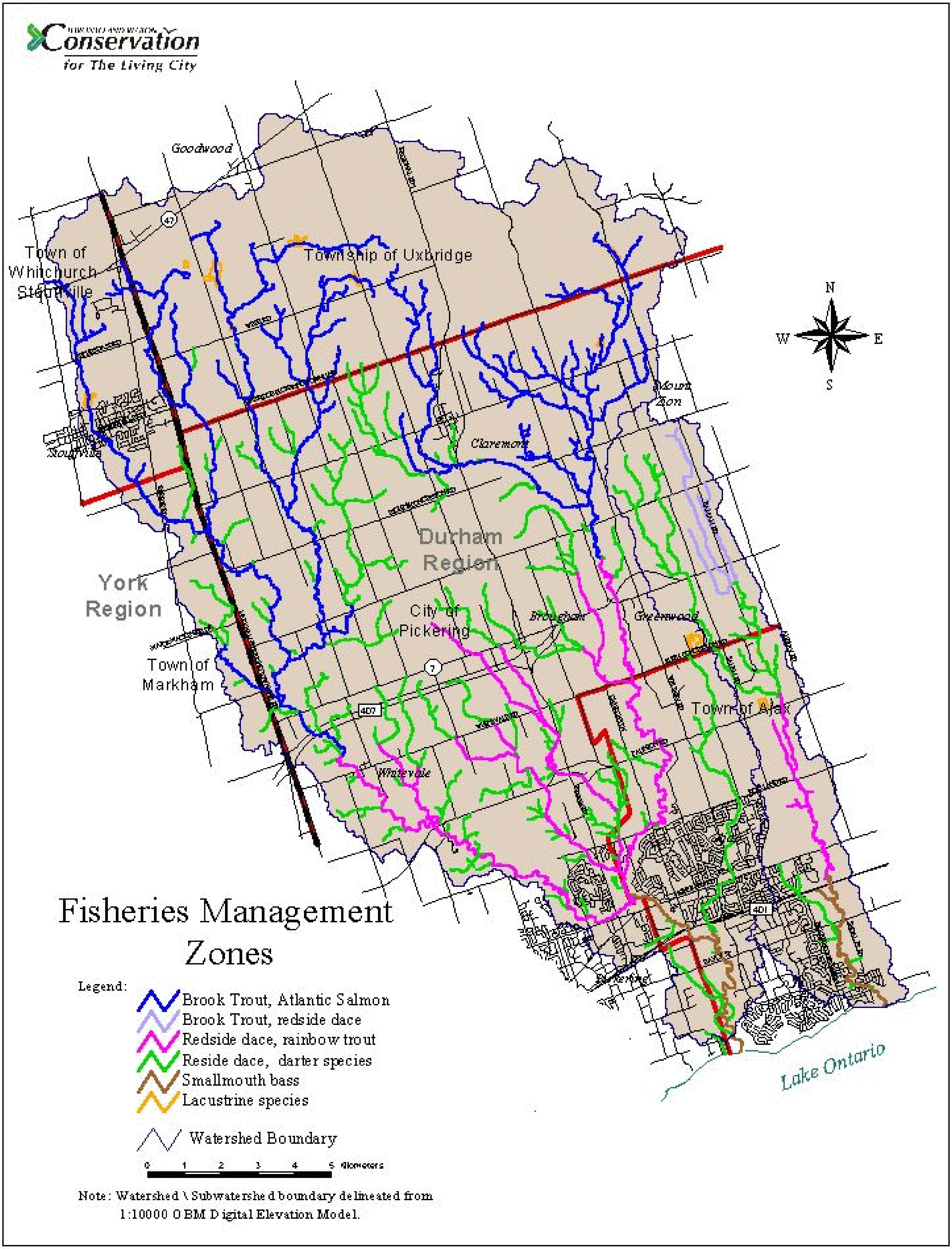


Figure 3-15: Duffins and Carruthers Watersheds - Change in Proportion of Total Annual Flow from Groundawater Sources under Future Land Cover and Future Land Cover with Enhanced Natural Heritage System

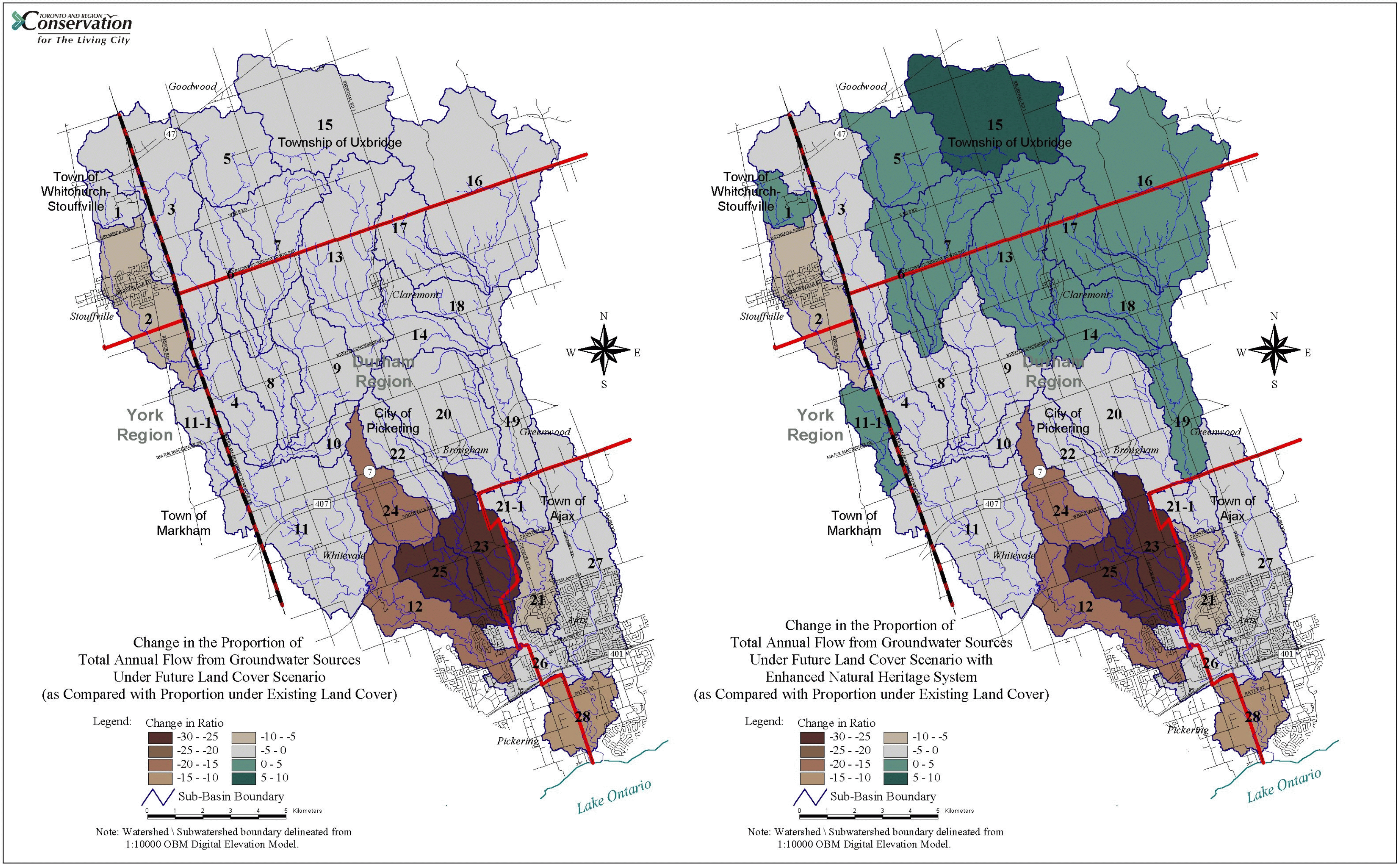
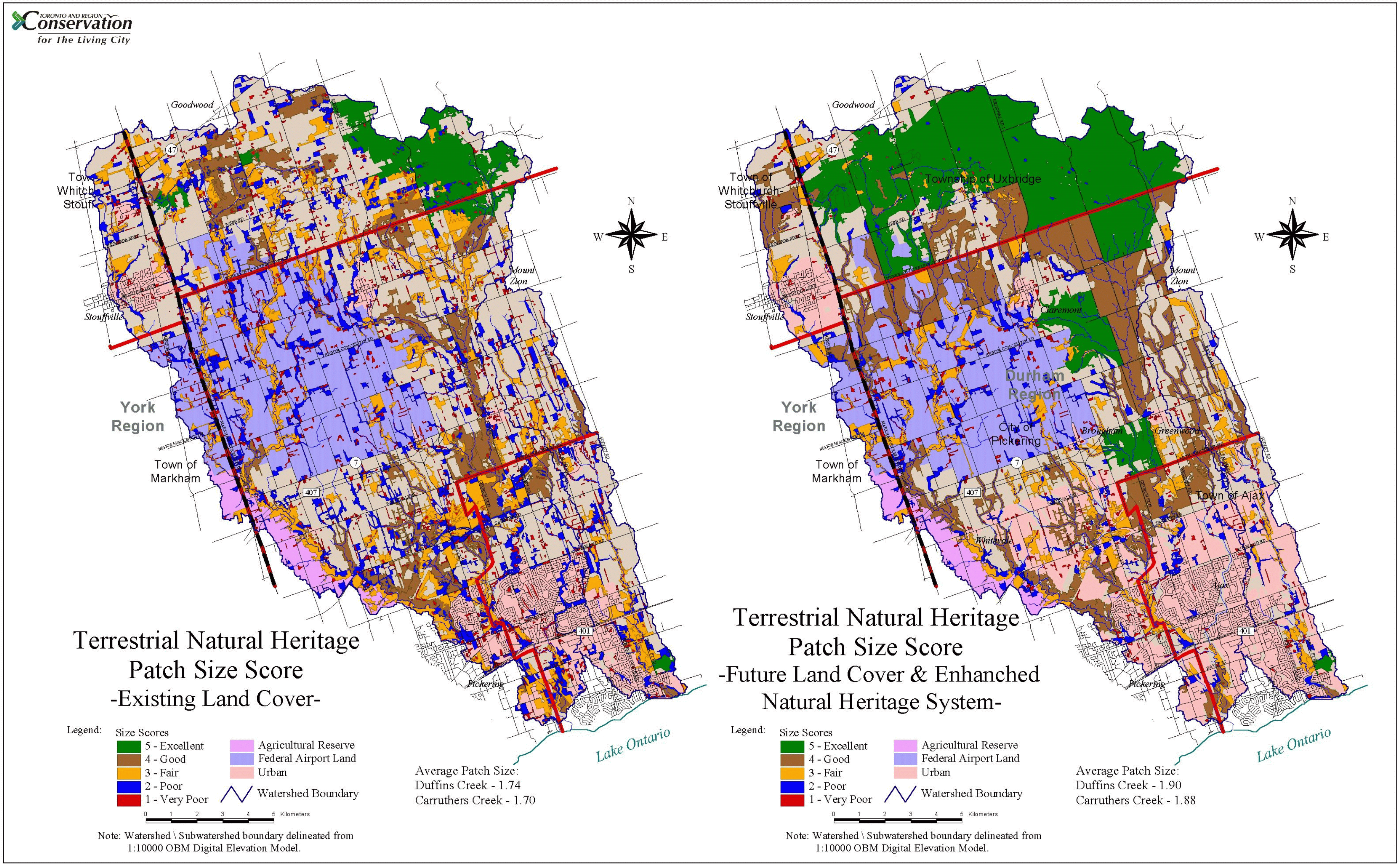


Figure 3-16: Duffins and Carruthers Watersheds - Terrestrial Natural Heritage Patch Size Scores
Existing Land Cover and Future Land Cover with Enhanced Natural Heritage System



4.0 DEVELOPMENT OF RECOMMENDED MANAGEMENT APPROACH

4.1 Evaluation Criteria and Selection of the Preferred Approach

Based on the results of the technical studies, the Watershed Task Forces have recommended that the most effective approach for managing the Duffins and Carruthers Creek watersheds would involve achievement of the targeted natural heritage system, together with the application of state of the art management practices that would be employed in all aspects of land use activities. The concept of a targeted natural heritage system, at the watershed scale, is depicted in the "Future Land Use (as per Official Plans) with Enhanced Natural Heritage Cover" scenario. The scenario was not intended to limit revegetation to these specific geographic areas. Implementation of the watershed plan would involve a review of opportunities for enhancing natural heritage systems at subwatershed and site scales. The technical studies have recommended guidelines and criteria for the design and application of best management practices that would contribute to maintaining the function of the natural heritage system.

The selection of this preferred management approach was based on a number of considerations:

Consistency with Task Force Management Philosophy

The Task Forces articulated a management philosophy that was to be used to guide in the achievement of their vision for the watersheds. The management philosophy consists of five key elements:

- Net Gain
- Environment First
- Balance Land Use
- Human Health and Safety
- Everyone Counts - Ownership, Commitment & Follow Through

The establishment of a natural heritage system, together with sustainable agricultural and urban land uses, is consistent with this Task Force's management philosophy.

Effectiveness

Technical analysis of the watersheds' response to alternative land use and management scenarios enabled the Task Forces to establish benchmarks of watershed condition, which were used as a guide in formulating and justifying this management plan. Results from the analysis of the "Future Land Use (as per the Official Plans) with an Enhanced Natural Heritage System" scenario repeatedly demonstrated the multiple watershed management benefits that can be realized by achieving a targeted natural heritage system. In addition to benefits associated with terrestrial habitat and species objectives, a natural heritage system was shown to contribute to the management of hydrological, hydrogeological, water quality, aquatic resource, recreation, and human heritage concerns.

Long Term Sustainability

At a watershed scale, the protection of a viable natural heritage system, will provide the foundation for a sustainable watershed. By protecting the ability of natural systems to carry out watershed management functions, there will be:

- less need for costly maintenance of infrastructure;
- less risk involved with unproven technological solutions to watershed management; and
- cost savings in taking a preventitive approach rather than a reliance on remedial or "end-of-pipe" solutions.

Wise choices regarding "backyard practices", urban form, and transportation design, made at site and community scales within the watershed will complement the level of protection provided by natural systems and contribute to overall watershed sustainability.

Feasibility

Due to unique opportunities in the Duffins and Carruthers Creek watersheds, the Task Forces deemed the achievement of an enhanced natural heritage system to be feasible in these watersheds. Unique opportunities in these watersheds include:

- Provincial legislation - Since the Task Force began its work, the Ontario Government passed the Oak Ridges Moraine Act and Conservation Plan, which effectively protects a significant area of land for a natural heritage system in the headwaters of the Duffins Creek

- Public land holdings - Federal, provincial, and municipal governments and the TRCA own significant lands in these watersheds and expect to be able to realize watershed plan objectives with public support. For example, in March 2001, Transport Canada identified lands surplus to its needs for an airport and announced that these lands would be protected as greenspace in perpetuity. There may be further lands deemed surplus as airport planning proceeds.

- Private landowner willingness to participate in environmental programs in these watersheds, as has been demonstrated by the significant number of conservation easements that have been established since the watershed planning process began.

Consistency with Great Lakes Basin Management Objectives

The Canada-Ontario Agreement on Great Lakes Water Quality (2002) commits Canada and Ontario to increase natural areas and practice sound watershed management as a means of protecting coastal wetlands and the overall health of the Great Lakes.

4.2 Integral Management Actions

A detailed list of management actions was identified for the achievement of each of the watershed plan's objectives. These actions are presented within the watershed plan document. Following a review of these management actions, it was recognized that a number of them are common, in that they contribute toward the fulfillment of numerous objectives. Certain actions are considered especially important because they have benefits that are realized upstream, downstream, or well beyond their site specific application. These particular management actions are considered to be so important that they are integral to the overall health of the watersheds and should be afforded Top Priority for implementation.

The Integral Management Actions are presented in **Table 4-1.**

Table 4-1: Integral Management Actions

- ✔ Protect existing meadows, wetlands, and forests identified in the targeted terrestrial natural heritage system and secure lands to be restored.
- ✔ Actively restore areas within the targeted natural heritage system, which contribute multiple watershed benefits, and allow passive restoration to occur in the remaining areas.
- ✔ Provide stormwater quantity controls for new and existing development, including transportation corridors.
- ✔ Manage land uses and water withdrawals to maintain or enhance infiltration patterns, groundwater pathways, and resultant baseflows.
- ✔ Eliminate the remaining point source of pollution (i.e. Stouffville Water Pollution Control Plant) and manage non-point sources of pollution, in particular stormwater runoff and infiltration from urban land uses, transportation corridors, and rural contributions.
- ✔ Enforce stringent erosion and sediment controls for construction and infrastructure maintenance activities.
- ✔ Protect and restore natural streams and stream processes by managing runoff and sediment loss at source, and protecting valley and stream corridors, and naturalizing altered streams.
- ✔ Remove and/or mitigate human-built barriers to fish passage and sediment transport, including on-line ponds, where recommended by the Fisheries Management Plan.
- ✔ Maintain self-sustaining, resident/migratory fish and wildlife populations as barometers of a healthy natural heritage system
- ✔ Identify and raise awareness of past and present human influences on the watersheds and the strong link between human heritage, watershed recreation and human and environmental health.

4.3 GIS Based Mapping of the Multiple Benefits of Natural Heritage

Objective of this exercise

As part of the integrated watershed planning process, key management related mapping products from each of the technical study components were correlated with one another in order to identify lands where the protection or restoration of natural heritage cover contributes to the achievement of multiple watershed management goals. The resulting maps were intended to serve two purposes:

1. Provide further rationale and spatial justification for the targeted terrestrial natural heritage system; and

2. Direct initial management activities associated with land securement, outreach/education, and active regeneration and stewardship to areas where the greatest net benefits could be achieved.

The resulting maps illustrate locations in the watersheds where protection and/or active restoration of natural heritage cover would result in additional benefits, above and beyond the goal of protecting and enhancing terrestrial habitats and species.

The maps are strictly intended to be used as a guide, which will be supported by the more detailed technical studies, policies, and criteria.

Method

The various mapping products, or layers of information were correlated by utilizing the data processing capabilities of a Geographic Information System (GIS). For each technical component, a map, or layer of information was generated that delineated all of the portions of the watershed where the protection or restoration of natural land cover would contribute to achieving the primary management goal associated with that component. **Table 4-2** identifies the information layers used for each component. Individual layers are illustrated in **Figures 4-1 (a-g) and 4-2 (a-d)**. Each of these maps or data layers were converted into a common mapping data format, the raster, or "grid" data format, where each grid cell that makes up a layer of information has a value associated with it (i.e., all vector-format maps were converted into raster-format maps using a common grid-cell size). The "grid" data format enables the planner to easily quantify the extent to which overlap occurs between the multiple data layers.

For each map or information layer, a value of 1 was assigned to all grid cells representing portions of the watershed where the presence of natural vegetation cover was identified as having a high potential to contribute to achieving the respective management goal, and a value of zero (0) was assigned to the grid cells representing the remaining portions of the watershed.

Using the overlay and data processing capabilities of the GIS, a new map was generated by overlaying all of the layers and adding the overlapping grid cell values together to generate a common grid. This resulting map can be thought of as a representation of the number of management goals that are addressed by preserving or restoring natural land cover in the areas indicated. Areas where the highest grid cell values occur can be thought of as being where the greatest "net benefits" can be achieved by protecting or enhancing natural land cover.

This map also suggests that areas with high grid cell values that fall outside of areas of existing natural land cover are locations were active restoration of natural land cover would provide the greatest net benefits.

Table 4-2: Layers of Information included in the Management Integration Map: "Multiple Benefits of Natural Heritage Cover"

Management Component	Information layer	Condition	Rationale
Groundwater Quantity and Quality*	**grid surface of the change in groundwater infiltration (GWI) (by sub-catchments) between the "Official Plan with Enhanced Natural Heritage" scenario and the "Existing Conditions" scenario**	**all grid cells where "Existing" GWI values are maintained or enhanced in the "Official Plan with Enhanced Natural Heritage" scenario get a value of 1**	**represents all sub-catchment areas where the targeted terrestrial natural cover contributes to maintaining the existing water balance (through maintaining or enhancing infiltration and evapo-transpiration contributions) and protecting and enhancing groundwater quantity and quality**
Surface Water Quantity*	**grid surface of values for % reduction in 100 year peak flow rate (by sub-catchments) for the "Official Plan with Enhanced Natural Heritage" scenario**	**all grid cells where % peak flow reduction is ≥ 10%**	**represents all sub-catchment areas where the targeted terrestrial system contributes significantly to minimizing risks to human life and property due to flooding, and maintaining natural stream channel stability as a result of the reduced run-off and increased evapo-transpiration rates associated with the enhanced natural cover**
Surface Water Quality	**output of AGNPS modelling identifying Predominant Pollutant Source Areas in terms of suspended sediment loading**	**all areas identified as contributing the greatest portion of the total suspended sediment load during storm events (areas where ≥ 1% of the soil is made up of clay-sided particles) get a value of 1**	**represents areas which contribute the greatest proportion of the total sediment load and where natural land cover would reduce erosion rates.**

Aquatic Habitat and Species (Also addresses Water Quantity and Quality Goals)	**the valley and stream corridor = combination of the fill regulation line and the fill extension line**	**all lands within the stream and valley corridor, as defined by TRCA's Valley and Stream Corridor Management Program, get a value of 1**	**captures the riparian zone, floodplain hydrologic function, streambank and valley slope erosion - all of which benefit from natural cover**
Terrestrial Habitat and Species	**the targeted natural heritage system, as per the "Official Plan with Enhanced Natural Heritage" scenario**	**all lands within the targeted natural heritage system get a value of 1**	**protection or restoration of natural cover in areas identified for the targeted system maintain or improve habitat quality**
Recreational Use*	**existing and proposed trail right of way (5 m buffer on either side of the line)**	**all lands within the right-of-way of existing trails get a value of 1**	**natural land cover along trails adds value to the outdoor recreation experience.**
Human Heritage	**combination of a 250 metre buffer around known archaeological sites and all lands within 250 metres of a waterbody which are located on well-drained soils (represents areas with a high potential for archaeological significance)**	**All lands within the areas of existing or potential archaeological significance get a value of 1**	**Maintaining natural cover on known and potential archaeological site areas protects them in situ.**

*Mapping outputs from the watershed plan components indicated with an asterik were used in the analysis for Duffins Creek watershed only, as these layers of mapping information are not yet available for Carruthers Creek.

It should be noted that, since the design of the enhanced natural heritage scenario did not aggressively pursue gains in natural cover in sub-catchments where urbanization was planned to occur as per the Official Plans, any modelling results drawn upon to form information layers for this "integration map" may not reflect all the potential benefits of natural cover in those subcatchments.

The information layer chosen to highlight lands where there are groundwater management benefits of natural heritage cover is not ideal. By using water budget modelling results of the enhanced natural heritage scenario, this method introduces two limitations: 1) design of the enhanced natural heritage scenario did not aggressively pursue gains in natural cover in sub-catchments where urbanization was planned to occur as per the Official Plans, so the map may not provide a true indication of the potential groundwater benefits of natural cover in these areas; and 2) it is suspected that the water budget model has limitations in its ability to estimate the effects of natural cover on infiltration rates. Furthermore, at this time, the information layer does not address groundwater quality. When improved groundwater management mapping becomes available, the layer of information used to integrate groundwater quantity and quality management will be updated. Improved mapping will involve a combination of the following: aquifer vulnerability areas, well-head protection zones, groundwater discharge areas, and critical groundwater recharge areas. The latter may be delineated with reference to flow path mapping that links sensitive discharge areas and aquifers with recharge areas.

Additionally, this analysis assumes a flat weighting scale where each management component (i.e. input layer of information) is considered to be of equivalent importance or value in the analysis. The assumption of equivalent ratings is not necessarily valid in all cases, as the presence of natural cover in a given area does not always produce equal benefits to water management objectives as to habitat objectives. However, in the absence of a stronger basis upon which to assign a relative rating of value within each management component, an equal rating system was used. This method for identifying areas for active regeneration/stewardship/acquisition and/or enumerating the benefits of integrated management could be refined through the use of weighting factors assigned to each information layer that are based on a mutually agreed upon value system. These weighting factors could be based on watershed issues, concerns, or opportunities identified through characterization studies, issues scoping work, public input (i.e. social values), or economic values in terms of monetary costs/benefits associated with the anticipated outcomes of land use change.

Findings

Duffins Creek

The integrated GIS mapping analysis for Duffins Creek strongly supports the axiom that maintaining or restoring natural land cover in the headwaters of a watershed, and along the valley and stream corridor provides the greatest net benefits to overall watershed health (**Figure 4-3**).

Table 4-3 summarizes the values calculated for the total area of land (in hectares), and the proportion of the total watershed area (% of total) where protecting or restoring natural land cover would address multiple management goals and thereby provide multiple benefits, beyond those related to improving the quality of terrestrial habitat. Based on the degree to which all of the layers of mapping information overlap with one another, it was found that maintaining or restoring natural land cover on a total area of land equivalent to approximately half (49%) of the total watershed area would significantly contribute to three or more management goals. These results help to further illustrate the multiple watershed management benefits that could be achieved by the targeted terrestrial natural heritage system and highlights the importance of planning and implementing management measures using an integrated approach that considers interconnections between all of the components of the natural system.

Carruthers Creek

In the absence of GIS mapping information pertaining to peak flow rates, groundwater infiltration rates, and recreation trails, a similar GIS mapping analysis was conducted for the Carruthers Creek watershed. In this analysis, four layers of mapping information pertaining to findings from the Surface Water Quality, Aquatic Habitat and Species, Terrestrial Natural Heritage, and Human Heritage components of the watershed plan were correlated with one another. As in the Duffins, the output of this analysis generally supports maintaining or restoring natural land cover along the valley and stream corridor (see **Figure 4-4**). It was found that maintaining or restoring natural land cover on a total area of land equivalent to approximately 37% of the total watershed area would significantly contribute to two or more of the four management goals considered in this analysis (**Table 4.3**). This analysis should be repeated in the future when layers of mapping information pertaining to all of the components of the watershed plan are available in order to provide a more detailed analysis and quantification of the benefits derived from the targeted natural heritage system.

Table 4-3: Percent of Watershed Area Where Natural Heritage addresses Multiple Goals

Duffins Creek				Carruthers Creek			
# of goals addressed	Area (ha.)	% of total watershed area	Cumulative % of total watershed	# of goals addressed	Area (ha.)	% of total watershed area	Cumulative % of total watershed
6	246.5	0.9	0.9	4	58.5	1.5	1.5
5	1930.8	6.8	7.7	3	530.7	13.8	15.3
4	4231	14.9	22.6	2	848.5	22.1	37.4
3	7460.1	26.4	49	1	1499.2	39	76.4
2	6049.7	21.4	70.4	0	903	23.5	99.9
1	5070.9	17.9	88.3				
0	3312.4	11.7	100				

Targeted Areas for Active Stewardship, Regeneration and/or Securement

The output of the GIS mapping analysis also provides a means of targeting areas on the Duffins and Carruthers Creek watersheds where management actions to protect and restore natural land cover would result in the greatest net benefits to the natural system, and therefore, where such management actions should be focussed in the immediate future. To demonstrate this, a map was prepared for the Duffins Creek watershed showing only areas where three or more management goals are addressed by the targeted terrestrial natural heritage system (**Figure 4-5**). Areas where the protection or restoration of natural land cover would significantly contribute to achieving multiple management goals were found to be concentrated in and around the valley and stream corridor and in the headwaters areas, with particular emphasis on the sub-catchments of West Duffins Creek, Mitchell Creek, and East Duffins Creek.

For the Carruthers Creek watershed, a map was prepared showing where two or more management goals are addressed (**Figure 4-6**). The areas indicated in these figures can be thought of as generally representing locations on the watersheds where management actions such as promoting stewardship activities in existing natural areas, initiating active restoration on lands where permitted by current landownership/land use, or pursuing protection through securement should be focussed in order to maximize net benefits to the natural system.

Considerations for Future Studies

In future watershed planning processes, this type of exercise should be considered at an interim point in the study process. The results could then be used to design a targeted natural heritage system, where the distribution of natural cover is such that the number of other management goals addressed are maximized while also meeting the terrestrial goals. Then, the technical studies and modelling exercises could undertake a more detailed analysis and quantification of the benefits derived from the targeted natural heritage system.

4.4 Implementation Strategy

The specific management directions were presented in the watershed plan in several user-friendly formats, in an effort to facilitate implementation by multiple partners. The implementation strategy consisted of a set of implementation mechanisms, a model policy framework, and a map illustrating the multiple benefits of natural heritage. The latter mapping product was intended to facilitate or direct initial implementation efforts.

4.4.1 Implementation Mechanisms

Common to many watershed plans in Ontario, key implementation mechanisms include:

- Policy and planning tools
- Regulations and permits
- Stewardship and Regeneration
- Land Securement and Acquisition
- Education and Awareness
- Monitoring and Reporting

The watershed plan identifies specific actions and responsibilities in these areas, and provides supportive mapping, guidelines and criteria, as generated by the technical studies.

4.4.2 Model Policy Framework

A framework of model policies was prepared as part of the watershed planning process to illustrate effective policy approaches which could be used to achieve the watershed plan's objectives. The framework was developed by the Policy Working Group, a sub-committee of the Task Forces, together with TRCA and municipal staff. The framework is based on a review of numerous existing policy documents of the local and regional municipalities within the watershed and leading municipalities from other jurisdictions. The framework borrows heavily on a state-of-the-art provincial environmental policy document, the Oak Ridges Moraine Conservation Plan. The framework was intended to facilitate amendments to Regional and Local Official Plans and operating policies of the municipalities, TRCA, and other watershed implementors that could assist in implementing the watershed plan.

Figure 4-1: Duffins Creek Watershed Integration Map

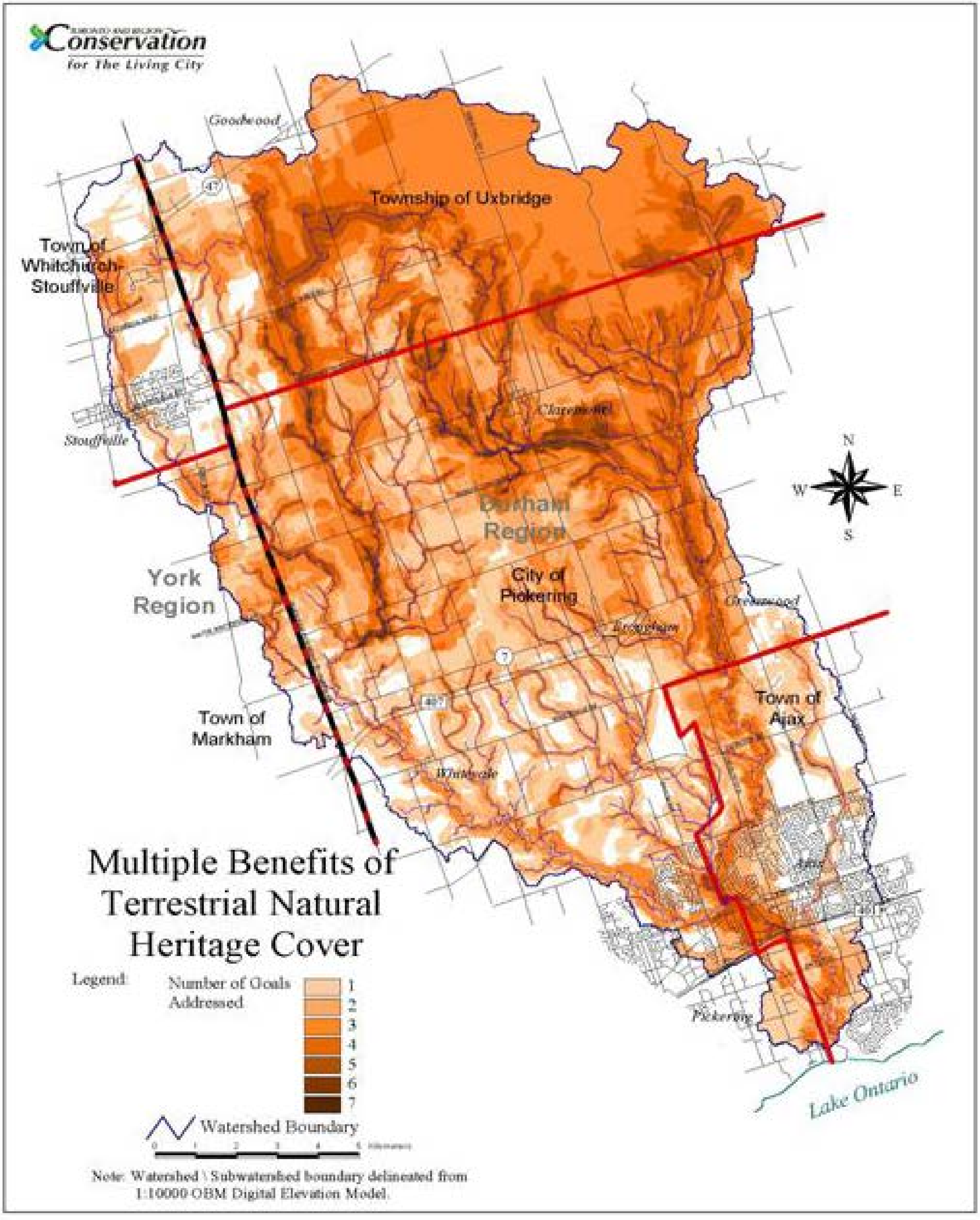


Figure 4-2: Carruthers Creek Watershed Integration Map

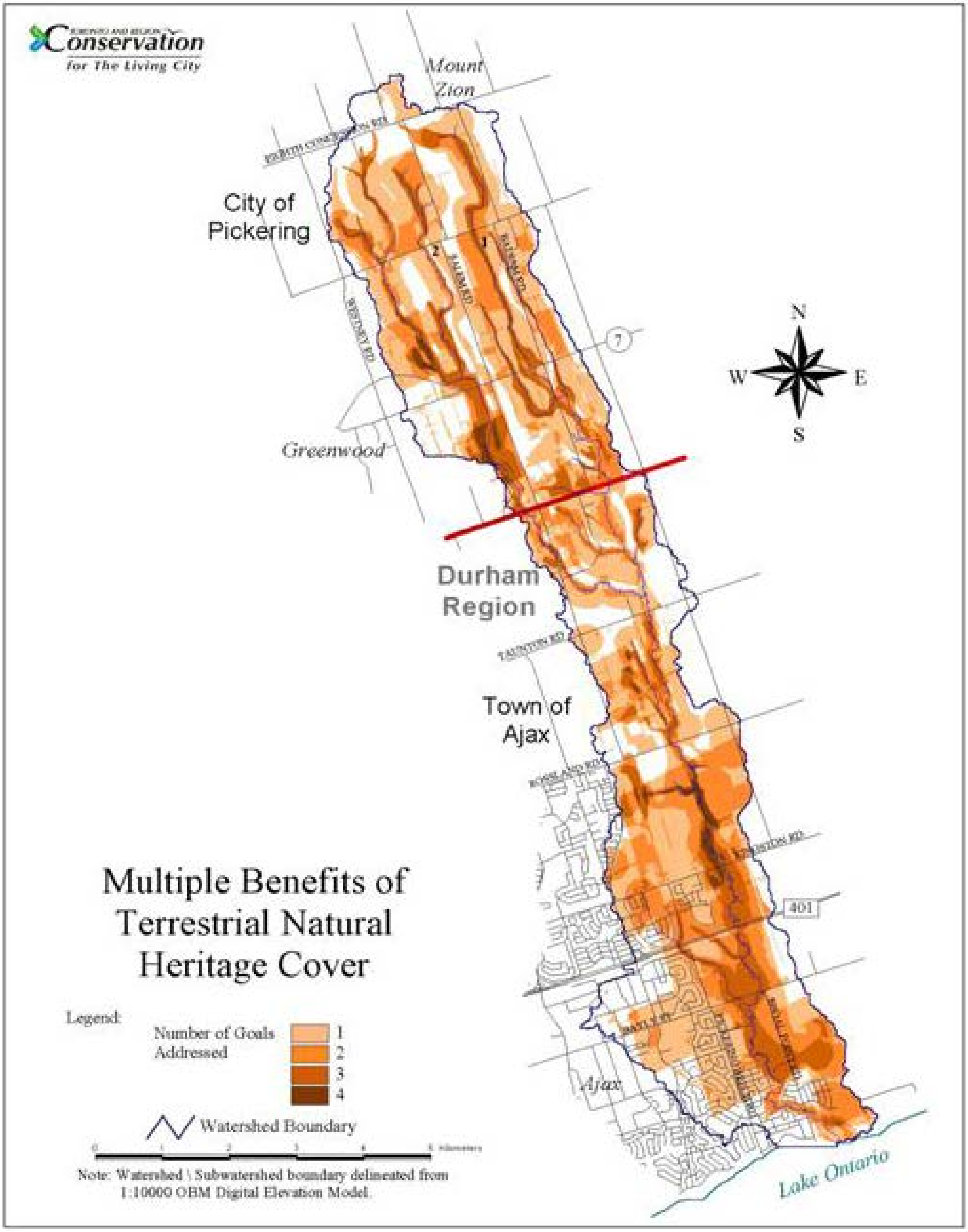


Figure 4-3: Duffins Creek Watershed – Targeted Areas for Active Stewardship, Regeneration and/or Securement

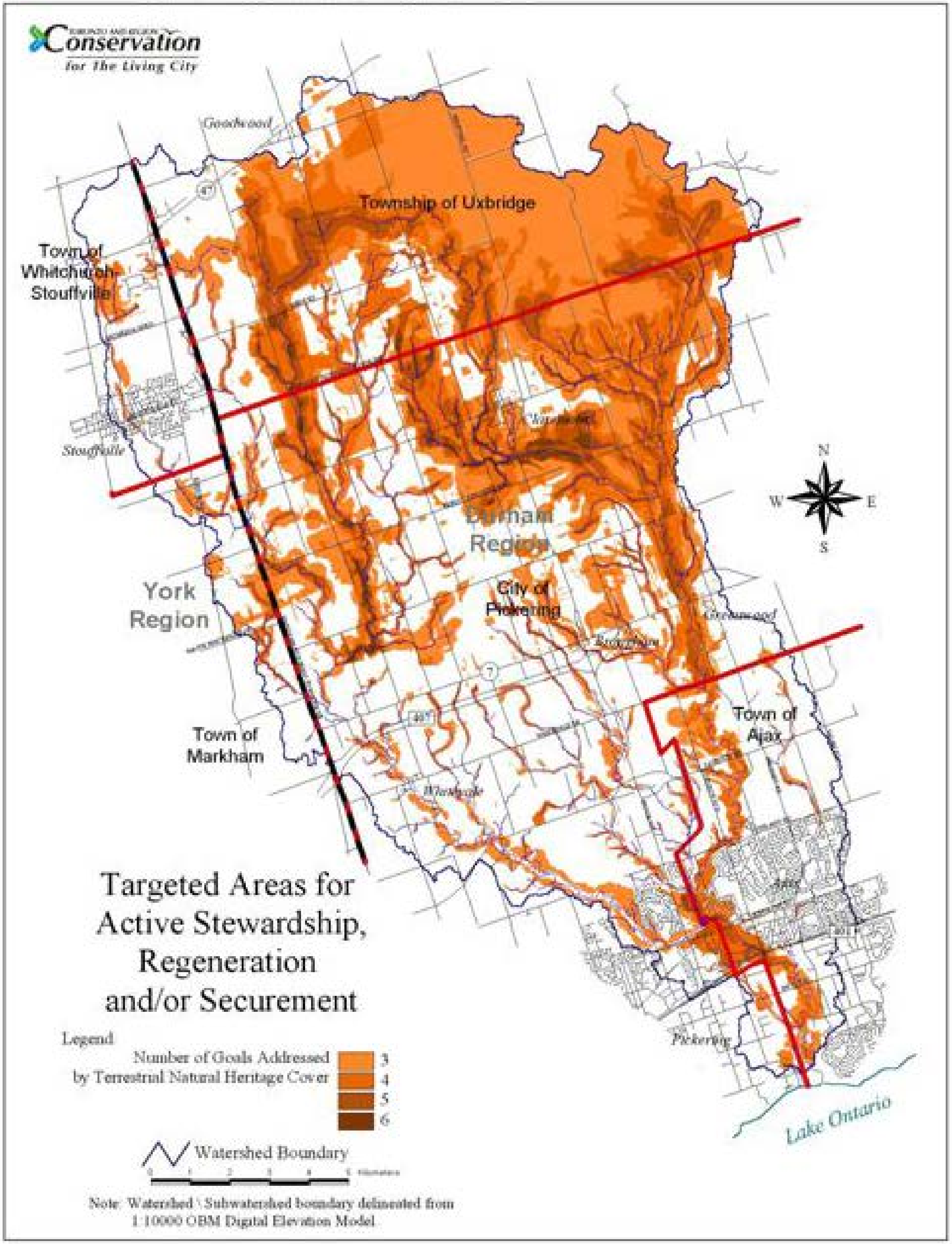
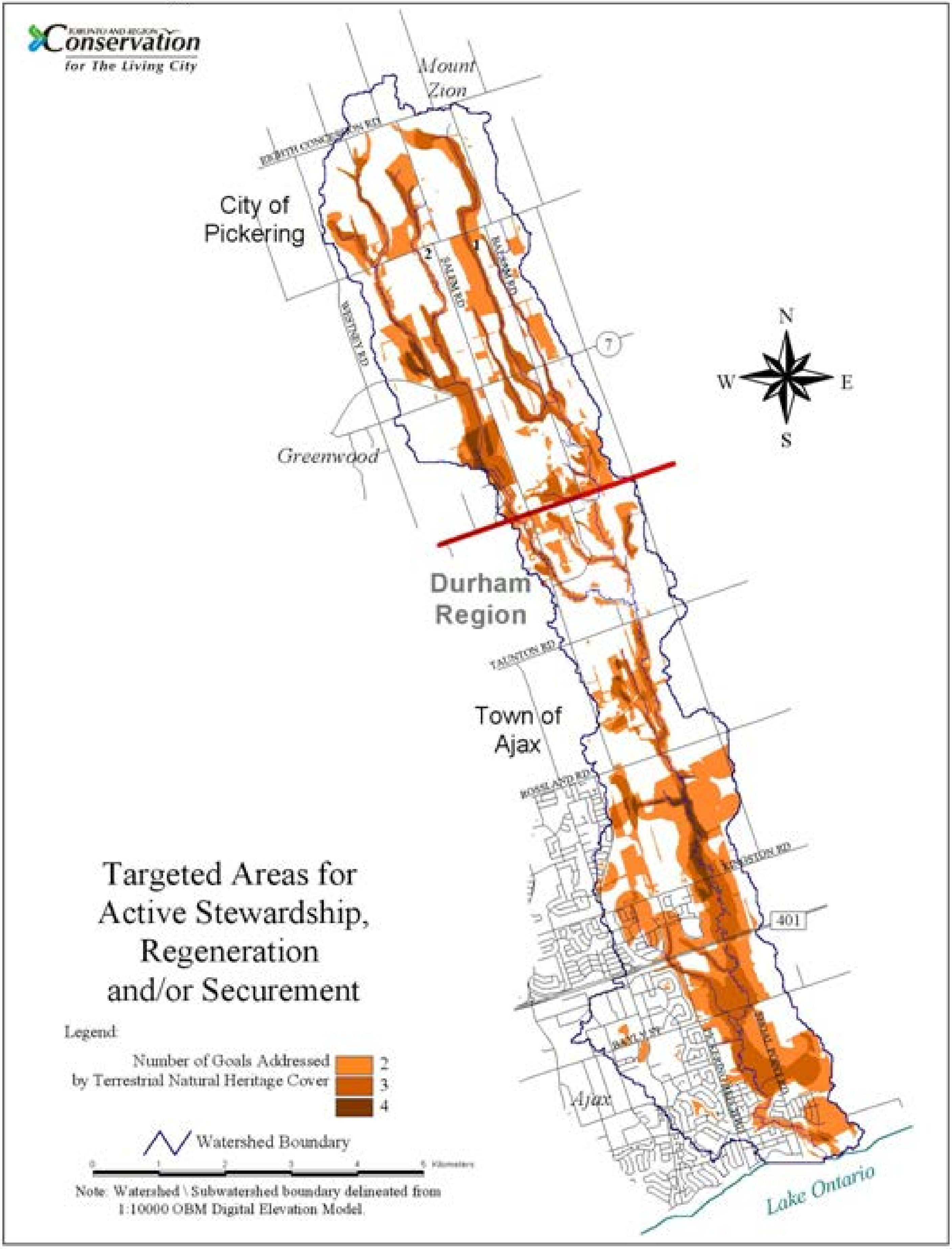


Figure 4-4: Carruthers Creek Watershed- Targeted Areas for Active Stewardship, Regeneration and/or Securement



5.0 PUBLIC CONSULTATION AND PEER REVIEW

5.1 Watershed Task Forces

Continuing its very successful model for empowering watershed stakeholders, TRCA formed two Watershed Task Forces in June 2000 and charged them with the responsibility of developing a Watershed Management Strategy for the Duffins and Carruthers Creek Watersheds over a 24 month term. The Task Forces or their designated Working Groups were presented with proposed technical approaches and findings on a regular basis throughout the process so that they could provide input and guidance. Task Force members helped to ensure that all key issues were being addressed, and that the strategy document that was being developed would be understood and supported by municipal and agency politicians and staff, community groups, business and industry, watershed residents and the general public.

Membership of the two Task Forces consisted of elected municipal representatives, watershed residents, and representatives from key stakeholder groups **(see Table 5-1)**. In each Task Force a citizen member was elected as Chair of the Task Force and a municipal councillor was elected as Vice-Chair. Staff from the planning and engineering departments of local and regional municipalities regularly attended meetings to support their elected representatives. The provincial ministries of Natural Resources and Environment were invited, but declined to participate. Staff from the Ministry of Natural Resources participated in an advisory role on matters pertaining to the preparation of the Fisheries Management Plans. The Task Forces are accountable to the TRCA's Watershed Management Advisory Board (WMAB), and as such minutes and reports from the monthly Task Force meetings were provided to the WMAB.

Table 5-1: Watershed Task Force Membership

Duffins Creek Task Force	Carruthers Creek Task Force
One elected representative from each of: Region of Durham Region of York City of Pickering Town of Ajax Town of Whitchurch-Stouffville Town of Uxbridge Town of Markham Five residents One representative from each: Aggregate Producers Assoc. of Ontario Urban Development Institute Watershed golf courses Transport Canada	One elected representative from each of: Region of Durham City of Pickering Town of Ajax Four residents One representative from each: Aggregate Producers Assoc. of Ontario Urban Development Institute Watershed golf courses Citizens for Carruthers Ministry of Transportation

The two Task Forces and their Working Groups often convened joint meetings and workshops, where they considered technical advice from staff. During 2000-2001, a Land and Water Working Group provided input to the draft State of the Watershed Reports. A Policy Working Group assembled and reviewed existing policy documents at the local and regional municipal level and the new provincial Oak Ridges Moraine Conservation Plan. The Policy Group identified key issue areas and associated "best policy practice" for which watershed policy concepts were to be refined.

During 2001-2002, the Task Forces refocused their Working Groups. The new Strategy Working Group developed the Vision for the two watersheds and reviewed the proposed management strategy framework consisting of goals, objectives, indicators, measures, targets and management actions. TRCA staff consulted with the Strategy Group and the Task Force as a whole on: the choice of alternative land use scenarios to be analysed; the choice of subwatershed units; the overall management philosophies; and development of the final management strategies and policy concepts. The Public Outreach and Education Working Group assisted in promoting the opportunities for public consultation.

5.2 Public and Stakeholder Consultation

Throughout the process, numerous opportunities were provided for key stakeholders and members of the public to share their views on the emerging strategy. Members of the public were invited to comment on watershed issues, vision and proposed management goals, objectives, and approaches at a series of open houses that were held throughout the watersheds during November and December 2001. Open houses were held in the Township of Uxbridge, Town of Ajax, City of Pickering (urban and rural), and the Town of Whitchurch-Stouffville. At those meetings, a commitment was made to return to the public with a refined document in the spring of 2002. In keeping with that commitment, a second round of public open houses was held in Claremont and Ajax and completed in June 2002.

During the 24 month mandate of the Task Forces, TRCA staff and Task Force members also convened an average of 2-3 individual meetings with representatives from each of the key stakeholder groups. These meetings allowed an opportunity to discuss issues and implications of the strategy that pertained to the specific interests of each group. Four meetings were held with the agricultural and golf course communities. Two meetings were held with the Durham Chapter of the Urban Development Institute. Separate meetings were also held with municipal staff, Environmental Advisory Committees, Green Door Alliance, Uxbridge Conservation, Durham Conservation, Uxbridge Naturally, and Citizens for Carruthers.

5.3 External Technical Peer Review

Prior to the formation of the Task Forces, TRCA established a Technical Advisory Committee (TAC) in 1999 to oversee the initial scientific studies that contributed to the development of the State of the Watershed Reports and set the stage for the ensuing technical analysis and integration process. The TAC consisted of scientists and experts from federal, provincial, and municipal governments, academia, and the consulting field. TAC members examined groundwater, surface water, terrestrial and aquatic resources information, climate change, and land use planning for the Duffins and Carruthers Creek Watersheds. Although this Technical Advisory Committee discontinued formal meetings as a group, once the Task Forces were established, individual expertise from the committee was called upon on an ad hoc basis throughout the study.

Although the Task Force members and watershed stakeholders possessed a significant and somewhat unique level of technical expertise, which they shared throughout the process, TRCA and Task Force members convened a final peer review workshop near the end of the process (April, 2003) to obtain expert feedback on the strengths and weaknesses of the technical analysis and integration process and the resulting watershed plan. Prior to the workshop, participants were invited to review the final draft reports. A professional facilitator was hired to facilitate the discussion. The workshop was attended by 22 participants with expertise in watershed planning and associated disciplines from a variety of sectors, including conservation authorities, universities, government agencies, consultants, and power generation. A number of TRCA staff members who had been involved in the plan's development also took part in the workshop in a resource capacity.

Feedback from the peer review workshop can be summarized as follows:

- *The watershed response model used to guide the technical analysis and integration process was described as state-of-the-art.*

- *The integration process represents a major step forward, particularly in the links between surface and ground water models and between natural heritage cover and water management.*

- *The need to rely on professional judgement as a predictive tool for changes in aquatic habitat and species is a weakness, but it was acknowledged that there are no current models available for use in this area. Practitioners were cautioned against placing too much reliance on the baseflow to total flow ratio, as it may not be very sensitive to changes imposed by water withdrawals (i.e. they affect both the nominator and denominator).*

- *Water budget modelling is a key strength of this study. Future studies should address the significance of closed drainage storage systems on local water balance and the effects of lawn watering in areas to be supplied by Lake Ontario water sources. A significant difference was noted between recharge rates generated by the water budget model, which relies on soil/land use data, and the groundwater flow model, which relies on surficial geology, with the recommendation that the source of these differences be investigated.*

- *More attention should be given to recreational fishing usage and associated values within the watershed and on the impacts of sport fishing on game fish.*

- *The plan was found to be well communicated to the public and the "buy in" of watershed partners was noted.*

- *The framework of goals, objectives, indicators, measures, and targets is very good. It provides a clear description and benchmark against which to measure progress.*

- *Sustainability concepts need to continue to be developed, as part of watershed plans.*

- *Clarify the scale over which the targets are to be met, as part of the preparation of user-friendly implementation policies and guides.*

Overall, workshop participants agreed that the Duffins and Carruthers technical process and plan has advanced the state-of-the-art in integrated watershed planning, but that similar to other jurisdictions, further work is needed to refine predictive tools, particularly in the area of aquatic resources, and to translate science into policy.

The outcome of the workshop will be used to identify further work needed to supplement the existing knowledge base for the Duffins and Carruthers Creek Watersheds and to guide TRCA as it designs its next integrated watershed management approach.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Key management issues in the Duffins and Carruthers Creek Watersheds are associated with urban growth, the potential development of a regional airport, the ongoing stewardship needs associated with existing agricultural and urban land use activities, and the protection of existing natural lands. Alternative land use scenarios were defined for further analysis, including existing, future, and future land use with enhanced natural heritage cover.

Technical studies were conducted to develop benchmarks of watershed condition in response to these alternative land use and management scenarios. Results were evaluated according to defined watershed management objectives, indicators, measures and targets.

An innovative integrated approach was followed when undertaking the technical studies, in that common units and scales of study were defined, opportunities for communication and information exchange among study teams were provided, and the resulting primary management directions were correlated. Based on the results of the technical studies and other management considerations, the Task Forces recommended that the most effective approach for amanging these watersheds would involve achievement of the target terrestrial natural heritage system together with the application of state of the art management practices.

The technical studies repeatedly demonstrated the multiple watershed management goals addressed by the protection and enhancement of terrestrial natural heritage cover. A GIS-based mapping technique was used to illustrate this finding. The map product was further interpreted to show areas targeted for active stewardship, regeneration and/or acquisition activities. This tool will assist in directing initial implementation efforts.

The technical studies have generated a valuable set of data, modelling tools, information, and criteria that will greatly assist in the future management of these watersheds.

This study advanced the state-of-the-art in integrated watershed planning studies, but much work remains to be done to further refine predictive modelling tools and develop relationships, particularly in the areas of aquatic resources, recreation, and human heritage links to changes in terrestrial natural heritage cover and subsequent impacts on the watershed water systems.

6.2 Study Limitations and Recommendations for Further Work

Further studies and applications of the available modelling tools within the Duffins and Carruthers watersheds

- verify the database on actual surface and ground water use

- develop long term water use projections for all water users

- re-run the Water Balance Model and Groundwater Flow Model, and interpret the results according to water quality and aquatic resource management objectives, once improved databases on actual water use and long term water use projections are available

- develop climate change scenarios and re-run the models to evaluate potential watershed management concerns

Initiatives to Guide Implementation of the Watershed Plan

- develop a road salt management strategy for ORM municipal roads

- undertake more intensive monitoring of the impacts of urban development in the Seaton community and the Regional Airport (if built), to track watershed changes and the effectiveness of watershed plan recommendations. Groundwater infiltration and stream baseflow and temperature should be a monitoring focus.

Refinement of Predictive Tools and Science of Integrated Watershed Planning

- develop improved predictive tools for evaluating the response of the aquatic community to changes in watershed hydrology, etc. (i.e. refine the relationships between aquatic community composition and changes in baseflow, flow, temperature, and water quality)

- develop improved predictive tools for assessing impacts of recreation on the terrestrial natural heritage system (i.e. for defining recreational carrying capacity)

- develop methods for valuing the benefits of watershed management

This body of technical work and the integrated watershed plan it supports provide a blueprint for the management of a sustainable watershed and its community. There is a further need for innovation in the application of sustainable living practices and in the planning for sustainable communities that will be necessary to fully realize the objectives of the plan and apply the knowledge developed thus far.

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APPENDIX A

Summary Evaluation of Study Findings According to Watershed Management Objectives, Indicators, Measures, and Targets

Surface Water Quantity

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: to maintain the existing hydrologic function of the watershed						
1. Maintain the existing water balance within the watershed.	• Watershed hydrology (as measured by sub-catchment)	• Total annual infiltration rate (mm/yr) • Run-off volume (m^3/yr) • Seasonal and annual baseflow (m^3/yr) at indicator sites	• Maintain or reduce baseline run-off volume • Maintain or reduce baseline run-off volume • Maintain or enhance baseline seasonal and annual baseflows	Existing	The hydrologic response of the Duffins and Carruthers Creek watersheds reflect non-urbanized conditions, or watersheds that are predominantly under a combination of rural/agricultural land use and natural land cover, with a minor amount of urban development (7% urban land use in Duffins Creek and 13% in Carruthers Creek). In the Duffins Creek watershed, the water balance model output is as follows: 58% evapo-transpiration, 24% Groundwater Infiltration (GWI), and 17% run-off. A water balance model for Carruthers Creek is scheduled to be developed in 2003/04.	
				Future (OP)	Total annual run-off volume would increase by an estimated 3% and evapo-transpiration would decrease by 2% with uncontrolled development as a direct result of higher imperviousness and reduced vegetation cover. A 1% reduction in GWI is predicted to occur. Impacts associated with this change would be significant at the subwatershed level. Modelled reductions in baseflows would range from 0 to 26% when examined on a subwatershed basis.	Analysis to be completed following water balance model completion and hydrology model update in 2003/04. Similar responses would be expected as predicted in the Duffins watershed.
				Future (OP) + Enhanced Natural Heritage	This scenario would result in a smaller increase in run-off (2%) and a smaller decrease in evapo-transpiration (1%) than the Future (OP) scenario due to the increased vegetation cover. Due to limitations within the current state-of-the-art water budget tool, this scenario is predicted to result in lower GWI than the Future (OP) scenario.	Analysis to be completed following water balance model completion and hydrology model update in 2003/04. Given the relatively small increases in natural cover on the watershed scale and limitations of the model, it is not expected that significant responses could be modelled.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
2. Maintain or enhance baseflows	• Baseflow	• Seasonal and annual baseflow (m^3/yr) at indicator sites	• Maintain or enhance baseline seasonal and annual baseflows	Existing	In general, baseflow in Duffins Creek remains continuous for the majority of the reaches in the watershed throughout the year. The Duffins Creek watershed baseflow assessment shows that the majority of the overall system baseflow is split between the East Branch (57 %), and the West Branch (38 %) of the creek, with the combined contributions of Urfe, Ganatsekiagon and Millers Creek subwatersheds contributing the remaining flow (5 %). Known surface water takings represent a maximum withdrawal of about 5% of annual baseflow for the overall watershed. Reesor Creek and West Duffins are most impacted with withdrawals of up to 17%.	In the Carruthers baseflow contributions are evenly distributed along its length. Baseflow losses were observed along the Lake Iroquois shoreline where porous sands and gravels become exposed. Surface water takings are occurring in this watershed to a greater extent than in the Duffins. Continuous stream flow data and additional baseflow monitoring data from indicator sites is needed to better characterize typical low flow conditions. A permanent stream flow gauge was installed in Carruthers Creek in 2002 to address this information deficiency. There are no active permits to take water. Permit applications under review have the potential to cause detrimental effects.
				Future (OP)	Modelled reductions in baseflows would range from 0 to 26% when examined on a subwatershed basis. Baseflow reductions by sub-watershed are modelled as; the Lower Duffins (26%), Ganatsekiagon (17%), Urfe (14%) and Millers Creeks (4%). Little change would be anticipated within the East (1%) or West branches (3%) which contribute the majority of the overall baseflow.	Analysis to be completed following water balance model completion 2003/04 and upon availability of improved records of water users and projected needs.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP) + Enhanced Natural Heritage	Due to limitations in the current state-of-the-art water budget tool, this scenario is predicted to result in slightly lower Groundwater Infiltration than the Future (OP) scenario and this effect may in turn reduce baseflow. This is deemed to be more a reflection of the tool's limitations as opposed to a true reflection of how additional vegetative cover would affect GWI and baseflows.	Analysis to be completed following water balance model completion 2003/04 and upon availability of improved records of water users and projected needs.
3. Minimize or reduce risks to human life and property due to flooding	• Number of flood vulnerable areas (FVAs) and flood vulnerable roads (FVRs)	• Peak flow rate (unit flows) • Water level (floodlines) • Number of Flood Vulnerable Areas (FVA) and Flood Vulnerable Roads (FVR) • Ice jams (frequency and location)	• Maintain baseline peak flows (2-100 year and Regional control if required) • Maintain baseline water levels (floodlines) • Reduce or as a minimum maintain the baseline number of FVAs and FVRs (and the design storm frequency at which they flood) • Develop and maintain documentation of the number of sites and frequency of ice jams	Existing	Existing peak flow rates are described by the newly updated Duffins Hydrology Model (Aquifor Beech Ltd.,2002). Existing floodlines are based on future scenario peak flows from the 1991 Duffins Creek Hydrology by Aquafor Beech. The current FVAs and FVRs are based on these floodlines. The number of FVAs and FVRs will be updated based on the forthcoming floodplain mapping updates based on the 2002 peak flows (Marshall Macklin Monaghan, 2003).	An updated hydrology model is scheduled for completion for the Carruthers Creek watershed in 2003/04, which will be the basis for establishing baseline peak flow rates, flood lines, and FVA/FVRs. Existing floodlines are based on future scenario peak flows from the 1999 Carruthers Creek Hydrology Update by Totten Sims Herbieki. The current FVAs and FVRs are based on these floodlines.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP)	Peak flow rates would increase in this scenario between 15% and 120% for the 100 year event, for subcatchments that have future urban development area. Floodlines will be updated based on the future scenario peak flows for the regional storm from the newly updated Duffins Hydrology Model (Aquafor Beech Ltd, 2002) in the forthcoming floodplain mapping updates in 2003. As regional storm peak flows have decreased from the 1991 Hydrology model, floodlines are expected to possibly decrease as well as the number of FVAs and FVRs.	Analysis to be completed following the hydrology model update in 2003. Updated floodplain mapping is scheduled for 2004, which would be the basis for new floodlines, FVAs and FVRs.
				Future (OP) + Enhanced Natural Heritage	Peak flow rates would increase in this scenario between 10% and 110% for the 100 year event, for subcatchments that have future urban development area. This scenario also results in a number of subcatchments having peak flow decreases that are expected to be approximately 0% to 25% less than existing flows for the 100-year event. If peaks flows for the regional storm from this scenario were used in the floodplain mapping updates, further possible decrease in floodlines, FVAs and FVRs could be expected.	Analysis to be completed following the hydrology model update in 2003.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
4. Maintain or restore natural stream channel stability	• In-stream erosion	• Erosion index • Percent of developed area that has adequate erosion controls in place (according to 2003 criteria) • Rate of erosion at indicator sites	• Maintain baseline erosion index • 100% of developed area with adequate erosion controls in place • Maintain or reduce the baseline rate of erosion	Existing	Studies to determine the baseline erosion index, establish erosion control criteria for SWM facilities, and to determine the baseline rate of erosion at indicator sites are scheduled for completion in 2003.	Baseline erosion index and erosion control criteria have been established for the A8 Secondary Plan area, which represents most of the future urban growth in the Town of Ajax.
				Future (OP)	Erosion rates will increase with future development if no stormwater controls are put in place.	Erosion rates will increase with future development if no stormwater controls are put in place.
				Future (OP) + Enhanced Natural Heritage	Erosion rates will increase without controls but not as drastically as in the OP scenario.	Erosion rates will increase without controls but not as drastically as in the OP scenario.

Groundwater Quality and Quantity

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
GOAL: to protect groundwater quality and quantity						
5. Maintain or enhance groundwater levels and baseflow for watershed functions	• Water table level • Aquifer water level elevations • Baseflow	• Water table levels at indicator sites • Piezometric surfaces at indicator sites • Seasonal and annual baseflow	• Establish and maintain baseline water table levels • Maintain baseline piezometric surfaces • Maintain or enhance baseline seasonal and annual baseflows	Existing	Groundwater levels are monitored regularly at six nested piezometer locations within the Duffins Creek watershed, providing a database of natural groundwater fluctuations over various temporal scales. Existing data shows no long term decline in water levels. Baseflow surveys have been conducted in 1995 (Geological Survey of Canada) and 2001 (TRCA). Groundwater discharge contributing to baseflow occurs mainly along the south flank of the Oak Ridges Moraine as well as along and south of the Lake Iroquois shoreline.	No groundwater monitoring stations are located within the Carruthers Creek watershed. Trends observed in data obtained from the six locations on the Duffins Creek watershed will be considered to be generally reflective of groundwater conditions within the Carruthers Creek watershed.
				Future (OP)	The estimated reductions in Groundwater Infiltration (GWI) associated with this land use scenario are predicted to reduce aquifer water levels and baseflow. It is predicted that water table elevations will be reduced by up to 8 metres in subwatersheds subject to urbanization. Areas most sensitive to reductions in GWI include the south slope till plain. The predicted decline in water table levels over this area is greater than for areas of sand and gravel because of the lower effective porosity and permeability of the till, silt and clay deposits.	A water balance model is not yet completed for Carruthers Creek watershed, which prevents predictions to be made with regard to Groundwater Infiltration (GWI) associated with future land use scenarios. Continuous stream flow data being collected in 2002/03 will be used to develop and calibrate the Carruthers Creek water balance model. In general, it is predicted that increased urban land use will result in reduced water table elevations and annual baseflow volumes.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP) + Enhanced Natural Heritage	Using the water balance model outputs, the estimated changes to Groundwater Infiltration (GWI) from increasing vegetation cover is negligible, therefore this scenario was not modelled using the numerical groundwater flow model. Predicting the impacts of reforestation on groundwater recharge is uncertain at this time, as examples from scientific literature predict both increases and decreases in recharge under different site conditions.	Predicting the impacts of reforestation on groundwater recharge is uncertain at this time, as examples from scientific literature predict both increases and decreases in recharge under different site conditions.
6. Protect groundwater quality to ensure provision of safe water supplies and ecological functions	• Groundwater chemistry	• Chlorides • Nutrients • Total Organic Carbon (TOC) • Phenols • Conductivity • Metals • pH • Bacteria • Parameters in MOE Ontario Drinking Water Standards	• MOE Ontario Drinking Water Standards	Existing	Groundwater quality regionally within these basins appears to be good, with local quality concerns attributed to occurrences of nitrates and bacteria associated with septic system effluent entering private wells and high chloride concentrations above Ontario Drinking Water Standard criteria (250 mg/L) occurring in private wells situated near salted roadways (Gerber Geosciences Inc., 2003).	
				Future (OP)	No predictions were made with regard to changes to groundwater quality associated with this land use scenario.	
				Future (OP) + Enhanced Natural Heritage	No predictions were made with regard to changes to groundwater quality associated with this land use scenario.	
7. Ensure sustainable rates of groundwater use	• Water table levels • Aquifer water levels • Baseflow • Groundwater withdrawals	• Water table levels at indicator sites • Piezometric surfaces at indicator sites • Seasonal and annual baseflows • Maximum annual volume of groundwater withdrawal permitted by active MOE Permits To Take Water	• Establish and maintain baseline water table levels • Maintain baseline piezometric surfaces • Maintain or enhance baseline seasonal and annual baseflows • Sustainable rate of groundwater use to be determined pending further study	Existing	The majority of the water wells within the Duffins and Carruthers Creek watersheds are for private potable supplies, which typically involve less than 175 L/person/day and discharge to the groundwater system via tile beds. However, larger scale users, including golf courses (irrigation), municipal water supplies, and commercial enterprises do have PTTWs on file with the MOE (Gerber, 2002). The largest active PTTW in these two watersheds is the municipal water supply for the Town of Whitchurch-Stouffville (4,000 m^3/day), which draws water from the upper and middle aquifers. This volume of groundwater represents approximately 29% of the total streamflow in Stouffville Creek and 2% of the total streamflow in Duffins Creek (Gerber, 2002).	

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP)	Comprehensive assessments of water use in these watersheds are required to properly establish existing conditions and to predict the response of the natural system to future land and water use scenarios. The Region of Durham is currently conducting a water use assessment for the entire region, which is scheduled for completion in 2003.	
				Future (OP) + Enhanced Natural Heritage	Comprehensive assessments of water use in these watersheds are required to properly establish existing conditions and to predict the response of the natural system to future land and water use scenarios. The Region of Durham is currently conducting a water use assessment for the entire region, which is scheduled for completion in 2003. Furthermore, improvements in the state-of-the-art water balance modelling tool will enhance the ability to estimate changes in groundwater infiltration and subsequently groundwter levels.	

Surface Water Quality

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: to protect and improve surface water quality						
8. Manage the quality and quantity of runoff from rural and urban areas to maintain in-stream uses.	• In-stream water chemistry • Stormwater management (SWM)	• Concentrations of nutrients (phosphorus and nitrogen), suspended solids, bacteria, chloride • Annual loads of suspended sediment and phosphorus • Percent of developed area within watershed having adequate stormwater controls in place (both quantity and quality control)	• Concentration targets (PWQO or other guideline): • Total P <0.03 mg/L • NO_2 < 0.06 mg/L • TSS < 30 mg/L • Bacteria < 100 counts/100 mL • Chlorides < 250 mg/L • Unionized NH_4 < 0.02mg/L • Maintain annual loadings at or below the targeted "background annual load" • Stormwater management - 100% of area having Level 1 water quality control (80% TSS removal) for all new and retrofitted development	Existing	Elevated P, TSS and bacteria levels, particularly during wet weather periods, attributed to various urban and rural non-point sources. Wet weather load is 13 times higher than the dry weather load. 62% of existing urban areas in the watershed have no stormwater treatment measures in place.	Elevated P, TSS and bacteria levels, particularly during wet weather periods, attributed to various urban and rural non-point sources. Wet weather load is 20 times higher than dry weather load. 29% of existing urban areas in the watershed have no stormwater treatment measures in place.
				Future (OP)	TSS wet weather loads increase by 25% TP wet weather loads increase by 23% Cl wet weather loads increase by 45% Although pollutant concentrations don't very much, loads increase due to increased volume of runoff.	TSS wet weather loads increase by 23% TP wet weather loads increase by 22% Cl wet weather loads increase by 46% Although pollutant concentrations don't very much, loads increase due to increased volume of runoff.
				Future (OP) + Enhanced Natural Heritage	TSS wet weather loads increase by 15% TP wet weather loads increase by 11% Cl wet weather loads increase by 24% Increased area of natural cover helps moderate the adverse effects of urban development on water quality.	TSS wet weather loads increase by 21% TP wet weather loads increase by 18% Cl wet weather loads increase by 40% Increased area of natural cover helps moderate the adverse effects of urban development on water quality.
9. Minimize in-stream sediment associated with construction activity	• Compliance with Municipal Erosion and Sediment Control Bylaws	• Percent of construction permits found to be in compliance with Municipal Erosion and Sediment Control By-laws • Percent of sediment ponds checked annually • Percent of sediment ponds maintained when required	• 100 % compliance with approved permits under Municipal Erosion and Sediment Control By-laws • 100% of sediment ponds checked annually • 100% of sediment ponds maintained when required	Existing	Currently, Erosion & Sediment Control By-Laws have been implemented in the Municipality of Ajax and are lacking in the remaining municipalities within the watershed.	Currently, Erosion & Sediment Control By-Laws have been implemented in the Municipality of Ajax and are lacking in the remaining municipalities within the watershed.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP)	Estimates cannot be made until Bylaws are in place and data in compliance rates are available.	Estimates cannot be made until Bylaws are in place and data in compliance rates are available.
				Future (OP) + Enhanced Natural Heritage	Estimates cannot be made until Bylaws are in place and data in compliance rates are available.	Estimates cannot be made until Bylaws are in place and data in compliance rates are available.
I0. Reduce water quality contamination associated with wastewater discharges	• In-stream water chemistry • Effluent quality • Sewage treatment plant bypasses	• Phosphorus levels in stream due to sewage treatment plant • Sewage treatment plant effluent quality • Number of sewage treatment plant bypasses	• In-stream phosphorus concentration due to sewage treatment plant should meet PWQO (0.03 mg/L) for all flow levels upon leaving sub-catchment (i.e. at 8th Concession and Reesor Creek) • Sewage treatment plant effluent quality meets Certificate of Approval • Zero sewage treatment plant bypasses	Existing	Phosphorus levels attributed to plant effluent exceed the Provincial Water Quality Objectives in the Reesor Creek tributary and 8th Concession about 25% of the monthly average flows and in the West Duffins Creek at Green River during extreme low flow conditions. .	Not applicable*
				Future (OP)	The Stouffville STP is scheduled to be decommissioned in 2003. A decrease in Phosphorus concentration is expected.	Not Applicable*
				Future (OP) + Enhanced Natural Heritage	The Stouffville STP is scheduled to be decommissioned in 2003. A decrease in Phosphorus concentration is expected.	Not Applicable*

* There are no point source discharges of Sewage Treatment Plant effluent in Carruthers Creek.

Aquatic Habitat & Species

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: to protect aquatic habitat and species						
11. Protect and restore native aquatic species and communities.	• Fish and invertebrate communities • Instream habitat • Water chemistry • Fish passage to critical habitat (breeding, rearing, foraging grounds)	• Invertebrate indices • Index of Biotic Integrity (IBI) • Indicator species and abundance • Percent instream woody cover • Per cent riffle substrate • Ratio of baseflow to total annual flow • Water temperature • Total Suspended Solids (TSS) • Phosphorus • Chlorides • Presence of instream barriers	• To be determined pending further study • Minimum IBI of "Good" • Maintain/achieve historical distribution of targetted indicator species (as specified for reach in Fish Mgmt. Plan) • To be determined pending further study • To be determined pending further study • As specified for reaches in FMP • As specified for reaches in FMP(*) • Only strategic barriers for fisheries management to remain	Existing	Median IBI score of "Fair" stream quality indicates that there are some issues relating to the health of aquatic habitat, however, there were few stations with "good" stream quality. In terms of the presence of indicator species, there is a good diversity of cold water species of fish that have been observed. Three indicator species not found in 2000 were redside dace, Atlantic salmon and smallmouth bass. Reintroduction of Atlantic salmon is a long term goal. Water chemistry conditions are generally good throughout the watershed. Poorer water chemistry conditions are found in more developed areas of the watershed. Three existing barriers (west of Church St., north of Whitevale Rd. On the West Duffins Creek, north of Highway 7 on East Duffins Creek) are to remain as fisheries management barriers. Numerous barriers in headwater areas have thermal and fish passage impacts. Ratio of baseflow to total annual flow considered to be "good" on average for the lower Duffins creek, and generally high in many reaches.	Median IBI score of "fair" stream water quality indicates that there are some issues relating to the health of aquatic habitat. Indicator species not found in 2000 were brook trout and smallmouth bass. Additional surveys should be done to assess the presence of smallmouth bass. Reintroduction of brook trout is a long term goal. Water chemistry conditions are generally good throughout the watershed. Poorer water chemistry conditions are found in more developed areas of the watershed. Barriers concentrated north of Taunton Road likely have thermal and fish passage impacts. .

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP)	Ratio of baseflow to total annual flow is predicted to decrease with the most significant changes occuring in sub basins where urbanization will occur. The resultant increase in water temperature and loss of habitat may cause a shift to warm water tolerant fish communities in certain basins. Duration and frequency of elevated TSS and Chloride concentrations could be of concern, especially downstream of urbanizing areas. Typically as areas are developed aquatic health decreases ut these changes were not modelled for the other measures.	Duration and frequency of elevated TSS and Chloride concentrations could be of concern, especially downstream of urbanizing areas. Typically as areas are developed aquatic health decreases but these changes were not modelled for the other measures.
				Future (OP) + Enhanced Natural Heritage	Ratio of baseflow to total annual flow is predicted to increase sub basins with enhanced natural cover. As only limited to no enhanced cover was assumed in the sub basins identified for urban development and due to the localized groundwater system in these areas, the scenario is not expected to moderate the decreases in the ratio under the future scenario. Typically as areas are developed aquatic health decreases but these changes were not modelled for the other measures. Achievement of Natural Heritage goals will help ameliorate impacts from development.	Typically as areas are developed aquatic health decreases, but these changes were not modelled for the other measures. Achievement of Natural Heritage goals will help ameliorate impacts from development.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
12. Protect and restore the riparian zone and associated functions.	• Riparian zone vegetation	• Percent of total stream bank length with riparian vegetation cover • Percent of total stream bank length with woody riparian vegetation cover	• 100% coverage with riparian vegetation • Minimum 75% coverage with woody vegetation	Existing	76% of total stream bank length with riparian vegetation (all categories except Bare). 51% of total stream length with woody riparian vegetation cover (Forest and Successional categories only). Achievement rating of "Fair".	75% of total stream bank length with riparian vegetation (all categories except Bare). 42% of total stream length with woody riparian vegetation cover (Forest and Successional categories only). Achievement rating of "Poor".
				Future (OP)	Additional development will likely mean loss of riparian vegetation.	Additional development will likely mean loss of riparian vegetation.
				Future (OP) + Enhanced Natural Heritage	Loss of riparian vegetation still occurs in urbanized areas. Gains in riparian cover in upstream areas where Natural Heritage System is increased.	Loss of riparian vegetation still occurs in urbanized areas. Gains in riparian cover in upstream areas where Natural Heritage System is increased.
13. Maintain or restore the natural variability of annual and seasonal stream flow	• Stream hydrograph (annual and seasonal variation in hydrological regimes).	• Flow events (timing, duration, frequency, and rate of change)	• To be determined with consideration for maintaining or restoring historical variability of the hydrograph, and consideration of the timing of flows with respect to sensitive life cycle requirements of aquatic communities	Existing	Further study required to predict the timing, duration, frequency and rate of change of flow events.	Further study required to predict the timing, duration, frequency and rate of change of flow events.
		• Ratio of baseflow to total annual flow		Future (OP)	Modeling suggests impacts to the ratio of baseflow to total annual flow in developing sub-basins.	N/A
		• Ratio of seasonal baseflow to total seasonal flow		Future (OP) + Enhanced Natural Heritage	Modeling suggests impacts to the ratio of baseflow to total annual flow in developing sub-basins and some improvements in areas with increased natural cover.	Further study required

(*) Reach-specific targets will be specified in the Fish Management Plans, based on literature-supported physical and chemical requirements associated with each indicator species/community.

Terrestrial Habitat and Species

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: to protect and enhance terrestrial habitat and species						
14. Increase the percent natural cover to a quantity which provides targeted biodiversity and supports recreational uses	• Quantity • Distribution • Size • Shape	• Percent natural cover • Distribution of the natural cover in relation to total watershed area (distance- to-centroid) • Average patch size scores • Average patch shape scores	• ≥ 49% in Duffins Creek and, ≥30% in Carruthers Creek • ≤2351 m for Duffins Creek ≤1750 m in Carruthers Creek • ≥ 3.87 in Duffins Creek and, ≥ 2.89 in Carruthers Creek • ≥2.79 in Duffins Creek and ≥1.89 in Carruthers Creek	Existing	37% natural land cover 992 m distance to centroid 2.23 average patch size score 1.621 average patch shape score Existing conditions provide good habitat potential, but improvements are needed to achieve biodiversity targets.	28% natural land cover 784 m distance to centroid 2.1 average patch size score 2.02 average patch size shape Existing conditions provide only fair habitat potential.
				Future (OP)	Not modelled	Not modelled
				Future (OP) + Enhanced Natural Heritage	48% natural land cover, adjusted to 49% on revised map base. All other results are as per terrestrial system targets. Represents an overall improvement to existing conditions.	27% natural land cover, adjusted to 30% on revised map base. All other results are as per terrestrial system targets. Represents an overall improvement over existing conditions, but as the targeted system was established with implementation constraints in mind, it will not achieve biodiversity targets as fully as opportunities in Duffins Creek watershed will allow.
15. Protect the natural system quality and function from the influence of surrounding land uses	• Matrix influence	• Compatibility of surrounding land uses within 2 km of the edge natural cover patch	• Targeted ratio of urban, natural and rural/agricultural land cover surrounding each cover patch, as defined by the Regional Terrestrial Natural Heritage model matrix influence scores (4 in the Duffins Creek Watershed; 3 in the Carruthers Creek Watershed)	Existing	The average matrix influence score is 2.68.	The average matrix influence score is 2.67.
				Future (OP)	Not modelled	Not modelled
				Future (OP) + Enhanced Natural Heritage	The average matrix influence score is 4.16, which is an improvement over existing conditions. This is due to the increased proportion of natural area relative to urban or rural land uses, and suggests an increased potential for habitat to support sensitive species.	The average matrix influence score is 3.11, which is an improvement over existing conditions. This is due to the increased proportion of natural area relative to urban or rural land uses, and suggests an increased potential for habitat to support sensitive species.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
16. Protect and restore all native vegetation communities and the flora and fauna within them.	• Vegetation type diversity • Species diversity	• Number of vegetation types represented • Number of species represented	• To be determined pending further technical analysis • To be determined pending further technical analysis	Existing	Further study required	Further study required
				Future (OP)	Further study required	Further study required
				Future (OP) + Enhanced Natural Heritage	Further study required	Further study required

Public Use - Recreation

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: To provide appropriate and sustainable public use which promotes environmental awareness and enhancement						
17. Create continuous watershed trails in the greenspace system linking Lake Ontario and Oak Ridges Moraine	• Inter-regional trail network	• Percent completion of the inter-regional trail network	• 100% completion	Existing	40 km of trails completed, with plans to complete a total of 120 km, which represents a total achievement of 33% of the target. The demand and use of public trails has increased steadily. With a limited formalized and maintained existing trail network the natural system is being heavily impacted by the random establishment of all types of use trails. Trail widths, side trail use and spread of invasive plants is increasing.	3 km of trails completed, with plans to complete a total of 33 km, which represents a total achievement of 9% of the target. The demand and use of public trails has increased steadily. With a limited formalized and maintained existing trail network the natural system is being heavily impacted by the random establishment of all types of use trails. Trail widths, side trail use and spread of invasive plants is increasing.
				Future (OP)	If development moves forward without an integrated trail development and maintenance plan, part of the integrity of the natural system will be strongly compromised. The demand for watershed trails will increase. There will be an increase of informal trail blazing, use and spread of non-invasive plants within sensitive watershed areas. Active membership of trail associations should increase along with casual volunteers for trail maintenance and general clean-up. Over time municipalities may have increased monetary resources to construct and maintain watershed trails, as a result of the increased tax base associated with urban development.	
				Future (OP) + Enhanced Natural Heritage	The public will have an enhanced natural experience and a greater chance to make connections with various user groups and communities. Informal trail blazing, habitat impact and boundary issues will most likely increase, without programs dedicated to greenspace and trail management. Municipalities may have increased monetary resources to support such programs, as a result of the increased tax base associated with urban development.	

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
18. Maintain the greenspace system for planned sustainable uses and public enjoyment	• Sustainable public use and enjoyment • Management plans	• Participation in planned uses as defined in the Management Plan • Number of Management Plans completed for areas identified	• Increase participation in planned uses and decrease participation in unplanned uses • 100% completion	Existing	To be determined pending further technical analysis. There is currently a fair variety of outdoor recreation destinations. A great amount of potential exists to improve the number of sites offering outdoor recreation opportunities, considering the extensive amount of land in public ownership inthis watershed.	To be determined pending further technical analysis. There is not currently much variety in the outdoor recreation destinations, indicating that there is a considerable need to improve the number and variety of facilities and destiantions in the watershed.
				Future (OP)	The demand and use of public greenspace for a variety of uses will increase and unplanned uses will increase, creating a need for the expansion of publically owned greenspace lands and for the preperation and implementation of management for public lands.	
				Future (OP) + Enhanced Natural Heritage	The demand and use of public greenspace for a variety of uses will increase and unplanned uses will increase, creating a need for preperation and implementation of management for public lands.	
19. Improve greenspace accessibility while ensuring compatibility between social benefits and ecological health	• Accessible greenspace	• Number of access points to publically owned greenspace as identified in the management plan	• 100% completion of the development of all planned access points	Existing	50% of the total watershed is under ownership of the TRCA, Federal and Provincial governments and regional and local municipalities. The large amount of publicly owned land in the watersheds is very positive and, coupled with private landowner cooperation, provide very good opportunities for achieving an accessible and integrated greenspace system.	Only 25 hectares of public greenspace exists, representing less than 1% of the total watershed area.
				Future (OP)	If urban development proceeds without integrated planning for greenspace and recreation, the available public use opportunities will fail to meet the demands of the increased population base. Furthermore, over use of existing greenspace areas will negatively impact the environment, through over use of existing trails, creation of informal trails, and other impacts, and the quality of the user's experience will deteriorate due to crowding ad user conflicts.	
				Future (OP) + Enhanced Natural Heritage	There will be greater opportunity for the creation of integrated, accessible and extensive greenspace system under this scenario. However, without planning for recreational use opportunities, the potential may fail to be realized and negative impacts from informal, unplanned use may result.	

Human Heritage

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: To preserve and interpret our evolving human heritage resources						
20. Identify and document human heritage resources for protection	• Number of human heritage resources	• Number of registered archaeological sites • Number of designated structures (i.e. built heritage) • Number of listed structures (not yet designated)	• Maintain or increase the number of registered archaeological sites • Maintain or increase the number of designated structures	Existing	Predictive model suggests that many more archaeological sites exist than those that have been identified. Similarly, relatively few archaeological heritage sites have been identified and designated.	
				Future (OP)	As urban development proceeds under this scenario, there will be opportunities through the normal development process to identify archaeological sites and arrange for their protection. There will likely be a reduction in the number of heritage sites, unless the municipal policies and tools for their protection are strengthened.	
				Future (OP) + Enhanced Natural Heritage	Under this scenario, there will be an increase in the number of archaeological sites identified and protected *in situ* (within natural heritage restoration areas). There may be a reduction in the number of built heritage sites identified, as in the OP scenario, but an increase in the level of protection afforded to existing listed sites, where they are located in areas identified for the targeted natural heritage system.	
21. Increase awareness and appreciation of the inherent value of human heritage resources	• Awareness and appreciation	• Percent of population which places value on Human Heritage	• Net increase of awareness and appreciation of Human Heritage	Existing	N/A - need to conduct survey to define baseline.	
				Future (OP)	N/A	
				Future (OP) + Enhanced Natural Heritage	N/A	
22. Apply a standardized approach to protecting human heritage resources at all levels of government *	• Standardized approach	• Number of agencies who agree to applying a standardized approach	• 100% agreement	Existing	No standard beyond that provided in the Heritage Act and individual LACACs	
				Future (OP)	Awareness of the need for a standardized approach may or may not become evident as urban development proceeds.	
				Future (OP) + Enhanced Natural Heritage	Awareness of the need for a standardized approach may or may not become evident as urban development proceeds.	

* (NOTE: currently a MTCR* archaeological standardized approach exists, but not for built heritage sites) Ministry of Tourism, Culture and Recreation

Sustainable Communities

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: To achieve a behavioural shift in lifestyles, community design and resource use in keeping with environmental objectives for the watersheds						
23. Increase awareness of watershed issues and use of available watershed knowledge in decision making to foster sustainability and sustainable living practices	• Awareness • Outdoor Environmental Education	• percent of surveyed population having awareness of watershed issues • Number of students participating in outdoor education programs	• Increase the level of awareness of watershed issues • Increase the number of students participating in outdoor education programs	Existing	Further studies are required to define baseline conditions and to understand the factors that contribute to change, such that more accurate predictions can be made about the impacts of future land use management strategies.	
				Future (OP)		
				Future (OP) + Enhanced Natural Heritage		
24. Promote lifestyles that are ecologically sustainable	• Water efficiency • Materials and resources • Energy efficiency • Renewable energy • urban forests • Naturalization on private lands • Stewardship initiatives	• Amount of water used per capita • Degree of waste generation/diversion • Non-renewable energy consumption • Number of homes and industries using green power • Hectares of urban canopy • Hectares of unaturalized lawns and gardens • Participation in stewardship initiatives	• Reduce the amount of water used per capita • Reduce degree of waste generation and increase diversion • Decrease non-renewable energy consumption • Increase proportional use for renewable green vs. non-renewable energy • Increase urban canopy • Increase hectares of naturalized lawns and gardens • increase participation in stewardship activities	Existing	Further studies are required to define baseline conditions and to understand the factors that contribute to change, such that more accurate predictions can be made about the impacts of future land use management strategies.	
				Future (OP)		
				Future (OP) + Enhanced Natural Heritage		

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
25. Use sustainable urban design approaches to guide urban growth and development	• Sustainable communities • Sprawl	• Application of sustainable community principles • Public transit opportunities • Neighborhood mixture of jobs, shops and housing • Density	• Increased % of land developed or redeveloped using sustainable community principles • Increase public transit opportunities • Increase percentage of neighborhoods offering a mixture of jobs, shops and housing	Existing	Further studies are required to define baseline conditions and to understand the factors that contribute to change, such that more accurate predictions can be made about the impacts of future land use management strategies.	
				Future (OP)		
				Future (OP) + Enhanced Natural Heritage		

APPENDIX B

Municipal Land Use Maps and Their Use in Scenario Development

Chapter 3.1 (Land Use and Management Scenarios) of this Technical Summary Report describes three land use scenarios that were developed and analysed within each of the technical studies, as a means of benchmarking the watershed response to existing and future land use states. For the purposes of analysis, land *use* was interpreted as its associated land *cover* type. Various data sources were used in the development of these scenarios, as described in the following sections.

Existing Land Use [Cover] Scenario

Existing land cover mapping was assembled from the 1999 Digital Ortho-photography interpretation. Natural heritage cover was interpreted from the 1999 Ortho-photography using the TRCA's terrestrial natural heritage methodology (TRCA, 2003 Draft).

Future Land Use [Cover] Scenario

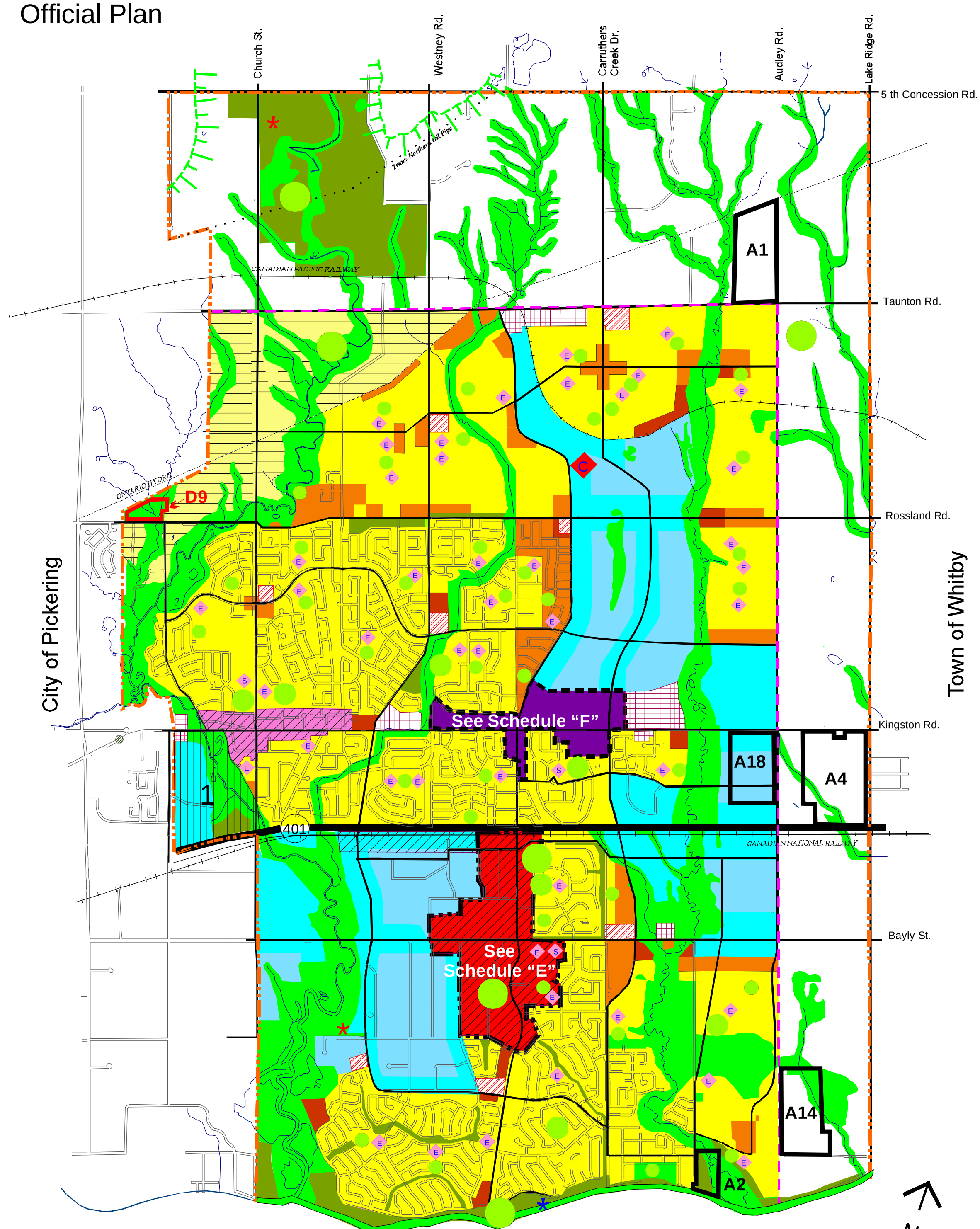
Municipal Official Plan information from the City of Pickering, Town of Ajax, and Community of Stouffville, as shown in Figures B-1, B-2, and B-3, was used to modify the "Existing Land Cover" map, to illustrate where changes would occur with the full implementation of the approved, municipal plans. Municipal plans designate areas for specific land uses, which had to be interpreted in terms of a land cover value. Each municipal plan is somewhat unique in that it uses slightly different land use classifications and codes. Therefore, some interpretation was necessary, based on the TRCA's understanding of the associated municipal policies, as to what the resulting land cover might be.

Land cover on the Oak Ridges Moraine (ORM) was to remain the same as under the "Existing" scenario map, assuming implementation of the ORM Act. TRCA Fill Regulation Mapping was also used, by assuming that Fill regulated areas would remain as natural areas. Given little information at the Official Plan level for the Seaton community, these "urban" designated lands were assumed to be low/medium residential. The federally owned lands being considered as the site of a future airport were classified as "agricultural" with the maintenance of their existing "natural" areas.

Future Land Use [Cover] with Enhanced Natural Heritage System

This scenario was created by increasing the area of natural cover, where revegetation opportunities were expected to exist, such as along stream and valley corridors and adjacent to existing habitat patches. The criteria used in the development of this scenario is more fully described in chapter 3.1.3.

TOWN OF AJAX
Official Plan



SCHEDULE A
Land Use

Greenlands Framework
- Environmental Protection
- Open Space
- Town-Wide Park
- Community Park
- Neighbourhood Park
- Lake Iroquois Shoreline

Residential Areas
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Future Urban Development
- S Secondary School
- E Elementary School
- C Secondary School Multi-use Campus

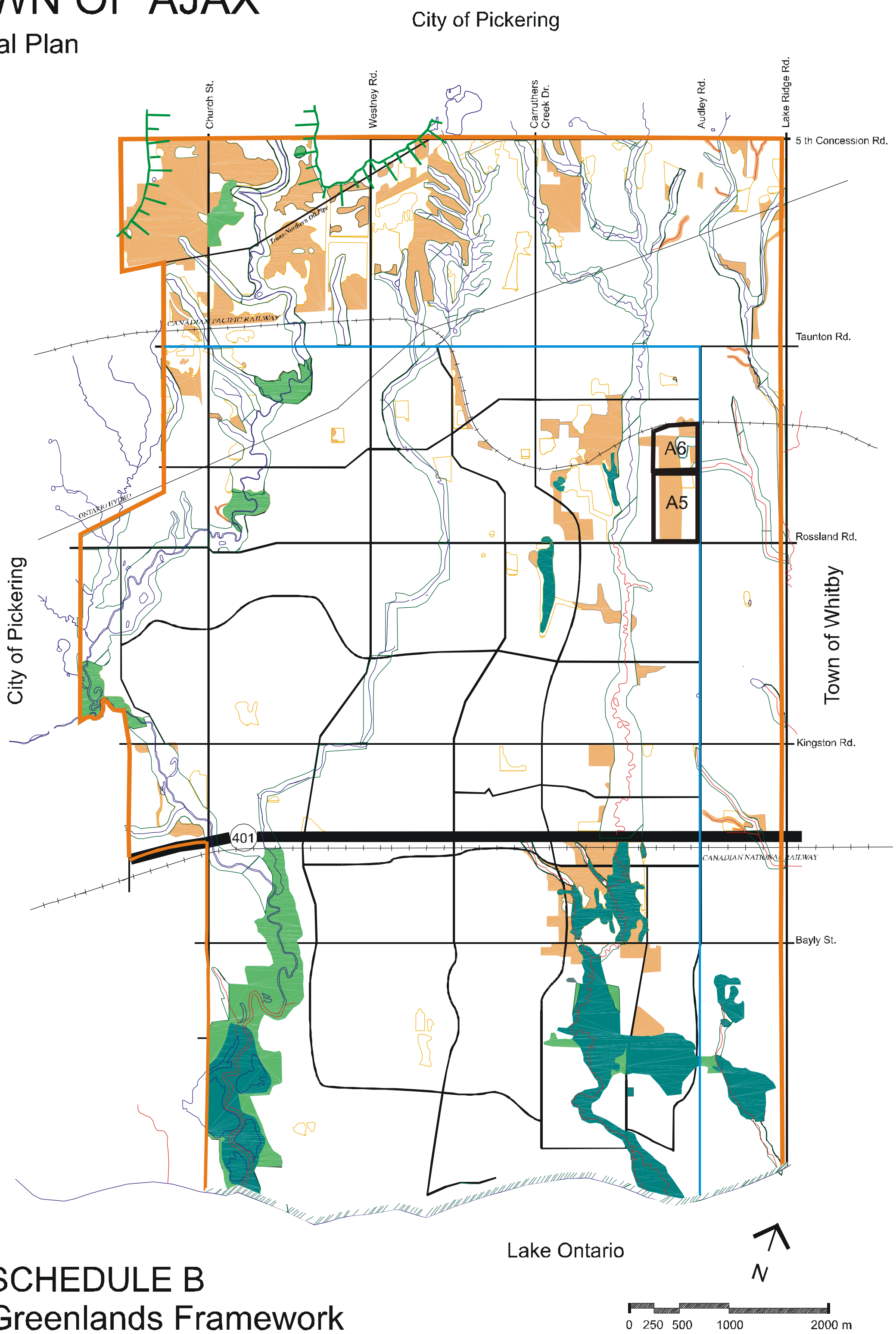
Mixed Use Areas
- Downtown Central Area
- Uptown Central Area
- Village Central Area
- Local Central Area
- Mixed Commercial Corridor
- Community Improvement Area
- Former Landfill Site
- Water Supply Plant

Employment Areas
- Prestige Employment
- General Employment
- Employment Policy Area

Rural Area
- Rural
- Town Boundary
- Urban Area Boundary

FEBRUARY 28, 2002

TOWN OF AJAX
Official Plan



SCHEDULE B
Greenlands Framework

Environmental Protection Areas

- Valley (Hazard) Systems
- Evaluated Wetlands
- Wetland
- Other Significant Natural Features (ESA's, ANSI's)

Environmental Resources Overlay

- Woodlands
- Other Supporting Natural Areas
- Intermittent Warm Water Stream

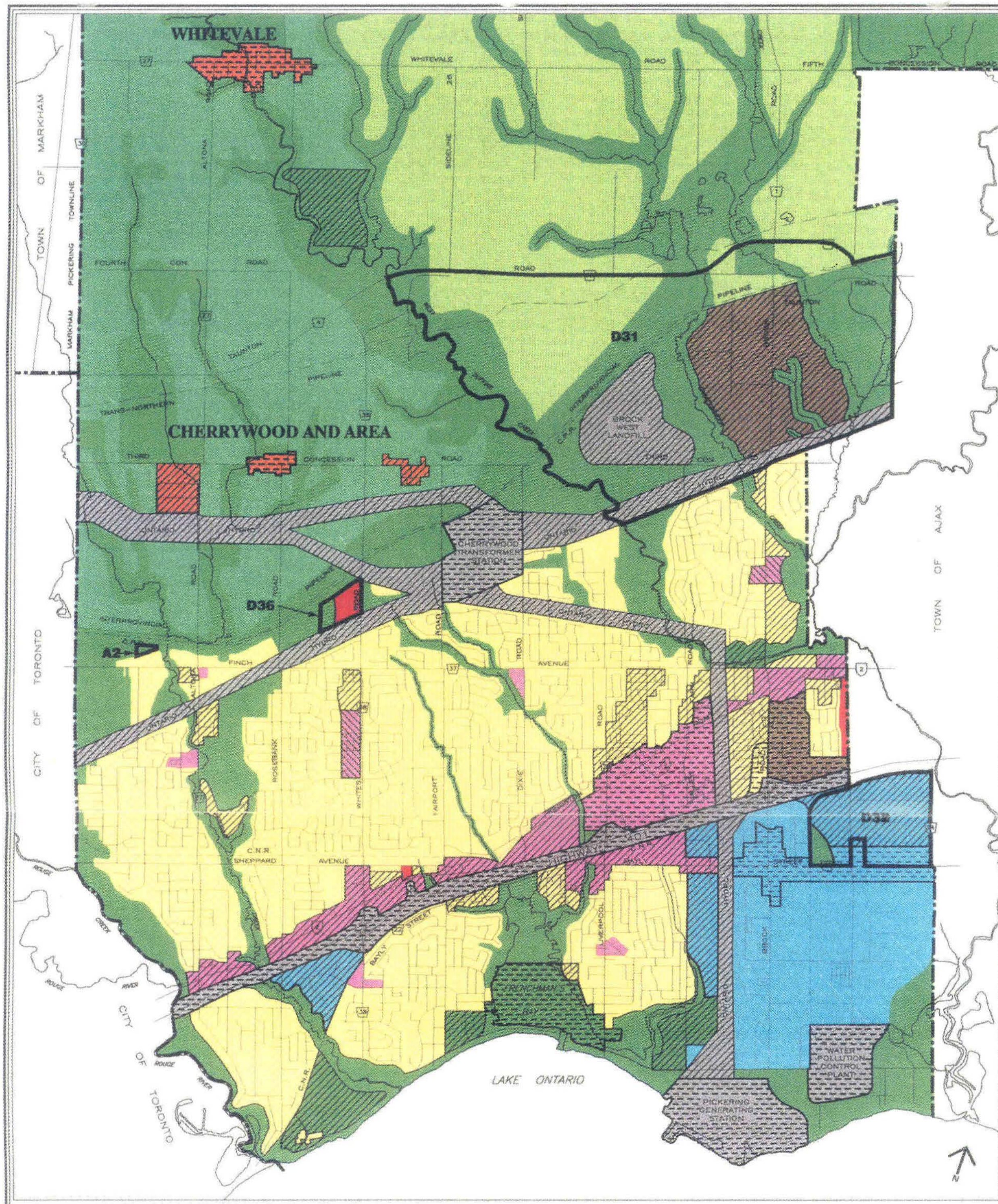
- Lake Iroquois Shoreline

- Warm Water Stream
- Cold Water Stream
- Intermittent Cold Water Stream

- Town Boundary
- Urban Area Boundary

FEBRUARY 28, 2002

Note: *The Environmental Protection Areas are outlined in black*



SCHEDULE I TO THE

PICKERING OFFICIAL PLAN

EDITION 2

LAND USE STRUCTURE

OPEN SPACE SYSTEM
- NATURAL AREAS
- ACTIVE RECREATIONAL AREAS
- MARINA AREAS

MIXED USE AREAS
- LOCAL NODES
- COMMUNITY NODES
- MIXED CORRIDORS
- DOWNTOWN CORE

REGIONAL NODES
- REGIONAL NODE 1
- REGIONAL NODE 2

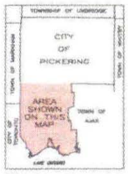
EMPLOYMENT AREAS
- GENERAL EMPLOYMENT
- PRESTIGE EMPLOYMENT
- MIXED EMPLOYMENT

URBAN RESIDENTIAL AREAS
- LOW DENSITY AREAS
- MEDIUM DENSITY AREAS
- HIGH DENSITY AREAS

RURAL SETTLEMENTS
- RURAL CLUSTERS
- RURAL HAMLETS

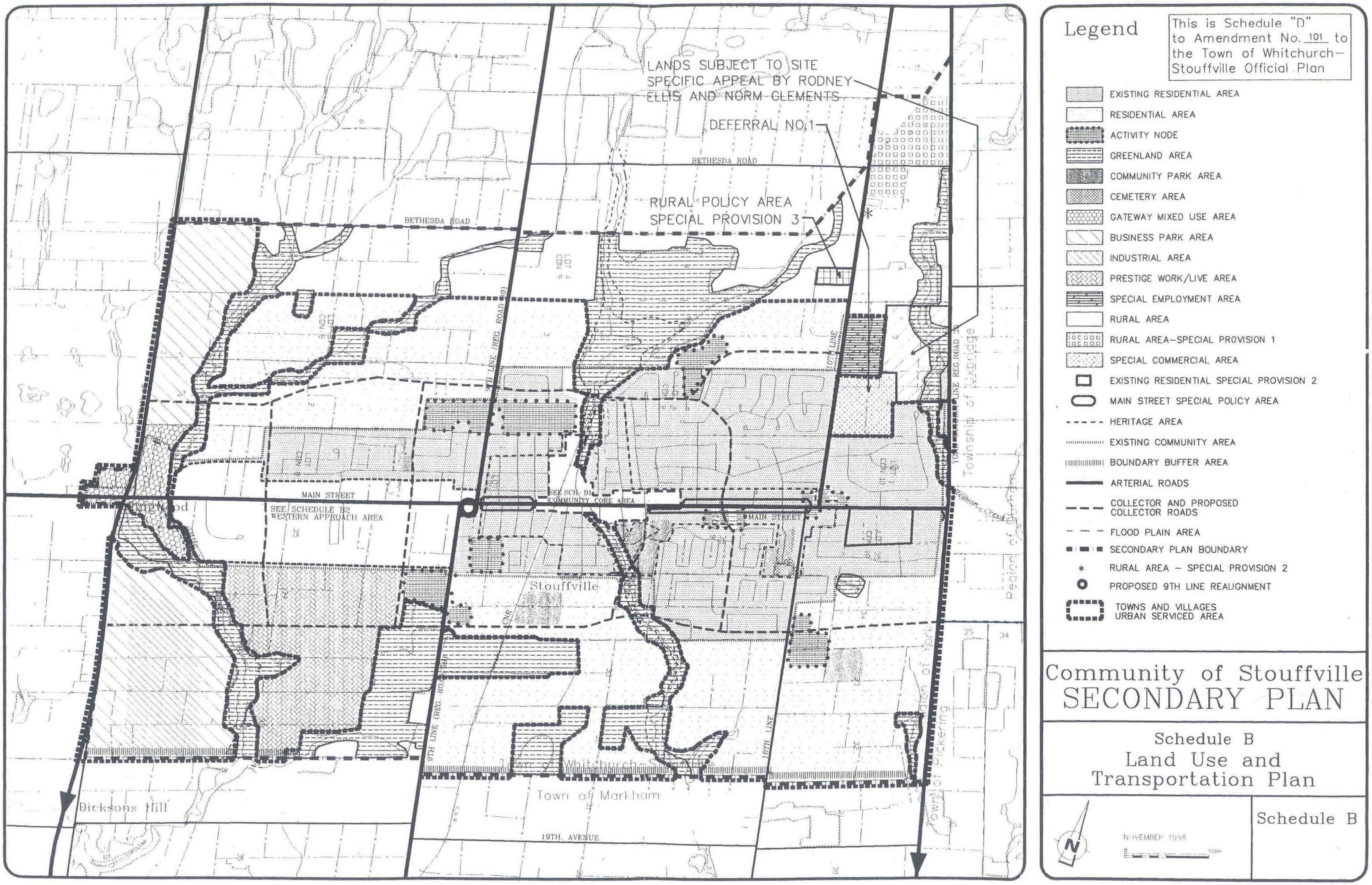
FREEWAYS AND MAJOR UTILITIES
- POTENTIAL MULTI—USE AREAS
- CONTROLLED ACCESS AREAS

OTHER DESIGNATIONS
- URBAN STUDY AREAS
- SEATON URBAN STUDY AREA
- AGRICULTURAL AREAS
- D1 DEFERRALS
- A1 APPEALS



SHEET 1 OF 3

CITY OF PICKERING
PLANNING & DEVELOPMENT DEPARTMENT
© SEPTEMBER, 2000
THIS MAP FORMS PART OF EDITION 2 OF THE PICKERING OFFICIAL PLAN AND MUST BE READ IN CONJUNCTION WITH THE OTHER SCHEDULES AND THE TEXT.



Legend
This is Schedule "D" to Amendment No. 101 to the Town of Whitchurch-Stouffville Official Plan
EXISTING RESIDENTIAL AREA
RESIDENTIAL AREA
ACTIVITY NODE
GREENLAND AREA
COMMUNITY PARK AREA
CEMETERY AREA
GATEWAY MIXED USE AREA
BUSINESS PARK AREA
INDUSTRIAL AREA
PRESTIGE WORK/LIVE AREA
SPECIAL EMPLOYMENT AREA
RURAL AREA
RURAL AREA-SPECIAL PROVISION 1
SPECIAL COMMERCIAL AREA
EXISTING RESIDENTIAL SPECIAL PROVISION 2
MAIN STREET SPECIAL POLICY AREA
HERITAGE AREA
EXISTING COMMUNITY AREA
BOUNDARY BUFFER AREA
ARTERIAL ROADS
COLLECTOR AND PROPOSED COLLECTOR ROADS
FLOOD PLAIN AREA
SECONDARY PLAN BOUNDARY
RURAL AREA - SPECIAL PROVISION 2
PROPOSED 9TH LINE REALIGNMENT
TOWNS AND VILLAGES URBAN SERVICED AREA
Community of Stouffville
SECONDARY PLAN
Schedule B
Land Use and Transportation Plan
Schedule B
NOVEMBER 1998
LANDS SUBJECT TO SITE SPECIFIC APPEAL BY RODNEY ELLIS AND NORM CLEMENTS
DEFERRAL NO.1
RURAL POLICY AREA SPECIAL PROVISION 3
BETHESDA ROAD
MAIN STREET
SEE SCHEDULE B2 WESTERN APPROACH AREA
SEE SCH. B1 COMMUNITY CORE AREA
Stouffville
9TH LINE (REG. ROAD 30)
10TH LINE
Township of Uxbridge
Region of Durham
Town of Pickering
Town of Markham
Dicksons Hill
19TH. AVENUE

DUFFINS AND CARRUTHERS CREEK WATERSHED PLAN

SUPPORTING DOCUMENTS

Aquafor Beech Ltd. 2002. Duffins Creek Hydrology Update.

Clarifica Inc. 2002. Water Budget in Urbanizing Watersheds: Duffins Creek Watershed.

Gerber Geosciences Inc. 2003. Duffins Creek Watershed Hydrogeology and Assessment of Land Use Change on the Groundwater flow System. Including Appendix on Water Use.

Marshall Macklin Monaghan Ltd. 2002. Duffins Creek Watershed Hydraulic Modelling and Flood Plain Mapping Project.

Stantec Consulting Ltd. and Aquafor Beech Limited. 2003. Dry and Wet Weather Modelling of Water Quality under Alternative Land Use Scenarios in the Duffins and Carruthers Creek Watersheds - A simple Spreadsheet Approach.

TRCA. 2002. Carruthers Creek State of the Watershed Report.

TRCA. 2002. Duffins Creek State of the Watershed Report.

TRCA. 2003. Agricultural Non-Point Source (AGNPS) Modelling of the Duffins and Carruthers Creek Watersheds.

TRCA. 2003. Duffins and Carruthers Creek Watersheds Fisheries Management Plan.

TRCA. 2003. Duffins and Carruthers Creek Low Flow Study and Management Plan.

TRCA. 2003. Ratings Report for the 2003 Duffins and Carruthers Creek Watersheds Report Card.