BIODIVERSITY AND URBAN DESIGN: SEEKING AN INTEGRATED SOLUTION

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"The cities of the 21st century are where human destiny will be played out, and where the future of the biosphere will be determined. There will be no sustainable world without sustainable cities."

—Herbert Girardet

INTRODUCTION

Life on earth is remarkably diverse. Plants, animals, and microorganisms, in response to local and regional environmental conditions have created distinct adaptations that collectively form the interconnected "web of life." This biological diversity and its associated ecological processes represent the planet's "natural capital" that underpins human activities, providing us with the air we breathe, the water we drink, the food we eat, the materials that clothe and shelter us, countless medical remedies, and the cathartic psychological relief green spaces provide for us. This biological diversity also helps shape our "sense of place."

There is a growing awareness that the health of the planet's biological diversity will, to a large degree, determine our own destiny. There is also a growing sense of urgency that biodiversity requires substantially more protection than has occurred to date (Millennium Ecosystem Assessment 2005). The Convention on Biological Diversity (1992), adopted by over 150 countries, provided a strategy for addressing the decline in biodiversity around the world. The 2002 World Summit on Sustainable Development identified the centrality of biodiversity and the importance of setting conservation targets. And the IUCN's Countdown 2010 program was established to help monitor progress toward stemming biodiversity loss.

In terms of urban biodiversity the Curitiba Declaration on Cities and Biodiversity (2007) affirmed the importance of biodiversity within cities, signalling the need "to integrate biodiversity concerns into urban planning and development, with a view to improving the lives of urban residents . . ." Yet, while enhancing biodiversity within cities is a laudable goal, it is a daunting challenge. The scale and pace of urban growth is responsible for the radical transformation of the spatial configuration and ecological processes of local and regional landscapes around the world (Alberti 2005, Dale et al. 2000, McDonnell et al. 1997, Dramstad et al. 1996, McDonnel and Pickett 1990). Natural areas are fragmented. Indigenous fauna are marginalised and extirpated. Hydrologic cycles are irrevocably altered while impervious surfaces increase. Productive soils, centuries in the making, are contaminated, compacted, and/or removed.

One key challenge in addressing urban biodiversity is overcoming the misunderstanding that biodiversity conservation is an optional field of action, despite overwhelming evidence to the contrary. Few local governments have dedicated resources to establishing planning frameworks and implementation strategies to explicitly address biodiversity. This complacency can be attributed, in part, to the complexity and abstraction as to what constitutes biodiversity. Consequently urban planners, elected officials, the development community, and the public continue to focus on land use, zoning, transportation, and infrastructure in isolation of their ecological consequences.

Fortunately in North America some local governments have begun to engage the complexities of biodiversity conservation by developing regionally integrated spatial frameworks based in large part on Landscape Ecology's patch-corridor-matrix principles (Forman 1995). Simultaneously, proactive site planning and design practices at the neighbourhood and site scale are including biodiversity conservation as an essential program objective. Collectively these initiatives begin to illustrate how urban design can conserve and enhance biodiversity across a region.

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EDMONTON'S ECOLOGICAL NETWORK

The City of Edmonton (Alberta) is among one of North America's more proactive cities in developing a strategic plan to conserve and enhance the city's rich biological diversity. For over 20 years the City has developed a broad range of environmental conservation policies and plans, including the Urban Parks Management Plan (2006) that identified the "preservation of natural capital and the use of ecological decision-making" as key principles.

The recent Natural Connections Strategic Plan: Edmonton's Integrated Natural Areas Conservation Plan (2007) furthers the biodiversity agenda by directing conservation activities to consider all natural areas in Edmonton as part of an "ecological network." An ecological network (Bascompte 2007; Montoya et al. 2006) combines the protection of a variety of natural "patches" with a network of ecological corridors that enable flora, fauna, nutrients, and genetic material to move through the network and maintain critical ecological processes.

The guiding principles for Edmonton's plan include: Building capacity for ecological protection in the city; thinking continentally and regionally, and planning locally; promoting Edmonton's ecological network as a context to which urban development must be tailored, not the opposite; and engaging the community in conservation and management of natural areas to harness existing local knowledge and raise awareness.

The Natural Connections plan is organised around four key spatial design goals:

1. Large patches of natural vegetation that support entire populations of plants and animals and associated ecological processes represent the backbone of the ecological network.
2. Maximize the width and function of riparian corridors as the "preferred corridor for wildlife movement."
3. Retain and protect connections/linkages between large patches, using corridors and stepping stones as these "linkages support ecological connectivity such as daily movements, seasonal migrations, dispersal, habitat connectivity and species persistence."
4. Within developed areas "heterogeneous bits of nature" should include natural vegetation so as to facilitate movement within the developed areas and through the developed areas to adjacent corridors and patches.

The first three points that inform the plan's ecological network are consistent with the core tenets of Landscape Ecology that emphasize the need to develop a robust network of patches and corridors. It is the fourth point, however, that is arguably the most noteworthy in terms of advancing biodiversity conservation through urban design. Few jurisdictions have supported their respective regional biodiversity initiatives (and ecological networks) with neighbourhood and site scale strategies, despite the fact that the form and character of neighbourhood and site development directly affects regional ecosystem function. And while architects, landscape architects, and engineers may reference regional objectives their design control points are typically specific to the neighbourhood and site. It is at these scales that the notion of ecological networks and biodiversity conservation requires more investigation.

To that end Edmonton's Natural Connections Strategic Plan describes a number of strategies as to how neighbourhood–based design interventions can support the regional framework. These include:

- Ensuring that development proponents clearly understand natural systems, information requirements will be part of the evaluation of development applications.
- Ensuring that natural areas are considered early in the planning process so they can be effectively integrated into structure plans and protected through development.
- Working to improve the quality of stepping stone sites, ecological corridors, and the matrix generally through naturalization (of the urban landscape).
- Facilitate community engagement in stewardship, monitoring, and restoration of natural areas on public and private lands.
- Working with developers and landowners to achieve "win-win ecology" that protects natural systems and processes, is economically rewarding, and respects the interests of property owners.

An Implementation Plan is being developed to support the Natural Connections Strategic Plan. A

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FIGURE 1. Edmonton's Ecological Network.

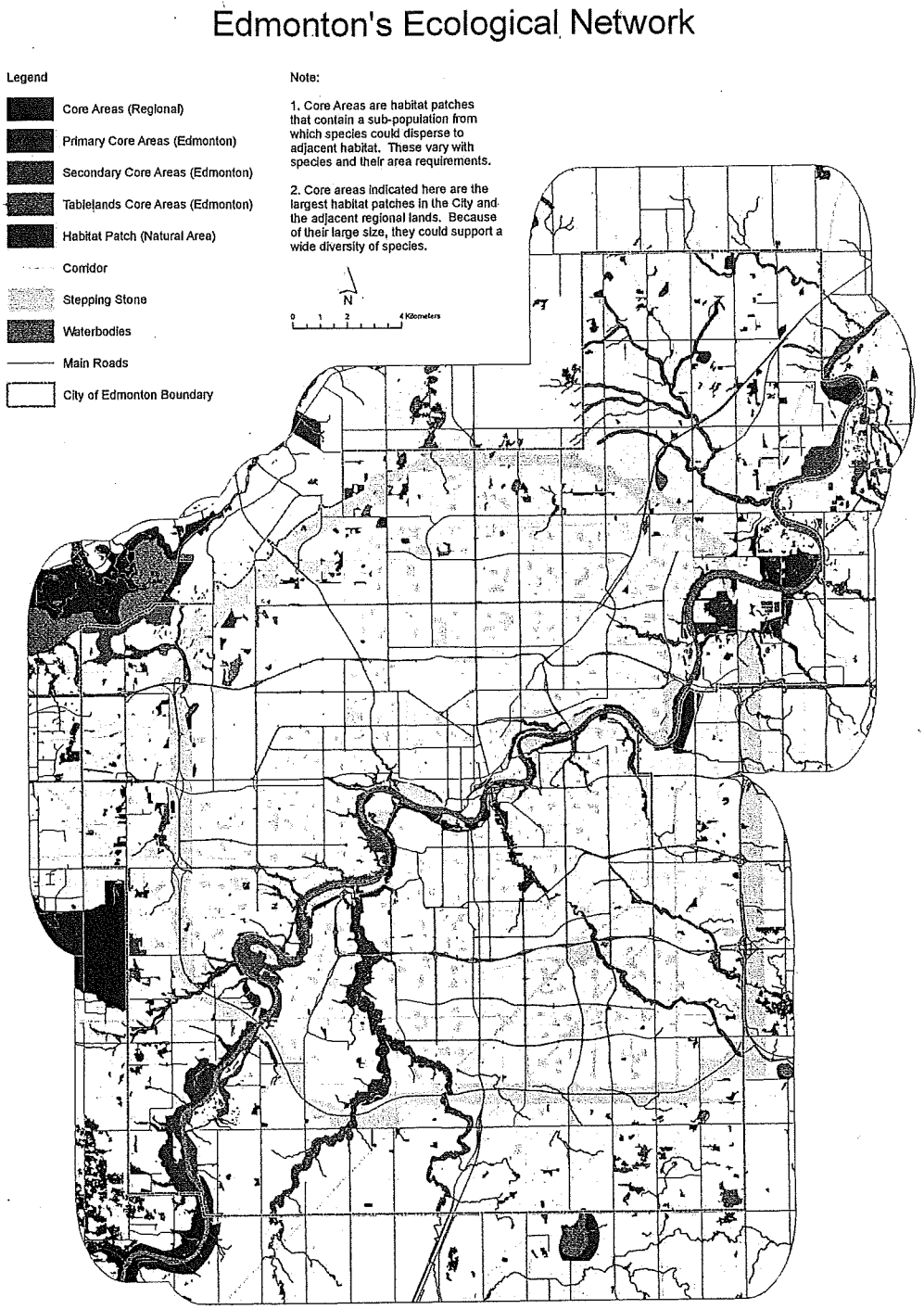
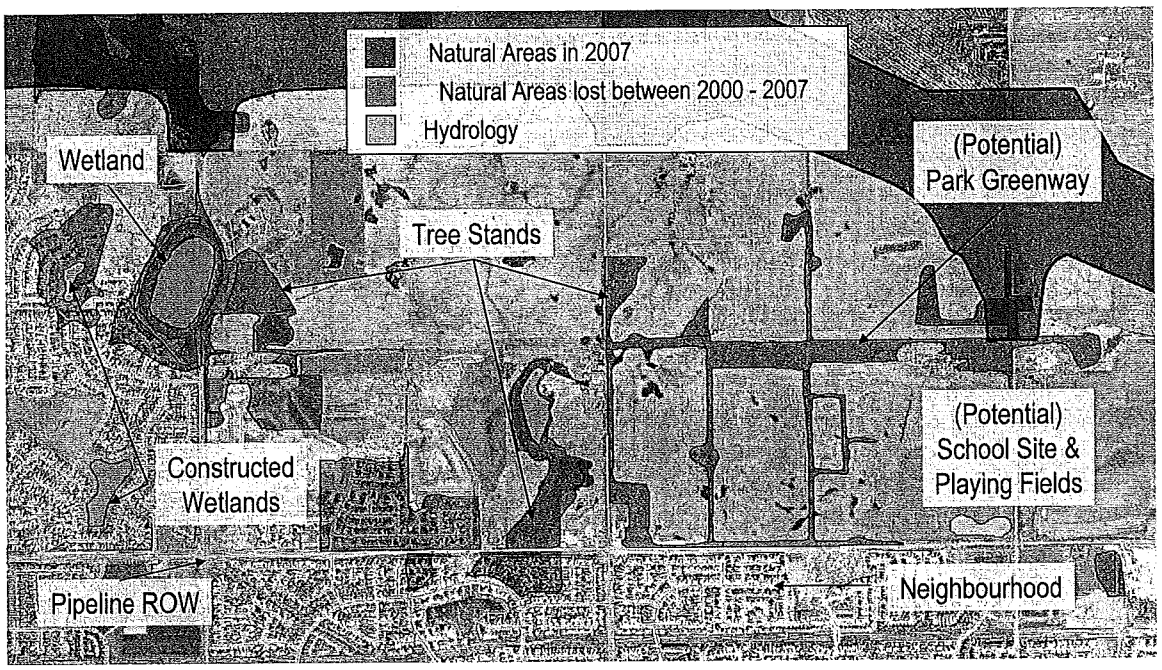


FIGURE 2. North Edmonton Ecological Network.



suite of specific outcomes to be achieved and indicators to measure progress are part of the implementation strategy. One example relates to the plan's desired outcome number two which is "Connectivity within Edmonton's ecological network is increasing." In order to measure if this is happening a number of indicators are being developed that include:

- The percentage of stepping stones/linkages protected between each core area.
- "Nearest neighbour" index, which measures the proximity of each stepping stone to others in area.
- Structural/functional connectivity, which assesses the quality of the spaces (gap tolerance) between the core areas and stepping stones.

Ultimately Edmonton aspires to ensure conservation is given equal weight to other considerations in the planning process and that decisions concerning natural systems are based on the best available conservation science.

NEIGHBOURHOOD BIODIVERSITY—AN INTEGRATED APPROACH

Another example of a neighbourhood focused on biodiversity conservation and enhancement is a new development being planned for Vancouver, British Columbia. East Fraserlands (EFL) is a 130 acre, brownfield site located adjacent to the Fraser River. For several decades the site was home to a large lumber mill. It now represents one of Vancouver's last large scale neighborhood planning projects and is envisioned to be a sustainable neighborhood for approximately 13,000 people and approximately 200,000 ft^2 of commercial space. The new community will also include parks, a community centre, schools, childcare facilities, a riverfront walk, and other public amenities. It is expected to take approximately 25 years to fully develop.

What distinguishes this development from others is the extent to which environmental considerations have guided the planning of the neighborhood's open space. With the site being part of critical avian

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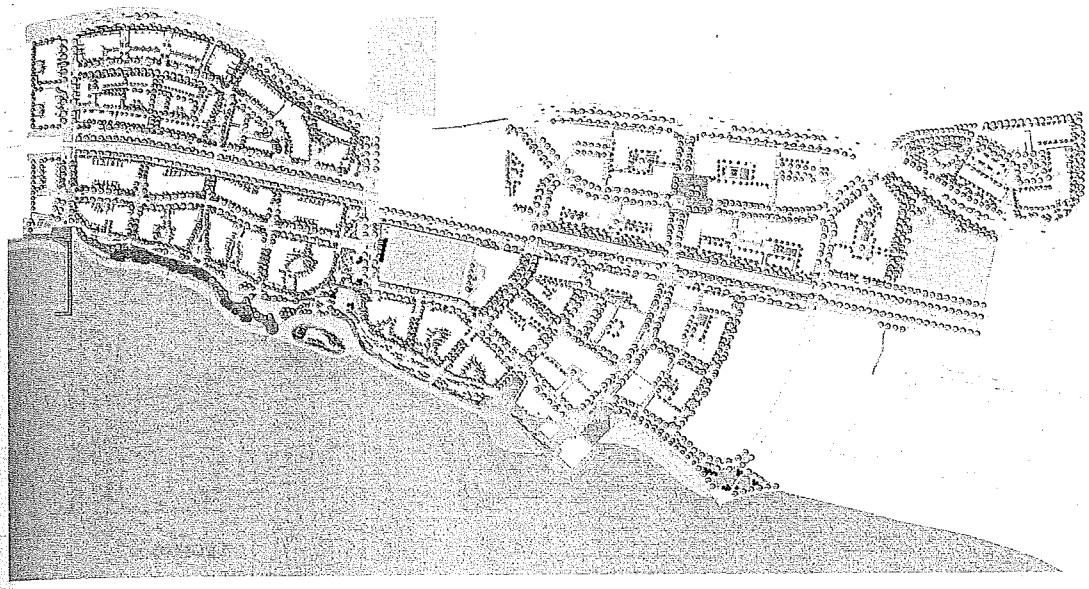
FIGURE 3. East Fraserlands Illustrated Plan—Phase 1 and 2, Vancouver BC.



flyways and adjacent to the Fraser River, one of the world's most important salmon bearing rivers, it was clear that the rich ecological context required a comprehensive development approach. A number of key environmental objectives were set including:

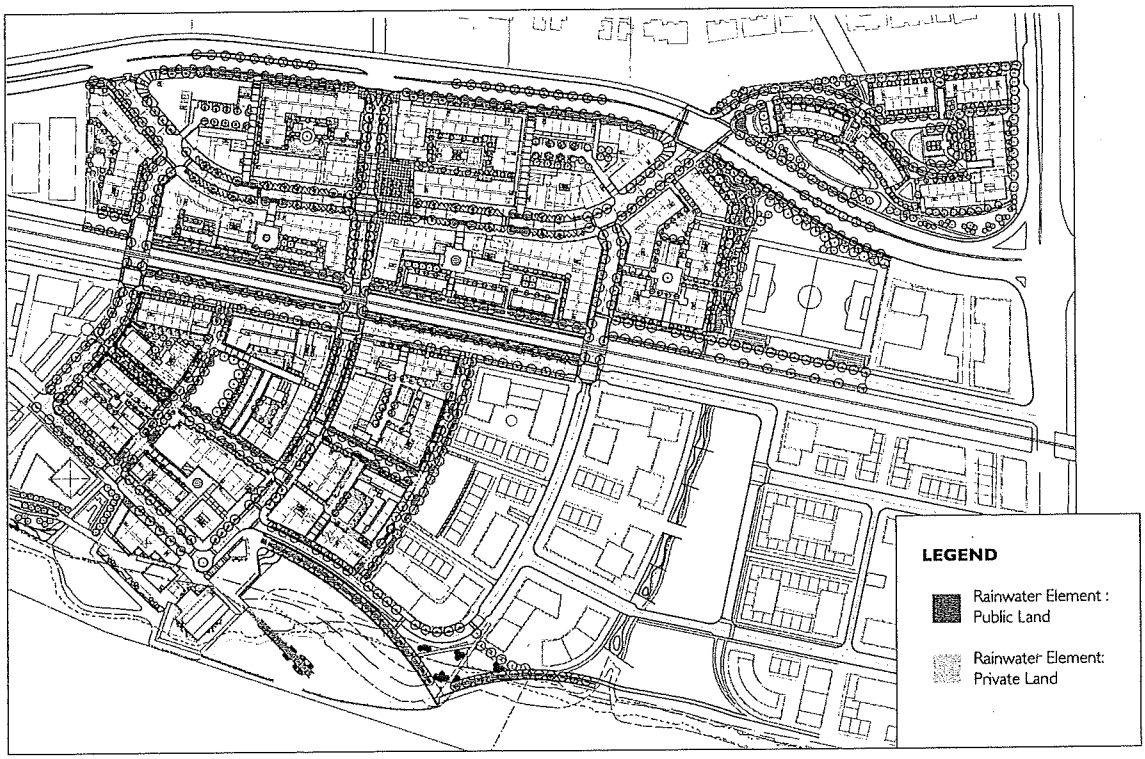
- Implementing a rainwater management strategy that celebrates rainwater, channelling it naturally in swales along streets, in parks, and in the eco-corridors following the site's natural hydrology;
- Implementing an urban songbird habitat strategy that creates food sources for the widest range of songbirds possible and provides habitat corridors linking Everett Crowley Park to the Fraser River flyway;
- Enhancing fish, bird, and wildlife habitat along the river;
- Restoring or enhancing nearly one kilometre of Fraser River foreshore;
- Providing an extensive and productive wetland area along the river.

Rainwater Management Strategy

The rainwater management strategy establishes a framework for managing rainwater throughout the development. The strategy includes the following design criteria:

- Capture rainwater runoff close to where it falls (at source);
- Target the "first flush" as the primary objective for rainfall capture;
- Incorporate rain gardens throughout to maximize at-surface facilities for rainwater capture and treatment;
- Create a "pervious fingers network" to maximize runoff infiltration into the ground (note: pervious fingers refers to the construction of interconnected, pervious zones of granular material under rain gardens and/or roadways in order to create continuous flow paths for sub-surface water movement toward the Fraser River);
- Make roadways self-mitigating by managing rainwater runoff within road rights-of-way;
- Prevent roadway runoff from flowing directly into the piped conveyance system (i.e., provide hydraulic disconnect by routing through rainwater management facilities), except during extreme events and extended wet periods;

FIGURE 4. East Fraserlands Rainwater Management Plan—Phase 1, Vancouver BC.



Landscape Based Rainwater System Plan
N.T.S.

- Require private parcel developments to provide rainfall capture on-site prior to overflowing run-off into the roadway conveyance system.

While the focus of rainwater management is on water quality and quantity, it is expected the system's components will also be designed as civic amenities.

The effectiveness of the rainwater management strategy depends to a large extent on the success of such distinct features as biofiltration swales, rain gardens detention ponds, and wetlands—landscape features that utilise a broad range of emergent and riparian plant communities to detain and treat run-off. The assemblage of these features can make for a biologically rich and diverse landscape.

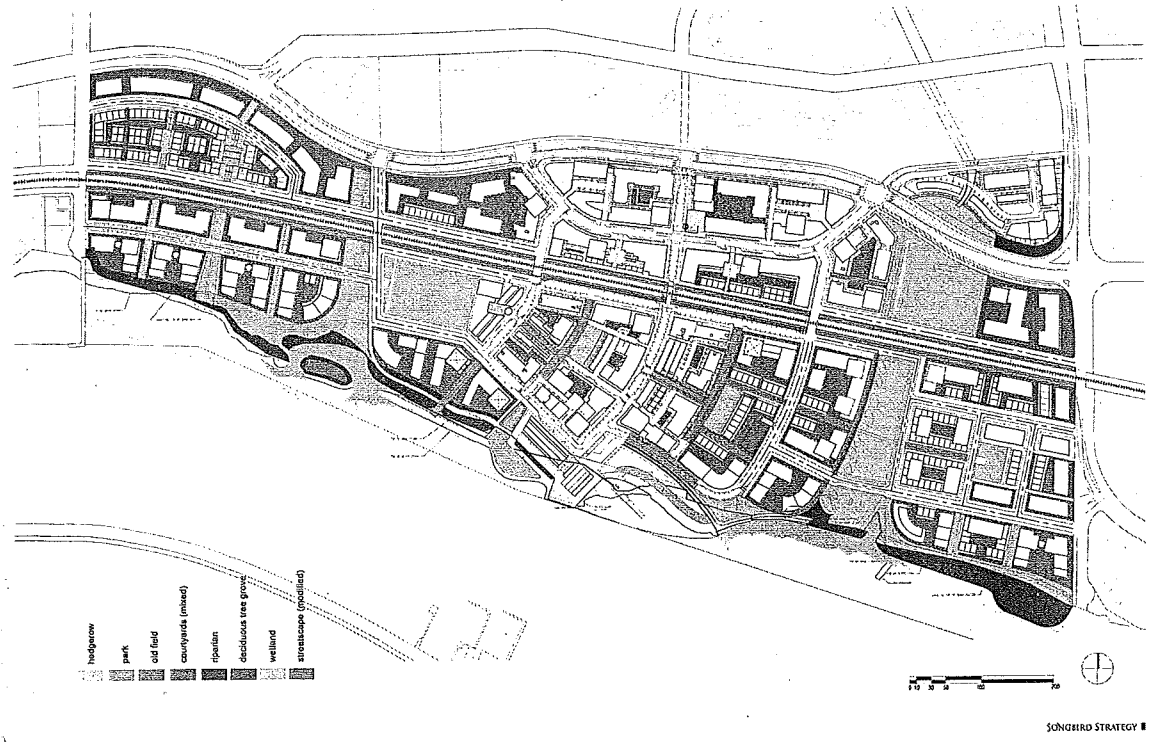
Biodiversity Planning—Songbird Strategy

The site's location adjacent to the Fraser River and the internationally important Pacific Flyway also presented an opportunity to develop a comprehensive strategy to integrate urban songbird habitat throughout the public and private landscapes. This marks the first neighbourhood in the region to develop guidelines in support of songbird habitat. The guidelines serve as a design tool for landscape architects as well as assist the regulatory review during the development permit and building permit stages.

The guidelines incorporate key elements of natural songbird habitat, particular foraging areas, and adapt them to a range of landscape spaces occurring throughout the neighborhood where similar ecological structure and function can be achieved.

Native and adaptive plant species play a prominent role in the planting design for the parks, open spaces, and residential neighbourhoods at East Fraserlands and reflect the regional landscape. Individual development parcels create opportunities to

FIGURE 5. East Fraserlands Songbird Strategy Plan, Vancouver BC.



feature combinations of native species that are adapted to site conditions and begin to inform a new landscape aesthetic. The diverse collection of deciduous (e.g., Alder, Serviceberry, Flowering Currant) and evergreen (Douglas Fir, Western Sword Fern) within patches and corridors provide opportunities for songbirds (e.g., Warbling Vireo and Evening Grosbeak) to forage for insects, seeds, and berries, and construct nests.

Shoreline Ecology Design Features

The Fraser River foreshore represents another part of the neighborhood's biodiversity enhancement strategy. To enhance the shoreline's ecology, four approaches were used to maximize fish and wildlife habitat:

- preserving highly productive habitat
- creating new habitat features (tidal channel, sanctuary island)
- enhancing existing habitat productivity (marsh benches, riparian plantings)
- using innovative design for infrastructure (concealed armour stone with riparian plantings, soil addition to rip rap to promote natural vegetation, addition of habitat features such as root wads)

The shoreline treatment results in a net gain of fish and wildlife habitat, through the creation of large areas of intertidal marsh, a unique off-river tidal channel and sanctuary island habitat, and enhanced riparian areas. Riparian benches are planned above high water; adding soil to encourage natural colonization of herbaceous vegetation and greening of the rock; and installing rocks and root wads to increase habitat diversity. Intertidal sedge marshes that line the shoreline provide a refuge for salmon fry migrating downstream from upriver spawning beds, and also provide productive feeding areas when the high tides inundate the marsh.

TABLE 1.

Landscape Unit	Description of habitat characteristics
Waterfront promenade	The promenade will offer modified wetland, riparian, hedgerow, park, and mixed forest environments. It will provide habitat in the protected areas along the river, a wetland / intertidal marsh area, as well as islands of trees and shrubs throughout the grassed park areas along the promenade.
Mill Bay wharf	The wharf area will be a highly urban space, offering some modified wetland, riparian, and deciduous forest environments. It will provide habitat in the river's edge grass and sedge zones adjacent the beach area.
Large Park (Avalon & Kinross)	The larger park areas will offer modified riparian, wetland, park, old field, hedgerow, deciduous, and mixed forest habitat patterns. They will provide significant urban habitat value along the rainwater runoff channels in the parks, along with the forest and shrub corridors and islands throughout the park area.
Small (Pocket) Park	The small pocket parks throughout the neighbourhood will offer modified park, hedgerow, and deciduous forest habitat patterns. These parks will provide habitat through shrub and tree clusters in these open spaces, as well as rain-gardens in select areas.
Sports field	Sports fields will offer modified park and deciduous and mixed forest habitat patterns. Viewing areas around sports fields will include islands of trees and shrubs that create valuable songbird habitat.
Rights of way / Greenway	Rights-of-way will offer modified park and hedgerow habitat patterns. Trees of high habitat value and various forms of hedgerows will frame pedestrian and cyclist paths and possible future transit routes located with the rights-of-way. The rights-of-way will provide habitat connections to other significant habitat spaces.
Boulevards and Streets	Boulevards and streets will offer modified park and hedgerow habitats. Streets will be planted with a diversity of tree species of high habitat value, in conjunction with the private land adjacent to the street. Habitat will be further enhanced with a diverse shrub layer in appropriate areas beneath the street trees.
Rooftops	Rooftops will offer a variety of supporting habitat. Areas with "extensive green roofs" (not for human access) will accommodate a wide variety of drought tolerant plants. More intensively managed green roofs can offer a greater diversity of habitat.
Commercial storefront	Commercial storefronts will offer interstitial and modified hedgerow habitats. Storefronts will provide a space for the implementation of highly unique small-scale songbird habitat features such as vertical wall panels for vines and well-designed planters, along with elements associated with trees along the street and in plazas.
Residential frontage	Residential frontages will offer modified park, hedgerow, and interstitial habitat. Park habitat is particularly suitable for this area due to the opportunity for mown grass with a rich diversity of trees and shrubs.

SITE DESIGN—THE FINE GRAIN OF URBAN BIODIVERSITY

If the regional-scale ecological network represents the first tier of urban biodiversity conservation, and neighbourhood open space planning the second, then what occurs on-site can be characterized as the third tier of urban biodiversity. And just as the regional initiatives depend upon the neighborhood scale ecological strategies, the neighbourhood strategies depend on the success of a number of site scale design interventions to ensure biological function happens across and throughout the region.

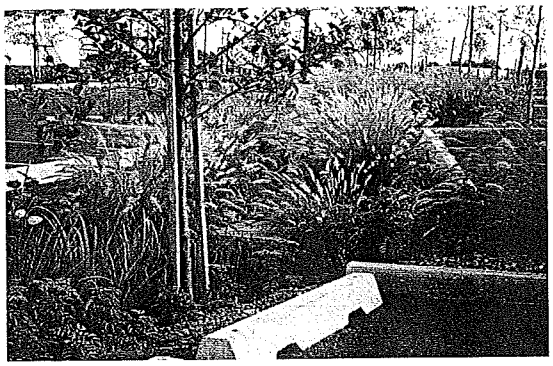
These fine grain features are among the basic building blocks for enhancing biodiversity in the city due to their relatively high intrinsic biological diversity, compact footprints, and multi-functionality with many being used for stormwater best management practices.

The previously noted **biofiltration swales** and **rain gardens** are two such examples. Both receive stormwater runoff and temporarily detain the water allowing resident emergent and or riparian plant communities to remove contaminants and some water to infiltrate. **Detention ponds** and **constructed wetlands** are another pair of design strategies that offer tremendous opportunities to enhance urban biodiversity. To be functional they require significantly more room than biofiltration swales and rain gardens and this can limit their appeal. However, both ponds and wetlands provide numerous opportunities for more complex assemblages of plants and more diverse aquatic/terrestrial interfaces. Individually, each of these design elements can represent small environmental patches that begin to add more diversity to site development. When inter-connected they collectively create a rich ecological network at the site scale.

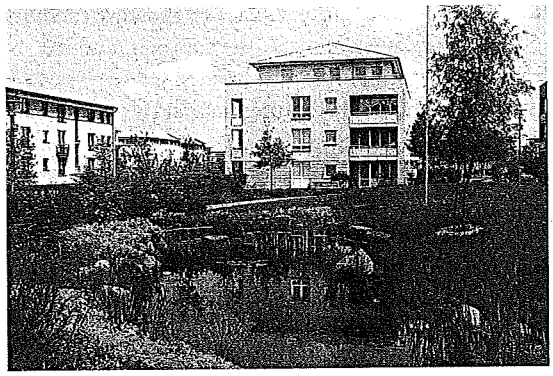
Notwithstanding their biodiversity contributions, the demands development places on land to accommodate various project objectives often results in some or all of these elements being minimized or abandoned altogether. Roofs, on the other hand, are a prerequisite of virtually all urban development. In some inner-city and industrial locations roofs may cover 100% of the site. For this reason roofs, and more particularly green roofs, offer some of the most significant areas in the city for enhancing biodiversity.

The use of green roofs in North America has, in the last decade, shifted from a curiosity to a widely available off-the-shelf product available from most major roofing manufacturers. In addition to regulating thermal conductivity and heat island gain, improving air quality, and slowing rain water runoff, green roofs are proving to have tremendous potential for enhancing urban habitat and ecological function. Indeed in Europe (Switzerland, Germany, Denmark, and others) green roofs are viewed as contributing significant natural habitat or green space with many hosting a diverse collection of vegetation

Kennedy Heights Bioswale, Surrey BC.



Detention Pond, Kronsberg Germany.



and providing habitat for insects and birds (Brenneisen 2003). The roofs have proven particularly helpful in providing space for rare and endangered species of plants that can grow with few of the disturbances common to urban settings (Liu 2004).

In Basel Switzerland, a long-term research project found green roofs to be providing habitat for dozens of endemically rare insects (Brenneisen 2003). The research led to a number of design principles for enhancing biodiversity on green roofs:

- The use of local substrates as growing mediums on green roofs helps replicate soil conditions at ground level.
- Varying the depth of the substrate provided microhabitats for rare spiders and beetles associated with brownfields in the city.
- Planting with a local seed mix.

- The placing of objects associated with natural habitats such as dead wood and old branches increased the biodiversity of the roofs.

Overall, it is clear that green roofs have the capacity to improve local biodiversity by replacing/regenerating habitat, and providing stepping stones for wildlife through the city that connect to larger natural areas (Köehler 2007).

Vancouver Convention Centre Expansion Project—Green Roof

The new green roof at the recently expanded Vancouver Convention Centre is an example of how green roofs can enhance urban biodiversity. The 6-acre "living roof" design has been modelled after a native British Columbia coastal grassland ecosystem to respond to the extremes in growing medium depth, water availability in the summer, and microclimate the roof plants will be exposed to. The roof functions as a self-sustaining habitat in terms of nutrient exchange with decaying organic matter providing the nutrients necessary for the living plants. The assemblage of native plants that are colonizing the roof form distinct colonies in response to the roof's varied microclimate, in much the same way a native coastal grassland does. It is expected various plants will thrive in some areas of the roof and be less visible in other areas of the roof.

Maintenance of the roof is expected to be passive in nature with an annual cutting of the plants ensuring that the leaf matter is left behind to decompose adding nutrients and organic matter. Selective weeding done on a monthly basis to ensure undesirable volunteer species such as European Blackberry, tree species, and invasive vine and grass species do not become dominant. Drip irrigation will be part of the seasonal régime adding water to the growing medium throughout the summer months to maintain a predetermined moisture content. The water source will be treated blackwater from the facility.

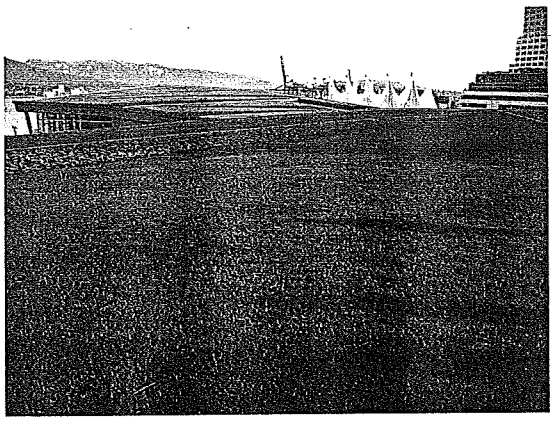
The Vancouver Convention Centre's living roof is the final piece in a series of green spaces that originates with Vancouver's iconic Stanley Park to the west and collectively form a green necklace of landscapes ending at the convention centre site.

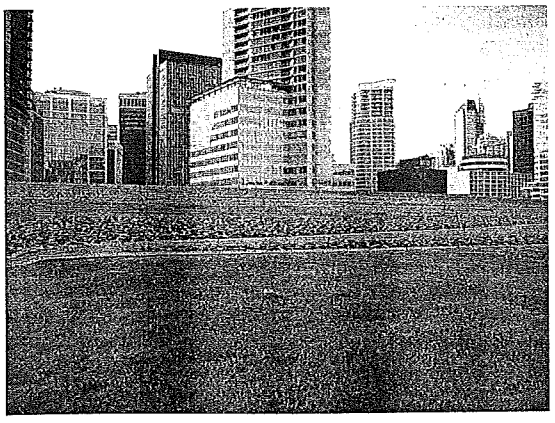
Urban Soils

A less obvious but equally important facet of urban biodiversity pertains to soils—more specifically the ecological integrity of urban soils. Although not widely acknowledged, ecologically productive soils are essential for maintaining biological diversity and human aspiration alike. Without soil, the earth's surface would be incapable of supporting life as we know it.

Within cities native soils are subject to a range of anthropomorphic forces that compromise their ecological integrity and their contributions to environmental health: cutting, filling, and paving that irrevocably alters soil structure and soil profiles; reduced fertility and organic matter content; increased

Vancouver Convention Centre Green Roof.





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bulk density; and changes to drainage characteristics and soil pH. They often become inert and mineralized with limited capacity to support the plant communities. Combined with a net loss in soil volumes, ecological function within the city is severely compromised.

Beyond minimizing the disturbance to existing soils two approaches are emerging to improve the ecological viability of urban soils, particularly those found in the central business districts city with their high percentage of impervious surfaces. The first involves the use of structural soils that take advantage of the potential soil volume under paved surfaces such as sidewalks, parking areas, and low volume roadways. Structural soils are primarily comprised of evenly graded, relatively large (2–3″) angular rock that can be compacted to meet the structural subgrade requirements for the paving above. The faceted shape of the rock, its even sizing, and the lack of clays and silts creates upwards of 25–30% void space that can accommodate growing medium and tree roots.

Structural soils are typically used adjacent to tree pits to extend and significantly increase the amount of functional growing medium. Considering the prevalence of walkways, parking areas, and some drive aisles replacing the conventional subgrade with structural soil would represent a dramatic increase in growing medium for urban trees, which in turn improves the health of the urban forest and the numerous ecosystem services urban forests provide.

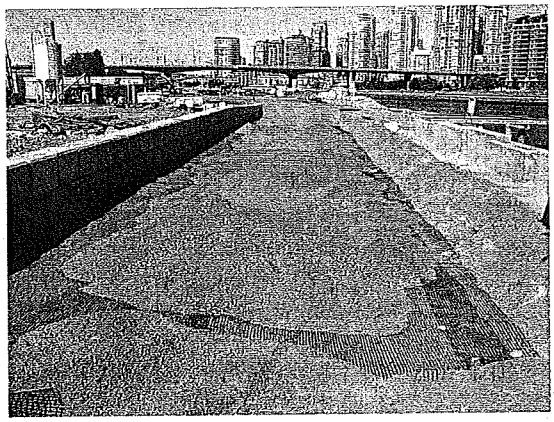
The use of structural soils is not without some challenges. Maintaining a consistent ratio of rock to growing medium during the mixing phase can be a challenge. The first costs of supplying and installing structural soil are significantly higher than conventional subgrade preparation. And with interstitial space representing 20 to 30% of the matrix, the amount of growing medium available to tree roots, while better than conventional subgrade preparation under paved surfaces, is still limited relative to what would be available to trees on undisturbed sites.

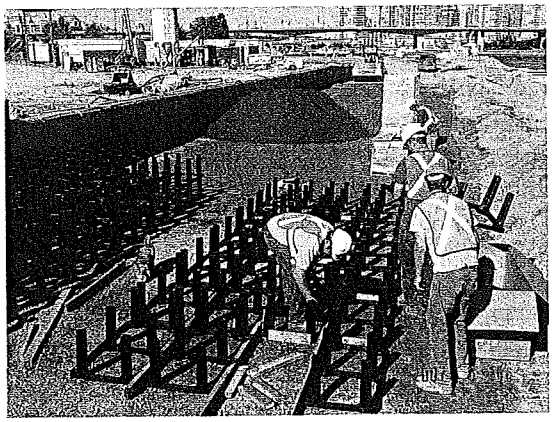
The second, and arguably more promising approach to inner city soils, is the use of structural soil cells such as Deep Root's Silva Cell. The soil cell is a table-like, rigid structure, 48″ long, 24″ wide, and 18″ tall. Made of polypropylene reinforced with strands of fibreglass, the soil cells are typically placed side by side, and at times on top of one another in a "building block" format, on a compacted granular base. The cells can accommodate support vehicle weights up to 20,000 pounds (H20 loading) allowing them to be used under sidewalks, parking areas, and low traffic volume roadways.

The appeal of Silva Cells is that unlike structural soils which provide a maximum of 30% of the matrix for growing medium, the Silva Cell's structural characteristics allow in excess of 90 percent of the volume to be available for growing medium. Equally appealing is the growing medium is not subject to compaction.

Vancouver's Southeast False Creek (SEFC) Neighbourhood is one of Canada's leading sustainable community developments. When fully developed, the 80-acre site will house 10,000–12,000 people in

Southeast False Creek Silva Cell Installation





Southeast False Creek Silva Cell
Finished Treatment

market and non-market housing. SEFC will provide a mix of land uses and demonstrate exemplary practices in energy and water conservation, innovative infrastructure practices, and transit-oriented development. The seven (7) hectare centre of the SEFC neighbourhood will be home to the 2010 Winter Olympic Athlete's Village. Approximately 30,000 ft^2 of Silva Cells are being incorporated into a number of locations under the waterfront promenade and several of the neighbourhood's sidewalks. This equates to approximately 31.4 cubic yards per tree which, while less than James Urban's (2008) recommended target of 44.5 cubic yards, is more than the 28 cubic yard minimum Urban signals, and an order of magnitude more than any other urban tree installation in Vancouver.

FUTURE EXPLORATIONS

Biotope Area Zoning

A little explored tool for enhancing the biological productivity of individual properties and neighbourhoods is the notion of Biotope Area Factors (BAF). Berlin's (Germany) BAF programme is a leading example of this approach. It seeks to improve the urban ecosystem by requiring each development or redevelopment project to dedicate a minimum amount of the site for plants or other ecosystem functions.

The BAF expresses the ratio of the ecologically effective surface area to the total land area. It addresses all *potential* horizontal and vertical surfaces, such as courtyards, roofs, and walls, and their respective contribution to ecological enhancement. The factors range from 0.3 to 1.0 depending on the type (e.g., residential, commercial, and infrastructure) and size of property to be developed, whether it is a new development or an addition, and targets which neighbourhood it is located in.

$$\text{Biotope Area Factor} = \frac{\text{ecologically-effective surface areas}}{\text{total land area}}$$

The BAF program is performance-based rather than prescriptive, allowing design professionals to determine how best a given design will meet the BAF Factor. Berlin's approach provides a quantifiable method of assessing the ecological performance of individual sites and works in conjunction with other conventional bylaws and zoning restrictions, and floor area ratios.

There is potential for a BAF model to be used more proactively to specify ecological development criteria for different parts of the urban landscape in relationship to meet ecological goals, including development in proximity to the core areas, corridors, and buffer zones identified during the earlier gradient analysis of this scenario. For example, adjacent to core ecological patches, a BAF coefficient could be established to direct certain types of landscape treatments on and around, and adjusted to rank indigenous biotopes higher than exotic biotopes. Depending on the prevailing wildlife species in the core area the biotopes could be defined to provide supplementary sources of food or refuge.

The ecological appeal of the BAF rests with its attempt to quantify the ecological contribution the horizontal and vertical surfaces of each development makes toward local ecology. It asks that all development be responsible for reducing their ecological footprint, and contribute positively to local ecosystems rather than undermine their integrity. The BAF could be used in a similar manner to more familiar planning requirements (e.g., density, zoning) to more explicitly address urban biodiversity on individual development sites.

Neighbourhood Native Plant Assemblages

One seemingly obvious approach to enhancing urban biodiversity is to maximise the use of native trees, shrubs, and groundcovers throughout the urban landscape. This is particularly true at the resi-

FIGURE 6. Berli

Calculating the B

The BAF expresses t
the total land area.

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Types of surfaces
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Weighting factor /
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FIGURE 6. Berlin Biotope Area Factor Table.

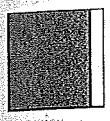
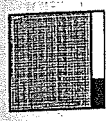
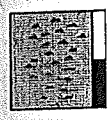
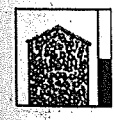
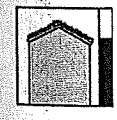
Calculating the BAF

The BAF expresses the ratio of the ecologically effective surface area to the total land area.

$$\text{BAF} = \frac{\text{ecologically-effective surface areas}}{\text{total land area}}$$

In this calculation, the individual parts of a plot of land are weighted according to their "ecological value".

Types of surfaces and weighting factors:
(Surface types not mentioned can be calculated as long as they have a positive effect on the ecosystem)

Weighting factor / per m² of surface type	Description of surface types
 Sealed surfaces **0.0**	Surface is impermeable to air and water and has no plant growth (e.g., concrete, asphalt, slabs with a solid subbase)
 Partially sealed surfaces **0.3**	Surface is permeable to water and air; as a rule, no plant growth (e.g., clinker brick, mosaic paving, slabs with a sand or gravel subbase)
 Semi-open surfaces **0.5**	Surface is permeable to water and air; infiltration; plant growth (e.g., gravel with grass coverage, wood-block paving, honeycomb brick with grass)
Surfaces with vegetation, unconnected to soil below **0.5**	Surfaces with vegetation on cellar covers or underground garages with less than 80 cm of soil covering
Surfaces with vegetation, unconnected to soil below **0.7**	Surfaces with vegetation that have no connection to soil below but with more than 80 cm of soil covering
Surfaces with vegetation, connected to soil below **1.0**	Vegetation connected to soil below, available for development of flora and fauna
Rainwater infiltration per m² of roof area **0.2**	Rainwater infiltration for replenishment of groundwater; infiltration over surfaces with existing vegetation
 Vertical greenery up to a maximum of 10 m in height **0.5**	Greenery covering walls and outer walls with no windows; the actual height, up to 10 m, is taken into account
 Greenery on rooftop **0.7**	Extensive and intensive coverage of rooftop with greenery

dential neighbourhood scale where several opportunities exist with backyards, along boulevards, and in rights of way to add more vegetative complexity to the urban landscape. Rearyards are particularly appealing as they are often buffered from the noise and activity found along local roads that for many wildlife species can be a sufficient enough disturbance to effect nesting and foraging habits.

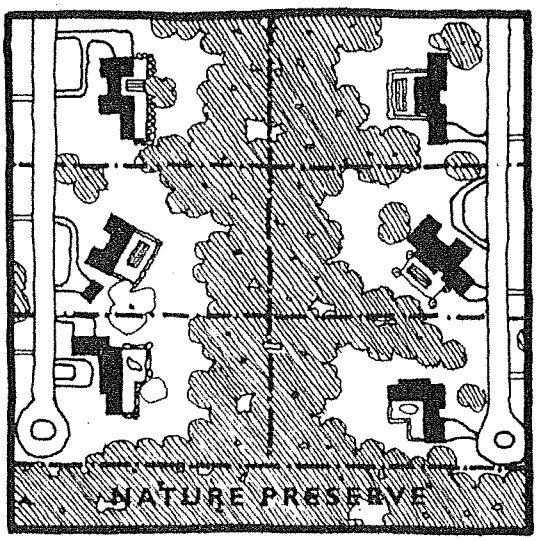
By adding more complex selections and arrangements of native plants along the shared property lines within backyards, continuous green corridors can emerge. Dramstad et al. (1996) illustrated conceptually how planting native trees and shrubs in rear yards, along common property lines can create a continuous vegetative corridor through the middle of the block. When linked with street trees and naturalised treatments of boulevards, a green network throughout the neighborhood begins to surface that provides pathways for birds and small mammals to migrate along

Currently, however, the coordinated use of native plants within cities to enhance local ecological function is rare. Few local governments have developed guidelines that help homeowners choose and use native plants in their gardens to maximise ecological function. And few homeowners possess the knowledge of local environmental conditions (Orr 2004) to make informed choices. The problems of native plant use are compounded by a highly variable supply of native plants within each region of North America, and large scale garden centers that tend to focus on more widely propagated exotic species.

When native plants are used they are rarely organised with ecological functionality in mind. One reason for this is the prevailing modern/picturesque aesthetic in North America (Pizzoni 1997, Hunt 1992) that tends to favour exotic plant species, organised with little consideration for ecological functionality. For many the use of native plants, organised in ecologically appropriate ways with minimal maintenance, challenges their landscape aesthetic (Orr 2004, Daniel 2001, Nassauer et al. 2001, Nassauer 1997).

A more proactive approach would see local governments provide more definitive direction on the value and preferred use of native plants for residential applications. Furthermore, local authorities, in their review of development proposals, could seek to

FIGURE 7. Backyard Planting Strategies (Dramstrad et al. 1996).



consolidate development to maximise the effective open spaces available for native vegetation. And for subdivision development emphasise the need for interlinked natural corridors through the subdivision, and connecting where possible with neighborhood and regional open spaces.

Ecological Development Zoning

An additional means of enhancing urban biodiversity involves elaborating the patch-corridor model discussed earlier by describing specific ecological targets for different neighbourhoods across the city depending on the proximity to patches and corridors. Currently most applications of the patch-corridor occur at the regional scale. This results in a crude classification of landscapes into either patches, corridors, or the dominant matrix consisting of commercial, industrial, and residential areas and infrastructure. The scale lacks the capacity to consider the inherent heterogeneity found within urbanised landscapes and ecological contributions made by such heterogeneity. It oversimplifies the landscape's inherent structure and function so that what might be significant heterogeneity at a site or neighbourhood scale, often disappears at a regional scale (McGarigal and Cushman 2005).

One approach to making the patch-corridor model more effective at the neighbourhood scale is to combine it with another landscape ecology model—Landscape Gradients. Gradients in the landscape are well documented phenomena (McDonnell 1997, Forman 1995) particularly along urban-rural transects where there can be discernable changes in vegetative cover, temperature, noise, etc. Establishing a gradient of native flora, with higher concentrations closer to ecologically sensitive areas, could enhance the effectiveness of environmental patches and corridors.

For example, once an ecological network of core patches and corridors is established, different ecological zones can be defined relative to the patches (e.g., Zone One: 0 to 500 ft, Zone Two: 500 ft to 1,000 ft, Zone Three: 1,000 ft to 2,000 ft, Zone Four: beyond 2,000 ft). The intensity of development would vary across these zones with limited urban development within 500 ft of core areas and maximum development opportunities found beyond 2,000 ft of core areas.

No development would be allowed within the core areas and corridors. These are intended for use in restoring some of the area's indigenous flora and fauna. Passive recreation would be limited to strategically located footpaths only after the ecological requirements (e.g., nesting, rearing) of key species had been determined and embedded in the landscape. In *Zone One* the emphasis would be on supporting the ecological restoration efforts in the core areas. However, where compatible relatively low impact uses such a recreation, field based agriculture, and low density residential housing could be included. It is envisaged that *Zones Two* and *Three* would be capable of accommodating a range of residential and mixed use development as long as the fundamental ecological components of water flows and connected, vegetated corridors were maintained.

CONCLUSIONS

The meaningful integration of biodiversity into urban planning remains, for most cities, illusive. Few jurisdictions have sought out truly integrated solutions and developed clear implementation strategies for biodiversity on public and/or private land. More commonly, the goals for indigenous biodiversity in urban areas are focused on enhancing the function-

FIGURE 8. Ecolo

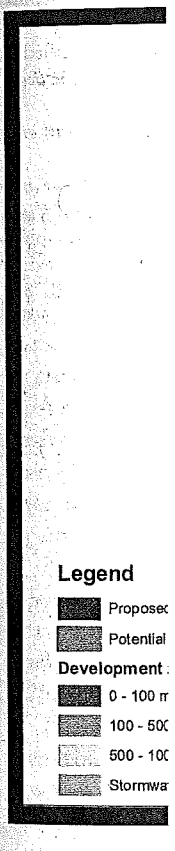


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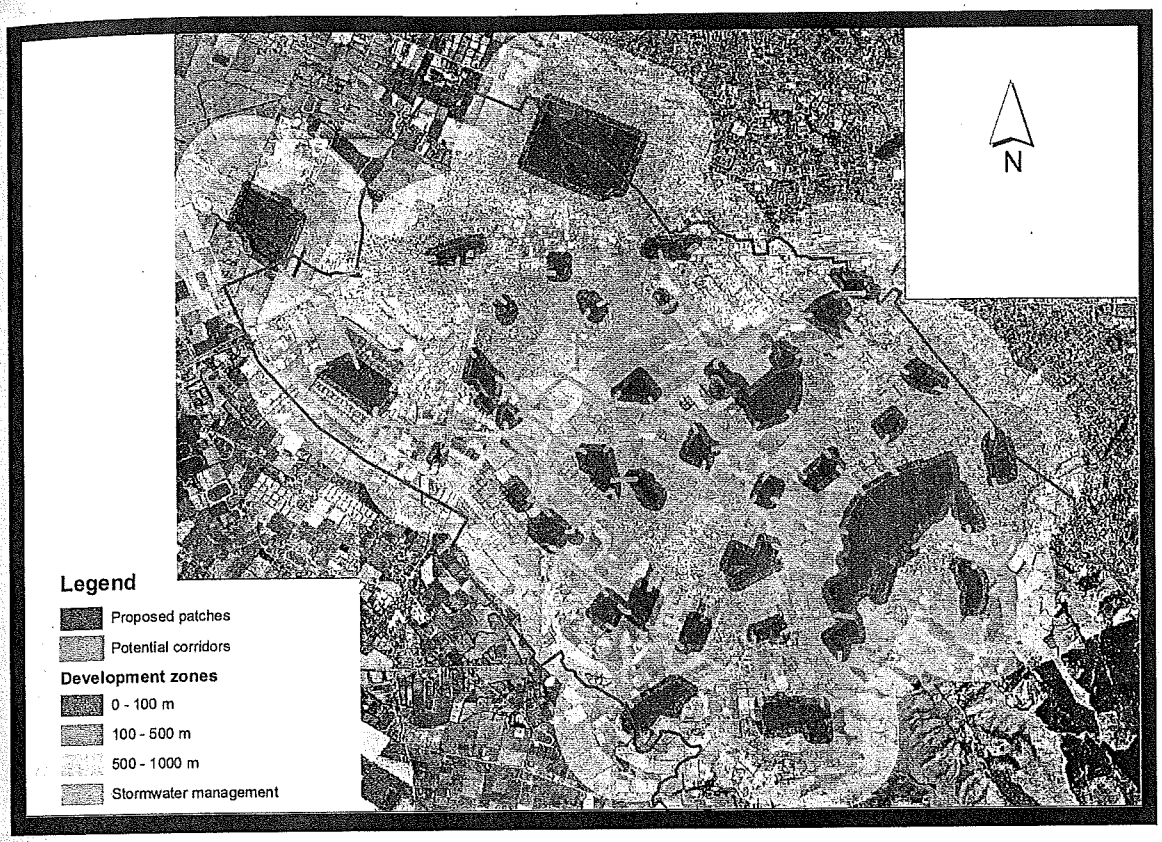
FIGURE 8. Ecological Development Zones, Christchurch, New Zealand.



ality of those remaining pieces of former ecosystems, rendering those aspects of indigeneity to virtual museums. There are several planning and design practices that are emerging, however, that suggest urban biodiversity can be meaningfully addressed across a range of scales. The challenge resides not so much with the efficacy of these approaches but with our interest in adopting them.

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