

THE RIVER IN THE URBAN LANDSCAPE
LANDSCAPE ECOLOGICAL PRINCIPLES FOR THE DESIGN OF RIVERFRONTS

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ABSTRACT

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River corridors have become important resources for the preservation of nature and habitat restoration because they remain a continuous natural feature within urban landscapes. This study develops riverfront design principles to enhance habitats and species diversity, restore hydrological processes, and provide opportunities for human activities. The design principles are developed from an assessment of literature on waterfront design and landscape ecology, and a case study that integrates ecological and human concerns. The resulting principles were applied to a riverfront in Guelph, Ontario, to illustrate and understand their usefulness. Mitigation and restoration measures could be applied to enhance the ecological function of the riverfront. The principles were applied to re-establish the lost connectivity by enhancing vegetation on the riverbanks and part of the floodplain, and by removing barriers. In some sites, the principles could not be applied because of the presence of buildings. Their removal would represent a costly initiative and a loss of cultural landmarks. The design principles are considered useful for designers and planners because they have the potential to equip professionals with tools to establish and create healthier natural systems, while addressing human needs in riverfront environments.

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1

Introduction

Research Problem

Since the 1960s, cities have settled on the edges of water bodies (rivers, lakes, and oceans), and have experienced changes that have altered the way waterfronts are seen, used and developed. Migration of port facilities and industries has left abandoned areas that have become opportunities for re-development.

In the same period, awareness of environmental quality has increased with the need to regenerate degraded urban areas, preserve and restore natural resources, and improve water quality. Ecological approaches in design and planning have emerged, and a new discipline has appeared: landscape ecology.

Urbanization have generally caused major impacts on water resources, and rivers are among the most sensitive and transformed water bodies. They have been modified, corrected, channelized, polluted, and as Pedroli and Harms note, “none of today’s rivers in the economically active regions of the world is freely flowing anymore” (Pedroli and Harms (2002:01).

Nonetheless, river corridors have become important resources for nature preservation and restoration of habitats because they remain as a continuous natural feature/resource within suburbanized landscapes. City development on agricultural fields and the suburbanization processes have caused the disappearance and fragmentation of remnants of forests, diminished the size and divided patches of vegetation, causing a substantial loss of habitat and biodiversity. Cities present small portions of isolated patches of vegetation on parks and private properties, though poorly connected or completely disconnected from each other. Urban rivers, with the imposition of restrictions on floodplain areas and the relocation of industries, have become places for development of designs adopting ecological approaches without eliminating human use. Waterfronts are considered to be areas for restoration of natural processes, where hydrological processes can be used to enhance habitats and improve conditions of rivers and water quality. Foremost, urban rivers provide links among disconnected patches and connections between different background matrices (urban/rural).

In addition, as a consequence of the destruction of natural resources, rivers have become important places for human leisure and recreation. As such, waterfront design and planning initiatives have increased in recent years. However, conservation and human use are primarily dealt by two different groups of disciplines, landscape ecology,

and landscape design and planning. This thesis aims to bring these disciplines together to inform the practice of landscape architecture. Hence, this study is based on two sets of literature. One discusses the history, planning and design of waterfronts, while the other examines landscape ecology.

Approach

The first set of literature addresses waterfront development from three different perspectives. The first perspective is represented by a group of authors who are concerned with utilizing historical lenses to examine the transformations that have occurred in waterfronts in the last four decades (e.g., Marshall 2001, Breen and Rigby 1994 and 1996, Torre 1989, Frieden and Sagalyn 1989, Hoyle 1988, Mann 1973). The second perspective is represented by a group that proposes normative design and planning frameworks for specific locations (e.g., Reid 1997, Landplan Collaborative 1995, Metropolitan Toronto Planning Department 1994, Good and Goodwin 1990, Department of City and Regional Planning 1980, Central Waterfront Planning Committee 1976). The third perspective encompasses built designs, generally published in professional magazines, such as *Landscapes/Paysages*, *Landscape Architecture Magazine*, *Progressive Architecture*, and *Topos*.

From the broad range of topics in the landscape ecology literature, two groups of literature were important for the development of this study. The first one deals with definitions of the scope of landscape ecology and its main assumptions and concepts (e.g. Moss 2000a, 2000b, and 1999, Wiens 1999, Forman 1995, Naveh 1994, and Forman and Godron 1986 and 1981) and its different approaches; the second group deals more

specifically with applications of landscape ecology to river corridors (e.g. Pedroli *et al* 2002, Ward 2002, Décamps 1998 and 1984, Noss 1993, Baschak and Brown 1995).

Although the literature provides a broad overview of waterfront development and landscape ecology, the application of landscape ecology to urban waterfronts remains to be explored. Most design and planning frameworks and waterfront designs present a superficial perspective on the ecology of the landscape. In addition, most landscape ecology research on river corridors is dedicated to non-urban landscapes (rural and agricultural landscapes, and natural reserves), leaving the urban landscape open for exploration.

Purpose and Objectives

The purpose of this study is to explore how landscape ecology can contribute to an ecologically sensitive design of urban riverfronts, attempting to integrate the landscape ecology and landscape architecture literature in the design of riverfronts. The goal is to develop a set of principles from a review of existing concepts and frameworks in this literature, i.e., waterfront design and landscape ecology. The objectives undertaken to meet this goal are as follows:

1. To assess the literature on waterfront design to identify the historical context of urban waterfronts, proposed design and planning frameworks and built waterfront designs;
2. To assess the literature of landscape ecology to identify the strengths and weaknesses of its application to riverine landscapes in general and urban landscapes in particular;

3. To combine principles identified in the literature and one case study of waterfront design in order to develop a set of landscape ecological principles for the design of riverfronts;
4. To illustrate the usefulness of such guidelines for design practice by applying them in an urban river landscape.

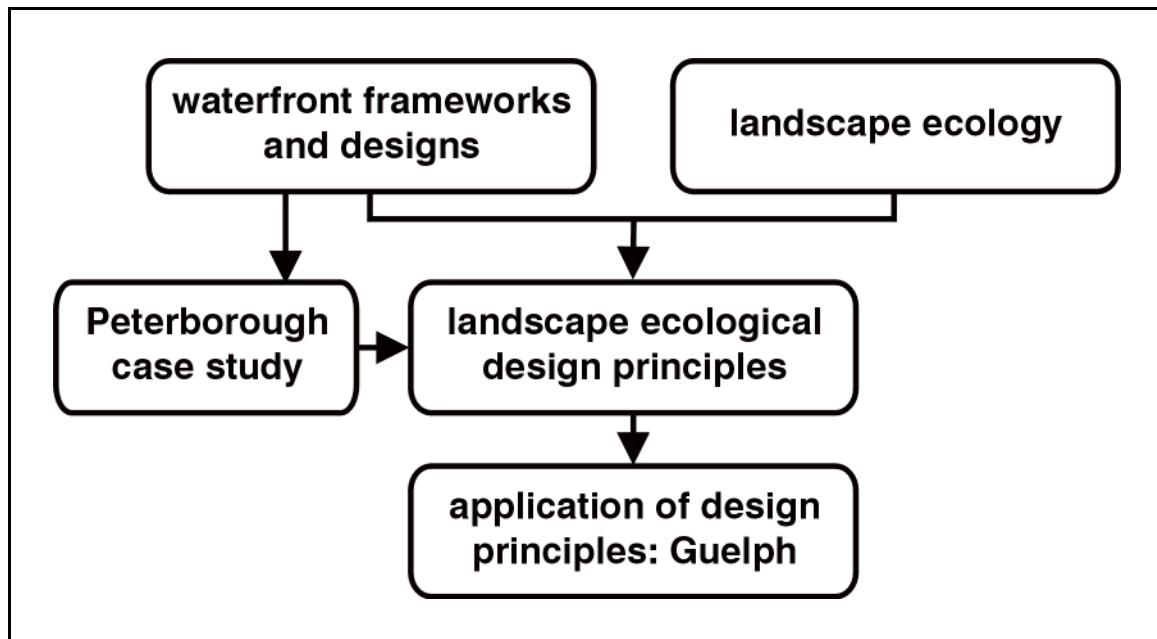


Figure 1.1 Research design diagram.

Chapter Outlines

Each of these objectives is addressed in a different chapter. Chapter One introduces and contextualizes the research problem. The literature review is presented in two chapters. Chapter Two examines the development of waterfronts and the design and planning approaches of waterfront designs and frameworks. Chapter Three reviews the landscape ecology literature to define the concepts and highlight the principles that will guide the development of landscape ecological design principles in Chapter Four. These design principles, presented in Chapter Four, are preceded by a description of the case

study, which is used to illustrate the principles. In Chapter Five, these principles are applied to the downtown Guelph riverfront on the Speed River. Chapter Six summarizes the findings of this study, discusses the application of the principles in Guelph, and presents areas of further research.

It is considered that the design principles here proposed will be useful for designers and planners because they provide guidelines for adopting ecological measures in riverfront design. Hence, it is expected that they will help designers in establishing and creating healthier riverfronts with respect to natural systems, while addressing human needs in the urban environment.

2

Waterfronts

In the last four decades, North American cities have experienced changes in their waterfront areas (Jones 1998, Breen and Rigby 1994, Torre 1989). Waterfront space has been made available by the transformation of cities into service-based societies and the migration of industrial plants and port facilities to outside city areas and underdeveloped countries (Marshall 2001, Hall 1993, Hoyle 1988, Desfor *et al* 1988).

In Europe as well, from England to Russia, the renovation of waterfront cities has become usual. More recently, Asian, African and South American cities have started to re-develop their waterfronts (Hoyle 2000, Jones 1998, Breen and Rigby 1996).

In all cases, waterfront development has become an instrument of economic development. Now, in a service-based society¹, cities compete not for industries, but for a better image. In this scenario, waterfront redevelopment areas – sites for both nature preservation and restoration, human leisure and recreation – have become a perfect display for cities (Marshal 2001). Moughtin (1999) exemplifies this belief in the power bestowed upon waterfronts as display when he affirms that “it is a place where both dangers and possibilities abound. It is here where the docklands are located, where prostitution, drink, drugs and crime abound but also the place which presages a new beginning in a new world” (Moughtin 1999:171). Most importantly for the citizens, waterfront development restores people’s contact with the water in dynamic public spaces. With such significance, quality of waterfront design is of critical importance.

The main purpose of this chapter is to address how the design of waterfronts has developed in the last decades, which is done in four parts. First, waterfront is defined for the purpose of this paper, since it is necessary to have a broad understanding of waterfronts, although the research deals specifically with river environments (riverfronts). Second, this chapter gives a historical overview of waterfront development. However, there is no intention to pursue a detailed historical review of waterfronts, since a number of authors have already done this (e.g., Jones 1998, Breen and Rigby 1996 and 1994, Torre 1989, Mann 1973). Third, the categories and themes under which authors divide waterfront projects are discussed. Fourth, the last section reviews waterfront design and planning frameworks.

¹ About the characteristics of “service-based societies” see also Jameson (1979).

Definition

Urban waterfront, for Breen and Rigby (1994), refers to the interface of land and water in general,

...the water's edge in cities and towns of all sizes. The water body may be a river, lake, ocean, bay, creek, or canal. By a waterfront "project" we include everything from a wildlife sanctuary to a container port, and the full spectrum of uses in between (Breen and Rigby 1994:10).

They acknowledge that waterfronts are "...the most intense area of planning and development in our communities" (Breen and Rigby 1994:10). From their definitions it is possible to conclude that waterfront projects may differ in scale, from a neighbourhood park to regional planning. It is not without reason that Torre (1989) affirms that "...the waterfront is a melting pot of issues and interests..." (Torre 1989:10).

To summarize, urban waterfront is the interface between a city and a body of water, the place where humans and the water meet, making visible the dichotomies between the urban and the ecological, the cultural and the natural. It presents complex relationships, with conflicting and matching functions; on one side, the natural processes; on the other, human needs.

Historical Review

According to Hoyle (2000, 1993), Canada was a pioneer in waterfront redevelopment studies when, early in the 1970s, a joint program to deal with river transportation was established, involving York University and the University of Toronto.

However, in the United States waterfront regeneration experience started in the 1960s (Marshall 2001; Jones 1998; Breen and Rigby 1996). In the 1980s, restoration and improvement of urban waterfronts became an instrument for economic development and opportunities; new social facilities expanded employment and provided a real foundation for environmental regeneration (Jones 1998). According to Hoyle (1988), the focus was primarily on rehabilitation and redevelopment, consisting of a wide range of development including residential, recreational, commercial, retail, service and tourist facilities. According to Jones (1998), “in the more sobering economic climate of the late 1990s, many development projects... [took] a much more pragmatic approach to regeneration” (Jones 1998:434), with an emphasis on a mix of residential and commercial/leisure-oriented approach that became the paradigm of the 1990s (Breen and Rigby 1998). At the end of the 1990s, the opinion was that waterfront redevelopments should “...rely more upon a balanced economic and social provision of facilities” (Jones 1998:439).

In general, both Americans and Canadians are optimistic about the possibilities of waterfront redevelopment. According to Marshall (2001), the urban waterfront provides space which allows expressions of hope for urban vitality in the United States. In Canada, the Ontario Ministry of Municipal Affairs (1987) says that “urban waterfronts are a very special community resource which can provide unique and exciting opportunities to serve the diverse needs of many different groups” (Ministry of Municipal Affairs 1987:01).

The revival of North-American waterfronts has been attributed by several authors to the growing amount of leisure time available and the consequent need for more recreational space (Jones 1998; Breen and Rigby 1994; Torre 1989). Other reasons include public awareness of the need to preserve historical and architectural heritage,

often found in old dockland areas. Growing environmental and social concerns, especially relating to the ecology of the waterfront; and governmental regeneration action grants, also contributes to this revival. Waterfront regeneration is also related to the decrease of port activities within cities due to containerization (Jones 1998, Hoyle 1991, Central Waterfront Planning Committee 1976). This opinion is not prevalent, though. As Hoyle (1991) asserts, a study conducted in Canadian port cities demonstrated that Canadian developers, urban planners and port authority representatives see waterfront redevelopment as a consequence of, or derived from, urban changes rather than changes in maritime transportation.

Waterfront development in Europe has also occurred since the 1960s (Hoyle 2000, Breen and Rigby 1996). The European approach to waterfront development in the 1990s demonstrated the need to develop “perspectives that tend to integrate design, environmental, social and economic objectives more effectively” (Jones 1998:441). European examples emphasize small-scale and public-oriented, as well as innovative regeneration schemes. Manning (1997), talking specifically about European riverfronts, affirms that “no use or treatment of a river should be allowed to exclude recreational value, that no feature or operation however mundane needs to lack an aesthetic aspect, and finally that even the demands of conserving fragile nature need not exclude people from the scene” (Manning 1997:67).

The development of waterfront areas is relatively recent in other parts of the world. In South America, the Puerto Madero waterfront in Argentina is a well recognized example (Breen and Rigby 1996). In Brazil, waterfront designs on ocean fronts of major cities have been made since the 1960s (Macedo 1999, Franco 1997 and 2000). Proposals for

waterfront projects have been presented there since the early 1990s, but few have been implemented (Franco 2000). In Africa and Asia there has also been more attention paid to urban water edges (Marshal 2001, Hoyle 2000, Jones 1998).

Categories and Themes

Breen and Rigby (1994) divided waterfront projects into six categories²: historical, cultural, recreational, environmental, residential, and working waterfronts. However, projects usually comprise characteristics from one or more categories, and have indeed a mixed-use. As an example, a project that has historical features may be designed to incorporate housing, recreation and public open space.

Waterfronts that have a clear emphasis in one aspect but have several other characteristics abound (Table 2.1). Categorization does not seem to play a significant role in influencing the design or frameworks either (see next section). Hence, categorizations, when used, should be taken as heuristic devices to highlight the emphasis of each project (Figures 2.1 to 2.6 present images of waterfronts in Canadian and US cities that present either an emphasis on one characteristic and include diverse programs, or emphasis and program coincide).

² The categorization was used by Breen and Rigby (1996) for publication purposes, as a tool to compile a huge number of designs.

Table 2.1 Waterfronts and their emphasis and uses.

Project/City	Emphasis	Program	Source
Aarhus (Denmark), Aa River	Public open space	Stream daylighting; Pedestrian oriented	Nielsen 1998
Baltimore, Waterfront	Mixed use	Urban renewal; apartment, office, residential and cultural complex	Breen and Rugby 1994; Ditch 1991; Progressive Architecture June 1975
Boston, Charles River	Greenway	Trails, education, recreation	Thompson 2001
Boston Waterfront	Historic preservation	Hotels, housing, and public promenades	Progressive Architecture June 1975; Department of City and Regional Planning 1980
Buenos Aires, Puerto Madero	Mixed use	Residential, open space, service, commercial	Schneier-Madanes 2001
Charleston, Waterfront Park	Public space	Pier, park	Thompson 1991
Denver, South Platte River	Public space	Park, industrial landscape	Leccese 2001
Dresden, Elbe River	Open space	Gardens, arts and entertainment	Friedrich 1998
Georgetown, Potomac River	Historic preservation	Public space, offices, residential	Progressive Architecture June 1975
Hamburg, Elbe River	Mixed use	Service, residential, transportation	Trelcat 2001
Lisbon, Tejo River	Public space	Planning for Expo 98	Salgado 1998
London Docklands, Thames River	Mixed use	Historical preservation, recreation, university, public space	Chaline 2001
London, Millennium Dome, Thames River	Public space	Cultural, recreation	Arnold 1998
London, Millennium Village, Thames River	Mixed use	Residential, commercial, school, health centre, promenades	Burdett 1998
Louisville, Ohio River	Mixed use	hotel, offices, Historic District, apartments, integration of highway	Progressive Architecture June 1975
Louisville, Ohio River	Public space	Plaza, garage buildings, offices	Progressive Architecture June 1975
Melbourne, Yarra River	Cultural and entertainment	Mixed use: retail, commercial, and residential	Sandercock and Dovey 2002
Nancy, Meurthe River	Public space	Promenades	Bruel and Delmar 1998
New Orleans, Mississippi River	Mixed use	commercial, hotel, residential, business district	Progressive Architecture June 1975
New York, East River (Figure 2.6)	Public space	Promenades	Freeman 2003

Project/City	Emphasis	Program	Source
New York, Battery Park (Figure 2.5), Hudson River	Public Space	Residential, open space, cultural, commercial	Bone 1997; Breen and Rigby 1994, P/A June 1975; Peterson 1995
Peterborough, ON (see Chapter 4)	Public space	Trail, café, boathouse, ecological restoration	Basterfield 2002, Middleton 2002
Portland, Willamette River (Figure 2.3)	Public space	Esplanade, parks	Hinshaw 2001; Greenberg 1991; Progressive Architecture June 1975
Richmond, VA, Canal Walk	Public Space	River walks (promenades)	Mays 2001
Rotterdam, Maas River	Mixed use	Offices, residential, public space	Meyer 1998
San Antonio, San Antonio River	Public space	development of public spaces since the 1930s	Posner 1991; Progressive Architecture June 1975
San Jose, Guadalupe River	Public space	River walks, habitat restoration	Woodbridge 1991; Gillette 1998
Seattle, Central Waterfront	Mixed use	Residential, recreational, educational (aquarium), commercial (restaurants, public market) and public open space	Breen and Rigby 1994
Tempe, AZ, Rio Salado	Mixed use	Entertainment district, hotels, shops, parks	Cook 1991
Vancouver, Coal Harbor (Figure 2.2)	Residential	Open space, offices, residential, marina	Quayle 1991
Vancouver, Granville Island (Figure 2.1)	Public market	Recreation, entertainment, public market, and workshops	Breen and Rigby 1994
Vienna, Danube River	Public space	Dam, power generation, ecological restoration, leisure	Hansjakob and Hansjakob 1998

Table 2.1 Continued.



Figure 2.1a and b. Granville Island in Vancouver. Development of an industrial site into a mix of uses: recreation, entertainment, public market, and workshops.



Figure 2.2a and b Coal Harbor, Vancouver. Residential high-rise buildings dominate the landscape permeated by public open space, restaurants, retail and marina.



Figure 2.3a and b Portland, Willamette River. The promenades on the East Bank Esplanade along the Willamette River provide recreation opportunities.



Figure 2.3c Portland, Willamette River. Tom McCall Park. Bridges connect Tom McCall Park to the East Bank Esplanade, creating a circuit for bikers and joggers.



Figure 2.4a and b Seattle Central waterfront. A mix of residential, recreational, educational (aquarium), commercial (restaurants, public market) and public open space.



Figure 2.5 New York, Battery Park (South Cove). Battery park is an example of mixed use with emphasis in public open space.



Figure 2.6 New York, East River Waterfront. Creation of an urban park renovates the industrial waterfront on the east banks.

Frameworks for Design and Planning of Waterfronts

The Design and Planning Frameworks herein examined are intended to serve as guidelines to waterfront design and development. They were originally developed by researchers, government agencies, and private consultant firms. The concept of design applied in this study is based on the definition by Lyle (1999). For Lyle, design activity

equals “creative participation in natural processes”, and “means giving form to physical phenomena...at every scale” (Lyle 1999:17). By accepting Lyle’s definition of design, this study also accepts his distinction between design and planning: planning thus involves “administrative activity rather than physical-form shaping” (*ibid*). Lyle’s encompassing definition of design, referring to creative physical activity in all scales, follows Steinitz³ and McHarg approaches to design (Lyle 1999).

Although this thesis discusses the design of riverfronts, some planning frameworks are also presented below. The reason for this is that they all touch on design issues and do not confine themselves to “administrative activities” as defined by Lyle. As Lyle acknowledges (1999), design and planning are so closely linked that sometimes they become indistinguishable.

The frameworks are not presented in extensive detail since it is not the main purpose of this research to provide a comprehensive analysis of frameworks; they were examined to identify to which extent they address ecological issues in general, and landscape ecology in particular.

Toronto, together with Boston and Baltimore, is recognized as a city playing a pioneering role and being a model in waterfront issues. Since the 1970s, various publications have provided analysis of these cities waterfronts (e.g., Breen and Rigby 1996 and 1994, Brutomesso 1993). For Toronto specifically, different frameworks were produced for design and planning and the metropolitan region’s water’s edge (e.g., Reid

³ Steinitz refers to design at the regional level, ‘regional landscape design’ (in Lyle 1999:18). However, this approach to design is not prevalent. Most often, design is linked to site scale (Baschak and Brown 1995). Issues of scale will be discussed in more details in the next chapter.

1997; Landplan Collaborative Ltd. 1995; Royal Commission on the Future of Toronto Waterfront 1992; Central Waterfront Planning Committee 1976).

In Toronto, the Central Waterfront Planning Committee (1976) lists the physical attributes that influence waterfront quality. They argue that it depends on use, history, landscape, immediacy, views, activity, contrast, drama, intimacy, sounds, and wildlife. The Committee focuses mainly on design, and explores/suggests construction details and materials, building and water's edge forms (visual quality and variety of uses).

The Ontario Ministry of Municipal Affairs (1987) addresses the design of the waterfront by examining the following topics: shoreline protection, public access areas, beaches, recreational boating, landscaping for improving the waterfront, and urban design.

The Royal Commission on the Future of Toronto Waterfront - RCFTW (1992) proposed a design framework that encompassed 9 principles:

- Clean: incentive of natural processes instead of engineering solutions;
- Green: infrastructure composed of natural features and topography, such as habitats, aquifers, and parks;
- Connected: links among wildlife habitats, social communities, people and nature;
- Open: maintenance and restoration of vistas;
- Accessible: incorporation of public transit;
- Usable: mix of public and private uses; public access;
- Diverse: variety of uses and programs;

- Affordable: efficient use of government resources, and an integration of “socio-economic and environmental objectives” (RCFTW 1992:59);
- Attractive: excellence in design to create memorable places.

These principles are the most comprehensive ones among the frameworks reviewed. They deal with both human uses and natural systems in an integrative way. An example is the principle of connectivity, which closely resembles one found in landscape ecological principles (as will be seen in Chapter 3).

The Metropolitan Toronto Planning Department (1994) prepared a planning framework based on: accessibility, sharing the benefits, balance and diversity, and responsible stewardship.

The Landplan Collaborative Ltd. (1995), a Canadian firm based in Guelph, presents a design framework called “Generic Guidelines for Managing Visual Change in the Landscape” for the Toronto Waterfront. These guidelines touch on issues related to residential, industrial, commercial, recreational, rural, and historic areas: community character, vegetation, signage, lighting, hierarchy of open spaces, among others.

Reid (1997) presents design guidelines to minimize impacts on natural habitats when designing trails along Lake Ontario. The suggestions are a) to avoid most sensitive zones; b) to balance the effects of alternatives; c) to use previously disturbed areas; d) to maintain natural processes; e) to limit access (number of visitors); and f) to incorporate habitat enhancements. The study does not mention wildlife in urban areas along the shore.

Several authors have formulated frameworks for waterfront development in the United States. The design guidelines for East Boston (Harvard School of Design 1980) deal with open space and public access, orientation and views, neighbourhood scale and activity, and parking.

Torre (1989) presented a planning framework for a successful project based on theme (history, climate, special element or elements to attract people), image, authenticity, function, public perception of need, financial feasibility, environmental approvals, construction technology, and effective management.

Good and Goodwin (1990) provide a planning framework, which they call “Tools and Techniques” for revitalization of small waterfront cities. They list six points that must be addressed: a) waterfront uses and activities; b) land use control and incentives; c) land acquisition; d) financing of waterfront revitalization; e) choosing and using consultants; and f) obtaining waterfront development permits.

For Coolman (in Breen and Rigby 1990), the following general issues must be addressed when developing design guidelines: a) simplicity and clarity; b) compatibility with zoning; and c) publication and communication. Table 2.2 summarizes the information presented above.

Table 2.2 Interpretation of concerns present in planning and design frameworks. The shaded cells indicate the issues addressed by each framework.

Source	Open space	Human use	Character	Ecology	Accessibility	Land use	Management	Design issues
Central Waterfront Planning Committee (1976)								
Department of City and Regional Planning (1980)								
Torre (1989)								
Ministry of Municipal Affairs (1987)								
Coolman (in Breen and Rigby 1990)								
Good and Goodwin (1990)								
Royal Commission on the Future of the Toronto Waterfront (1992)								
Metropolitan Toronto Planning Department (1994)								
Landplan Collaborative (1995)								
Reid (1997)								

Summary

This chapter has given a brief history of waterfront development, the different ways waterfronts have been designed, and the ways cities, architects, planners, and landscape architects would like to see waterfronts designed and built.

The main reason for human settlement in a certain area and the creation of cities was the association of water with survival and transportation. The “waterfront movement” put people in contact with the water again.

The frameworks and guidelines presented above demonstrate that there are efforts in place to produce better urban waterfront areas. From the guidelines and frameworks presented here, little concern has been shown for the ecological aspects of riverfronts and less, if any, for urban riverfronts, as Mann (1973) already pointed out in the early 1970s.

Not much has changed since then. Few studies examined the adoption of ecological procedures or the incorporation of ecological enhancements within the urban fabric. The common use of the words ‘environment’ or ‘environmental’ does not necessarily indicate concern with ecological issues. These words can represent any quality of space or place and are sometimes wrongly used as a synonym for ecology, ecological, natural or ecosystem.

Most of the cities have taken a business approach to the development of their waterfronts, exploring the relationship between people and the water in a superficial way. Less has been done for the natural and ecological aspects of the problem. Much has been said about the need to restore and protect natural resources, but the frameworks described show a focus on human use without proposing conservation and regeneration approaches.

Waterfront development boomed in the 1980s, was less intense in the middle 1990s, but is still relevant (Marshall 2001, Hoyle 2000). The 2003 International Federation of Landscape Architects (IFLA) Congress held in Calgary, Alberta, for example, had “waterfronts” as one of its sub-themes; Memphis has recently completed a master plan for its riverfront and launched a design competition to further detail a portion of it; the CSLA 2003 Professional Awards received several submissions with one of the main awards being given to the design of the Windsor Riverfront. These examples show there is much effort going on and there is still much to contribute to the discussion of the practice of landscape architecture and the visions for the future of life in the cities. As stated by Marshall (2001), “it is in the spaces provided by the urban waterfront that planners and designers wrestle with the appropriateness of their intentions for the present and for the future” (Marshall 2001).

3

Landscape Ecology and the Riverfront Environment

In the previous chapter, waterfronts were defined as the interface between urban areas and water. Various waterfront designs and frameworks were analysed. This chapter narrows the scope to that of riverfronts. Riverfronts, for the purpose of this study, are defined as the interface between urban areas and river. As such, riverfront implies an urban context.

Similarly to waterfront developments examined in the previous chapter, revitalization of riverfronts has taken place in North America and Europe in the last four decades. These revitalization developments have successfully addressed human activities, but the incorporation of ecological issues has occurred to varying degrees. Some design frameworks propose improvements for wildlife (Central Waterfront Planning Committee

1976); some propose to maintain natural processes and incorporate habitat enhancements (Reid 1997); others base their proposals on balance and diversity (Metropolitan Toronto Planning Department 1994), showing concern for biotic and abiotic components of the landscape. Some of the designs, although emphasizing ecological issues, merged contradictory approaches. An example of this is the design for the South Saskatchewan River in Saskatoon. It included a program that aimed at the enhancement and protection of wildlife habitat, while opting to “celebrate and integrate existing engineered works” (Edwards and Crosby 1999:28).

On the other hand, a few designs successfully integrated human use and ecological issues. In the Hamilton harbour, the re-establishment of a “travel corridor for spawning and rearing of fish” was linked to the design of urban trails (Logue 2001:24). In Peterborough, a design concerned with the history of the site, and with reintegrating the downtown with its river edge, developed a “complete river edge and river bottom restoration plan” (Basterfield 2002). Among the frameworks, only Baschak and Brown’s (1995) framework integrate landscape ecology as a basis for investigation of a riverfront.

This chapter examines landscape ecology to identify the principles that can be applied to the design of riverfronts. It aims to provide design practitioners with encompassing guidelines to an ecological design of riverfronts. The first section of this chapter reviews the field of landscape ecology and its basic concepts and principles. The next section studies rivers from a landscape ecological point of view. The last section investigates urban rivers specifically.

Landscape Ecology

As summarized by Wu and Hobbs (2002), “a primary goal of landscape ecology is to understand the reciprocal relationship between spatial pattern and ecological flows or processes” (Wu and Hobbs 2002:358). The role of humans is also relevant to the scope of landscape ecology, as noted by IALE Executive Committee (1998) and Naveh and Liebermann (1994), who emphasize the “interrelationship between man and his open and built-up landscapes” (Naveh and Liebermann 1994:03).

A landscape might range in size from hectares to square kilometres in area (Forman and Godron 1981), comprising a heterogeneous area where ecosystems are repeated in similar form and interact (Forman 1995, Forman and Godron 1986 and 1981). Landscape ecology is the analysis of this space.

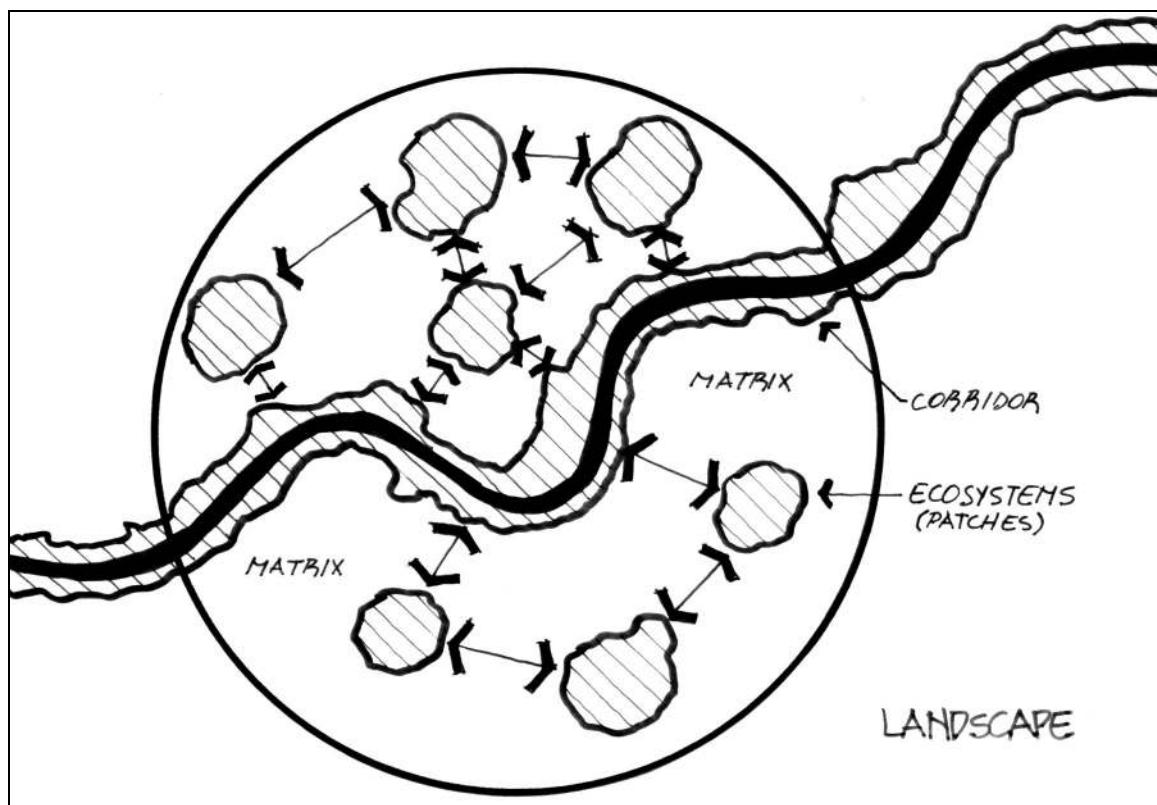


Figure 3.1 The landscape. The landscape is formed by patches, corridors, and matrix.

Landscape ecology has developed as a discipline in the last three decades and several attempts have been made to define its scope (Wu and Hobbs 2002, Moss 2000, Wiens 1999, IALE 1998, Forman 1995, Naveh and Liebermann 1994). However, as a young discipline it still requires consensus (Moss 1999, Wiens 1999), although basic premises and concepts are shared by most researchers. These include the relationship between ecology and its spatiality, a landscape where ecosystems function according to a given structure (form). The most recent efforts to define landscape ecology emphasize the need for integration between bioecological and geoecological perspectives (Moss 2000a, 2000b) to achieve a better understanding of the landscape.

Moss (2000b) defends the idea that landscape ecology must

add the abiotic landscape elements to these biotic considerations and evaluate these as the fundamental landscape units – their functional properties, their spatial interrelationship, across heterogeneous landscapes, and how these together provide an additional basis for solutions to landscape problems (Moss 2000b:179)

However, two paradigms still persist among landscape ecologists: one, with a strong biotic content, is derived from the biological sciences and emphasizes the spatial dimension of plant and animal populations, and community scale issues; the second one, founded in geography, focuses on the interpretation of land-related components such as landforms, soils, vegetation, human land use impact, and energy (Moss 2000b).

Structure, function and change⁴ are seen as the critical foci for the study of landscapes (Moss 2000b, Hobbs 1997, Baschak and Brown 1995, and Forman and Godron 1986).

Pattern has been used interchangeably with structure, while process has been used as a synonym of function. As Hobbs (1997) succinctly describes, a common theme in landscape ecology:

is the study of patterns, processes and changes....Landscape structure (or pattern) can be considered to be the spatial relationship between landscape elements or patches. Landscape function (or process) is, then, the interaction between these spatial elements, and landscape change is the alteration in structure and function occurring through time (Hobbs 1997:03).

Structure

The main structural components of landscapes, according to a bioecological perspective, are patches, corridors and human habitation (Forman and Godron 1981), matrix (Forman 1995), and networks that consist of “systems of interconnected patches and corridors woven into a (...) landscape matrix and connected to external and internal source areas” (Cook 1991:7).

According to Forman and Godron (1981), “patches are communities or species assemblages surrounded by a matrix with a dissimilar community structure or composition” (Forman and Godron 1981:734). In other words, “a patch is a wide relatively homogeneous area that differs from its surroundings” (Forman and Godron 1981:734). The surroundings are the matrix, a heterogeneous portion of the landscape

⁴ Wiens (1999) considers that landscape ecology relies on the study of pattern, processes and scales.

crossed by corridors. These are usually linear form environments that work as habitat and conduit. Corridors contain edge species and can be remnants of human intervention such as hedgerows and train tracks. Habitation is, as pointed out by Forman and Godron (1981), any structure or disturbance associated with human dwelling, examples being the house itself and its surroundings.

While the bioecological approach to landscape ecology (used mainly in the US) focuses its structural analysis on the patch/corridor/matrix level, the geoecological perspective focuses on the hydrological, pedological, and geomorphic substrate. According to Moss (2000b), a more comprehensive and integrative approach should

incorporate...a range of pedological, hydrological, geomorphic, lithospheric and atmospheric processes *as they interact with these land systems [ecosystem]*” (Moss 2000b:174; emphasis added).

Function

Function or processes are the concepts that have been used to indicate the interaction between structural elements. This interaction happens through “(1) hydrologic flows, (2) particle flows, (3) animal activities, and (4) human activities” (Forman 1995:216). These processes are responsible for landscape patterns (structure) (Forman 1995). Among the “hydrological flows”, floods are the primary agents of landscape change and maintenance of processes, “determining the pattern and development of the habitat mosaic” (Pedroli *et al* 2002). Pedroli and Harms (2002) reinforce the importance of hydrological processes referring to their capacity to determine the type of natural systems occurring at the scale

of a river section in a natural fluvial landscape. Restoration of morphological and hydrological processes, for Pedroli *et al* (2002), is a prerequisite.

Change

Change is the alteration in structure and function (Hobbs 1997, Forman and Godron 1986). This alteration is driven by natural or human processes and includes rainstorms, stream flow, fires, land use, soil formation, and plant growth (Marsh 1997). In the city, change might be related to the abandonment of port facilities, deactivation of dams or locks, or as result of massive sedimentation caused by runoff. For Marsh (1997), “the form-function concept also reveals that any actions taken as part of land use planning and engineering that result in changed landscape forms, such as cut and fill grading, soil preparation, and vegetation alteration, must produce a change in the way the landscape processes work” (Marsh 1997:58).

Scale

Scale has different meanings for landscape architects and landscape ecologists and these meanings are related to the emphasis of each professional’s work (Baschak and Brown 1995). Landscape architects usually design areas emphasizing the site scale or master plans. Landscape ecologists, on the other hand, deal with the landscape scale and ideally should be looking for the relationship between biotic and abiotic components of the whole landscape.

In the field of design, the site scale comprises a portion of land, whether private or publicly owned; at the broader scale (master planning), the activity of the landscape architect involves the public interest. The site might comprise several land owners,

including the possibility of suggesting land reclamation (such as park planning, waterfronts or community design).

How then can a landscape architect apply landscape ecology at the site scale? Lyle (1999), although in a different context, suggests an answer. He is aware that landscape architects work at site scale, but they can take into consideration the broader context when dealing with it. In Lyle's own words, landscape architects work in

...a limited unit of landscape, one of a certain size with definite boundaries, which means that we can deal with it only at a certain scale. The concerns that we can address in detail are likewise limited to those that are appropriate to that scale. Nevertheless, we need to work within the context...of the larger-scale unit, in this case the watershed unit... (Lyle 1999:17)

Then, the landscape architect, although working at the site scale needs to be aware of processes at the landscape scale in order to apply landscape ecology principles. By drawing upon Moss (2000b), it could be suggested that the landscape architect thus should look both at biotic and abiotic elements *and* the interaction between them, and consider the landscape scale when designing at the site scale. In a sense, this approach herein proposed has similarities with the framework proposed for greenways by Baschak and Brown (1995).

The consequences of local (site) interventions on the landscape must be understood. Local actions on the river corridor may reflect elsewhere. The landscape architect must therefore understand the ecological processes involved in the landscape to be affected by design. It is also necessary to set up the context, from a broader scale (a watershed, for example) to a finer one (how groundwater works on the site, for example).

Landscape Ecology of Rivers

Rivers are corridors and, as corridors, they are structural components of the landscape. This section explores, in a general way, the nature of river corridors, their structure, function, and change. As rivers differ from each other, the commonalities rather than the differences are explored.

The river or stream corridor as defined by Forman and Godron (1981) is formed by the channel, the river banks, and the floodplain, surrounded or limited by hillslopes and uplands. The same area, Ward *et al* (2002) call riverine landscape, and define it as an area influenced by the river where terrestrial and aquatic units interact. More simply put, stream corridors include a vegetation belt accompanying running waters (Décamps 1984). For the purpose of this study, the river corridor is divided into three landscape units identifiable in the corridor cross section (Figure 3.1): 1) channel and river banks, 2) floodplain, and 3) hillslope and uplands. This division into units is based on similarities in structure and processes.

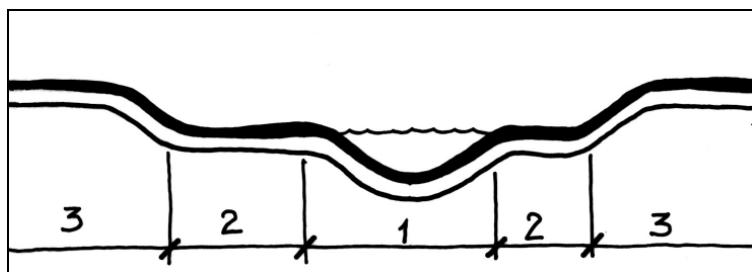


Figure 3.2 Landscape units:
1) Channel and river banks;
2) Floodplain;
3) Hillslope and uplands.

The division of the river corridor into landscape units is a way to better study and understand it, since these units “are interdependent and form a single system” (Pedroli et al 2002).

Landscape units are operational elements adopted in both landscape architecture and landscape ecology, with some different connotations. For landscape ecology, they are

units of evaluation of the landscape where biotic and abiotic considerations come together, considering “functional properties, their spatial relationships, across heterogeneous landscapes, and how these together provide an additional basis for solutions to landscape problems. These units are critical elements with which cultural and socio economic factors interact” (Moss 2000a:308).

This definition may also apply to landscape architecture. However, for landscape architects spatial relationships are thought of in terms of suitability for human use, and this suitability often considers ecological structure but rarely contemplates ecological function. The landscape unit approach consists of a classification of land according to a set of physical characteristics, each class sharing common attributes that define its limitations and potentials (Lyle 1999).

Each landscape unit plays different roles (or has a specific function) in the corridor. For example, nutrient flow and erosion are inhibited by stream bank vegetation (Forman 1995). The stream bank provides shade, overhanging vegetation for cover, detritus in the form of leaves, and large woody debris (Forman 1995). The floodplain, also known as the riparian zone (Tabacchi *et al* 2000), provides stream with organic matter (Forman 1995). The uplands help control the input of dissolved substances, such as N and P in fertilizer, road salt, pesticides, and other organics as well as heavy metals (Forman 1995). Table 3.1 summarizes the physical and biotic components of the river corridor.

Table 3.1 The relationship between ecological components and the landscape units. Objects operate as a continuum among the three landscape units but might present different characteristics. For example, habitats on the uplands present vegetation less tolerant to water than vegetation on the floodplain, determining what may attract different species of birds and mammals, and different rates of sediment retention, nutrient assimilation, or production of organic matter. The complexity of the objects confirms the need to integrate geoecological and bioecological aspects in the study of the landscape.

Ecological Components		Landscape Units		
		River Bank and Channel	Floodplain	Uplands and Hillslopes
Hydrological processes	River continuum	Flow of water, organic matter, sediments, plankton, and animal movements with no artificial interruption	Supplement of organic matter and habitat during floods	
	Floods	Carriage of sediments and organic matter	Temporary waters for wetlands and oxbows, connectivity, deposition of sediments, carriage of organic matter	
	Ground water	Recharge or discharge, depending on climate, season, water table level	High water table. Flows according to materials, substrate, water table level, season, and saturation	Low water table. Flows according to materials and substrate
	Stormwater and Drainage	Overland flow and interflow on the river banks	Overland flow, interflow. Poor drainage, saturation by water table and flood waters	Generally slow flows depending on slope, vegetation type, infiltration, turbulence, retention. Transport of nutrients, sediments and organic matter, most of it deposited before reaching main channel. Good drainage, spread, infiltration
Geomorphological structure/function	Soils		Floodplain alluvium	Varies
	Erosion	Water erodes and deposits material, changing the river channel: scouring	High during floods; naturally controlled in the riparian zone	Independent of river regime. Controlled by vegetation
	Slopes	Diverse, protected by vegetation	Diverse, vegetated	Protected by vegetation
Particle flow	Sediments	From natural erosion on banks	Deposited by floods	
	Pollutants Nutrients	Filtered by riparian vegetation	Filtration and Assimilation	Infiltration from agricultural fields

Ecological Components		Landscape Units		
		River Bank and Channel	Floodplain	Uplands and Hillslopes
Biological structure/function	Vegetation	Water tolerant	More or less water tolerant. High species richness	Less tolerant to water. Erosion resistant on slopes
	Seeds propagation	Transport of floating seeds	Deposited by floods and wind	Depends on wind and runoff or other vectors
	Habitats	Diverse, interior and edge species, grasses to mature trees, plankton	Corridor, mature vegetation, connectivity. Rich in habitats. Depends on flood pulse. Wetlands	Edges with agricultural fields or city; buffer to floodplain. Connectivity. Matrix
Biological structure/function	Wildlife (birds, terrestrial, insects)	Continuous and diverse. High diversity	Continuous, interior species	Continuous. Edge species. Multi habitat animals
	Fish populations	Natural dynamics, free migration	Provides food and habitat, controls temperature	
	Plankton	Natural dynamics		

Table 3.1 (continued)

River corridors vary along their length (see Table 3.3). Forman (1995) views rivers as “...a series of ecological gradients, a river continuum, in which water flow, organic matter, fish populations and other factors change somewhat gradually” (Forman 1995:209).

The cross section of the river changes along its course. According to Pedroli *et al* (2002), “Upper, middle and lower course can be distinguished, with distinctive plants and animals, water behaviour and banks and floodplain” (Pedroli *et al* 2002:08). In a study on the Val Roseg in Switzerland, Ward *et al* (2002) identified 6 channel types: the main channel, side channel, intermittently-connected channel, groundwater channel, mixed channels channel and tributaries, indicating the diverse geomorphic structures that may occur in a river corridor. The diversity of channel types defines the species present and their movement, extension of floods, flow of runoff and particles towards the stream (Figure 3.4). In other words, river structure governs its present function.

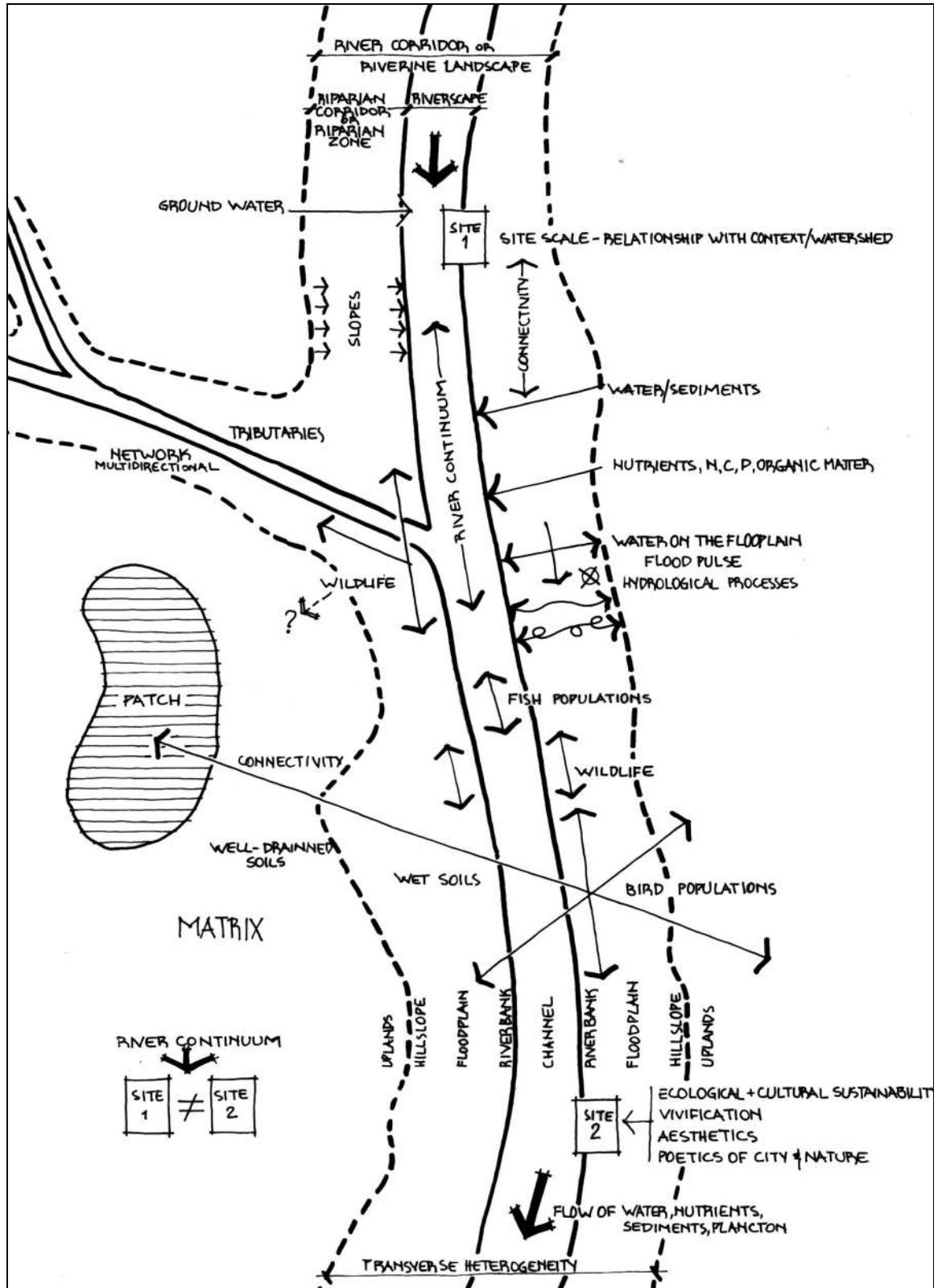


Figure 3.3 Schematic structure and function of ecological objects and processes on a river corridor. Along the river, corridor characteristics may differ (Sites 1 and 2).

Table 3.2: Landscape differentiation along river course (Based on Forman 1995 and Large and Petts 1996)

	Upper course or Low order river	Middle course or Middle order river	Lower course or High order river
Water velocity	High.	Mid.	Low.
Channel bottom	Rough bottom: rocks, wood, gravel, and sand.	Rooted aquatic vegetation.	Smooth: silt and other fine material.
Channel	Straight.	Intermediate, with pools and riffles, silt, sand and rocks.	Curvilinear with short straight stretches and meanderings.
Erosion	High. Sediment production.	Sediment transportation.	Low. Sediment deposition.
Base of fish food chain	Dead organic matter from leaf fall.	Attached algae and rooted aquatic vegetation; soil organic matter from floods; washed organisms.	Phytoplankton; soil organic matter from floods; washed organisms.
Habitat	More heterogeneity.		Less heterogeneity.
Vegetation	Mosses and ferns.		
	Production zone.	Transfer zone. High environmental heterogeneity. High species richness.	Storage zone. Depositional zone.
			Where most urbanization and agriculture are.

Pedroli and Harms (2002) reinforce the importance of hydrological processes referring to their capacity to determine the type of natural systems occurring at the scale of a river section in a natural fluvial landscape. Restoration of morphological and hydrological processes, for Pedroli *et al* (2002), is a prerequisite. In other words, for Pedroli *et al* (2002) artificial manipulation of the river structure, which directly influences its functioning, should be used in order to create the necessary changes that would generate a new structure and consequently new function. Ward *et al* (2002) have the same opinion. However, Ward *et al* (2002) further suggest that rivers, once the conditions are restored by hydrological changes, should not be further manipulated;

Pedroli et al (2002), on the other hand, defends a continuous management of the river structure.

Ward *et al* espouse a less dynamic view of landscape when he refers to engineering works: “...landscape patterns may be ‘frozen in time’ by dams and artificial levees...” (Ward *et al* 1999). According to Marsh (1997), landscape is dynamic. Any change in the river structure modifies its functioning. An example of riverfront dynamism is the weir built in the Saskatchewan River, in Saskatoon, in 1939. In a few decades, sedimentation on the upper side of the weir created a silt bar where hundreds of species of birds settle and pelicans fish (Edwards and Crosby 1999).

Other contributions

From a river conservation perspective, the ideal “...attitude would be to protect and rehabilitate entire river corridors, including floodplains and contiguous groundwater aquifers” (Ward 1999:100). However, river restoration could mean the loss of invaluable public open space. Nevertheless, the literature on river restoration provides useful information for the development of riverfronts.

Rosgen (1996), a hydrologist, classifies rivers into 7 different groups according to 4 levels of characteristics: geomorphic, morphological, state or condition, and a validation level where processes are verified. This classification shows the predominance of a structural analysis in the three initial levels that will lead to an evaluation of functioning in the last level. Riley (1998) affirms it is fundamental to start by identifying the river class before any design or restoration action.

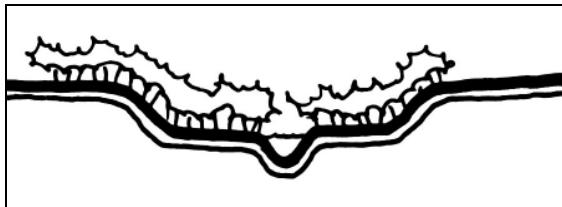


Figure 3.3a Section. On the left margin, the upland interior environment creates a route for movement of interior species; eroded particulate is arrested and deposited; absorption of water occurs in light precipitation, as well as slow dispersion of water toward stream; dissolved substances are partially arrested.

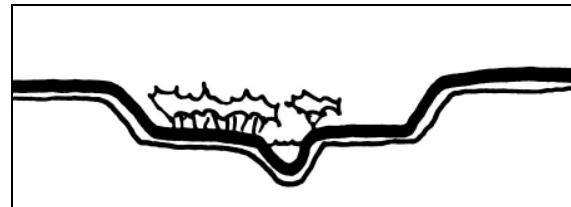


Figure 3.3b Section. Narrow line of vegetation provides shade, organic matter and habitat for edge species and fish.

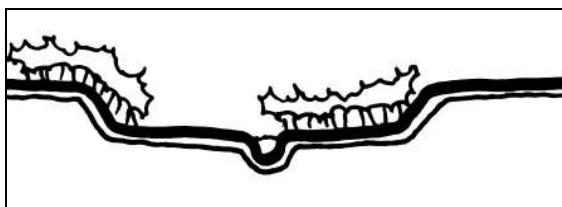


Figure 3.3c Section. Vegetated floodplain slows water velocity during floods (right).

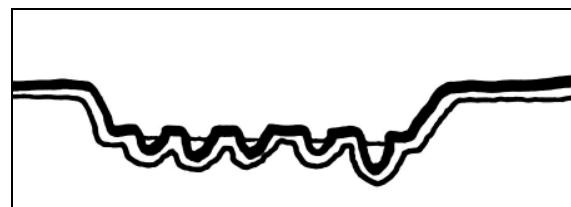


Figure 3.3d Section. Braided channel: full of sediments.

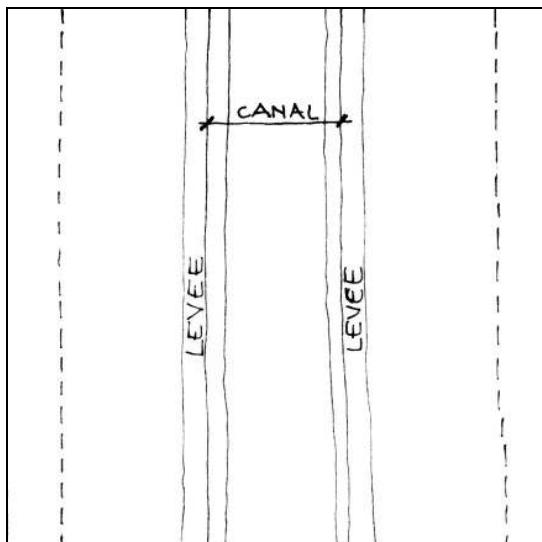


Figure 3.3e Plan. Channelized river

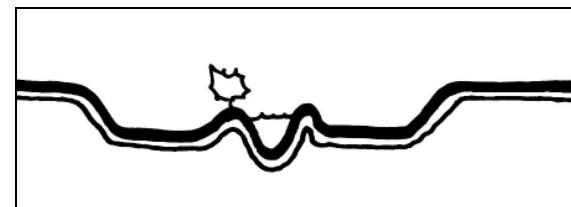


Figure 3.3f Section. Channelized river. Channel lowers diversity, biomass, density, has limited habitat value and low water table.

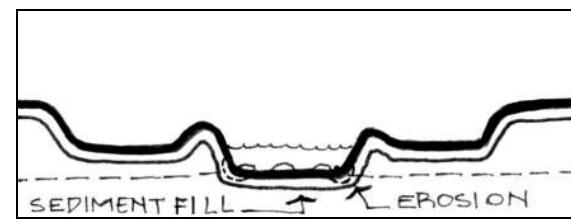


Figure 3.3g Section. Channelized river. Channel lowers diversity, biomass, density, has limited habitat value and low water table.

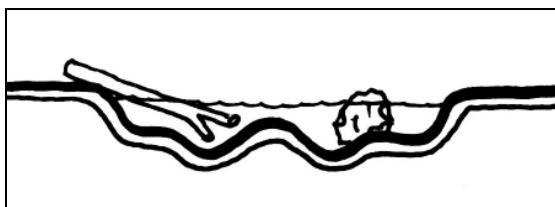


Figure 3.3h Section. Large woody debris or rocks create deep holes that may create habitat for big fish.

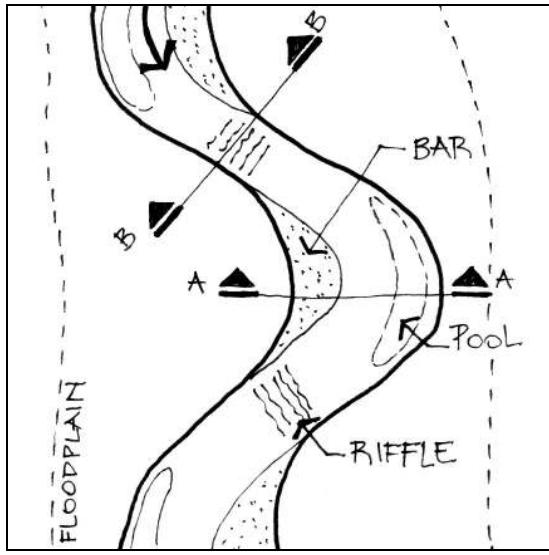


Figure 3.3j Plan View of a meandering portion of a river

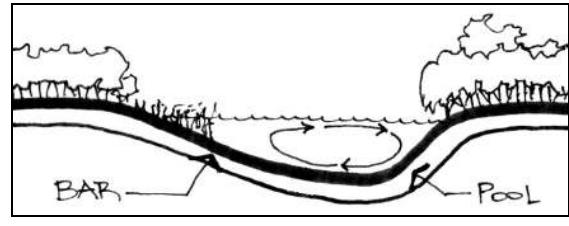


Figure 3.3i: Section AA. Pool - Erosion on bank on the pool side, sedimentation and deposition on bar.

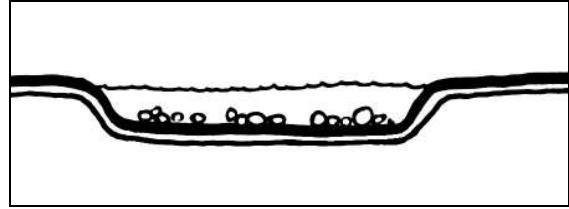


Figure 3.3k Section BB. Riffles are shallow and present coarse gravel.

Figure 3.3: Cross sections along river corridors show different conditions/geomorphology that might be found in a single river along its course. Adapted from Forman (1995), Marsh (1997), McHarg (1999), Rosgen (1996), and Riley (1998).

Most research on landscape ecology of rivers focuses on river restoration. The object is often the non-urban river, where processes and patterns have more space for restoration and less human interference. However, an understanding of the issues involved in landscape ecology of river corridors helps understand the urban river regime and the possibilities for enhancing the urban river condition through the manipulation of its structure. The design and development of riverfronts should consider the findings of river restoration and bring together landscape ecological principles with the possibilities for human use. This approach will be further discussed in the next chapter with the transference to design solutions.

Riverfront: Landscape Ecology of Urban Rivers

Riverfronts have different characteristics from those in a more natural condition. While urban areas have been an important agent of harm to river corridors, landscape ecology of riparian zones in urban areas has not been well investigated. The literature shows concern about non-urban areas, usually represented by agricultural fields that occupy the largest area on the landscape.

One exception is the framework developed by Baschak and Brown (1995). They focus on assessment of natural and cultural resources and networks. However, although it is an urban river, it is also a greenway, with more natural conditions than average urban river corridors. Yet, even in such favourable conditions, one area still requiring further research is “...urban habitat design, planning and management...” (Baschak and Brown 1995:223).

The urban landscape consists of remnant parks within a densely built up matrix (Forman and Godron 1986). According to Baschak and Brown (1995), “in the city, landscape ecology has dealt with the management of individual patches and corridors as elements of the whole landscape” (Baschak and Brown 1995:212). This section discusses the relationship of the site with the landscape. The riverfront is on the interface between the river channel and the uplands and includes the river bank and the floodplain, where the riparian vegetation originally existed. Much has been said about the consequences of intervention on river environments: alteration of spatial and temporal dynamics, reduction of diversity in habitats and patterns (Pedroli *et al* 2002).

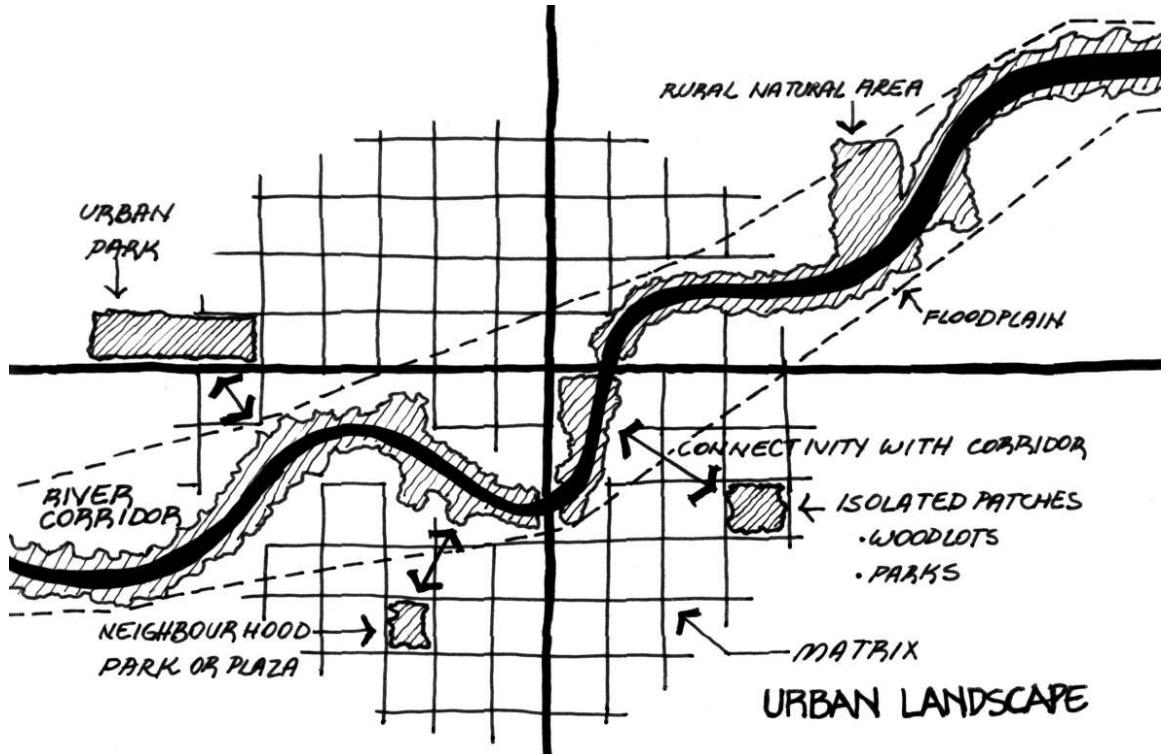


Figure 3.4 The Urban Landscape Scale.

Modification (engineering) of rivers for human activities or settlements changes their dynamics and reduces flood area, consequently interrupting the river continuum, altering the flood pulse, and the hydraulic stream ecology (Pedroli et al 2002). As a consequence, diversity in habitats and patterns is reduced. Ecological function is lost with the substitution of vegetal cover by buildings, urban infrastructure, port facilities, or flood control structures on the floodplain. The transformation of the landscape structure into an urban structure creates an urban change regime, different from the natural river regime governed by cycles of floods. The urban structure demands stability and prevention of hazards (biotic and abiotic structure and processes of urban river corridors are summarized in Table 3.3).

Table 3.3 Relationship between structural and functional objects and landscape units in an urban landscape.

Ecological Components		Landscape Units		
		River Bank and Channel	Floodplain	Uplands and Hillslope
Hydrological processes	River continuum	Discontinued by dams, locks, weirs. Controlled by levees, dikes, dams, weirs. Slower flow. Loss of rapids (habitat and oxygenation of water)	Less contribution to natural processes	Source of sediments and chemicals
	Floods	Vertical movements depend by dams	Vertical movements controlled by levees, dikes, dams	
	Ground water	Recharge or discharge, but influenced by built structures on flood plain and the presence of retaining walls on river bank	High water table, affected by city infrastructure and buildings' foundations; polluted by infiltration of chemicals	Low water table, affected by city infrastructure and buildings' foundations. Polluted by infiltration of chemicals
	Stormwater and Drainage	Overland flow and interflow on the river banks. Eroded banks or need of concrete slabs where pipes reach the channel	Fast flows on hard surfaces, to pipes, becoming linear and discharging in specific places. Transport of sand, salt, oil, etc	Flows on hard surfaces, fast, to pipes, becoming linear and discharging in specific places. Transport of sand, salt, oil, etc
Geomorphological structure/function	Soils	Carried from erosion on floodplain and uplands (construction sites)	Manipulated, eroded	Manipulated, eroded
	Erosion	Artificially controlled: city edges cannot change	Artificially controlled by retaining walls: concrete	Artificially controlled: concrete. Common in construction sites
	Slopes	Hard edges, retaining walls	Flattened for human use	Usually flattened for human use, retaining walls
Particle flows	Sediments	Accumulation. Loss of depth. Increased sedimentation	Sand, silt, gravel	Sand, silt, gravel
	Pollutants	Receives sewage and oil, sand, and salt carried by runoff	Source of oils, sand, salt and other	Source of oils, sand, salt and other
	Nutrients	Receives excess of nutrients from fertilizers	Fertilizer	Fertilizer
Biological structure/function	Vegetation	Damaged, reduced, manicured, non-native.	Damaged, reduced, manicured, non-native.	Damaged, reduced, manicured, non-native.
	Seeds propagation	Less seeds available.	Less seeds = less propagation.	Less seeds = less propagation.
	Habitats	Damaged, reduced by human activities. Elimination of river bank species.	Fragmented, reduced, small patches.	Fragmented, small patches, no or rare interior habitats.

Ecological Components		Landscape Units		
		River Bank and Channel	Floodplain	Uplands and Hillslope
Biological structure/function	Wildlife (birds, terrestrial, insects)	Reduced by loss of habitats; isolated patches, edge species. Low diversity.	Edge species. Loss of habitat, isolated patches.	Interrupted, isolated patches. Edge species.
	Fish populations	Reduced, habitat loss due to temperature, BOD, pollutants, vegetal cover, shade, substitution of species.	Loss of shade, large woody debris and organic matter.	
	Plankton	Depends on pollution levels.		

Table 3.3 Continued.

Using an object, vegetation, to compare urban (table 3.3) with a more natural landscape (table 3.1), it can be seen that vegetation in the three landscape units still differ according to water tolerance in the more natural situation. On the other hand, substitution of native plants by exotic species, fragmentation of clusters, and reduced patches, in the urban situation, create conditions for edge species to proliferate in all three landscape units, reducing biodiversity. In the landscape, objects that present more natural conditions operate as a continuum among the three landscape units. In the urban landscape, the capacity of an object to work as a continuum depends on the level of alteration and degradation due to urbanization that create different ecological conditions.

The riverfront is an area that has been transformed by urbanization. Any intervention on these sites must take into consideration whether restoring their natural or original state is possible or desirable. The attempts to restore natural conditions have to contemplate the problems caused by urbanization on the landscape, its ecosystems, and the function of the ecological objects within the city, as summarized in the table above. When large park areas are available, where flooding may be allowed, restoring ecological processes may

be easier than in the traditional North American settlement, where corridors were narrowed and the floodplains occupied and controlled. The allowance for natural changes such as floods may also represent a challenge. Allowing floods could result in damage to property and material losses. The presence of humans in the city must also be considered, and is part of the success of the design incorporating human use, culture and identity into the process.

Summary

This chapter has examined the ecology of riverfronts through an understanding of landscape ecology, its implication for river corridors and specifically for the urban river landscape. From this examination, the following concepts/principles are adopted for the development of this study:

1. Landscape ecology comprises both bioecological and geoecological studies and is able to provide the principles needed to develop river environments.
2. River corridors are mainly dominated by hydrological cycles.
3. Riverfronts must consider the confluence of natural and human processes. Landscape ecology provides a model for this analysis.
4. The consequences of local (site) interventions on the landscape must be understood. Local actions on the river corridor may reflect elsewhere. The landscape architect must understand the ecological processes involved in the landscape to be affected by design and it is necessary to set up the context, from a broader scale (a watershed, for example) to a finer one (how groundwater works on the site, for example).

4

Landscape Ecological Principles for the Design of Riverfronts

This chapter focuses on the development of a set of principles to be applied to the design of riverfronts. The principles derive from the literature of the various disciplines that form landscape ecology, and from an analysis of a case study site. They address the issues raised in the previous chapter, where the main structural and functional components and issues of a typical urban river corridor were identified (Table 3.3).

“Principles” are understood to be ideas on which the design process is based and from which the design is developed⁵. The principles presented in this chapter are based on the

⁵ “**Principle** (...) 2 RULES OF A PROCESS a) [C] a rule which explains the way something such as a machine works, or which explains a natural force in the universe (...) b) **principles** plural the general rules on which a skill, science etc is based ...” (Longman Dictionary of Contemporary English 2001).

landscape scale and are used to develop recommendations as well as design solutions to restore or to enhance ecological function at the site scale.

According to the concept of landscape defined in Chapter Three (“a heterogeneous area where ecosystems repeated in similar form interact”), the landscape in this case is represented by a city of any size. Patches might be present in the form of woodlots and parks; the matrix consists of the urban fabric, permeated by corridors that range from hedgerows to a river or a network of rivers. In this study, the site is the riverfront.

Rivers differ from each other in size, shape, and slope, occupy different geographic and climatic regions, and have been altered by various types and degrees of urbanization. These differences suggest a range of possible approaches to a landscape ecology study. For example, Boon in Pedroli *et al* (2002) proposes that five levels of intervention could be adopted for a river depending on its level of degradation: 1) preservation, 2) limitation of watershed development, 3) mitigation, 4) restoration, and 5) dereliction. Preservation is the aim when remnants of vegetation and hydrodynamic processes are still intact; limitation of watershed development is the goal when there is “high ecosystem quality and with ecological key factors functioning without major impediments” (Predoli *et al* 2002:06). Mitigation is required to guarantee survival of habitats and organisms in places where there are economic or recreational activities. In the case of “natural hydrodynamics [being] hardly recognizable” (*ibid*), restoration is necessary. Dereliction is the worst case scenario, when it is not worth investing in any type of project (Boon in Pedroli et al 2002).

The primary objective of developing design principles is to provide the tools to help designers to transform the landscape structure, aiming to enhance habitats and species

diversity, restore hydrological processes, and provide opportunities for human contact with the river environment. It should be emphasized that the objective is to provide guidelines to help create structure(s) that provide function that is appropriate to the urban environment and compatible with the presence of human activities. In essence, this involves what could be called enhancement of ecological function; mitigation, as described by Boon (in Pedroli *et al* 2002), would be the closest concept to describe this type of intervention at the site scale. It should be noted that Boon's categories relate to the landscape scale.

The principles herein proposed do not attempt to return the riverine landscape to its original function through the re-establishment of the river's original structure. It is accepted that urban rivers have already been largely transformed and present conditions different from those found in a more natural state. Urban areas rarely present conditions for preservation (see Table 3.3); spatial limitations, land ownership, presence of buildings and structures in the river corridor restrict the scope of intervention. Preservation is mostly feasible in non-urban areas, agricultural matrices or greenways, where a large width of riparian corridor, habitat quality and less human impact is possible.

The design principles are not intended to be "mechanical and prescriptive methods", as Corner (1997) suggests when discussing the exchange between ecology, creativity and landscape design. Instead, they aim to be keys to creative solutions that consider, for example, aesthetics and regional or traditional characteristics in design.

The Otonabee River Trail Case Study

The Otonabee River Trail in Peterborough, Ontario, was used as a case study. The criterion for selection of this case study was the integration of ecological and human concerns, recognized by the Canadian Society of Landscape Architects (CSLA) with the Professional Award of Honour in 2002. In addition, availability of published material and its proximity to Guelph - to facilitate visits to the site - were other influential criteria that helped define the Otonabee River Trail as the case study. The methods of data collection for the site involved consultation of published material and a jurors' report (CSLA Professional Awards), web search, and visits to the site.

The purpose of having a case study was to examine the adoption of ecological design measures in the constructed/implemented design of an urban riverfront, in order to more fully inform the development of the landscape ecological design principles.

Peer Reviews

The Otonabee River Trail was awarded the Professional Award of Honour by the Canadian Society of Landscape Architects (CSLA). The Professional Awards jurors' report affirms that "the project encompasses environmental, historical, and social issues, responds well to its site and masterfully uses water in its many forms" (CSLA 2002). According to Middleton (2002), the trail "ties together existing open spaces and fills in key gaps to breathe new life into the City of Peterborough's park system, resulting in a whole much greater than the sum of its parts" (Middleton 2002:9). The design is

considered to present a significant balance between human and aesthetic concerns and ecological achievement⁶.

Context

The Otonabee River is part of the Trent-Severn Waterway. The construction of dams caused the disappearance of rapids and interrupted much of the fish migration routes. Water level is maintained at a constant level throughout the year, and floods are controlled. Removal of dams to restore ecological function is not feasible because of the high economic, cultural and social costs of restoring a riverbed that has been transformed for more than one century.

Beyond the limits of the designed area, to the south, is the Holiday Inn, where the river bank is stabilized with gabions and grassed areas, and the building and a parking lot are close to the river. A pedestrian bridge links the motel with the Del Crary Park and marina, where the river bank is substituted by concrete walls and the park has an extensive grassed area.

South of the park, a residential area surrounds the Little Lake (wider river surface on the bottom left in Figure 4.1). The river bank is “paved” with interlocked concrete pavers followed by a grassed surface to facilitate access and make it safer for swimmers or kayakers to go in and out of the water.

⁶ This balance is recognized as a means to enhance the success of ecological endeavours (Décamps 2001, Nassauer 1995a, 1995b).



Figure 4.1 Aerial photo of downtown Peterborough. The design area is shown in the centre (highlighted); downtown surrounds the highlighted area (image from the posters submitted by the design team to the CSLA 2002 Professional Awards Program).

The eastern margin is occupied by residential neighbourhoods. The river bank usually presents alternately grassed surfaces or a more natural cover with trees and shrubs. The most intense use of the riverfront remains on the western riverbank.

Design Description and Program Elements

The Otonabee River Trail is located adjacent to the downtown area of Peterborough, Ontario, on the western margin of the Otonabee River. On the river margin, north of Simcoe Street (Figure 4.2), is the Quaker Oats Company, surrounded by roads, a parking lot, a loading area, and a relatively well vegetated riverbank. South of Simcoe Street the designed riverfront begins with a mix of vegetated river banks, asphalt trails, resting areas with benches and decorative plantings.

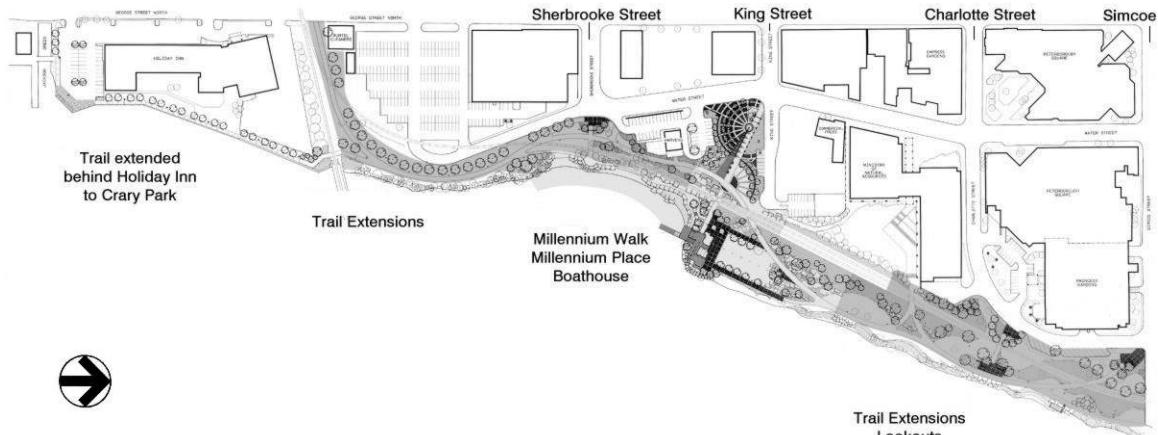


Figure 4.2 Otonabee River Trail Master Plan (www.otonabee-river-trail.org)

The central area of the trail, between King and Sherbrook Streets, is the plaza (Millennium Walk), the café, and the boat house. This area presents a mix of restored banks with adaptation for a more intense human use. Moving south, the trail and river bank present diverse vegetation, from grasses to canopy trees, until the rail bridge, where the trail diverts to the west.

The design considers the city as a source of its concept. The main points are its historical references, the native inhabitants, the industrial area, and the river as an attraction and an ecological resource.

The program encompasses a multi-use path running north/south (the trail itself – Figures 4.5, 4.6, and 4.7); shoreline rehabilitation; creation of fish habitat (island); an interpretive walk connecting downtown to the river, with panels describing the history of the site and the region (Figure 4.3); space for public recreation; boathouse and café (Figure 4.4); and community gardens. Site visits showed great acceptance of the trails. Several people could be observed during the period of observation. Especially at lunch time, the presence of downtown workers could be noted.



Figure 4.3 Millennium Walk. A central plaza links and reinforces the connection of downtown Peterborough to the river. Panels tell the history, culture and environmental characteristics of the city and region.



Figure 4.4 (above) Boathouse and café. Large limestone blocks re-create the shoreline, creating conditions for plants to grow and identity for the design. These blocks are applied to other portions of the riverbank and on the Millennium Walk fountain.



Figure 4.5 Trail and riverbank. Openings on larger riparian vegetation create viewpoints and points of attraction for people.



Figure 4.6 Multi-use trail. A 3.2m wide asphalted trail links the several portions of the project.



Figure 4.7 Trail and sculpture, with river on the right. Image shows treatment of riverbanks with the restoration of part of the riparian vegetation while enhancing human use.

All images from the posters submitted by the design team to the CSLA 2002 Professional Awards Program.

Design Principles

This section presents landscape ecological design principles. The principles derive from the literature of landscape ecology, and from the analysis of the Otonabee River Trail case study. They address the 16 structural and functional components identified in Chapter Three (Tables 3.1 and 3.3). In this chapter, these components are grouped, according to the similarities between them, into ten components, that generate 28 principles. Most principles are illustrated with examples extracted from the Otonabee River Trail case study, and from observations carried out in the City of Guelph.

The sequence in which the groups of principles are presented does not reflect any order of priority. In fact, in landscape ecology, priority depends on the approach. The geoecological perspective prioritizes the restoration of hydrological and geomorphologic processes (Pedroli et al 2002; Pedroli and Harms 2002; see also pp. 38), which mean giving priority to certain groups of ecological components, namely *River Continuum, Floods, Groundwater, Stormwater and Drainage, Soils and Erosion, and River Bank and Slope Stabilization*. On the other hand, the bioecological perspective tends to give priority to habitat and vegetation (Baschak 1992). This perspective gives priority to *Vegetation, Habitats and Wildlife, Fish Populations and Habitats*. The approach adopted here aims at incorporating both perspectives, and sees the landscape as an interaction between biotic and abiotic elements. As such, it is argued that the adoption of principles will depend on the conditions of the site and the river where they will be applied. The relevance of their application also varies according to the landscape unit, i.e., if the design site is the riverbank and channel, floodplains, or uplands and hill slopes (see Table 4.1). However, the importance of water issues for a riverine landscape must be acknowledged.

The next sections describe the ten groups of ecological components. Within each group, the principles are listed according to the priority of application; the first is considered the most relevant to the functioning of the respective ecological component.

River Continuum

“...from headwaters to downstream extent, the physical variables within a stream system present a continuous gradient of conditions including width, depth, velocity, flow volume, temperature, and entropy gain” (Vannote et al 1980:132).

Rivers have been discontinued by dams, locks, and weirs in order to control floods and make navigation possible. According to Décamps (1984), depending on their location, “dikes and dams generally either halt the succession of riparian vegetation or, on the contrary, encourage the development of hardwoods” (Décamps 1984:172). For Pedroli *et al* (2002), “these engineering works are designed to control the dynamics of the river, and involve the loss of natural dynamics and of river-floodplain interactions, as well as the loss of flooding area and fragmentation of habitats” (Pedroli *et al* 2002:5).

Recovering the river continuum might require removing those engineering works or adapting them to ecological requirements. Many dams already have structures to allow fish migration; however, they still create environments with little relation to the natural or even appropriate conditions for several species of fish, aquatic vegetation, and invertebrates. An alternative approach could focus on establishing species that are adaptable to this artificial habitat. However, this could mean the substitution of native by non-native species. The example of the Saskatchewan River, cited in Chapter Three shows, shows that the retention of water by a weir creates sedimentation on its upper portion and changes habitat. As result, native/endemic species are reduced, attracting

others that are typical of other regions, further affecting those areas. The loss of bird species and the change of migration routes are examples.

Altering the engineering works may not be part of the scope of riverfront design, since they are not directly located on the riverfront and the design professionals involved may not be allowed to interfere with the functions of such works. However, actions on the river channel may be fundamental in enhancing ecological function on the riverfront, since "...flow is the major factor modified by human activities, and it influences the whole system by deposition and re-suspension of sediments and by action on temperature and on the processes of photosynthesis and biodegradation" (Décamps 1984:166).

Principles: River Continuum

- 1. Remove engineering works to restore natural dynamics.***
- 2. If engineering works are kept, propose alternative structures to allow function⁷.***
- 3. Avoid proposing new structures that interrupt the river continuum.***

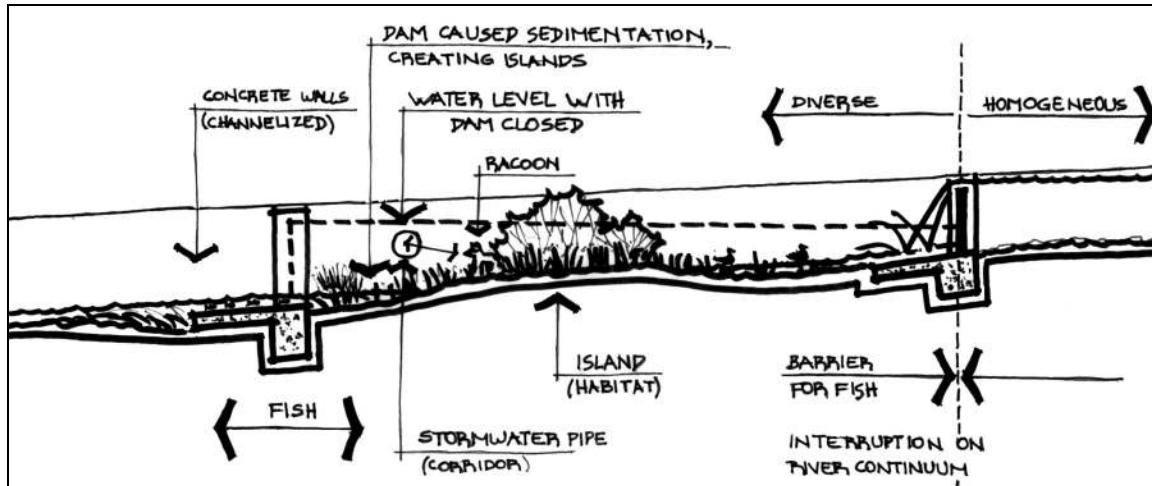


Figure 4.8 Longitudinal Section of Speed River at Riverside Park in Guelph, Ontario. The opening of a dam provided the conditions for a number of species to adopt the area as their habitat. Islands created by sedimentation appeared after the lowering of the water level as did host grasses and shrubs that attract fish, birds and small mammals. Running water and rapids attract fish and birds. A stormwater pipe functions as a corridor for a racoon to move from land to its fishing spot. A remaining dam upstream shows algae attached to the river bottom, but little diversity is observed.

⁷ Some alternative structures, such as steps for fish migration in dams and locks, are well known.

Floods

“Flooding is the key process determining the pattern and the development of the habitat mosaic (...) ...as floodwater recedes, so the rivers receive an input of nutrients, contributing substantially to the functioning of the lotic and riparian communities” (Pedroli et al 2002:6).

Although important for natural processes, floods are usually undesired in urban areas. Various engineering works built on the river bed and on the floodplain (levees) guarantee protection to buildings erected directly on the floodplain and riverbanks.

Knowing the different flood levels (1, 2, 5, 10, 25, 100-year floods) might be an instrument for creating diversity. Places where 2-year floods are prevented (lower elevation) could have its control changed to a 5 or 10-year control to allow some flooding and ecological functioning. The control might be done thorough dam operation or by lowering portions of existing levees or river banks to create areas of sediment deposition, where wetlands could form. These measures could increase biodiversity and ecological function in areas where homogeneous plantings or highly managed areas occur. Also, controlled flooding becomes an instrument to reconnect existing patches once isolated, represented in the city by remnant woodlots, parks and plazas, or even neighbourhood parks. Demonstration areas in parks on the river corridor could also be adopted to improve environmental education and diversity.

<i>Principles: Floods</i>
4. Allow flooding where it does not represent risks for consolidated urban areas and structures (e.g., parks).
5. Create alternative structures to retain temporary waters or controlled flooding: ponds, oxbows, wetlands (Figure 4.9).

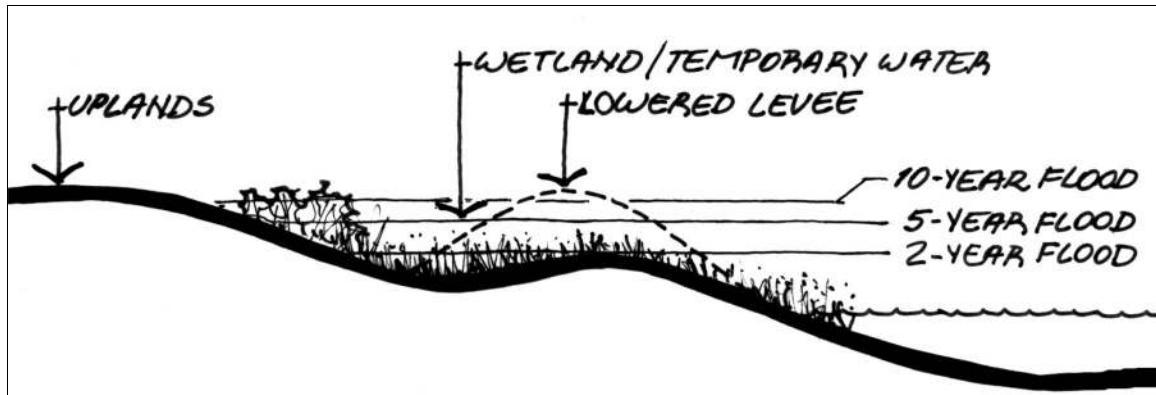


Figure 4.9 Lowering of levee to allow partial flooding.

Groundwater

Groundwater in the city is affected by built structures (buildings and roads, for example) that diminish its quantity and quality, divert its flow, or pollute it. Protection of the water table should be predicted in urban legislation, as should setbacks from water courses. Existence of buildings near streams can directly interrupt the flow of water; it also compresses lower portions of bed rock, expelling water (Figure 4.10). The flow of water between land and stream is also an issue: adoption of retaining walls might represent a barrier that might cause lowering of the water level in a channel.

Possible solutions for the flow of water between channel and floodplain can include revegetation of the river banks and adoption of pervious materials such as gabions. This would facilitate groundwater flow and vegetation could attach to it, creating some opportunity for habitat. Throughout the city, regulation based on a careful mapping of water resources, defining capability and suitability for different kinds of development, should be considered.

Principles: Groundwater

- 6. Allow groundwater flow between channel and floodplain substrate by using permeable materials on the riverbanks.***
- 7. Allow water infiltration in the whole landscape to maintain continuous infiltration and flow and regular water table level.***
- 8. Avoid structures that interfere with the water table such as deep foundations, especially near the riverfront.***

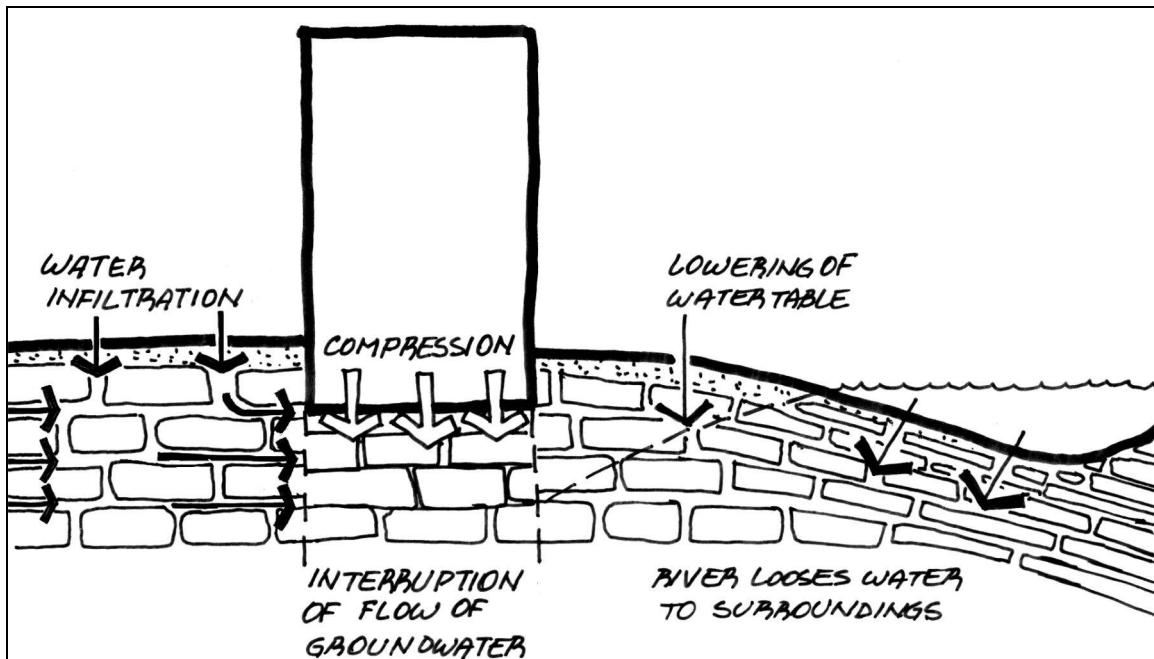


Figure 4.10 Large buildings compress bedrock, interrupting the flow of groundwater.

Stormwater and Drainage

Traditional drainage systems facilitate fast conveyance of water. Fast flows of water on impervious surfaces are conducted to pipes and discharged in specific places (point sources). This eliminates water from surfaces, causes loss of water table, erosion at the discharge points, and transport of sand, salt, oil, and other pollutants. The ideal drainage occurs when runoff flows as sheets of water on low slopes and pervious surfaces,

reducing speed and allowing infiltration and filtration. Herson-Jones *et al* (1995) suggests that infiltration and filtration is more efficient with slopes less than ten percent.

Marsh (1997) lists three strategies to manage stormwater: on-site storage of water for slow release (detention); return of water to the ground; and a development planning for low runoff increase. Ferguson (1998) recommends vegetated swales where rainfall would infiltrate and be stored, be treated and discharged gradually after storms. Riparian vegetation is also effective in processing and storing water: “deep-rooted trees improve drainage or infiltration by increasing substrate porosity and capillarity” (Thorne in Tabacchi *et al* 2000).

Stormwater can only be controlled, treated, and used as a resource in the landscape if decisions extend beyond the limits of the riverfront. For example, the use of gabions to stabilize riverbanks allows the flow of groundwater. However, if actions are not taken to allow water to infiltrate instead of flowing inside pipes, the river will lose water to its surroundings (discharge) instead of receiving groundwater (recharge) and reaching an equilibrium. As examples of structures, trenches, swales, retention and detention ponds can be used to postpone water discharge, delay runoff, and be the base for sedimentation and filtration (Figure 4.4).

Principles: Stormwater and Drainage

- 9. Adopt retention, detention, infiltration and filtration structures and grading that encourage infiltration (see Figure 4.12).***
- 10. Maintain or restore vegetation on banks, floodplain and uplands to increase retention and filtration of stormwater before reaching the water table.***

Pollutants, Nutrients, and Sediments

Nutrients and pollutants originate mostly on the matrix and are carried by runoff toward rivers. Consequences for the environment include ecosystem unbalance, algae blooms, and deprivation of oxygen (caused by nutrients); reduction of resistance to disease and reproductive capacity, as well as alteration of behaviour by the presence of trace metals); and deoxygenation of water due to oils (Ferguson 1998).

The floodplain has the potential to function as a buffer for much of the occurrences on the urban matrix⁸. According to Herson-Jones *et al* (1995), “floodplains, and wetlands contained in the floodplain, are critical to the control of the quantity and quality of stormwater runoff” (1995). They store excess flood waters and act on nutrient recycling.

As defined by Herson-Jones *et al* (1995), “buffers (...) are forested areas adjacent to water bodies designed for the treatment and protection of stormwater” (Herson-Jones *et al* 1995). Other features that can work as buffers are swales, filter strips and setbacks. The primary goal of swales is to collect and redirect water, but they may provide some infiltration and remove some pollutants from stormwater. Filter strips are vegetated (grasses) strips where pollutants can settle. Setbacks can also be considered a buffer, but are usually used as a separation between different uses (Herson-Jones *et al* 1995). Tabacchi *et al* (2000) reinforce the buffer function of riparian vegetation, affirming that plants directly take up and store nutrients, providing organic matter to autotrophic nutrient transformers, and influencing water quality.

⁸ This view is not undisputed, and Décamps (1998) argues that the riparian areas’ role as a sink in the control of diffuse pollution is unclear, since this view rests on specific studies in agricultural areas from the humid temperate domain.

Pollutants removal depends, according to Herson-Jones' *et al* (1995) proposition for riparian buffers, on the width of the buffer, hydraulic load and flow velocity, pollutant load in runoff, sediment particle size, slopes, vegetation, soil composition, depth of water table, presence of organic matter, and adjacent activity.

Since riverfronts may need to accommodate diverse land use in a restricted area, pollutant removal methods might need additional mechanisms that extend beyond the site boundaries to treat pollutants originating outside the riverfront. Cleaning deposits periodically increases the efficiency of such mechanisms.

Principles: Pollutants, Nutrients, and Sediments

- 11. Adopt infiltration and filtration structures, such as swales and ditches.***
- 12. Reduce use of pesticides, fertilizers, road salt and other pollutants (MTRCA 1997).***



Figure 4.11 Gravelled parking lot during summer storm: a large amount of gravel and sand is being carried (notice parking spot for scale).

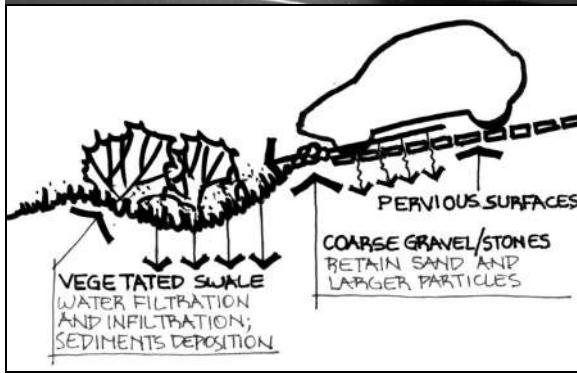


Figure 4.12 Mitigation structure. Examples of methods that could be adopted for retaining and filtering pollutants and sediments.

River Bank and Slope Stabilization

Within the city, natural erosion of riverbanks (and subsequent migration of the river bed) is not highly desired and is usually controlled by concrete retaining walls (Figure 4.5) or gabions (Figure 4.6). The substitution of natural riverbanks causes potential loss of both terrestrial and aquatic habitats, eliminates the buffer zone between land and water (see Pollutants, Nutrients, and Sediments), and impedes groundwater flow (concrete walls).

The stability of river banks and the flow of groundwater can be achieved with the use of gabions. However, if not integrated with native vegetation, gabions might facilitate the flow of pesticides and other chemicals to the river. Ideally, riverbanks should be restored with native riparian vegetation that stabilizes while absorbing water, pollutants and nutrients. Riley (1998) supports the view that if gabions “are used sparingly as structures to support revegetation in difficult situations, they can be considered a restoration alternative” (Riley 1998:385). She recommends gabions be covered with soil to protect gabion from damage.

Riley (1998) also suggests various biotechnical slope stabilization techniques. These involve the use of live and some times dead plant materials that are fixed to the damaged riverbank. Dead material slows down water velocity, and gives the initial stability for live material to develop. Geotextiles can also be used to guarantee permeability and stability.

<i>Principles: River Bank and Slope Stabilization</i>
<i>13. Use of permeable materials and/or vegetation to stabilize riverbank.</i>



Figure 4.13 Holiday Inn parking lot, Peterborough, Ontario. Retaining wall stabilizes riverbank, which represents a barrier for groundwater, elimination of habitats; lawn and parking lot generate pollutants and sediments delivered directly to river. All these factors represent obstacles to ecological processes.



Figure 4.14 Holiday Inn's lawn, Peterborough, Ontario. Gabions are permeable to water, which might represent a danger for ecological processes in such a case. Fertilizers and pesticides used on the adjacent lawn will infiltrate and drain directly into the river water, eliminating any chance of colonization of gabions by plants.



Figure 4.15 Otonabee River Trail. This section of the riverfront exemplifies the use of two different techniques to stabilize the riverbanks: native vegetation and piles of rocks contain erosion and create a small buffer while allowing human use.

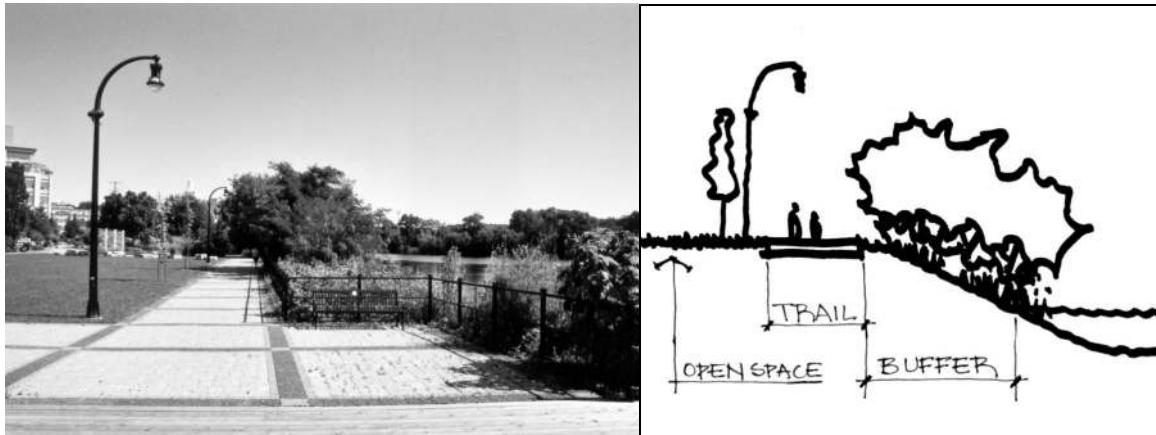


Figure 4.16 Strip of vegetation stabilizes riverbanks and functions as buffer (see principle 13).

Soils and Erosion

Two types of erosion affect the river corridor. One, natural and controlled by riparian vegetation, occurs on the river channel and banks and is responsible for natural transport and deposition of sediments, shaping the river channel. Another, “artificial”, occurs on degraded riverbanks and on exposed and unprotected soils. Construction sites are greatly responsible for the generation of sediments that will be carried by runoff to rivers as well as steep gravel surfaces such as parking lots (see Figure 4.11). Excess of sediments, as affirmed by Ferguson (1998), “abrades fish gills, carry excess nutrients and chemicals, block sunlight and cover gravel bottom habitats” (Ferguson 1998:7).

Principles: Soils and Erosion

- 14. Protect soils with vegetation.***
- 15. Adopt structures to deposit sediments before reaching the river bed (Figure 4.12).***
- 16. Use permeable pavements (Figure 4.12).***
- 17. Produce gentle slopes to reduce water speed (less erosion, more infiltration).***
- 18. Protect construction sites and exposed soils.***

Vegetation

Urban vegetation has been used as a means to change aesthetic aspects of landscapes and as an instrument for people to create links to their origins (Décamps 2001, Lassus 1998). Vegetation is usually manicured and preference is given to non-native species. These species have some ecological functions, such as evapo-transpiration, carbon dioxide sequestration, temperature control and biomass increase. However, their adoption lowers biodiversity and decreases the numbers of native species, usually better adapted to local conditions and integrated into animal, bird, and invertebrate species and hydrological processes. Tabacchi and Planty-Tabacchi (2003) warn that riparian corridors “seem to exhibit a particular sensitivity to invasions of exotic species compared with most other natural ecosystems, partly because of their linear structure which is likely to favour the regional spread of new species” (2003:252).

Several authors promote the reintroduction of native species to improve ecological function especially if dealing with the restoration of a river corridor. The integration of natural and cultural approaches is also desirable. This balance is obtained in designs such as Bernard Lassus’ Garden of Returns in Rochefort, France, where the riparian vegetation is manipulated to reinforce the presence of a historical building but also preserved to maintain its ecological function. Manicured and non-native species are kept in other areas of the design (Décamps 2001, Lassus 1998).

The propagation of native species depends on succession, which relies on species dispersal and seed propagation. In the urban landscape, fewer native seeds are available as well as less soil is exposed to them for germination. Also, maintenance and cleaning activities collect seeds in plastic bags and send them to waste disposals. Providing areas

for deposition (see figure 5.19 about riverbank stabilization with stepped gabions) allow seeds deposition even during small variations of water level and without bankfull flow. Birds, wind or water (by runoff or within the channel) transport seeds, which might be deposited kilometres down the river on its banks or floodplains during floods.

The riparian vegetation plays a fundamental role in establishing connectivity along the river corridor and between larger patches, which in the city might be presented in the form of a park or a woodlot. As Gurnel also highlights, “...riparian vegetation tends to control the connectivity between the main channel and dead arms or oxbow lakes within the riparian zone” (Gurnel in Tabacchi *et al* 2000:2964). Grasses and woody plants along the shoreline also function as buffers and help stabilize stream banks and limit channel erosion (Herson-Jones *et al* 1995). In addition, grasses and woody plants store sediment, generating floodplains with deeper soils than in floodplains without vegetation (Hawkins 1994). These deeper soils lead to deeper rooted vegetation and, consequently, to greater stability of river banks. These conditions further reduce bank erosion and nutrient concentration of water entering the stream channel.

Another important function of riparian vegetation is the control of water temperature: low temperature (shaded water) has more dissolved oxygen (National Academy of Science 2002). Root systems keep banks stable, which means preserving river depth and width, thus contributing to maintenance of cooler temperatures.

Although urban areas usually do not have enough land for the development of a complete riparian buffer, as suggested by Herson-Jones *et al* (1995), many are able to accommodate some kind of vegetation to enhance bank stabilization and habitats. A

larger operation would require land acquisition by the public administration to create open space with buffer characteristics.

Principles: Vegetation

- 19. Adopt of native species.***
- 20. Provide conditions for succession.***
- 21. Create conditions for seeds to be deposited.***

Habitats and Wildlife

Habitat is defined as the local environment of an organism ... a unit of space and its environmental features – principally microclimate, soil, topography, water, available nutrition, and other organisms (Marsh 1997:360)

Wildlife presence in the city has been a controversial topic and many times undesired in the overall matrix. Racoons, squirrels, or even bears are seen in the city in search of food because of the lack of good quality habitats. Simultaneously, habitats in the city are damaged and reduced by human activities. In particular, occupation of floodplains and river margins has eliminated riparian species. Disturbance of habitats by urbanization alters the natural dynamics of wildlife populations.

To foster wildlife habitat, Vizyova (in Herson-Jones *et al* 1995) recommends considering an assessment of species from the area or species to be targeted for preservation. This would involve evaluating the size of the habitat required, considering that diversity increases with size, and assessing the conditions of isolation and connectivity and the density and type of vegetative cover.

Habitat diversity depends on the connectivity of corridors to large patches of upland vegetation to provide large areas required by some species (Thorne 1993). Isolation of patches causes loss of migration routes, expansion of edge species, and in extreme cases the disappearance of species in certain patches, resulting in low diversity on the landscape.

One of the important roles of river corridors is their function as wildlife corridors. A landscape ecological approach to design has the potential to improve connectivity between patches. Dramstad et al (1996) present a series of useful principles in a practical guide for habitat regarding patch and corridor characteristics.

Noss (1993) argues that functions of wildlife corridors are basically twofold: “provide dwelling habitat for plants and animals and serve as a conduit for movement” (Noss 1993:44). Wildlife corridors work as they permit “daily and seasonal movements ... facilitate dispersal and gene flow between populations, and rescue of small populations from extinction; and allow long-distance range shifts of species” (Noss 1993:44).

The riparian vegetation plays an important role in promoting connectivity. Actions to promote wildlife involve restoring connectivity and re-establishing migratory routes. Where habitats can not be implemented on both sides of the river, at least one margin should be addressed. For Pedroli et al (2002) “the objective is to produce a river and an associated landscape, in which barriers and the accompanying isolation no longer put constraints on the free movement and dispersion of typical species” (Pedroli *et al* 2002:7).

Principles: Habitats and Wildlife

- 22. Maintain and/or provide functional connectivity along the entire length of the corridor.**
- 23. Provide a high-quality corridor for native species present, especially those that are most sensitive (Noss 1993).**
- 24. Restore where possible, the links between corridors and interior habitats (Figure 4.17).**
- 25. Create and protect wetlands, grasslands and meadows.**

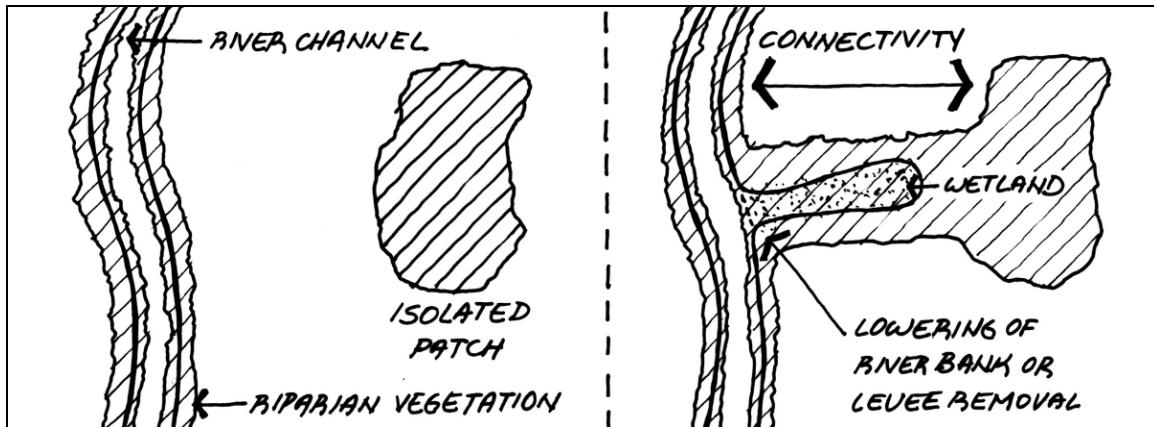


Figure 4.17 Example of creation of a small floodable area that can be useful to reconnect the channel to an isolated existing patch, increase diversity, and be used as a sample for educational purposes.

Fish Populations and Habitats

Fish populations in both rural and urban areas present reduced populations. Habitat is lost because of pollutants, alterations in temperature, low rate of dissolved oxygen, loss of vegetative cover and shade, and discontinuation of the river continuum. Recovering fish populations depends on pollution control at the watershed scale and the creation of artificially built structures or natural habitats (trunks, rocks). Habitat quality in the channel is also related to water quality, which depends on activities in landscapes in upper portions of the river and the watershed.

Emphasizing the ecological and cultural aspects, Forman (1995) defends the addition of logs to a stream or river as a means “to enhance fish habitat, fish populations, and fishermen” (Forman 1995:235). Big rocks create turbulence, causing big holes on the river bed, resulting in habitat for big fish.

Riparian vegetation also plays a definitive role in fish habitat quality. Hawkins (1994) argues that “stream systems that are surrounded by healthy riparian ecosystems (...) tend to have more productive and diverse fisheries than streams lacking riparian vegetation” (Hawkins 1994:04).

Principles: Fish Populations and Habitats

- 26. Enhance vegetation on banks; give preference to native species.***
- 27. Create artificial habitats or conditions to foster habitat formation.***
- 28. When building on a river bed, minimize impact or integrate structures with creation of habitats (shading, shelter).***

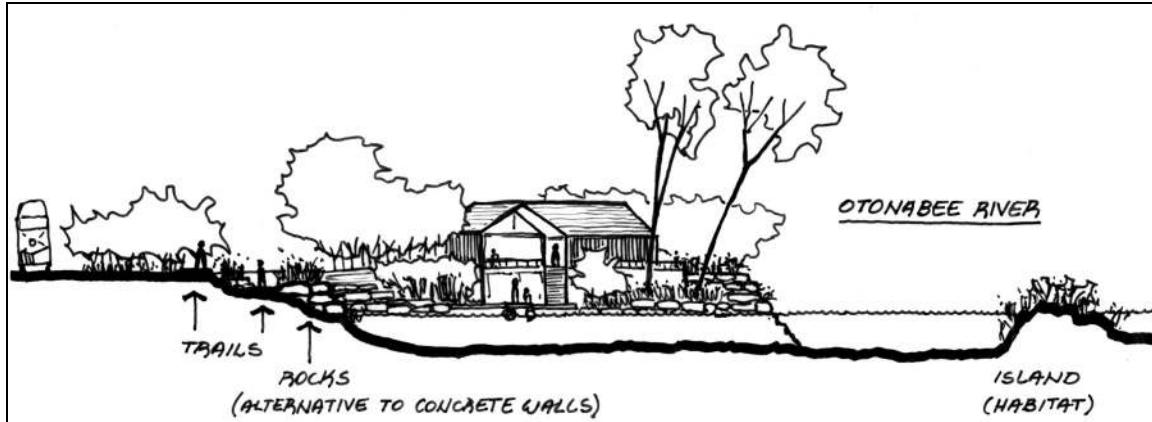


Figure 4.18 The Otonabee River Trail: cross section. Design proposed creation of artificial island and restored river bank with rocks and native vegetation to enhance fish habitat.

The landscape units of a river corridor (river banks and channel, floodplain, and uplands and hillslopes) present different bioecological and geoecological characteristics (see Tables 3.1 and 3.3). Hence, the landscape ecological design principles should be

applied in different ways depending on the degree of need and relevance for each landscape unit (Table 4.1 summarizes the design principles and attributes a degree of requirement in each landscape unit).

Table 4.1 Summary of design principles and their relevance for each of the landscape units (H: High Relevance; M: Medium; L: Low; empty cells show measures do not apply).

Design Principles		Landscape Unit		
		River Banks and Channel	Floodplain	Uplands and Hillslopes
River Continuum	1. Remove engineering works to restore natural dynamics	H	M	
	2. If engineering works are kept, propose alternative structures to allow function	H	H	
	3. Avoid proposing new structures that interrupt the river continuum	H	M	
Floods	4. Allow flooding where it does not represent risks for consolidated urban areas and structures. For example, parks		H	
	5. Create alternative structures to retain temporary waters or controlled flooding: ponds, oxbows, wetlands		H	
Groundwater	6. Allow groundwater flow between channel and floodplain substrate by using permeable materials on the riverbanks	H	H	
	7. Allow water infiltration in the whole landscape to maintain continuous infiltration and flow and regular water table level		H	H
	8. Avoid structures that interfere on water table such as deep foundations		H	H
Stormwater	9. Adopt retention, detention, infiltration and filtration structures and grading that encourage infiltration		H	H
	10. Maintain or restore vegetation on banks, floodplain and uplands to increase retention and filtration of stormwater before reaching the water table	H	H	H
Pollutants	11. Adopt infiltration and filtration structures, such as swales and ditches		H	H
	12. Reduce use of pesticides, fertilizers, road salt and other pollutants		H	H
Banks	13. Use permeable materials and/or vegetation to stabilize riverbank	H		

Design Principles		Landscape Unit		
		River Banks and Channel	Floodplain	Uplands and Hillslopes
Soils and Erosion	14. Protect soils with vegetation		H	H
	15. Adopt structures to deposit sediments before reaching the river bed		H	H
	16. Use permeable pavements		H	M
	17. Produce gentle slopes to reduce water speed (less erosion, more infiltration)	H	H	M/L
Vegetation	18. Protect construction sites and exposed soils		H	H
	19. Adoption of native species	H	H	H
	20. Provide conditions for succession	H	H	H
Habitats and Wildlife	21. Create conditions for seeds to deposit	H	H	L
	22. Maintain and/or restore functional connectivity along the entire length of the corridor	H	H	L
	23. Provide high-quality corridor for native species present, especially those that are most sensitive	H	H	L
	24. Restoration where possible, of links between corridors and interior habitats	H	H	H
Fish Populations and Habitats	25. Create and protect wetlands, grasslands and meadows	H	H	L
	26. Enhance vegetation on banks; give preference to native species	H	H	
	27. Create artificial habitats or conditions to foster habitat formation	H	M	
	28. When building on river bed, minimize impact or integrate structures with creation of habitats (shading, shelter)	H	M	

Table 4.1 Continued.

Summary

Twenty eight landscape ecological design principles were developed from the seventeen ecological components identified in Chapter Three. Those components of the landscape were grouped into ten new groups of components for examination and development of the design principles. The principles were summarized and rated (Table 4.1) according to the importance (high, medium, or low) of their application in each landscape unit (riverbank and channel, floodplain, and uplands and hillslopes).

The usefulness of the design principles will be evaluated in the next chapter by applying them to the downtown Guelph riverfront.

The principles above have demonstrated the need for integration of actions in both the riverfront and the overall matrix. Most actions have little effect if not integrated with other actions. Interventions on specific ecological components depend on simultaneous actions on other ecological components and/or other landscape units, or even beyond the boundaries of the riverfront and the river corridor. The site is not isolated in the landscape and alone is not able to provide the conditions for ecological function.

5

Design Principles Application: Downtown Guelph Riverfront

Guelph, Ontario, was chosen as the riverfront site for applying the design principles developed in the previous chapter are applied. This chapter presents possible actions on the riverfront's structure to enhance ecological function. Photos were used to identify and portray sites that could have a more ecologically sound solution through design. Cross sections and plans are presented to illustrate the application of the design principles.

Guelph Context

The object area is the riverfront adjacent to downtown Guelph, Ontario. Downtown Guelph is embraced by a meander of the Speed River and its riverfront alternates between

open public space and buildings lined up with the river channel, naturalized riverbanks and manicured park land.

Beside the interruptions on its floodplain and riverbanks, Speed River presents several weirs and a major dam control the river's level and flow (Guelph dam). A second dam controls water level on the southern portion, including part of the Eramosa River. These dams and weirs determine and limit some of the actions on the riverfront.

The downtown Guelph riverfront (the area delineated by heavier lines in Figure 5.1) is characterized by the presence of railway tracks, residential, service and commercial buildings (stores, restaurants), cultural facilities (River Run Centre), a church (Saint George), and a recreational trail. The opposite margin shows residential areas (single family detached) on its northern portion, industrial (W.C. Wood Company) in the central part, and apartment buildings to the south. In both margins, buildings turn their backs to the river, creating a barrier between downtown and the west side of the river, and between a residential neighbourhood and the east side of the river. The separation from downtown is reinforced by the presence of two four-lane streets (Wellington and Woolwich Streets). The whole extent of the riverfront is contained within the floodplain (Figure 5.2).

The 1993 City of Guelph Greenway Plan proposed a concept based on the connectivity of the city's natural areas linking major open spaces and river corridors, extending to Guelph Lake and rural areas. The plan (Figure 5.1) shows several gaps, notably the downtown area adjacent to Speed River described above. Some interruptions can be mitigated; other gaps represent a significant barrier to greenway (corridor) continuity.

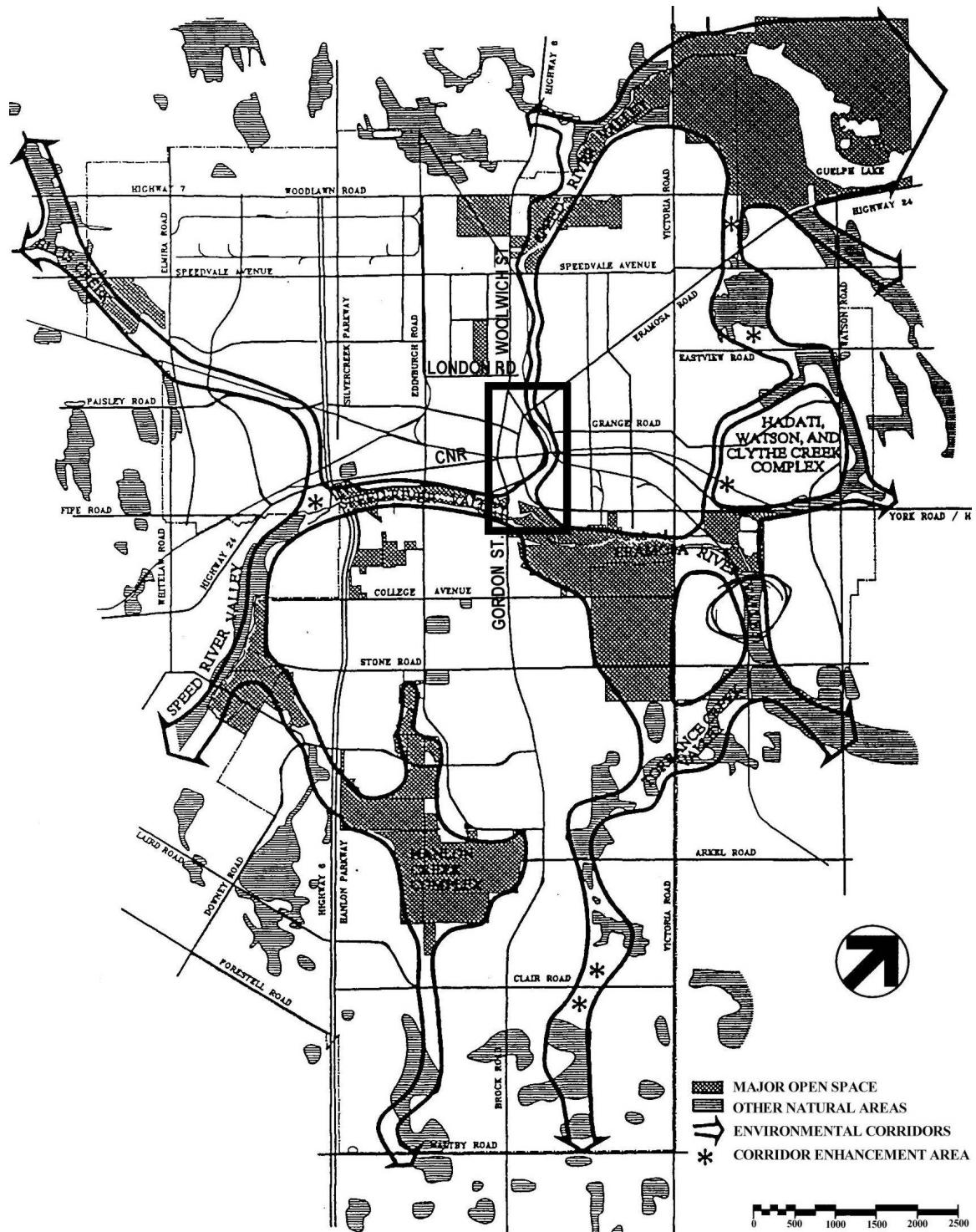


Figure 5.1 Greenway Plan - Concept: Major Open Space, Corridors and Other Natural Areas (City of Guelph). Downtown area is delineated by the rectangle (heavier lines).

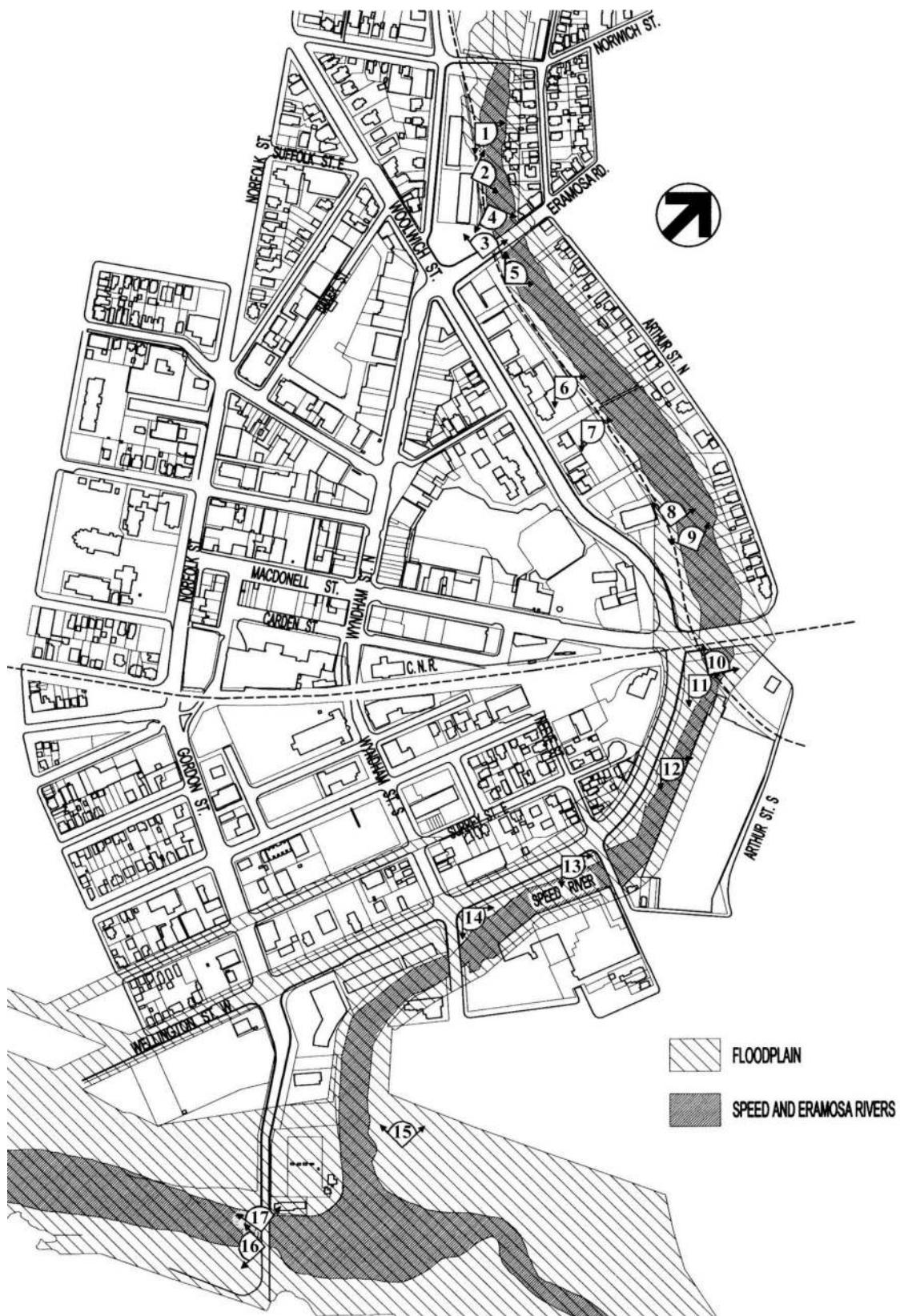


Figure 5.2 Downtown Guelph Map showing floodplain. Numbers refer to studied sites (adapted from map furnished by City of Guelph Planning Department).

Downtown Guelph Riverfront Study/Application

The downtown Guelph riverfront was studied sequentially moving from north to south. A series of photos were taken and 17 sites were used to identify problems and opportunities to enhance the riverfront by applying the landscape ecological design principles developed in Chapter Four. Recommendations are presented below referring to the principles they were based on.

In the area of study, the entire riverfront is in the floodplain (see Figure 5.2; see also Table 4.1 regarding actions highly needed on the floodplain).

Site 1

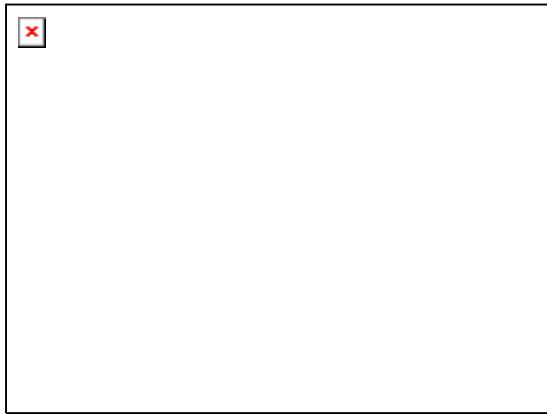


Figure 5.3a Retaining structure (Site 1). Two houses built on the floodplain show different structures on the riverbank.



Figure 5.3b Close up of retaining structure. Plants attached (Site 1) to rocks that simulate natural escarpment

Two methods of river bank treatment and stabilization (Principle 13) are seen in Site 1 (Figure 5.3a and b). The house on the left (Figure 5.3a), has a retention wall that creates a flat platform for the house's backyard. The rough wall hosts vegetation and allow flow and infiltration of water. The house on the right (still in Figure 5.3a) adopts a concrete wall that creates a sterile interface between water and floodplain. The first example offers a solution that blends more naturally in the landscape. However,

constructing on the floodplain interferes with groundwater flow (Principle 8), alters vegetation patterns (Principles 19-21), and damage habitats for terrestrial wildlife and birds (Principles 22-25) and fish (Principles 26-28).

Sites 2 and 8



Figures 5.4 Culverts (Site 2). Drainage structures interrupt continuity of the already small buffer/riparian vegetation.



Figures 5.5 Culverts (Site 8). Interruption of buffer/riparian vegetation and direct discharge of sediments and pollutants.

Rocks and wood piles, as shown in Sites 2 and 8 (Figures 5.4 and 5.5), and concrete slabs are commonly used to prevent erosion on river banks where culverts are settled. This causes the removal of vegetation and consequently an interruption of the continuity of the already small buffer/riparian vegetation and on its corridor function.

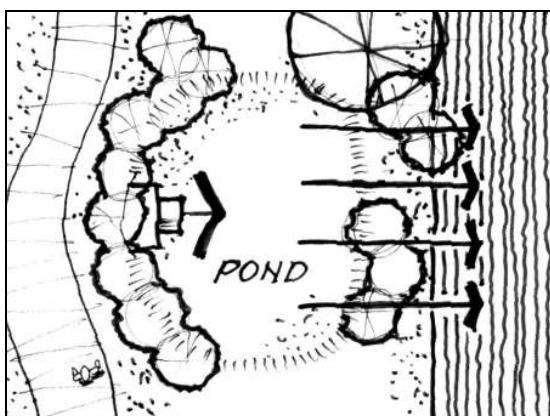


Figure 5.6a Mitigation Structure. Plan. Pond retains water and releases it through vegetation, which functions as filter (buffer).

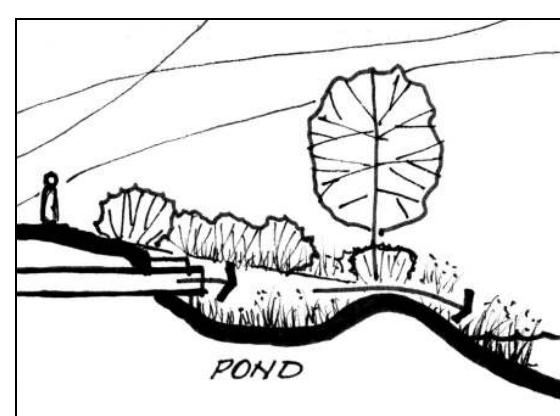


Figure 5.6b Mitigation Structure. Section. Culvert is moved away from the bank. Water is thrown in a pond that retains the first flush.

Solution for problems caused by traditional stormwater structures involves actions on the overall landscape and changing stormwater management standards (Principle 9). The scheme shown in Figure 5.6 proposes a mitigation structure: implementation of swales or ponds where stormwater would be discharged and accumulated before reaching the river bank and the channel, reducing water speed and intensity and avoiding interruptions on riparian vegetation, or even increasing vegetation and wetlands (Principle 10).

Site 3



Figure 5.7 Back of high-rise buildings on Cardigan Street (Site 3). Buildings represent harm to groundwater. Train tracks serve as corridors for dispersion of plant species. Riparian vegetation functions as buffer.

Large buildings require deep foundations and represent a threat to groundwater (Principle 8). The high rise buildings on Cardigan Street (Figure 5.7) also present a significant barrier for wildlife. Socially, they represent the loss of potential open public space and a connection between parts of downtown and the river. Their size and layout cause increased wind speed and dense shade. Chemicals from the tracks' wood beams probably still contaminate soil and runoff water. The tracks alone can have both positive and negative aspects, since they can function as corridor for plant species propagation. They can help propagate native species, but also exotic ones.

Site 4

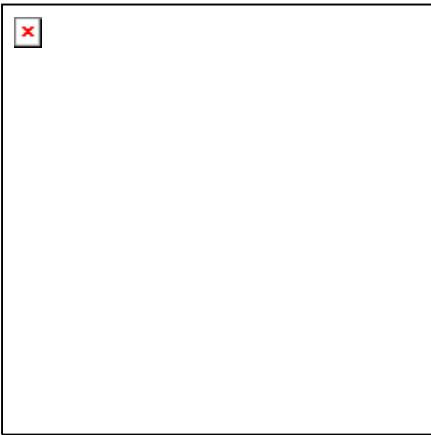


Figure 5.8a Eramosa Road x Speed River (Site 4). Bridge was built in a way the riverbank disappears, creating a barrier for species movement and discontinuity of corridor.

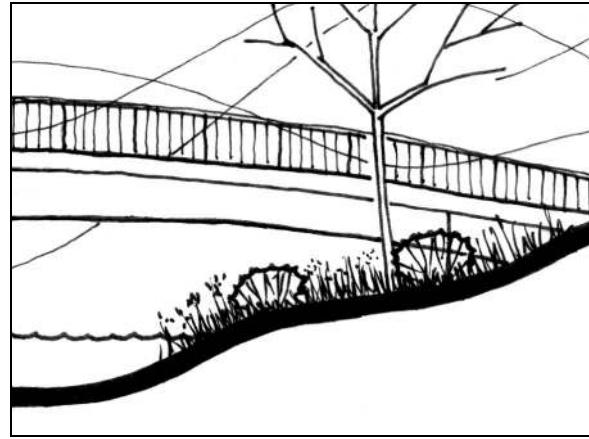


Figure 5.8b Bridge constructed to allow species movement. Keeping riverbanks free does not interrupt movements and migration routes.

According to Dramstad et al (1996), roadway bridges interrupt species movement; elimination of vegetation causes a gap in movement along a corridor. Site 4 (Figure 5.8a) shows a typical urban bridge that eliminates riverbanks in order to reduce the space between margins and consequently reduce structural requirements. Ideally, movements should be possible on both sides of riparian corridor (Principle 22). Another example is presented in Site 9.

Sites 5 and 7



Figure 5.9 Eramosa Road x Speed River (Site 5). Parking lot drains directly to riverbank.



Figure 5.10 Parking lot with traditional drainage (Site 7). Catch basin (white arrow), catches water, which is conveyed directly to river.

Parking lots on Site 5 (Figure 5.9) and Site 7 (Figure 5.10) represent potential threats to habitats and water quality. The first parking lot drains directly to riverbank, which presents insufficient vegetation and width to function as a buffer (Principles 9 and 10). Contrasting with the first example, the second parking lot has a relatively wide setback that could be used as a buffer between the parking lot and the river. However, stormwater is drained to a catch basin (see arrow on Figure 5.10) and delivered directly to the river. An example of how to reduce impact of the parking lot is presented in the next section (Figures 5.11a, 5.11b and 5.12).

Site 6



Figure 5.11a St. George's Church parking lot. Parking lot is graded to conduct water toward layers of rocks, shrubs and ground cover (wood particles); these elements act as a buffer for pollutants and sediments.



Figure 5.11b Detail of parking lot buffer. Sand and oil are retained by the rocks and wood particles that cover the ground.

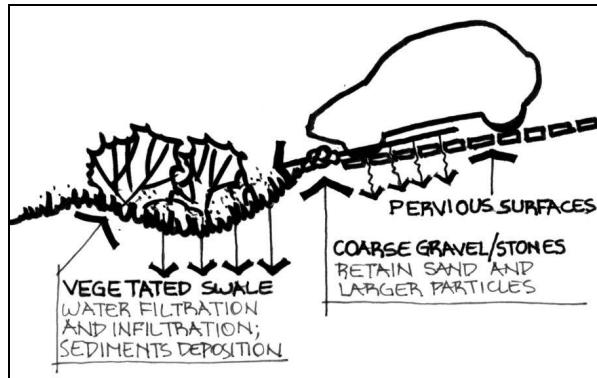


Figure 5.12 Mitigation Structure. The impact of the parking lot could be reduced by the adoption of a pervious surface.

The Saint George's Church parking lot is a good example of how to deal with pollutants (oil, anti-freeze, sand, and salt) on site. Rocks laid on the lower portion of the parking lot retain coarse sediments and sand, which can absorb oil. In this case, asphalt makes it easier to remove sand and oil. The excess water overflows to a planting bed with shrubs and ground cover plants. Additional layers of grasses and a depression (swale) would increase success of filtration and retard stormwater (see Figure 4.12).

Site 9



Figure 5.13a Pedestrian Bridge shows alternative to allow continuity corridor.

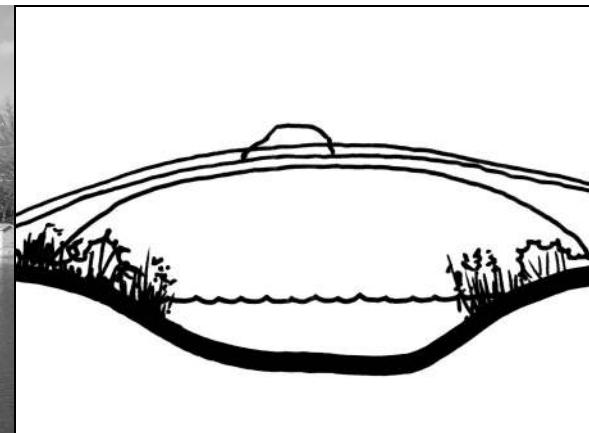


Figure 5.13b Bridges should allow free passage along both margins.

The pedestrian bridge does not completely interrupt riparian vegetation and corridor on the margins (Principle 23). This model could also be applied to vehicular bridges.

Site 10



Figure 5.14 Several engineering works obstruct corridor: Roadway bridge, weir, stormwater structures, and train tracks.

Site 10 (Figure 5.14) shows a critical place for connectivity (Principles 22 to 24) on the river corridor and for the river continuum (Principles 1 and 2). Several engineering works share the same area: a vehicular bridge, ground and overhead train tracks (Guelph Junction and CNR), and a weir considerably reduce the chances of providing connectivity. The economic and social (transportation) significance of these structures make their removal not viable (Principle 1).

Sites 11 and 13



Figure 5.15 Distillery and industry offices



Figure 5.16 Residential building

Several existing structures represent a threat to groundwater flow and water table level (Principle 8). Solution for these problems involve removal of structures such as buildings, or substitution of materials (impermeable by permeable). Several commercial, industrial and residential buildings line up with river channel in the studied area (Figure 5.15 and 5.16). Ecologically speaking, removal would be ideal. However, removing those buildings might represent a costly initiative and even the loss of cultural or historical landmarks (Distillery building, 1835 – Figure 5.15). This overly built margin, opposite to the downtown riverfront, interrupts the corridor and make it impossible to establish a vegetated buffer (riparian vegetation, Principle 26). Its historical significance makes removal undesirable.

Site 13 (Figure 5.16) shows a case where a bridge (transportation) and a residential building (historical significance) represent a constraint for re-establishing connectivity (Principles 22 to 24). This could be compensated to some extent by improving the opposite margin at the downtown riverfront.

Site 12



Figure 5.17 Industrial building. Building lining up with river margins.

The image above (Figure 5.17) shows buildings that overwhelm the eastern margin of the Speed River. The social, ecological and recreational benefits of their demolition would make these industrial buildings suitable for reclamation, unlike with the transportation structures (Figure 5.14) and the historical building (Figures 5.15 and 5.16), where economical, social and cultural constraints prevent physical changes. Benefits would include ecological restoration (margins, river bed, and corridor), revegetation, a possible plot for demonstrational wetlands, and connection of residential neighbourhoods east of Arthur Street, providing recreational and educational opportunities (Figure 5.18).

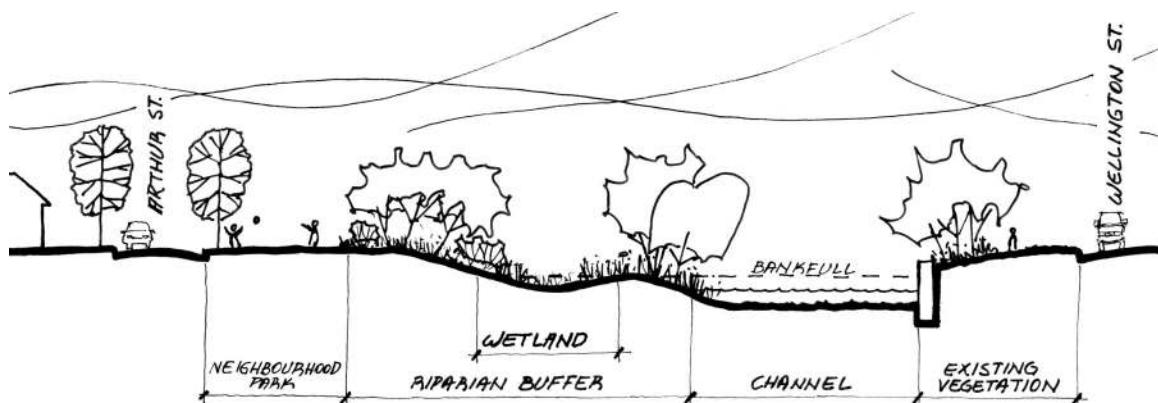


Figure 5.18 Section proposes reclamation of industrial area for demonstrational public/ecological open space.

Site 14



Figure 5.19a Apartment building at Wyndham
x Speed River.

kk
Figure 5.19b Trail is brought closer to building, leaving a wider area for riparian vegetation.

A recently built apartment building (Figure 5.19a) is located less than 20 meters from the river bed, which can cause harm to the water table and groundwater flow. The lawn between the river channel and building could be used to enhance the buffer and still accommodate existing trails (Figure 5.19). Site 14 (Figure 5.19a) also shows another interruption on the riparian corridor: the retaining wall on the right (see also Figures 5.8a, 5.14, and 5.16).

Site 15



Figure 5.20a Parking lot

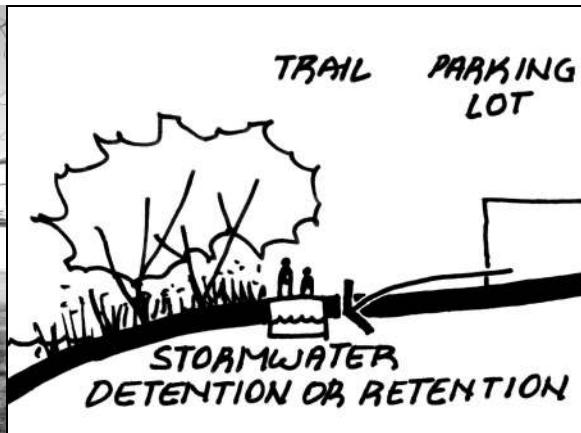


Figure 5.20b Infiltration/filtration structures

Site 15 shows a large parking lot that drains directly over the river bank. A trail follows parallel to the river and at this point it crosses the parking lot (undistinguished in the picture). In addition to existing vegetation on the bank (buffer), infiltration/filtration structures could be used for water treatment. These structures might consist of the use of existing products that store, filter and release water slowly; boardwalk could be constructed over trenches; or alternatively, the same solution as shown on Figure 5.12 could be adopted (Principle 11).

Site 16

Site 16 (Figure 5.21) shows river meanders contained between concrete walls. Dams and weirs control the river's water level, keeping it high during spring and summer and low during fall and winter. When the dam downstream is open, a sterile sand and gravel bar appears. The only lively spot on this section of the river is a small island shown in the lower right of the image. Although the dam has negative impact on the river dynamics, the loss of the spring/summer scenery might represent a negative impact on the identity of the river.



Figure 5.21 Channelized river. Existing concrete walls substitute natural riverbanks. Walls impede groundwater to flow between land and canal (in both directions), inhibit vegetation to develop on banks, and consequently make habitats unviable. Note also the uniform vegetation in the park (low diversity).

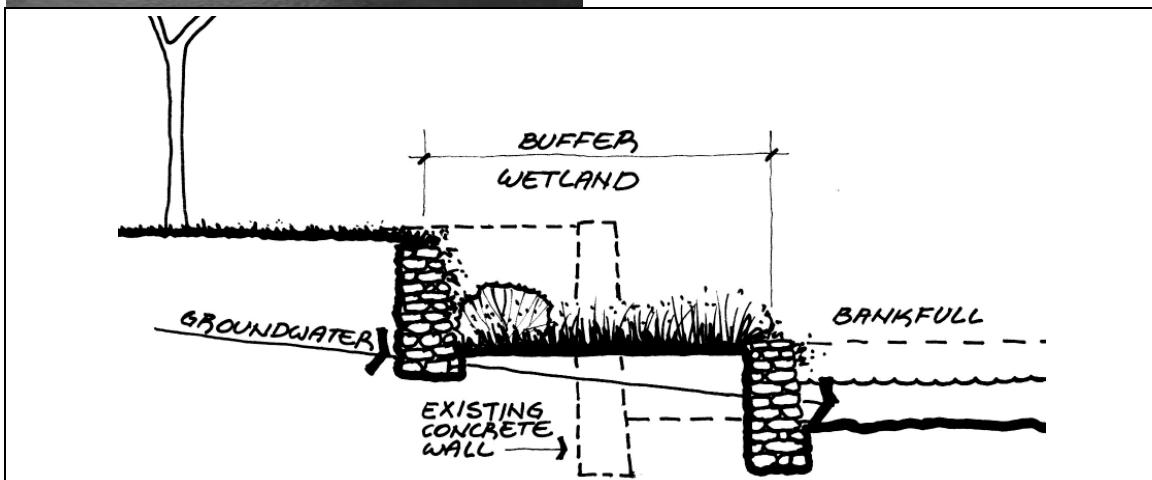


Figure 5.22 Substitution of concrete walls. The stepped cross section allows deposition of organic matter and sediments where seeds can develop and plants grow. This solution provides conditions to create wetlands, habitats for fish and amphibians, and depositional areas, creating richer soil and increasing biodiversity

Initially seen as a constraint, the water level management might be an opportunity to allow temporary and controlled flooded areas along the margins. Figure 5.22 shows the proposed alternative for riverbank stabilization. The stepped cross section allows deposition of organic matter and sediments where seeds can develop and plants grow. This design provides conditions to create wetlands, habitats for fish and amphibians, and depositional areas, creating richer soil and increasing biodiversity (Principle 25 – creation of wetlands).

Applying this scheme on a riverbank, gabions or biotechnical slope stabilization should be used to stabilize the slope and allow sediments deposition when water level on the channel varies. The use of permeable materials in substitution to the concrete walls would allow colonization of the margins with plants while stabilizing the banks. A first examination shows possible interruption by the walls of the groundwater flow to channel, which could be changed with use of vegetated river banks or gabions (Principle 6). The width of the park allows the creation of buffer areas as seen in the Peterborough case study, without keeping people away from the water (see Figures 4.15 and 4.16).

Site 17

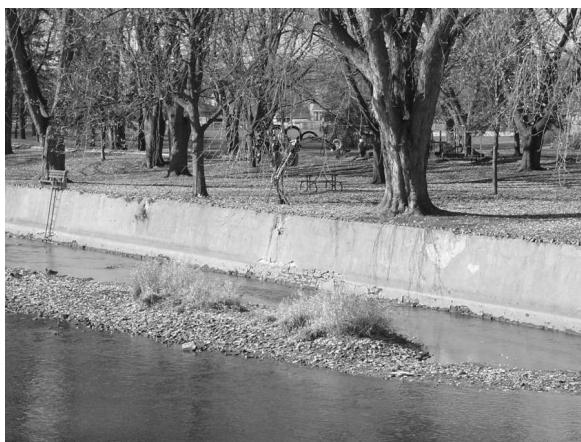


Figure 5.23a Gravel island. Present conditions do not offer opportunities for development of plant communities and fish habitats. Annual flooding leaves of the island under water

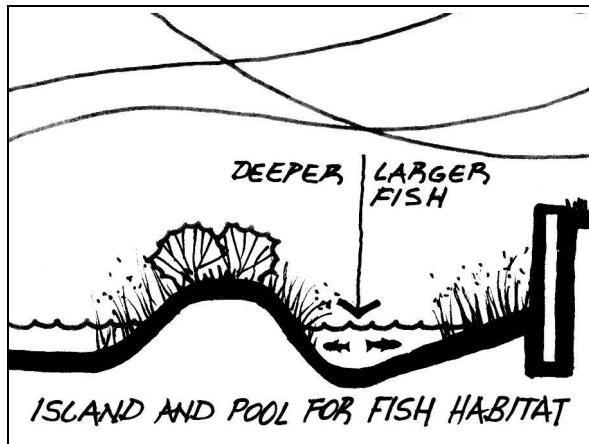


Figure 5.23b Island and pool for fish habitat. Deep holes and increasing of vegetation create conditions for fish populations to develop.

Site 17 (Figure 5.23a) shows a detail of the concrete retaining wall and the gravel island where vegetation starts to appear. According to Pedroli et al (2002), the formation of islands creates conditions for succession and the appearance of tree species such as willows. Increasing depth of holes and size and height of island, vegetation and fish populations will develop. Substitution of concrete wall (Figure 4.22) increases habitat quality and biodiversity.

Summary

This chapter investigated the applicability of the design principles developed on Chapter 4 to the ecological improvement of Guelph's downtown riverfront. The results are summarized below:

River continuum (Principles 1-3): The Speed River presents several weirs and a major dam controls its level and flow. These structures determine and limit the actions on the riverfront.

Floods (Principles 4-5): A system of dams and weirs control water level, keeping it high during spring and summer and low during fall and winter. Initially seen as a

constraint, these might be an opportunity to create some temporary and controlled flooded areas along the margins. The demolition of an industrial building was proposed to create wetland (see Site 12 – Figure 5.18), and substitution of concrete walls and the use of steps (see Site 16, Figure 5.22).

Groundwater (Principles 6-8): Several existing structures represent a threat to groundwater flow and the water table level. Solution for these problems involves removal of structures such as buildings, or substitution of impermeable by permeable materials. Several commercial, industrial and residential buildings line up with the river channel in the study area. Ecologically speaking, removal would be ideal. However, removing those buildings represent a costly initiative, and would result in a loss of cultural or historical landmarks. It was proposed the demolition of only one industrial building to restore the river margin as an experimental area (see Site 12 – Figure 5.18). The areas that present river banks retained by concrete walls could have those changed by alternative pervious materials such as gabions or vegetated slopes (see Site 16, Figure 5.22, Site 1, Figure 5.3a, and Site 14).

Stormwater and drainage (Principles 9-10): The study area shows a potential for treating the runoff generated on site by using swales and retention ponds, depending on water table level. However, proximity to downtown – a highly impervious area – requires additional measures to mitigate runoff. Ideally, ecologically sound stormwater structures should be adopted across the city. Because of unavailability of land, to retard and treat downtown stormwater, underground structures, diversion of runoff and even adoption of green roofs would be necessary. In the study area the adoption of alternative design solutions are proposed for Sites 5, 6 and 7.

Pollutants, Nutrients and Sediments (Principles 11-12): These components could be treated by riparian buffers. The restricted area of Guelph's riverfront requires measures to be adopted across the urban landscape. Swales, retention/detention ponds, trenches, phytoremediation structures should be built to fragment stormwater treatment in small amounts, taking further the efforts already being spent in new developments (see Figure 5.6).

Riverbank and slopes stabilization (Principle 13): As mentioned above, part of the river is contained by concrete walls, which could be substituted by more ecologically sensitive structures and/or vegetation (see Figure 5.22).

Soils and Erosion (Principles 14-18) No major erosion is identified on the site. Some culverts are already mitigated with paved surfaces, coarse gravel, and wood piles. These structures interrupt riparian vegetation and the corridor and bring pollutants and sediments from the matrix, creating areas subject to sedimentation and low habitat quality. Salt, oils and sand from streets and parking lots, sand and gravel from construction and gravelled parking lots are carried directly to the discharge points. Setback culverts with detention ponds are proposed (see Figure 5.6).

Vegetation (Principles 19-21): Much of the riparian vegetation is reduced and damaged in the studied area. Present land uses restrict large extensions of vegetative cover (parkland, buildings, railway, bridges, and parking lots). Functional connectivity was proposed at major barriers (see Site 4, Figure 5.8b). In all the sites, the re-establishment of the lost connectivity is proposed by enhancing vegetation on the riverbanks wherever possible (see also Figure 5.22).

Habitats (Principles 22-25): Extension of vegetative cover and corridor quality is recommended. In the present situation bridges and historical and industrial buildings represent significant barriers to establishing a consistent corridor. Application of the design principles proposed the elimination of major barriers (as an example see Site 4, Figure 5.8b).

Fish Populations and Habitats (Principles 26-28): Fish populations and habitat have been altered from their original status; the former by pollution, and the latter by interruption of habitats caused by weirs and dams. Interventions on the riverfront should consider increasing vegetation on banks (temperature/shade, wood debris/habitat), elimination of culverts (which bring sediments and pollution and cause erosion), and creation of structures to simulate natural habitats (e.g., islands and pools, Site 17, Figure 5.23b).

In summary, it is considered that the application of the design principles in Guelph fully demonstrates their usefulness in the design of riverfronts.

6

Discussion

Summary

The purpose of this study was to explore how landscape ecology can contribute to ecologically sensitive design of urban riverfronts. In other words, this study attempted to link landscape ecology and landscape architecture literatures to produce design principles for riverfronts. These principles were developed based on a literature review combined with a case study analysis. The principles were then applied to a riverfront in Guelph to illustrate and understand their usefulness.

The literature on waterfront design examined the historical context of waterfront development. This research also presented built waterfront designs and existing design

and planning frameworks - the way cities, architects, planners and landscape architects would like to see waterfronts designed and built.

The review of such literature and projects demonstrated that there are efforts in place to produce better urban waterfront areas. However, only a few considered the adoption of ecological procedures or incorporation of ecological enhancements within the urban fabric. Most of them focus on human use without proposing conservation and regeneration approaches.

The assessment of the landscape ecology literature identified strengths and weaknesses in its application to riverine landscapes in general and to urban landscapes in particular. Landscape ecology provides a model for an analysis of riverfronts as a confluence of natural and human processes. Furthermore, landscape ecology emphasizes the need for integration between actions in both the riverfront and the overall matrix. Interventions on specific ecological objects depend on simultaneous actions on other ecological objects and/or other landscape units, even beyond the boundaries of the riverfront and the river corridor. Landscape ecology applied to riparian zones in urban areas has weaknesses, because it has not been thoroughly investigated; the literature shows concern about non-urban areas, usually represented by agricultural matrices that occupy the largest area of the landscape.

Based on a synthesis of the literature, 17 structural and functional ecological objects of river corridors were identified. They were grouped into ten topics and generated 28 design principles. These principles were illustrated mainly with examples extracted from the Otonabee River Trail case study.

With these principles developed, the next step was their application. The Speed River riverfront in downtown Guelph was chosen as the site to illustrate how such principles could be used to design a more ecologically sensitive riverfront, demonstrating their usefulness in the design of riverfronts.

Approach

The approach adopted for the study aims at incorporating both landscape ecological approaches (bioecological and geoecological) and sees the landscape as an interaction between biotic and abiotic elements. It is argued that the adoption of the proposed principles would depend on the conditions of the site and the river where they would be applied. Hence, the principles were applied after an analysis of the Guelph situation, without prioritizing the restoration of hydrological and geomorphological processes (as recommended by the geoecological perspective espoused by Pedroli et al 2002 and Pedroli and Harms 2002), nor prioritizing vegetation and habitats. The fact that the Guelph riverfront rests mainly on floodplains also pointed to the principles relevant to this landscape unit (according to Table 4.1).

For Guelph, the bioecological analysis (identification of patches, corridors, and the overall matrix) was developed for the landscape scale. Hydrological processes permeate the various scales, from watershed (region) to site (wetland, groundwater). Stormwater can and has to be dealt with both locally and at the landscape scale, since effectiveness of solutions increases with the extension of solutions. For example, the substitution of a culvert for a retention pond could be done locally; such a solution would not be feasible for retaining all the stormwater from the downtown area. On the site scale, both bioecological and geoecological analyses were undertaken.

Use of Landscape Ecological Principles in Guelph

Design consists of a sequence of activities and phases, from programming and site selection to project implementation, and many times leads to a post-occupancy evaluation. Site inventory plays a fundamental role in landscape ecology-based design and involves a number of participants and techniques from site visits to satellite imagery, covering biotic and abiotic, natural, cultural, social, economic, and often political aspects of the landscape. Thorne (1993), discussing a landscape ecological approach to greenways design, affirms that “design must start by examining the context … [and] two aspects of landscape structure are important in this regard: the pattern of elements in the landscape and the trends of the surrounding matrix” (Thorne 1993:37). Baschak and Brown (1995), as well, focus on the assessment of natural and cultural resources and networks in developing a framework for urban greenways.

The application of the design principles in Guelph (Table 6.1) were preceded by an analysis at the landscape scale, as described below:

1. Interpretation of the landscape: analysis of patterns, examination of relationships, search for opportunities;
2. Examination of the opportunities of the site in relation to the landscape;
3. Creation of opportunities at site scale to enhance the overall landscape (avoid isolation): transformation of structure to enhance function.

An analysis according to the patch/corridor/matrix model (the bioecological approach to landscape ecology) showed gaps in the river corridor, which are crucial to establish connectivity (Table 6.2). The Speed and Eramosa Rivers are key corridors needed to link

larger patches present in the urban area and the surrounding landscapes, such as the Guelph Lake area (north), the Hanlon Creek Complex (south), or the Cutten Club Golf Course and the Eramosa and York Road Parks (adjacent to the downtown on the Eramosa River).

Table 6.1 Principles and their application in the Guelph riverfront. This table associates principles to sites where they were applied (mitigation or restoration, as defined in Chapter Four; see also Table 6.4). Where columns are blank no principle is associated (dereliction is chosen for sites 1, 3, 10, 11, and 13 because of social, cultural, or economical implications); site 9 refers to an exemplary solution.

Principles	Sites																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
River Continuum	1																
	2																
	3																
Floods	4																
	5																
Groundwater	6																
	7																
	8																
Stormwater	9																
	10																
Pollutants	11																
	12																
Riverbanks	13																
Soils/Erosion	14																
	15																
	16																
	17																
	18																
Vegetation	19																
	20																
	21																
Habitats and wildlife	22																
	23																
	24																
	25																
Fish	26																
	27																
	28																

The proposal for the Guelph riverfront aimed to re-establish the lost connectivity by increasing the vegetation on the riverbanks and part of the floodplain, and removing barriers. Some barriers, such as bridges and buildings, cannot be removed although they alter the groundwater level and prevent the application of any design principle. Other barriers, such as weirs and culverts, could be removed or replaced by alternative solutions, as shown in Figure 5.6. However, the alternative solution proposed for the culverts would need to be applied to the whole downtown area in order to be an effective stormwater management measure, and not only in the riverfront. In sum, the study demonstrates that the Guelph riverfront present some sites where no type of mitigation is possible. This shows the need to plan/predict for connectivity during the design of new riverfront developments.

Site and landscape scale, structure and function (Tables 6.2 and 6.3), were intertwined in the analysis and application of design principles in the Guelph riverfront.

Table 6.2 Landscape Structure. This table relates the sites to the structural objects that were affected by the application of landscape ecological design principles on the Guelph riverfront.

Structure		Sites															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Biotic	Patch																
	Corridor																
	Matrix																
Abiotic	Soil																
	Substrate																
	Landforms																

Function is the interaction of structural elements, which can be achieved by hydrological and particle flows, and animal and human activity. The use of design to remove barriers for habitat and provide connectivity by providing a continuum of

vegetation on the riverbanks addressed these issues. Hence, the enhancement of the ecological function of the Guelph riverfront could be achieved with the application of the design principles.

Table 6.3 Ecological Function. This table relates the sites to the ecological function affected by the application of landscape ecological design principles in Chapter Five.

Function	Sites																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Hydrologic																	
Particle flows																	
Animal activity																	
Human activity																	

The levels of intervention on the riverfront

The levels of intervention achieved by the application of the design principles in Guelph were mitigation, restoration, and dereliction (Table 6.4), as described by Pedroli *et al* (2002) and discussed in Chapter Four. Mitigation - the level of intervention needed to guarantee survival of habitats and organisms coexisting with economic and recreational activities - was the level of intervention throughout sites 2-8 (with exception of site 3), and sites 14-17. This portion of the riverfront is not channelized and still has vegetated riverbanks and less damaged hydrological processes. The riverfront is wide with few buildings on its margins. Mitigation was also the level achieved in sites 14 and 15. At sites 16 and 17, the creation of steps was proposed to attenuate the channelization of the river corridor.

Dereliction, the worst case scenario, when it is not worth investing in any type of project (Boon in Pedroli et al 2002), was the level of intervention recommended for sites

1, 3, 10, 11, and 13. Restoration was the level of intervention achieved on site 12, where “natural hydrodynamics [are] hardly recognizable” (Boon in Pedroli et al 2002:06). Here, the reclamation of an industrial property was proposed.

Table 6.4 Levels of intervention. This table relates the level of intervention in each of the sites studied in Chapter Five.

Level of intervention	Sites																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Mitigation																	
Restoration																	
Dereliction																	

Landscape Architecture: Scale and Scope

Scale has different meanings for landscape architects and landscape ecologists. These meanings are related to the emphasis of each professional’s work (Baschak and Brown 1995). Landscape architects usually design areas emphasizing the site scale or master plans. Landscape ecologists, on the other hand, deal with the landscape scale and ideally look for the relationship between biotic and abiotic components of the whole landscape.

However, the landscape architect, although working at the site scale, needs to be aware of processes at the landscape scale in order to apply landscape ecology principles. Based on Moss (2000b), landscape architects should also look at both biotic and abiotic elements *and* the interaction between them, considering the landscape scale when designing at the site scale.

The design of riverfronts is a process that involves stakeholders, community members, consultants, and the design team itself. The multi-disciplinary character of ecological design requires the participation of a broad range of consultants in several

disciplines and fields. According to Baschak and Brown (1995), the landscape ecological approach requires transdisciplinarity, the willingness to transcend separate disciplines and combine them in a coherent practice.

Another difference in approach between landscape ecologist and landscape architects is their focus. Landscape ecology focuses on structure, function, and change while the work of landscape architects focuses on transformations of the structure of the landscape. Nevertheless, landscape architects, using landscape ecological principles, are aware that it is these transformations in the structures - a type of induced change – that will generate new functions.

Table 6.5 Sites and Scale. This table relates the effects of the design principles used in each site on the landscape scale.

Scale	Sites																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Landscape																	
Site																	

The application of the ecological design principles to the Guelph riverfront (see Tables 6.2 and 6.3), and the process of analysis of the landscape described above, shows how landscape ecology can contribute to the practice of landscape architecture. Most important for the purpose of this research, the application of the ecological design principles to the Guelph riverfront shows how landscape ecology can contribute to a more ecologically sensitive design of riverfronts.

Implications

The development of landscape ecological design principles is seen to have implications for both the riverfront landscape and the practice of design.

The incorporation of landscape ecological principles into design allows landscape architects to think of the riverfront as a complex relationship between bio-ecological, geo-ecological and cultural factors. In addition, it requires landscape architects to consider the interconnection of actions on the riverfront with the overall landscape/matrix.

It is considered that the landscape ecological design principles will be useful for designers and planners since they provide guidelines for adopting ecological measures in riverfront design. Hence, it is expected that they will help designers in establishing/creating healthier riverfronts, with respect to natural systems, while addressing human needs within the urban environment.

The river environment would benefit from this understanding and the application of such principles. The use of landscape ecological design principles in Guelph indicated how the riverfront could be enhanced by their adoption.

Future Research

Further research on the adoption of landscape ecological principles in the design of riverfronts derives from both the limitations and implications of this study.

From Limitations

One of the limitations of this research is a consequence of the scope of the work of landscape architects, which is usually limited to the site scale. This research deals with the riverfront as the object of design, and it is a limited unit of landscape, while the discipline of landscape ecology deals with the landscape scale, which in this case is the city.

Why then limit this study to the riverfront? Because riverfronts are corridors that still remain as a continuous natural feature/resource in an overly suburbanized landscape and have become important resources for nature preservation and restoration of habitats. Foremost, urban rivers constitute links among disconnected patches and connections between different background matrixes (urban/rural). In other words, urban riverfronts present themselves as invaluable sites to apply landscape ecological principles to re-establish ecological function without eliminating human use. When designing at the site/riverfront scale, the landscape architect can look both at biotic and abiotic elements *and* the interaction between them, and still consider the landscape scale.

Nevertheless, five areas of research need to be further explored:

- 1) An ideal application of the design principles developed here should encompass the whole landscape/city (in this case downtown Guelph) to be able to identify the relationships among the elements (ecosystems) and examine their relationship with the surrounding landscapes/region. This would mean transcending disciplinary boundaries to integrate landscape architecture and urban planning to propose a plan for downtown Guelph and even the city as whole.
- 2) Further research should also consider developing a finer scale of design, detailing principles (e.g., retention walls, infiltration structures), and experimenting with materials and techniques.
- 3) Future research should consider examining the implementation of these principles in the City of Guelph. One method would be to use preference studies to evaluate the acceptability of their implementation by Guelph residents.

As a consequence of implementation of the design, two sub-areas of further research emerge:

- 4) Post Occupancy Evaluation (POE) could be undertaken to measure the ecological gain.
- 5) Post Occupancy Evaluation (POE) could be undertaken to evaluate the acceptance of built structures (and materials) by residents.

From Implications

This research focused on rivers. Future research should expand this knowledge base to city waterfronts on lakes, reservoirs and the ocean, as well as the mouths of rivers (where these encounter lakes, reservoirs or the ocean). These water bodies present ecological structures and functions different from rivers.

Whereas much of the research focuses on agricultural/rural landscapes, an extensive field of research remains open for the study of landscape ecology within the urban landscape. Further research is necessary to apply the design principles proposed here to different scales and variables, e.g., different city sizes and diverse land uses (such as port facilities).

In sum, this is an exploratory research, and the principles herein proposed need to be applied in other cases in order to be generalized.

7

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