WATER-CENTRIC APPROACH TO DEVELOPING GREEN INFRASTRUCTURE

Framework and Cost

DEPARTMENT OF BIORESOURCE ENGINEERING

Master Thesis

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Contents

Declaration of Originality

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material that to a substantial extent has been accepted for the award of any other degree or diploma at McGill University or any other educational institution, except where due acknowledgment is made in the thesis. Any contribution made to the research by colleagues with whom I have worked at McGill University or elsewhere during my candidature is fully acknowledged.

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List of Tables

List of Figures

List of Abbreviations

ACP	Alternative Compliance Path
AFTP	Agro-Food Techno-Park
AIA	American Institute of Architects
ALIDP	Alberta Low Impact Development Partnership
AM	Adaptive management
ASLA	American Society of Landscape Architects
BC	British Columbia
BedZED	Beddington Zero Energy Development
BMP	Best management practice
BREEAM	Building Research Establishment Environmental Assessment Method
BTM	Benefit transfer method
CaGBC	Canada Green Building Council
CFU/L	Colony forming units per liter
CI	Conventional infrastructure
CMHC	Canada Mortgage and Housing Corporation
CNT	Center for Neighborhood Technology
CNU	Congress for the New Urbanism
COST	Cooperation in the Field of Scientific and Technical Research
COTE	Committee on the Environment
CSTC	China Sustainable Transportation Center
DDE	Direction Départementale de l'Équipement
DIREN	Direction Régionale de l'Environnement
EPA	Environmental Protection Agency
EU	European Union
EVRI	Environmental Valuation Reference Inventory
GI	Green infrastructure
GMREB	Greater Montréal Real Estate Board
GVC	Green Values Calculator
ha	Hectare

HPM	Hedonic price method
IEE	Initial environmental evaluation
IMP	Integrated management practice
IWCA	Integrated Water-Centric Approach
IWCD	Integrated water-centric development
IWRM	Integrated water resource management
km	Kilometer
LCCT	Life Cycle Costing Tool
LEED	Leadership in Energy and Environmental Design
LEED-ND	Leadership in Energy and Environmental Design for Neighborhoods
LID	Low impact development
LIDC	Low Impact Development Center
LINU	Light Imprint New Urbanism
m^2	Square meters
m^3/d	Cubic meters per day
MDER	Maryland Department of Environmental Resources
mg/l	Milligrams per liter
MIWCA	McGill Integrated Water-Centric Approach
mm	Millimeters
MRC	Regional County Municipality
NDIP	Notre-Dame de L'Ile-Perrot
NDRC	National Development and Reform Commission
NGO	Non-government organization
NZEH	Net-Zero Energy Home
PMU	Project Management Unit
PRC	People's Republic of China
PV	Photovoltaics
RMLUI	Rocky Mountain Land Use Institute
SAT	Systems Approach to Training
SPA	Special Protection Area
SUI	Sustainable urban infrastructure

UNEP	United Nations Environment Programme
UPA	Union des Producteurs Agricoles
US	United States
US EPA	United States Environmental Protection Agency
USGBC	United States Green Building Council
VFPF	Vertical-flow planted filter
WAA	Williams Asselin Ackaoui Inc.
WSUD	Water sensitive urban design
WTP	Water treatment plant
WWTP	Wastewater treatment plant

Abstract

Green infrastructure (GI) has emerged as an active term of reference in project development planning. However, elaboration and discussion of integrated frameworks to assist engineering organizations in planning the start-up of new projects are largely absent from GI research literature, particularly in the context of greening and sustainability. The present study attempts to bridge this gap by developing and proposing an integrated framework focused on the start-up development of green projects relating to storm water, water supply, and wastewater.

The present study's first objective was to explore the use of fully integrated GI in the engineering design of a biophilic development incorporating sustainability principles. To achieve the desired teamwork, a clear sequence of tasks to define the workflow was required. A review of the literature led to the identification of several different approaches, from which I selected four, improved, and then employed them to build a ready-to-use framework of sequenced tasks. These tasks included all components of water management (precipitation and drainage, water supply and wastewater). A case study in China employed in testing this framework demonstrated that all GI components could be integrated into one approach. While the structuring of an integrated water-centric development (IWCD) approach was found to be applicable to a wide range of projects, appropriate capacity building was critical to its success.

In support of the study's second objective, the newly proposed framework was implemented to compare, in the form of a feasibility study, the economic benefits of investment and overall cost of designing green with those of designing conventionally in the case of a new institutional pole for the city of Vaudreuil-Dorion, Quebec, Canada. While the study showed increases in the value of GI projects to mirror the construction costs of such projects, it also found that implementing GI (vs. conventional) infrastructure can result in savings in both construction and life cycle costs. Therefore, GI can provide significant economic benefits to cities.

The study showed that a GI project including components from water source to wastewater disposal would cost 15 percent more, at the level of each housing unit, than a conventional infrastructure design. However, the study also demonstrated that the value of each housing unit would be 15 to 27 percent greater in a green neighborhood than in a conventionally designed neighborhood. This would provide an equivalent increase in tax revenues for the municipality. Although many frameworks have been proposed for stimulating a green urban agenda, few have offered a start-up methodology for incorporating biophilia within the engineer's design. This study served to develop a new integrated framework for storm water, wastewater, water supply, and street layout for GI projects.

Résumé

Le thème des infrastructures vertes (GI) est devenu un terme de référence dans la planification du développement des projets. Toutefois, les approches intégrées pour aider les organisations d'ingénierie dans la planification de la mise en place de nouveaux projets verts sont largement absents de la littérature, en particulier dans le contexte du développement durable. La présente étude vise à combler cette lacune en développant et en proposant une approche axée sur le développement d'une structure de démarrage des projets verts, et en tenant compte du drainage, de l'approvisionnement en eau et du traitement des eaux-usées.

Le premier objectif de la présente étude est d'explorer l'utilisation des infrastructures vertes pleinement intégrées dans la conception technique d'un développement durable et dans le contexte d'un développement biophile d'une ville. Pour supporter un travail d'équipe, l'élaboration d'une séquence claire des tâches à exécuter a été nécessaire. Une revue de la littérature a conduit à l'identification de plusieurs approches différentes, à partir de laquelle quatre propositions ont été retenues. De là une approche améliorée, a été conçue pour définir les tâches séquentielles permettant de démarrer un projet vert. Ces tâches comprennent toutes les composantes de la gestion de l'eau (drainage, approvisionnement en eau et eaux-usées). Une étude de cas en Chine a permis de vérifier l'acuité de cette approche. Cette étude a permis de démontrer que toutes les

composantes de l'infrastructure verte pourraient être intégrées dans un nouveau projet de développement. Cette approche est nettement centrée sur l'eau.

Pour satisfaire un deuxième objectif de l'étude, la nouvelle approche proposée a été utilisée pour comparer, dans le cadre d'une étude de faisabilité, les avantages économiques d'un investissement vert avec celle d'une conception classique, pour l'élaboration du concept d'un nouveau pôle institutionnel de la ville de Vaudreuil-Dorion PQ, Canada. Bien que l'étude ait montré que le coût de construction des projets verts était plus élevé, il a été constaté que sur un cycle de vie les infrastructures vertes peuvent entrainer des économies d'entretien. Les infrastructures vertes peuvent apporter des avantages économiques importants pour les villes.

Chapter 1: Introduction

Although architects and designers are beginning to incorporate biophilia into their work, planners and policy makers who think at the city scale have lagged behind. This raises serious questions about what a city is, or could be, and what constitutes a livable, sustainable place of residence (Beatley, 2009). A review of the literature found that greening actions can be categorized and grouped according to their different topics: green infrastructure (GI), green projects, green development, and green approaches. Some authors (e.g., Sim Van Der Ryn) have proposed the term "ecological design." Perhaps the most compelling theme of ecological design is the search for a unified approach to the design of sustainable systems that integrates scales ranging from molecular to global (Van Der Ryn & Cowen, 2007). Many authors have promoted the concept of GI in the design of sustainable urban systems. This study seeks to define the concept more closely.

One objective of this study is to define the start-up steps of a green development project, with the aim of establishing an integrated green approach to land development and servicing of infrastructure. A further objective is to link integrated water management to GI concepts. The concept of a green approach includes issues associated with water. Although extraordinary theoretical and technical advances have occurred in the field of ecological design in the past 10 years, the challenges facing the planet, ranging from loss of biodiversity to rapidly increasing effects of global climate change, have also accelerated (Van Der Ryn & Cowen, 2007). Storm water management is an increasing concern under increasingly erratic climatic conditions. Water supply is a definitive concern, in terms of both quality and quantity. Contamination of water sources by point- and non-point-source pollutants is another major concern. To secure the sustainability of life, each of these unique concerns must be addressed in the design of new green developments. Therefore, a philosophy of integrated water resource management (IWRM) must be promulgated and linked to the greening of cities. In this study, adaptive management (AM), a concept designed primarily to support managers in dealing with highly connected systems, is highly valued in facing uncertainty (Medema & Jeffrey, 2005). There is a need to develop new metrics (things to classify or measure), techniques (ways of classifying or measuring), and analytical frameworks (perspectives on the utility of classes or measures) (Jeffrey & Geary, 2006). Too often, the green urban agenda forgets the "green" and concentrates on energy efficiency and resource management, to the neglect of the life-enhancing and wonder-expanding dimensions of nature itself (Beatley , 2009). This study seeks to contribute to and meet the needs of incorporating green concepts into urban infrastructure design. The next sections will explore the meaning of different green concepts.

1.1 Green Infrastructure

GI can mean different things to different people, as well as according to the context in which it is used. Two main views of GI exist: some perceive trees in urban areas as GI for the "green" benefits they provide, while others use GI to refer to engineered structures (e.g., water treatment facilities or green roofs) that are designed to be environmentally friendly (Benedict & McMahon, 2006).

In this context, infrastructure is understood to represent the substructure or underlying foundation on which the continuance and growth of a community depends (*Webster's New World Dictionary* and http://www.sprawlwatch.org/greeninfrastructure.pdf). On that basis, GI may be defined as a resilient landscape supporting a multitude of ecological, economic, and social functions without compromising the sustainability of the resource base (Mell, Roe, & Davies, 2009). Therefore, GI includes the physical environment within, and between, our cities, towns, and villages. The term represents an interconnected network of open spaces, water bodies, and environmental features, and the natural systems that these support (Davies, 2011). However, gray infrastructure, such as roads and sewers, or social infrastructure, such as hospitals and schools, are what most people associate with the term "infrastructure" (Bao, 2010). In the municipal domain, these types of facilities are termed "built infrastructure." With this range of definitions of infrastructure, GI can be used to refer to hard infrastructure built respecting green principles.

A rapprochement needs to be built between the infrastructure design approach and the European hub-and-connecting-link concept of GI, which maintains that engineered infrastructures should be designed to support the greening process. The resultant integrated GI must combine both concepts in a single ideology while remaining respectful of ecological issues and mimicking nature. Taking a greener approach to infrastructure development not only mitigates the potential environmental effects of development (e.g., improving stream health and reducing energy use), but also makes economic sense when all the effects of conventional development on "natural capital" and the services rendered thereby are taken into account (Olewiler, 2004).

There is a reluctance to use GI in new developments because it is untested, according to Alexander and Tomalty (2002). In East Clayton, Surrey, BC, city engineers require that a natural drainage system be backed up by a conventional one, adding to project costs. The authors suggested that, given this uncertainty, the province should take the lead in research and develop demonstration projects highlighting the functionality and affordability of alternative infrastructure. In 2011, city of Montreal urban planners stated that city engineers' reticence was the main impediment to implementing low impact development (LID) techniques in brownfield and other new developments. When assessing infrastructure, the usual process is to examine the economic efficiency, effectiveness, accountability, transparency, equity, and ease of administration of different financing options. The link between infrastructure financing and planning is one that is often overlooked, not only in the literature on financing infrastructure, but also in professional practice (Tomalty, 2007). Wolf argued that monetizing benefits assists decision makers in developing public policy. She showed how some progress has been made in assigning a value to the human services of metro nature, but asserts that still more should be done. Economists have developed non-market valuation techniques for land and resources beyond city limits. Scientific understanding and economic valuation constitute tools for an effective integration of metro nature into a city, and represent true cornerstones of good city planning (Wolf, 2003). Sarté (2010) observed:

> Engineers are being asked to apply their technical and infrastructural expertise earlier and more comprehensively as an integral part of a holistic

> design process. Together, we are all trying to address critical questions: how can we plan, design, and build healthy cities, homes, and communities for burgeoning population? How can we provide food, energy, and transportation in ecologically sustainable ways? (page xvii)

The result of a multi-action concept, GI relies on potential multi-functionality—although a sole-action concept can be applied to individual sites and routes—to deliver a broad range of ecosystem services; when the sites and links are taken together, a fully multifunctional GI network is achieved (Benedict & McMahon, 2006).

A survey of different countries' interest in greening the planet indicates that GI is the preferred green measure; however, this term may be interpreted differently in different regions. In Europe, the similarity between "gray" and "green" infrastructure is assumed, so that gray infrastructure (such as public services, transport, information systems, and highways) clearly encompasses all hard infrastructure types required by our society and economy to function. However, for GI, the range of infrastructure included is less obvious (Murphy, 2009). Typically, the European concept of GI includes the network of green routes and hubs that preserves animal and plant biodiversity.

In contrast, the North American concept of GI consists of a network of structures that supports urban and rural development, based on the priority of protecting natural habitats and reducing the effects of development. This concept focuses on introducing green facilities such as parks, gardens, trees, and swales into the city's infrastructure. It also involves designing hard infrastructure in accordance with green principles and integrating LID techniques.

Originating in the 1990s, the North American concept of GI initially referred to land development planning ensuring a low impact of storm water management on the environment. Various global organizations expanded this definition to encompass the engineering of systems having a lesser impact on the environment and being more efficient in the use of resources. Today, the concept extends to integrating the European concept of hubs and links. In its broadest application, GI encompasses an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife (United States Environmental Protection Agency [US EPA], 2010).

In Europe, as early as 1996, the concept of sustainability was proposed to assist local authorities and practitioners in designing urban infrastructure. An action termed the Cooperation in the Field of Scientific and Technical Research (COST) was also initiated. Further, the European Science Foundation proposed the concept of best management practices (BMPs) applied to sustainable urban infrastructure (SUI).

In Asia, the concept of GI involves the introduction of parks and gardens into large existing cities. For example, in China, GI includes planting 20-meter-wide strips of trees along all the highways. The concepts applied differ depending on the demographics and the age of existing urban infrastructure and housing. In large cities, urban planners decide on the conceptual framework. Although further initiatives are planned for the future, so far, only three cities in China have developed Eco neighborhoods according to the principles of ecocity development: Quingdao, Dongtan, and Tianjin. Some of these projects were sponsored by companies with headquarters situated in Singapore, where work on recycling water and city greening was initiated many years ago because of the city's restricted area and water shortages.

1.2 Green Project

As defined by the Brundtland Commission, a sustainable development project that can meet present needs without compromising those of future generations can be termed a "green project." Such a project can imply multi-action implementation in a large-scale agglomeration, or a single action, such as installing solar panels on a building. In the 1970s, green projects mainly focused on land conservation, with non-profit organizations working to protect individual parcels of land. By the 1990s, the Conservation Fund realized that networks of open spaces must be protected. In 2001, Benedict and

McMahon of the Conservation Fund drafted pilot course modules for a conservation leadership network titled *Green Infrastructure: A Strategic Approach to Land Conservation.* From their perspective, "successful land conservation in the future will have to be more proactive and less reactive, more systematic and less haphazard, better integrated with other efforts to manage growth and development" (Benedict & McMahon, 2002, page 3)

In 2000, as a step toward certifying green projects, the United States Green Building Council (USGBC) developed a registration approach known as Leadership in Energy and Environmental Design (LEED). A strong case can be made for employing a holistic approach in assessing those design features that determine the multiple environmental effects of an entire building, and how these effects match the project's environmental goals. Buildings account for 39 percent of primary energy use, 71 percent of electricity consumption, and nearly 40 percent of carbon dioxide emissions in the United States (US) (Tolley & Shaikh, 2010). For this reason, buildings offer significant opportunities for pollution abatement (Enkvist et al., 2007). Promoting green buildings conserves energy and water, reduces greenhouse gas emissions, and provides state-of-the-art modern facilities for office and residential use (Tolley & Shaikh, 2010). In 2007, Gill, Handley, Ennos, and Pauleit explored the important role that GI can play in adapting to climate changes. This has become a green project in itself.

In the development of Asian cities, the addition of green spaces, techniques to reduce runoff and efforts to minimize the expanse of the city's heat islands represent the main green aspects of such projects. In the US, the Environmental Protection Agency (EPA), in its early stages, and the Low Impact Development Center (LIDC) focus mainly on storm water management.

In Australia, the concept of water sensitive urban design (WSUD) is based on formulating development plans that incorporate an integrated approach to the management of the urban water cycle, particularly with respect to storm water. WSUD involves a proactive process that recognizes that opportunities for urban design, landscape architecture, and storm water management infrastructure are intrinsically linked (Wong, 2006). Managing the urban water cycle needs to be underpinned by key sustainability principles of water consumption, water recycling, waste minimization, and environmental protection (Melbourne Water, 2005).

In Canada—mainly in British Columbia (BC) and Alberta (AB)—LID techniques introduced as new approaches to land development have constituted green projects. In the US, Smart Growth, a development principle aimed to preserve the natural environment, was developed by leaders in the municipal domain and urban planners. Douglas Farr initiated Sustainable Urbanism, a movement whose goal is to combine urban design with nature. Spontaneous actions at the US federal level are emerging as a burgeoning source of efforts to improve the environment. One such trend is the growing green building movement, which encompasses many cities, educational institutions, other non-profit organizations, and private developers (Tolley & Shaikh, 2010). In this environment, a group of single green projects may expand to encompass a concept of green development. Given the present study's focus on the start-up of green development, including housing development, the next section will discuss the green concept in the context of green development.

1.3 Green Development

Green development is a broader concept, which involves green space management and its ability to conserve natural ecosystem functions and provide associated benefits to ecosystems, as well as the human population. This type of development includes the construction or conservation of hubs and links. Hubs can include green hubs (e.g., forests and lakes) or functional hubs (e.g., housing, commercial, or institutional functions). Roads and pedestrian walkways constitute urban links, which may or may not be green. Conservation corridors, greenways, and greenbelts provide links between green hubs. Green development requires GI, and green links are essential to preserving green hubs. In 1996, Van Der Ryn and Cowen (2007) presented a new concept in ecological design when they reported on early efforts to implement large-scale land-use planning under which biodiversity was systematically conserved. This concept has also been documented in France and continental Europe.

In May 1992, governments throughout the European Union (EU) adopted legislation designed to protect Europe's natural resources. The Habitats Directive protects the most seriously threatened habitats and species across Europe. It complements the Birds Directive, adopted in 1979. At the heart of both these directives is the creation of a network of sites termed Natura 2000. The Birds Directive requires the establishment of Special Protection Areas (SPAs). All EU member states are required to manage and implement Natura 2000.

In France, a distinction is made between "green" and "blue" infrastructure because not all problems of continuity within water ecosystems can be managed using the same approach as those for terrestrial habitats and their associated species. In France, the GI concept was launched through the recent Grenelle process, which set out to renew efforts to improve the environment in France through an intensive series of discussions, negotiations, and dialogues between five key sectors: the central government, local authorities, employers, employees, and non-government organizations (NGOs) (Allag-Dhuisme et al., 2010). There has been increasing public and government interest in establishing green technologies in project development because of their demonstrated environmental benefits (Barlow, 2011). Growing greener cities involves the promotion of activities that employ, recognize, or conserve nature in its many helpful forms to sustain urban life while limiting or reducing its depletion (Birch & Wachter, 2008). Many cities in the US and Canada have adopted a green policy. Large cities such as New York, Boston, Toronto, and Vancouver have developed environmental guidelines to promote green buildings. The governments of Canada and Quebec have adopted policies on sustainable development. Even small cities such as Salaberry-de-Valleyfield in southwestern Quebec have adopted an action plan to promote green development. However, despite green development's potential as a climate change adaptation and mitigation tool, and its use in Europe and the US, there have been very few examples of green development in eastern Canada. One of the major barriers to an increase in the occurrence of extensive green projects and green development is the lack of scientific data to evaluate their applicability under local conditions. A second barrier is the absence of comparable costs to develop a project with a green approach. This costing problem is evaluated in the second part of this study. The next section explores the way to introduce greening into development projects.

1.4 The Green Approach

A green approach plays a part in the actions used to develop sustainability across the planet. How can new development be sustainable? How can a green approach be introduced into a new development? Are there other names for green development? In the 1990s, the United Nations (1992) proposed a strategy called the "ecosystem approach":

> The ecosystem approach is a strategy for the integrated management of land, water, and living resources to promote conservation and sustainable use in an equitable way. Application of the ecosystem approach will help to reach a balance of the three objectives of the Convention. It is based on the application of appropriate scientific methodologies focused on levels of biological organization encompassing the essential processes, functions, and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems. (https://www.cbd.int/ecosystem/)

Even if a green approach may be an appropriate strategy to manage land, water, and living resources, does any framework exist to start a green development project? Gill et al. (2007), exploring the role that GI can play in allowing one to adapt to climate change, concluded that the creative use of such infrastructure did indeed present one of the most promising opportunities for adaptation. They also stated that this fact should be recognized at all levels of the planning process: from regional spatial strategies, through local development frameworks, to development control within urban neighborhoods (Gill et al., 2007).

In 2006, COST Action C8 edited a synthesis of theories, methods, and tolls to assess SUI. However, they did not provide a road map on how to initiate green development. In the first part of the present research, an evaluation was made of the ability of 17 approaches to provide an entry point to new development conceptualization, whereby the design of infrastructure such as roads, water supply, drainage, and wastewater collection could be constructed using a green approach. Most of these approaches focus on a single topic such as transportation, urban density, energy, health or culture.

The selection, from different sources (e.g., EPA, state, and provincial governments), of analysis approaches (e.g., LID and LEED) was based on whether they related to water resources and proposed a starting methodology. The four approaches deemed to provide the most appropriate frameworks for the development of new conceptual methods in leading team action were selected and compared:

1. LID (Maryland Department of Environmental Resources [MDER])
2. Water Quality Scorecard (US EPA)
3. LEED (USGBC)
4. BC Guidebook (Government of BC, Ministry of Environment)

These approaches were selected because they contained standards widely used by practitioners as a baseline reference. Each of these four approaches was structured with a different number of steps.

In 1999, the MDER presented a structured approach. It proposed that to start a project, five steps must be taken: (1) site planning, (2) hydrologic analysis, (3) integrated management practices (IMPs), (4) erosion and sediment control, and (5) the establishment of a public outreach program.

The EPA offers a six-step scorecard approach: (1) review the scorecard, (2) review various sections, (3) collect existing ordinances and policies that will provide the necessary references, (4) coordinate between appropriate agencies or departments to complete the scorecard, (5) identify specific policy questions, and (6) identify short-, medium-, and long-term goals.

The USGBC's LEED suggests a three-step approach: (1) site analysis and programming, (2) preliminary planning, and (3) final design and public outreach.

Finally, the BC Guidebook presents a seven-step approach: (1) secure political interest and support, (2) frame the watershed problems, (3) develop objectives and alternative scenarios, (4) collect meaningful data and refine scenarios, (5) evaluate scenarios, (6) develop an implementation program, and (7) refine scenarios through AM.

After performing the analysis, a six-step approach was proposed: (1) taking an inventory, (2) hydrological and hydraulic assessment, (3) IMPs, (4) land planning, (5) consultation, and (6) preparing a master plan.

The term GI has multiple meanings as it relates to conservation efforts; however, it should generally present a framework for conservation and development, while still recognizing the essence of what GI is. McDonald, Allen, Benedict, and O'Conner (2005) contrasted gray and green infrastructure. Just as gray infrastructure describes the functional support system of urbanized areas, GI refers to nature's life support system (Benedict & Bjornlund, 2002). An innovative, integrated GI approach for new development could be defined if one allowed the complete integration and management of a closed water cycle—directed according to LID, WSUD, and BMP components as well as aspects of IMPs—to occur within the GI concept. This approach was implemented in the Qujing Agro-Park in Yunnan Province, China. It was also proposed in planning the development of the new Vaudreuil-Dorion institutional pole development. The next section identifies the parameters and boundaries circumscribing the search for a new green approach, and addresses how a green development project is to be initiated.

1.5 Research Objectives

Thus, the primary objective of this study was to define the steps involved in the start-up of a green development project, and the secondary objective was to link integrated water management to GI concepts.

The specific objectives of this study were to:

1. *Develop a new integrated framework for storm water, wastewater, water supply, and street layout for GI projects*. A case study in China illustrates this new concept. The concept is identified by the acronyms IWCA (Integrated Water-Centric Approach) and MIWCA (McGill Integrated Water-Centric Approach) in the final improved format.
2. *Evaluate the cost of green, integrated infrastructure projects* and compare them with standard development practices for a case study in Canada: the Vaudreuil-Dorion 540 development. The framework developed in the first case study was applied to the structure of the second case. Therefore, storm water, wastewater water supply, and street layout were designed from the application developed in the first case study, along with MIWCA.

An integrated approach that incorporated all parameters in green development needed to be developed. One of the objectives of the present study was to summarize all the criteria needed to initiate such a development in the present day. After identifying and analyzing different approaches drawn from America, Australia, and Europe, the framework necessary to elaborate a plan to initiate such a project in the present context was devised.

Wastewater treatment, water filtration, water supply, and water balance are not covered by LID or LEED. The present research intends to introduce new concepts, including all the components of water management, into GI through an integrated approach. Effectively, LID focuses on rainwater, and Leadership in Energy and Environmental Design for Neighborhoods (LEED-ND) focuses mainly on urban development techniques. The intent was to link all parameters together. The water cycle is central to the new concept, so urban planning should be restructured through the application of a closed loop. In Case 1, the cost of the project was not an issue in the decision-making process; however, it was in Case 2. Case 1 was used to elaborate the concept, whereas Case 2 was developed with the new concept MIWCA. Since project cost was relevant to decision makers in Case 2, the costs of conventional and green infrastructure were evaluated.

Many commonly cited environmental benefits of urban green space are still poorly supported by empirical evidence, adding to the difficulties in designing and implementing GI programs (Pataki et al., 2011). Given the unexpected lack of empirical data for evaluating the effectiveness of GI, the study explored the competitive costs and anticipated benefits of GI and the implementation and evaluation of its performance in a specific context and in concert with an application of the new concept MIWCA.

The organization of chapters is as outlined below.

Chapter 1 introduces the concept of GI and green development. It introduces different approaches to planning in green design and provides an overview of the GI situation in specific parts of different continents.

Chapter 2 reviews the literature of GI with a focus on water resources and ecosystem services. This chapter includes the methods, tools, and techniques available in different approaches such as the LID, LEED, BC Guidebook, and EPA scorecard. It explores different frameworks to start or structure an urban development project. It also discusses the methods, tools, and techniques used to cost projects.

Chapter 3 elaborates the concept of IWCA and discusses the Qujing Agro-Park case study. It describes the application of the framework designed in the first part of Chapter 3 to develop the project. It presents a detailed analysis of the existing frameworks and presents the new framework. The new framework, generated through MIWCA, is compared with the existing conventional approach.

Chapter 4 discusses the Vaudreuil-Dorion institutional pole development case study. The feasibility study was developed using the new framework MIWCA created in Chapter 3. The first case study (China) was of an industrial park including a housing development. The Vaudreuil-Dorion case study was designed to receive an institutional pole surrounded by a housing development.

This study evaluates the cost of two versions of an ecosystem service: one using a GI approach and the other using a conventional approach. It demonstrates the economic advantages of introducing green techniques into development. It presents a detailed analysis of costing methodologies for GI developments.

Chapter 5 provides a conclusion that summarizes the proposed framework, presents revenue and cost analysis, and provides recommendations for future studies.

1.6 Methodology

The methodology involved a literature review; electronic journal databases (e.g., Scopus; Google Scholar: Science Direct; McGill University's search engine) were first searched by "subject." The journals included in the literature review were those concerned with planning, sustainability, environmental science, and urban planning. Using the keywords green infrastructure, ecosystem, sustainability, framework, and conceptual models, relevant articles from these journals were classified by date, region, and subject. Additionally, book publications were included in the literature review. The search was done with Amazon.com, and books were bought for review. The articles and books were critically evaluated by conducting a strengths and weaknesses analysis of, first, the approach related to the start-up of projects and, second, the economic value.

In North America, large city green programs, Canadian provincial programs and some state programs were evaluated. US EPA publications and programs were scrutinized. With respect to Europe, research was conducted through journal article evaluation. In the case of Australia, evaluation was conducted through professional associations' publications. For Asia, analysis was mainly conducted through World Bank and Asian Development Bank Programs, and participation in congresses and workshops in Xiang (China) and Hanoi (Vietnam). The publications of Ecocity Builders were reviewed and participation in the Montreal Ecocity World Summit 2011 completed the search for information.

The literature reviewed revealed a number of themes and relationships that relate to GI. These themes and relationships were used to construct a conceptual framework.

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Chapter 2: Literature Review

2.1 Overview

The first part of this chapter provides a literature review of approaches to initiating green development. The second part presents a literature review of evaluation methods for costing green development.

2.2 General Practices

Most published sources focus on individual aspects of green development and on urban planning. For instance, Tzoulas et al. (2007) formulated a conceptual framework of associations between urban green space, ecosystems, and human health. Benedict and McMahon (2002, 2006) have focused on land conservation, defining a vision to face the challenge brought on by population growth. They proposed to build conservation networks linking land for nature and people. McDonald, Allen, Benedict, and O'Conner (2005) have also proposed a framework based on a landscape approach. Other examples include Mavsar (2010), who developed the forest component of GI; Amati and Taylor (2010), who studied greenbelts; and Lehmann (2010) who developed some of the principles of green urbanism. In 2008, Farr promoted sustainable planning to support sustainable urbanism for urban design phasing with nature.

GIs are usually integrated into the process of urban greening. In sustaining green cities, there are different approaches to urban planning and different urbanization philosophies, covering transportation, clean air, density of population, health, and water resources. Different trends have already been proposed toward the development of a concept of urbanization as presented below.

Lehmann (2010) proposed the principles of green urbanism, which are laid out as a step-by-step manual that can be adjusted for application in various contexts. Resulting in multiple benefits for both the environment and the economy, these energy conservation principles have a series of pillars: (1) the use of new technologies (such as combined heat and power, or solar cooling); (2) the use of renewable energy sources (such as solar photovoltaic (PV), solar thermal, wind on land and offshore, biomass, mini hydro, and geothermal); and (3) the concept of the "city of short distances."

In *The Sustainable Urban Development Readers*—an overview of the field by different authors—the editors Wheeler and Beatley (2009) proposed a new approach to sustainable urban development. Topics covered included land use and urban design, transportation, ecological planning and restoration, energy and materials use, economic development, social and environmental justice, and green architecture and building. The editors sought to bring certain basic questions to the forefront. What will our cities and suburban landscapes be like in 50 years—in 100 years? How can we plan and develop communities that will meet long-term human and environmental needs? The concept of sustainable urban development provides a way for citizens, planners, and policy makers worldwide to explore such questions (Wheeler & Beatley, 2009).

Along with many contributors, Ritchie and Thomas (2009) produced the work *Sustainable Urban Design: An Environmental Approach*, which identifies major issues in making cities environmentally sustainable. It is vital that we move toward sustainability in urban form, transport, landscape, buildings, energy supply, and all the other aspects of city living (Ritchie & Thomas, 2009). Ideas of planning, space, and form are a backdrop to many of the points made, but our built environment suffers enough at present from people who were too sure of their solutions and those who thought in "silo"-based terms and overplanned and, thus, overconstrained development. The book's contributors believe that an integrated approach is needed (Ritchie & Thomas, 2009).

Beatley (2009), supported by Newman, presented ''*Green Urbanism Down Under*''. Beatley had previously presented a book titled *Green Urbanism: Learning from European Cities* (1999), which documents the urban ecology and green urban planning work in 30 European cities. In *Green Urbanism Down Under*, Beatley explores positive stories of innovative practice in Australia. Australia represents a good model to illustrate the adage "think globally, act locally"; Australian cities are using a variety of planning instruments—usually including land-use and community plans—to give meaning to sustainability (Beatley, 2009).

Frumkin, Frank, and Jackson (2009) proposed urban planning with a health perspective. Their book *Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities* lays out how the constructed environment affects us all and how building smarter can promote health and well-being and protect the environment. They take the approach that both land use and transportation are intrinsic to sprawl. This approach promotes densification of the city to reduce its footprint.

Birch and Wachter (2008) proposed *Growing Greener Cities*, which, along with the collaboration of different authors, covers most urban green issues. The book presents an overview of green and sustainable cities and provides tools for measuring and managing success. The authors wrestle with the difficulties of breaking old, anti-greening habits and introducing new practices. They detail successful strategies and practices ranging in scale from regional watershed management to rain barrel placement.

Van Der Ryn and Cowen's *Ecological Design* (2007), first published in 1999, introduced the concept of ecological design and was a benchmark pioneering work in the field of ecodesign. Rather than a design handbook, the book represents a quest toward creating a design process that has the preservation and restoration of the ecological commons at its core.

Most of these concepts or approaches do not propose an integrated framework. There remains a lack of structure in organizing the work of professionals in different specialties from start-up to delivery of a final plan. In particular, existing planning and development models do not offer a holistic approach for addressing water issues. Only two publications address water as an important element in sustainable development.

Novotny, Ahern, and Brown (2010) published *Water-Centric Sustainable Communities*, which proposed to combine landscape, water management, transportation, infrastructure, and a triple bottom line assessment into a single integrated system. This book covers best practices in GI and sustainable development. Reuse has become a necessity because a city and its water and waste management cannot be separated from its potable water sources and cannot have an unsustainable adverse effect on downstream users, and cities (Novotny, Ahern, & Brown, 2010).

Sarté (2010) published *Sustainable Infrastructure. The Guide to Green Engineering and Design*, a book that offers an extensive examination of sustainable engineering practices in an urban design context. It addresses processes and systems of sustainable design focused on greening infrastructure. It also offers a technical guide approach to working with water, wastewater, energy, and site design. Creating GI is about designing regenerative systems and establishing new ecologies that thrive in their own right (Sarté, 2010). Sarté discusses a four-framework approach to structuring the project's organization: (1) pillars of sustainability, (2) the scale-density framework, (3) the transect, and (4) the built form-ecology framework. These frameworks constitute a matrix to identify elements covered by a sustainable project.

Both, Novotny, Ahern, and Brown (2010) and Sarté (2010) present an extensive description of techniques to improve sustainability. However, neither of these works formally presents a formal framework for starting a project. To extend beyond these proposals, the present study proposes fixing water as the central element of any green concept of housing development and offers a starting framework to initiate a planning process.

In the past in Europe, green practices have been introduced in infrastructure design without any framework. The concept of sustainability has been taken into account together with the ecological aspect in decision making for urban infrastructure selection. Practitioners such as urban planners and civil engineers have tried to respect the Brundtland Commission definition of sustainability in designing infrastructure, namely, that sustainability is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development [WCED], 1987).

In 2009, Natural England published *Green Infrastructure Guidance*, which included the following definition:

> Green Infrastructure is a strategically planned and delivered network comprising the broadest range of high quality green spaces and other environmental features. It should be designed and managed as a multifunctional resource capable of delivering those ecological services and quality of life benefits required by the communities it serves and needed to underpin sustainability. Its design and management should also respect and enhance the character and distinctiveness of an area with regard to habitats and landscape types. (p. 7)

In France, the concept of the “trame écologique” was developed from the 1990s to 2000, and was thereafter implemented in different regions. In 2010, Allag-Dhuise et al. updated the document, and the term “green and blue infrastructure” was chosen to reflect the dual concept. It was deemed important that provinces and departments express their views on the spatialization of this concept. In 2004–2005, the Direction Régionale de l’Environnement (DIREN) Rhône-Alpes in association with the Loire Direction Départementale de l’Équipement (DDE) conducted an experiment along these lines, in the territory of South SCoT Loire (Chatain, 2005). France has since focused on the broad concept of sustainable development; this has led to the adoption of a green development strategy, the “trame verte et bleu,” which includes the concept of hubs and corridors. Ecology networks are the key to conserving biodiversity. An important document, the *Guides technique et méthodologique* (Chatain, 2005) addresses issues relating to all kinds of infrastructure.

In the US, the notion of LID has been formally structured since 1998, when the LIDC was established to design and provide information about new storm water management techniques. Developed in 2002 by the USGBC, LEED provides building owners and operators with a concise framework for identifying and implementing practical and measurable green building design, construction, operations, and maintenance solutions (USGBC, 2009).

In Shanghai, GI entails an increase in green spaces in the city. Park departments propose a scientific approach to ensure that all citizens will live within two kilometers (km) of a green space (park). An extensive program to develop public parks within the city is being implemented.

In Australia, GI is currently focusing mainly on green roof and green wall design because many green practices have already been introduced into design practices. Evolved from its earlier association with storm water management to provide a broader framework for sustainable urban water management, water sensitive urban design (WSUD) now offers a framework for common and unified methods of integrating the interactions between the urban built form (including urban landscapes) and the urban water cycle (Wong, 2006):

> Green Infrastructure is the network of designed and natural vegetation found in our cities and towns. It includes public parks, recreation areas, remnant vegetation, residential gardens and street trees as well as innovative and emerging new urban greening technologies such as green roofs and green walls (Barlow, 2009).

Integrating urban water management (UWM) has evolved in the water industry in Australia. New projects that have been successful support the concept of UWM in the functioning of urban operations. They include a significant reduction of the impact of urban development on the total water cycle, so there is a growing acceptance of the concept in the water industry in Australia (Mitchell, 2006). However, there is still room for greater integration of the water supply, storm water, and wastewater components of the urban water cycle, improved dissemination of knowledge, enhancement of skills in both public and private organizations, and monitoring of the performance of systems and technologies (Mitchell, 2006).

In Western Canada, the development of GI is promoted through partnership between the public, government departments, and the private sector. Organization of the partnership was established in 2006.

In Ontario, in 2008, the City of Toronto developed the Green Development Standards. Table 2.1 outlines the wet weather flow management guidelines for Toronto as one example of the guidelines that make up the Green Development Standards. The standards also cover the Better Buildings Partnership guidelines. Other terms originating from the same source as LID include sustainable urban drainage systems, innovative or integrated storm water management, WSUD, GI design, ecological engineering, and LEED-ND (Gyurek, 2009).

Table 2.1: The Green Development Standards: Wet Weather Flow Management Guidelines (City of Toronto)

	Development Feature	Existing City Standards, Guidelines or Targets	The Toronto Green Standard	Relationship to Other Standards	Possible Implementation Strategies
Water Quality • Official Plan • Wet Weather Flow Management Master Plan • Enviro Plan • TRCA	**Stormwater Retention (Water balance)** Minimize stormwater that leaves the site	• **WWF Water Balance:** Retention of stormwater on-site to the same level of annual volume of overland runoff allowable under pre-development conditions • Minimum Requirement: Retention of all runoff from small design rainfall events (typically 5 mm) through rainwater reuse, onsite infiltration, and evapotranspiration.	•► Retain stormwater on-site to the same level of annual volume of overland runoff allowable under pre-development conditions •► Retain all runoff from small design rainfall events (typically 5 mm) through rainwater reuse, onsite infiltration, and evapotranspiration.	• Addressed by LEED Sustainable Sites Credit 6.1 • Addressed by Green Globes Site Credit B.3	• Green roofs, rain barrels, permeable paving (e.g. eco stone, turf stone), green streets instead of curb and gutter, downspout disconnection, infiltration trenches, absorbent landscaping

Source: http://www.toronto.ca/planning/environment/pdf/lr_nonres_tech.pdf

There are a multitude of approaches to managing environmental projects. Some authors propose holistic approaches for planning projects. In 2004, John Randolf published *Environmental Land Use Planning and Management*, a textbook that presents a comprehensive approach to issues of land-use planning and management. The author described basic knowledge in planning theory and natural science. This approach focused on land planning.

In 1996, the EPA entered into a cooperative agreement with the American Society of Civil Engineers, led by members of the Urban Water Resources Research Council, to initiate the International Storm Water BMP Database Project (BMP Database). The BMP Database's goals were multi-faceted, although key goals included the development of a standardized set of monitoring and reporting protocols for urban storm water BMP performance studies. The 2002, version of this monitoring manual, included storm water management practices and a planning approach. Again, this approach was focused on a specific topic: storm water management. The methodology provides an eight-step approach for developing a monitoring plan that includes the following: define study objectives, identify study goals, identify information input/data needs, define study boundaries, develop the analytical approach, specify performance or acceptance criteria, develop a detailed plan for obtaining data, and assess the reasonableness of the plan and refine. In 2009, the EPA's Smart Growth Program, in conjunction with the Office of Water, edited the Water Quality Scorecard, incorporating GI practices at the municipal, neighborhood, and site levels. This scorecard offers policy options and a systematic approach for managing across multiple municipal departments. It proposes design-managing parameters for municipal officers. Again, this approach is oriented to storm water management. LID techniques were pioneered by Prince George County, Maryland, in the early 1990s. The first methodology proposed by the Department of Environment of Maryland has come to be used by most practitioners and many states in the US.

A universal methodology, including all aspects of GI and encompassing different specialties, is required. In Canada, in the provinces of British Columbia, Alberta, Manitoba, and Ontario, approaches have been proposed through partnerships with stakeholders. One outcome was the development of the BC Guidebook in 2002 (British Columbia Ministry of Environment 2005), which has since become a reference on GI in Canada. However, these approaches continue to focus mainly on storm water management. Practitioners require short comprehensive guidelines to plan their projects.

LEED is now a reference for green buildings. Since its publication, the USGBC (2011) has developed the *LEED for Neighborhood Development* (*LEED-ND*) rating system to guide and assess sustainable community development. It is the most recent publication on GI planning. Because it is a qualification program, the reference book is a rating system, and explains how to guide development and redevelopment projects toward more sustainable design. It is not considered a universal approach. This new study investigates these references to determine systemic activities for starting and developing a new green project.

2.3 Concepts and Approaches

2.3.1 Specific Frameworks

Leaders and members of professional associations in many disciplines have realized that the current infrastructure and urban planning paradigms have become impediments to achieving sustainable urban development and living (Novotny et al., 2010). Therefore, many new concepts and approaches have been developed and the most referenced are presented below.

2.3.1.1 American Institute of Architects (AIA) Committee on the Environment (COTE): Ten Measures of Sustainable Design

The Committee on the Environment (COTE) works to advance, disseminate, and advocate—to the profession, the building industry, the academy, and the public—design practices that integrate built and natural systems and enhance both the design quality and the environmental performance of the built environment. COTE serves as the community and voice of the American Institute of Architects (AIA) regarding sustainable design and building science and performance (http://www.aia.org/practicing/groups/kc/aias074684).

COTE's 10 measures of sustainable design and performance metrics are (American Institute of Architects [AIA], 2012):

- sustainable design intent and innovation;

- regional/community design and connectivity;
- land use and site ecology;
- bioclimatic design;
- light and air;
- water cycle;
- energy flows and energy future;
- materials and construction;
- long life; and
- loose fit, and collective wisdom and feedback loops.

2.3.1.2 American Society of Landscape Architects (ASLA) Sustainable Sites Initiative Benchmarks and Performance Guidelines

The Sustainable Sites Initiative is an interdisciplinary effort by the American Society of Landscape Architects (ASLA), the Lady Bird Johnson Wildflower Center at the University of Texas at Austin, and the United States Botanic Garden to create voluntary national guidelines and performance benchmarks for sustainable land design, construction, and maintenance practices (http://www.asla.org/sites.aspx). The Meadows Foundation and Landscape Structures provide major funding for the Sustainable Sites Initiative. The framework is presented in nine topics (ASLA, 2009):

- site selection;
- pre-design assessment and planning;
- site design—water;
- site design—soil and vegetation;
- site design—materials selection;
- site design—human health and well-being;
- construction;
- operations and maintenance; and
- monitoring and innovation.

2.3.1.3 BREEAM

The Building Research Establishment Environmental Assessment Method (BREEAM) is a building certification system that was established in 1990. It is a method of environmental auditing. BREEAM provides a set of standards for best practice in sustainable development for the design, construction, operation, and environmental performance of buildings (http://www.breeam.org/about.jsp?id=66). The main criteria for calibration include measures affecting energy, water use, indoor environment, pollution, transport, materials, waste, and ecology and management process (Building Research Establishment Environmental Assessment Method [BREEAM], 2012).

2.3.1.4 Light Imprint

Light Imprint New Urbanism (LINU) is a technical development based on the principle of minimum loan territory achieved by coordinating the engineering principles of new urbanism and sustainability. A set of solutions is offered through transitional areas. Light imprint principles are formatted in a handbook. The light imprint matrix is the primary organizing method.

The *Light Imprint Handbook* is a:

> Quick reference whose tools can be utilized to best implement LI techniques; it also shows where tools are most appropriately located along the transect . . . The Transect Zone Matrix is designed to serve as an organizational framework and is, by its nature, somewhat subjective. The LI Team suggests where on the rural to urban scale each tool is most useful. Depending on location on the transect, each project will have a specific set of needs. (http://lightimprint.org/I-howtouselightimprint.pdf)

The handbook is organized as follows:

> To create a simple framework, the LI tools are classified into four main categories: Paving, Channeling, Storage and Filtration . . . some tools can be

> used for more than one function. The LI Team's approach is to classify most tools by their principal function and refer to their benefits in other categories. (http://lightimprint.org/I-howtouselightimprint.pdf)

Over 60 tools are provided to apply solutions for different applications (Congress for New Urbanism [CNU], 2012).

2.3.1.5 Living Building Challenge

The Living Building Challenge is also a certification program. The proposed program is designed on the basis of conservation and restoration. It is an integrated tool that can be applied to landscaping, infrastructure, renovations to buildings, and campus and community development, and it comprises seven performance areas, or "petals": site, water, energy, health, materials, equity, and beauty. Petals are subdivided into a total of 20 imperatives, each of which focus on a specific sphere of influence; this compilation of imperatives can be applied to almost every conceivable typology, or project type, be it a building (both a renovation of an existing structure or a new construction), infrastructure, landscape, or community development. Naturally, strategies to create living landscapes, infrastructure, renovations, buildings, or neighborhoods will vary widely by occupancy, use, construction type, and location, but the fundamental considerations remain the same (International Living Future Institute [ILFI], 2012; https://ilbi.org/lbc/LBC%20Documents/LBC2-0.pdf).

2.3.1.6 Melbourne Principles for Sustainable Cities

An international conference held in Australia on April 2, 2002, was organized by the United Nations Environment Programme (UNEP) and the International Council for Local Environmental Initiative. Ten principles of sustainable development were retained to create a comprehensive framework for making better towns (http://www.unep.org/ietc/).

The Melbourne Principles (United Nations Environment Programme [UNEP], 2002) are intended to guide thinking and provide a strategic framework for action. The principles are not prescriptive. They allow cities to develop sustainable solutions that are relevant to their particular circumstances. They can help to bring together citizens and decision makers, whose participation and cooperation is essential in transforming our cities to sustainability. These principles are:

- Provide a long-term vision for cities based on sustainability, intergenerational, social, economic and political equity, and their individuality.
- Achieve long-term economic and social security.
- Recognize the intrinsic value of biodiversity and natural ecosystems, and protect and restore them.
- Enable communities to minimize their ecological footprint.
- Build on the characteristics of ecosystems in the development and nurturing of healthy and sustainable cities.
- Recognize and build on the distinctive characteristics of cities, including their human and cultural values, history and natural systems.
- Empower people and foster participation.
- Expand and enable cooperative networks to work toward a common, sustainable future.
- Promote sustainable production and consumption, through appropriate use of environmentally sound technologies and effective demand management.
- Enable continual improvement, based on accountability, transparency, and good governance.

2.3.1.7 Net-Zero Energy Development

In 2003, informal discussions began among a group of home builders and developers of new decentralized energy systems about how future Canadian homes could be better designed for responding to Canada's clean air and climate change objectives (http://www.netzeroenergyhome.ca/about). In 2006, the coalition was incorporated as a not-for-profit organization to promote energy efficiency in homes. The objective of Net-

Zero Energy Home (NZEH) is to promote the development of homes that consume a small amount of energy. The coalition has focused its efforts on activities that have the greatest impact on achieving the goals of reducing energy consumption (Net-Zero Energy Home Coalition, 2012). The coalition has now extended the membership to North America, and has a large membership, including 361 architects.

2.3.1.8 One Planet Living's Ten Principles

The One Planet Communities program is creating a network of the earth's greenest neighborhoods. By working with private and public property developers, it aims to help create places where it is easy, attractive, and affordable for people to live healthy, happy lives within a fair share of the earth's resources (BioRegional Development Group, 2012; http://www.oneplanetcommunities.org/about-2/what/). The One Planet Communities program uses ten guiding principles as a framework to help partners examine the sustainability challenges they face and develop appropriate solutions. These principles were developed as a result of lessons learned from BioRegional's work at the pioneering Beddington Zero Energy Development (BedZED) ecovillage in South London (http://www.oneplanetcommunities.org/about-2/approach/the-10-principles/).

The ten principles of One Planet Living (2012) are:

- zero carbon;
- zero waste;
- sustainable transport;
- sustainable materials;
- local and sustainable food;
- sustainable water;
- land use and wild life;
- culture and heritage;
- equity and local economy; and
- health and happiness.

One Planet Living uses ecological footprinting as its key indicator of sustainability.

2.3.1.9 Permaculture

Permaculture is a design system for sustainable development that affects all aspects of the human environment. The system teaches how to build ecohomes, grow food, restore the landscape, restore ecosystems, recover rainwater, and build a new community (http://www.permaculture.org/nm/index.php/site/index/).

This approach has been recognized since 1985 in more than 20 countries. There are 12 permaculture design principles (Permaculture Institute, 2012):

- Observe and interact.
- Catch and store energy.
- Obtain a yield.
- Apply self-regulation and accept feedback.
- Use and value renewable resources and services.
- Produce no waste.
- Design from patterns of nature.
- Integrate rather than segregate.
- Use small and slow solutions.
- Use and value diversity.
- Use edges and value the marginal.
- Creatively use and respond to change.

2.3.1.10 Regenerative Development

During the late 1970s, John T. Lyle (1934–1998), a Cal Poly Pomona landscape architecture professor, challenged graduate students to envision a community in which daily activities were based on the value of living within the limits of available renewable resources without environmental degradation. Over the next ten years, students and faculty researched the possibilities of creating a community that made use of on-site resources, operated with renewable energy, and worked with biologically based processes (Lyle Center, 2013; https://www.csupomona.edu/~crs/history.html).

The concept is to develop an environment that enhances human activities, from a personal residence to a complete district, thus generating human-made surroundings that provide the setting for human activity, ranging from large-scale civic surroundings to personal places (Jenkin, 2009).

2.3.1.11 Rocky Mountain Institute's Urban Framework

The sustainable community development code framework of the Rocky Mountain Land Use Institute (RMLUI) has a multidisciplinary approach. It includes environmental, economic, and social aspects. The innovation is to connect the natural systems and built infrastructure. The code integrates the functions of the zoning system and the basics of performance, and meets the regional characteristics of climate, ecology, and culture.

The basic organization and approach to each topic is to examine relevant obstacles, incentives, and regulations (Rocky Mountain Land Use Institute [RMLUI], 2009). The framework incorporates sustainability principles and practices, takes a multi-disciplinary approach, promotes the triple bottom line (environment, economy, and social equity), is innovative and distinctive, links natural and human-made systems, incorporates useful features of other zoning systems, responds to regional climate, ecology, and culture, and identifies relevant obstacles, incentives, and regulations (Shutkin & Duerksen, 2001).

2.3.1.12 SmartCode

SmartCode is a proposal for a unified land development plan that presents a codified set of zoning, subdivision rules, urban design, and architectural options. The code allows development of a community vision for different avenues of development. The code takes into account the human habitat of a rural location, transposed to the urban environment; the principle of transit areas is also applied in the code (Center for Applied

Transect Studies [CATS], 2012). The SmartCode is a tool that guides the form of the built environment to create and protect development patterns that are compact, walkable, and mixed use; these traditional neighborhood patterns tend to be stimulating, safe, and ecologically sustainable. The SmartCode requires a mix of uses within walking distance of dwellings, so residents are not forced to drive everywhere. It supports a connected network to relieve traffic congestion. At the same time, it preserves open lands because it operates at the scale of the region as well as the community (CATS, 2012; http://landuselaw.wustl.edu/3000-BookletSC.pdf_).

2.3.1.13 Ascertainment

Many of these concepts refer to LID techniques and to LEED. LEED has become a measure of acceptance for new buildings and subdivisions in developed countries (Novotny et al., 2010). The International Water Association panel considers LID a green scenario (Novotny et al., 2010). In their study, four main frameworks were identified as more heavily referenced. The next section presents these concepts and their framework.

2.3.2 LID Concept

LID is a:

> low cost, effective alternative to stormwater control technology. It combines resource conservation, a hydrologically functional site design with pollution prevention measures to reduce developmental impacts to better replicate natural watershed hydrology and water quality. Through a variety of small-scale site design techniques, Low-Impact Development controls runoff discharge, volume, frequency and quality to mimic development runoff conditions. (LIDC, 2011a)

The LIDC was established in 1998 in the US to promote the use of LID techniques and other sustainable storm water management techniques. The mission of the center is to help communities and institutions address increasingly complex and critical issues associated with their resource protection programs and storm water management regulations. The organization is a multidisciplinary group of technically skilled professionals. Their goal is to develop new approaches to storm water management, demonstrate their effectiveness, and assist in integrating them into master planning activities, manuals of practice, and personnel training:

> The source control [of the LID] concept is quite different from conventional treatment (pipe and pond stormwater management site design). Hydrologic functions such as infiltration, frequency and volume of discharges, and groundwater recharge can be maintained with the use of reduced impervious surfaces, functional grading, open channel sections, disconnection of hydrologic flow paths, and the use of bioretention/filtration landscape areas. LID also incorporates multifunctional site design elements into the stormwater management plan. Such alternative stormwater management practices such as on-lot microstorage, functional landscaping, open drainage swales, reduced imperviousness, flatter grades, increased runoff travel time, and depression storage can be integrated into a multifunctional site design. (LIDC, 2011a)

2.3.2.1 LID Features

There are numerous features to consider in the layout of a LID, with features typically selected and arranged according to the topography and landscape of the site. The LIDC proposes that the following features be incorporated into design.

2.3.2.1.1 Rain Gardens

Rain Gardens enhance local water quality by allowing water to be filtered naturally by soil instead of being piped untreated into large bodies of water (LIDC, 2011b; http://highbridge.org/government/environmental-commission/environmental-committee-initiatives/rain-gardens/). A rain garden is used to capture and infiltrate water during rainfall and direct it to the groundwater. It must be dug down, or planted in a slight depression, to catch the runoff in a shallow basin. Ideally, a rain garden is planted with a variety of native grasses, and other herbaceous or woody plants that are adapted to the soil and local climate. (The Native Plant Society of New Jersey, 2005)

Beyond their environmental use, rain gardens provide attractive landscaping and a natural habitat for birds, bees, and butterflies, while encouraging environmental stewardship and community pride (LIDC, 2011b).

2.3.2.1.2 Street Storage

Street storage refers to the technology of temporarily storing storm water (in densely populated urban areas) on the surface—on- and off-street—and, as needed, below the surface, close to the source (Carr, Esposito, & Walsh, 2001). The use of street storage and catchment basins reduces the rate of runoff entering storm sewer systems, reducing the required minimum size of water mains conveying storm water pipes (LIDC, 2011b).

2.3.2.1.3 Bioretention

Bioretention is an alternative to runoff treatment, acting on storm water before it is discharged into waterways (Hsieh & Davis, 2003). A landscaped island containing a curb inlet drains a large area or street, channeling rainwater through a small pipe into a municipal storm drain system. Bioretention consists of porous media layers that can remove pollutants by infiltrating runoff through mechanisms that include adsorption, precipitation, and filtration (Hsieh & Davis, 2003).

2.3.2.1.4 Permeable Pavement

Permeable pavement systems restore soil infiltration functions in the urban landscape. These systems are mainly composed of porous pavement systems in parking areas (LIDC). Permeable pavements offer one solution to the problem of increased storm water runoff and the decreased stream water quality associated with automobile usage (Brattebo & Booth, 2003; doi:10.1016/S0043-1354(03)00410-X). Permeable pavements with reservoir structures consisting of concrete paving stones offer the possibility for decentralized, sustainable storm water management and source control in urban areas (ascelibrary.org/doi/pdf/10.1061/40644(2002)40).

Runoff from streets and parking areas with low traffic densities can be infiltrated to support groundwater recharge and to reduce hydraulic stress in sewer systems. Infiltration can help to return the urban water cycle to its natural condition, increasing the level of groundwater (Dierkes et al., 2002).

2.3.2.1.5 Vegetated Roof Cover

Green roofs (roofs with a vegetated surface and substrate) provide ecosystem services in urban areas, including improved storm water management, better regulation of building temperatures, reduced urban heat island effects, and increased urban wildlife habitat (Oberndofer et al., 2007). The use of vegetation on a rooftop as an alternative to traditional roofing materials is an increasingly utilized GI practice. The vegetation and growing media perform a number of functions that improve environmental performance, including absorption of rainfall, reduction of roof temperatures, improvement in ambient air quality, and the provision of urban habitat (Carter & Keeler, 2007).

2.3.2.1.6 Bioswales

Bioswales are broad ditches with gentle slopes. Swales are vegetated open channels designed to accept sheet flow runoff and convey it in a broad shallow flow. Swales are used to reduce storm water volume through infiltration, improve water quality through vegetative and soil filtration, and reduce flow velocity by increasing channel roughness (Lukes & Kloss, 2009). Bioswales can take many forms. Generally, bioswales can be contained in approximately one percent of the land area draining into them. Since bioswales are linear, they work well along impermeable surfaces such as roads and sidewalks (Wahl, 2009).

2.3.2.1.7 Rainwater Harvesting

Rainwater harvesting, which involves the collection of rainwater from impervious surfaces and storing it for later use, is a technique that has been used for millennia. Although, rainwater harvesting has not been widely employed in industrialized societies, which rely primarily on centralized water distribution systems, with the increasing recognition of the need to address the problems of limited water resources and storm water pollution, and the emergence of green building design, the role of rainwater harvesting in water supply is being reassessed (Kloss, 2009).

Rainwater harvesting systems typically divert and store runoff from residential and commercial roofs. Often referred to as “clean” runoff, roof runoff contains pollutants (metals and hydrocarbons from roofing materials, nutrients from atmospheric deposition, and bacteria from bird droppings). However, this runoff contains lower concentrations of, or is missing, many of the toxins present in runoff from other impervious surfaces. Installing a rainwater collection system requires diverting roof downspouts to cisterns or rain barrels to capture and store the runoff. From the storage container, a dual plumbing system is needed to make use of the water indoors, and/or a connection to the outdoor irrigation system can be installed (Kloss, 2009).

2.3.2.1.8 Managing Wet Weather with Green Infrastructure

Lukes and Kloss (2009) prepared topics on green streets. By design and function, urban areas are covered with impervious surfaces: roofs, roads, sidewalks, and parking lots. Although all contribute to storm water runoff, the effects and necessary mitigation of the various types of surfaces can vary significantly. Of these, roads and travel surfaces present the largest urban pollution source and one of the greatest opportunities for GI (Lukes & Kloss, 2009).

2.3.2.2 LID Approach

In the US, many states are developing tools to manage LID programs. For example, in 1999, the MDER presented a structured approach. They proposed starting a project using the five steps listed below.

2.3.2.2.1 Site Planning

A few fundamental concepts that define the essence of LID technology must be integrated into the site planning process to achieve a successful and workable plan. These fundamental concepts include: using hydrology as the integrating framework; thinking micromanagement; controlling storm water at the source; using simplistic, non-structural methods; and creating a multifunctional landscape.

2.3.2.2.2 Hydrologic Evaluation

The purpose of the hydrologic evaluation is to determine the level of control required to achieve the storm water management goals for LID sites. The required levels of control may be achieved through the application of various hydrologic tools during the site planning process, the use of IMPs, and supplemental controls. The hydrologic evaluation is performed using hydrologic modeling and analysis techniques. The output of the hydrologic analysis provides the basis for comparison with the four evaluation measures (runoff volume, peak runoff, frequency, and water quality control).

2.3.2.2.3 Integrated Management Practices

LID IMPs are designed for on-lot use. This approach integrates the lot with the natural environment and eliminates the need for large centralized parcels of land to control end-of-pipe runoff. The challenge of designing a low impact site is that the IMPs and site design strategies must provide quantity and quality control, and enhancement. This includes groundwater recharge through infiltration of runoff into the soil, retention or detention of runoff for permanent storage or for later release, pollutant settling and entrapment by conveying runoff slowly through vegetated swales and buffer strips, and multiple uses of landscaped areas.

2.3.2.2.4 Erosion and Sediment Control

Erosion and sediment control and storm water management are closely interrelated. The application of LID concepts and the associated emphasis on minimizing the areas disturbed and breaking up drainage areas into small, manageable sub-catchment areas is in harmony with the basic principles of erosion and sediment control.

2.3.2.2.5 Public Outreach Program

Both the public and the developers must be committed to the program. A public consultation process is essential. The LID manual presents a four-step strategy: (1) define objectives, (2) identify target audiences, (3) develop outreach materials, and (4) distribute outreach materials. The program can be tailored to specific audiences with a specific message for each audience. Perceived as an education program, it may identify several objectives: create marketing tools, promote stewardship to initiate environmental protection measures, show the potential cost saving, encourage a sense of community, and ensure proper maintenance measures.

LID is one of the fundamental elements of the framework proposed for starting a new development. The approach of the LID framework developed by the MDER to start a project is described in Chapter 3 and will be considered one of the baseline scenarios. The next section presents LEED, which is the green scenario preferred by professionals of urban development.

2.3.3 The LEED Concept

LEED is an internationally recognized green building certification system that provides third-party verification that a building or district was designed and built using strategies aimed at improving performance across all metrics. These metrics include energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their effects (USGBC). There are six categories of certification: (1) new construction, (2) commercial interiors, (3) core and shell, (4) existing buildings, (5) homes, and (6) neighborhood developments. In the US, the USGBC manages the certification program and, in Canada, the Canada Green Building Council (CaGBC 2013) manages the program. The two organizations are independent, although the US certification may accredit Canadian projects. For example, the Toronto Waterfront Project was certified LEED-ND GOLD by the USGBC.

Because LEED is mostly dedicated to buildings, the USGBC has developed the *LEED for Neighborhood Development* (*LEED-ND*) rating system to guide and assess sustainable community development. For example, the LEED 2009 for neighborhood development rating system is a set of performance standards for certifying the planning and development of new neighborhoods. The intent is to promote healthful, durable, affordable, and environmentally sound practices in building design and construction. Prerequisites and credits in the rating system address five topics: smart location and linkage, neighborhood pattern and design, GI and buildings, innovation and design process, and regional priority credit. The system was created as a partnership between the USGBC, the Natural Resources Defense Council, and the Congress for the New Urbanism (CNU). Registration opened in April 2010. The CNU is the leading organization promoting workable, mixed-use neighborhood development, sustainable communities, and healthier living conditions. It is one of the major leaders of LEED. The CaGBC has developed Canadian Alternative Compliance Paths (ACPs) for the LEED-ND 2009 rating system. The ACPs are formally approved approaches that provide clarity and guidance for Canadian projects, addressing sections of the rating system that contain US-specific standards or wording (CBDCa, 2011).

2.3.3.1 The LEED Approach

Under the LEED approach, projects are accredited using a rating system. After registration, the project design team should begin to collect information and perform calculations to satisfy prerequisite and credit documentation requirements. To start a project, LEED concentrates on planning the following basic steps.

2.3.3.1.1 Site Analysis and Programming

Site analysis and programming includes property selection, stakeholder identification and outreach, information gathering, environmental review, conceptual planning, and development programming.

2.3.3.1.2 Preliminary Planning

Preliminary planning includes the initial planning for land use, transportation networks, and major facilities, public outreach, and the refinement of plans.

2.3.3.1.3 Final Design

The final design includes continued public outreach, preparation of the final site plan, infrastructure and building design, and the acquisition of a construction permit. LEED accreditation will be given if a score of 40 (certified), 50 (silver), 60 (gold), or 80 (platinum) is obtained. The total number of awardable points is 110, comprising 27 points for smart location and linkage, 44 points for neighborhood pattern and design, 29 points for GI and buildings, six points for the innovation and design process, and four points for regional priority credit. A detailed scorecard is published by the USGBC as a project checklist. The accreditation process follows the following steps: registration, smart location, linkage prerequisite review, conditionally approved plan, pre-certified plan, and certified neighborhood development.

LEED is one of the most widely used standards in the US (Sarté, 2010). Although the qualifications of LEED are very developed, starting a project from these criteria is still tedious. Nevertheless, the proposed framework for managing a LEED project is considered the baseline by many professionals of urban development. The framework proposed by LEED is one of the four approaches used to develop a formulation of synthesis in Chapter 3. One of the weaknesses of LEED is the fact that the framework focuses mainly on new development and is not adapted to brownfield development.

The next section presents the proposal developed by the US EPA to formulate a green development project.

2.3.4 US Environmental Protection Agency Green Approach

The EPA promotes GI development, in particular, through publishing a series of documents to support stakeholders interested in introducing green action in projects.

2.3.4.1 Municipal Handbook

The EPA has developed a municipal handbook (US EPA, 2009a), which is a series of documents aimed at helping local officials to implement GI in their communities. The documents cover specific terms to help municipalities introduce GI in the design of storm management facilities. One chapter identifies and discusses the most common funding options available to communities for funding green storm water infrastructure, storm water fees, and loan programs. Another chapter covers street design, and different topics are presented in the other chapters. The EPA has also developed the Water Quality Scorecard (US EPA, 2009b).

2.3.4.2 Water Quality Scorecard (EPA 231-B-09-001)

The EPA's Water Quality Scorecard (US EPA, 2009b) was developed to assist local governments in identifying opportunities to remove barriers, and revise and create codes, ordinances, and incentives for better water quality protection. It guides municipal staff through a review of relevant local codes and ordinances, across multiple municipal departments at the three levels within the jurisdiction of a local government (municipality, neighborhood, and site), to ensure that these codes work together to protect water quality goals. The two main goals of this tool are to help communities protect water quality by identifying ways to reduce the amount of storm water flows in a community and to educate stakeholders on the wide range of policies and regulations that have implications for water quality.

Some of the criteria proposed by the US EPA have been retained as one of the proposals studied in Chapter 3. In Canada, the provinces mainly manage the green scenario approaches. In Quebec, the Act on Sustainable Development was adopted in 2006, and it recognizes "the character inseparable from environmental, social and economic activities development." The law proposes sustaining development through the inclusion of a set of 16 principles of sustainable development. Nevertheless, there is no formal green scenario proposed as a framework to organize urban development. However, most provinces have oriented their sustainable development strategy to climate change actions and have adopted a strategy to manage river basins. Green scenario action plans are proposed mainly in two provinces: Alberta and British Columbia. In Ontario, cities such as Toronto have a program. The next section presents Alberta LID.

2.3.5 The Alberta Low Impact Development Partnership Approach

The Alberta Low Impact Development Partnership (ALIDP) approach was created in 2004 to address the need to protect and maintain the integrity of the natural environment, while promoting growth, prosperity, and quality of life in Alberta's communities. The formal creation of the ALIDP Society occurred two years later, in 2006. The ALIDP has a diverse base including municipal and provincial governments, watershed stewardship groups, universities, corporations, and individuals with an interest in promoting LID practices. The Edmonton LID Conference (September 29, 2009) covered a series of topics to qualify LID actions. The conference presented examples and lessons learned from different projects implemented mainly in Calgary and Edmonton. Van Duin and Gyurek presented an approach to LID planning from the point of view of project preparation.

Van Duin (2009) presented LID criteria. The rating system addresses environmental, economic, and social issues, allowing developers and their consultants, municipalities, and the public to evaluate the relative merits of developments from a watershed protection perspective. The keystone of the matrix to rate a LID project should consider these criteria:

- objectives: no adverse impact on the receiving water bodies;
- strategies: control pollutant loading;
- policy tools: land-use bylaw, watershed plan, and master drainage plan; and
- technology/implementation tools: conduct pollutant loading and removal computation, and implement all applicable source control practices.

Gyurek (2009) proposed LID as a multi-barrier approach that uses features at the lot, neighborhood, and watershed level to maintain on-site water balance. A multi-barrier approach at the lot level includes green roofs to reduce or delay runoff, the connection of downspouts to rain gardens and/or storage tanks and cisterns, minimum soil depth criteria, direct runoff to infiltration swales, and the use of harvested rainwater to irrigate vegetation or flush toilets. A multi-barrier approach at the neighborhood level may involve reduced road widths, using permeable pavement, the removal of curbs or gutters to direct runoff to swales, the promotion of infiltration box planters, the integration of natural wetlands, and/or the building of constructed wetlands to detain runoff, reduce total loadings, and convey parking lot runoff to swales, and bioretention areas. A multi-barrier approach at the watershed level was proposed for the integration of natural wetlands with constructed wetlands for major drainage systems to rehabilitate degraded natural features such as wetlands or creeks, maintain natural stream channels, use wide riparian buffer strips, provide sufficient flooding areas in riparian zones, and avoid direct discharge even after large rainfall events (Gyurek, 2009). The Alberta conferences presented the LID from a design point of view, but no formal framework was offered. Nevertheless, the multi-barrier approach is a concept used to develop our new integrated concept.

In contrast, BC was early to develop sustainability tools. Documentation is diffused largely on websites, and Canadian practitioners use many of the proposed guidebooks. The next section summarizes the BC approach.

2.3.6 The British Columbia Approach

In BC, the Rainwater Management and Green Infrastructure seminar was initiated by an Inter-Governmental Partnership (IGP) on June 11, (2007). The Water Sustainability Action Plan for British Columbia provides a partnership umbrella for an array of on-the-ground initiatives that promote a "water-centric" approach to community planning and development. One of the tools developed under this umbrella is the Water Balance Model for British Columbia. Developed by an IGP (BC and Fisheries and Ocean Canada) as an extension of ''*Storm Water Planning: A Guidebook for British Columbia''*, the Water Balance Model enables users to visualize ways to implement GI solutions to achieve rainwater runoff source control at the site level. The Water Sustainability Action Plan for British Columbia is sponsored by the Province of BC, and the action plan elements are delivered through partnerships. Under the action plan umbrella, the Water Sustainability Committee of the BC Water and Waste Association is the managing partnership and is responsible for providing leadership, facilitation, and organizational services for program delivery. Basic information is provided in a guidebook. The document refocuses the approach to sustainable ecosystem management. Storm water suggests there is a problem, whereas rainwater is perceived as a resource (BC Water & Waste Association [BCWWA] et al., 2005). Over the past two decades, there has been an evolution toward an integrated approach; this is summarized in the philosophy presented in Table 2.2.

Table 2.2: From Storm Water Management to Rainwater Management

Drainage System	To	Ecosystem
Reactive (Solve Problems)	To	Proactive (Prevent Problems)
Engineer Driven	To	Interdisciplinary Team Driven
Protect Property	To	Protect Property and Habitat
Pipe and Convey	To	Mimic Natural Processes
Limited Consultation	To	Extensive Consultation
Local Government Ownership	To	Partnerships with Others
Extreme Storm Focus	To	Rain Integrated with Land Use
Peak Flow Thinking	To	Volume Based Thinking

Source: BCWWA et al., 2005

Light showers account for most of the annual rainfall volume and, therefore, "green" or landscape-based solutions will achieve a variety of objectives encompassing both the site and watershed scales in the urban environment (BCWWA et al., 2005). Table 2.3 illustrates the integrated strategy for the protection of life, property, and the environment that is being implemented throughout BC as a result of the publication of the guidebook and the development of the Water Balance Model.

Table 2.3: Integrated Strategy in British Columbia

Rainfall Spectrum in BC		
Light Showers	Heavy Rain	Extreme Storm
75%	20%	5%
Integrated Strategy		
Site	Neighborhood	Watershed
Keep Rain On-Site	Delay the Runoff	Reduce the Flooding
Water Balance Modeling		Conventional Hydraulic Modeling

Source: BCWWA et al., 2005

The approach described in the guidebook also introduced the concept of performance targets to facilitate implementation of the integrated strategy for managing the complete rainfall spectrum. Means of “rainfall capture” are measures such as rain gardens and infiltration soak ways; runoff control, which delays overflow runoff by means of detention storage ponds to provide “runoff control”; and flood mitigation, which reduces flooding by providing sufficient hydraulic capacity to “contain and convey” (BCWWA et al., 2005).

Defining rainfall tiers simply enabled a systematic approach to data processing and identification of rainfall patterns, distributions, and frequency. The integrated approach proposed by the guidebook is presented in seven steps:

1. Secure political interest and support.
2. Frame the watershed problems and opportunities through a land-use working session, drainage working session, ecology working session, and interdisciplinary roundtable session.
3. Develop objectives and alternative scenarios through flood management scenario modeling and source control scenario modeling.
4. Collect meaningful data and refine scenarios according to concurrent rainfall and stream flow data, data on soils and groundwater, water quality data, and data on fish and their habitats.
5. Evaluate alternatives and develop component plans.
6. Develop an implementation program.
7. Refine through AM.

BC’s approach is one of the frameworks used for analysis, and some of its proposals were adopted to develop the new framework that is presented in Chapter 3.

2.3.7 Integration

With regard to integration, several aspects of the issue can be analyzed. For the first time, an integrated GI concept is to join the ecological links and public services. The rehabilitation and construction of new services provides an opportunity to unite the two GI concepts. Often, new services such as storm water or wastewater treatment require space. It would be appropriate to use these spaces to create green spaces and develop ecological relationships. Another integration to be discussed is the presence or absence of water in everyday life. Because it has been at the heart of human concerns in recent years, mainly because of climate change, it is important to integrate water management into the developing GI concept.

However, to develop GI, it is essential to integrate the work of professionals from different disciplines. To develop green concepts, the integration of multidisciplinary teams will establish a link between each concern: architecture, landscaping, biology, sociology, urban planning, and engineering.

Finally, in a world where resources are limited, it is important to determine the financial impact of measures to integrate GI design into civil engineering practice. The economy becomes a science to be integrated into the decision-making process of a city. Biodiversity loss and loss of green space may appear to create short-term savings, but in the long term, the cost of careless, shortsighted financial decisions will far exceed the short-term savings. It is important to demonstrate that the measures used to integrate green concepts in the decision-making process will not exceed the benefits that can result. Because there is an absence of data on profits incurred through the implementation of GI, it is essential to include an economic component to justify the proposed projects.

The next section introduces the notion of cost and value that is used in the second case study to compare the costs of GI and traditional infrastructure.

2.4 Costing and Values

2.4.1 Issues in Economic Values

The financial risks associated with a project's design are often significant factors in decisions on how to proceed. Given that infrastructure endures over years and sometimes decades, it makes sense for local governments to take a long view of the costs and savings to be realized with one design versus another (Rutherford, 2007). As more states and local governments decide to offer green building incentives and other programs to offset the impact of land uses that do not meet sustainable development standards, they must decide how to fund or offset the costs of their programs (Circo, 2009). In the context of this study, a new framework is proposed, and it is appropriate to test the economic efficiency of this new proposal in comparison with the conventional approach. The economic analysis of projects is similar in form to financial analysis: both appraise the profit of an investment. The concept of economic profit is not the same as financial profit. Economic analysis measures the effect of the project on the economy and, in this case, it is referred to as municipal economy. For a project to be economically viable, it must be financially sustainable, as well as economically efficient. If a project is not financially sustainable, economic benefits will not be realized. Both types of analysis are conducted in monetary terms, the major difference lying in the definition of costs and benefits.

An integrated GI approach for water infrastructure can deliver economic and environmental benefits as well as significant cost savings for municipal infrastructure. GI's value as a municipal or private investment depends in part on its effects beyond water management and, thus, upon a community's ability to model and measure these additional values (Center for Neighborhood Technology [CNT], 2009a).

The terms "value system," "value," and "evaluation" have a range of meanings in different disciplines. "Value system" refers to intra-psychic constellations of norms and precepts that guide human judgment and action (Costanza, 2001). The term "value" means the contribution of an action or object to user-specified goals, objectives, or conditions (Costanza, 2001). In the current context, ecosystem "evaluation" represents the process of expressing a value for ecosystem goods or services (such as biodiversity, flood protection, and recreational opportunity) to provide the opportunity for scientific observation and measurement (Farber, Costanza, & Wilson, 2002).

The parallel between conventional infrastructure (CI) and GI will show cost-efficiency and improved quality of services. Infrastructure investments have brought GI and LID practices to the fore of cities' water infrastructure investment strategies (Wise et al., 2010). Nevertheless, it is difficult to determine the value of these services. The exchange value of ecosystem services is the trading ratio for those services. When services are directly tradable in normal markets, the price is the exchange value. The exchange-based, welfare value of a natural good or service is its market price net of the cost of bringing that service to market. When there are no explicit markets for services, we must resort to a more indirect means of assessing economic values (Farber et al., 2002).

The concept of ecosystem service value can be a useful guide when distinguishing and measuring where trade-offs between society and the rest of nature are possible and where they can be made to enhance human welfare in a sustainable manner. Although win-win opportunities for human activities within the environment may exist, they also appear to be increasingly scarce in a "full" global ecological–economic system (Farber et al., 2002).

In the context of municipal planning and infrastructure investment, the prudent application of limited financial resources may appear at first as a constraint to sustainable development. However, there is growing evidence that strategies and technologies supportive of sustainability are possible and relevant, and provide services at lower costs and even at lower capital investment than conventional approaches (Centre for Sustainable Community Development, 2004). Conventional approaches to infrastructure, although continuously being improved, have usually been undertaken as separate departmental and, therefore, as compartmental activities; maximizing cost effectiveness for individual functions generally results in a suboptimal economic performance of total services (Centre for Sustainable Community Development, 2004).

GI and LID practices produce a range of economic and social benefits in conjunction with managing storm water. Incorporating the value of those benefits into investment decisions is essential in comparing GI's and CI's costs and their ecological, economic, and social effectiveness. Natural drainage practices improve storm water management and water quality. Recent studies also indicate that GI storm water benefits are accompanied by capital benefits and provide cost savings when compared with CI (US EPA, 2013).

Research has identified other economic effects of LID, including effects on energy consumption, property value, urban heat island effect, community health, and global climate change (Wise et al., 2010). This study deals with hard costs and soft values only. In the context of municipal infrastructure, the decision makers have to deal with revenues, which are taxes, and with expenses, which are the costs of a project. Taxes (revenues) are linked to property value. The next section explores the concept of value and costing evaluation.

2.4.2 Costing Methodology for Soft Costs and Values

Valuation tools provide monetary measures of project values. Non-monetizing methods do not require a connection between values and money but still provide information about relative values, equivalencies, or rankings. The equivalencies and relative rankings can be used to weight the changes in ecological services resulting from management decisions (Farber et al., 2006).

The economic dimension of value is only one of the many relevant factors that make humans value ecosystems (Villa, Ceroni, & Krivov, 2007). Traditional valuation techniques such as cost-benefit analyses and contingent valuation may not be able to cope with valuing the ecological and social functions of urban green spaces, which is required to strengthen their role in the decision-making process within local communities (James et al., 2009).

In 2009, the Center for Neighborhood Technology (CNT, 2009b), in Chicago, published details of their tool, ‘’Green Values Calculator (GVC)’’, and the benefits of GI. The CNT also sponsored a paper titled “Integrating Valuation Methods to Recognize Green Infrastructure’s Multiple Benefits” (Wise et al., 2010). The paper’s analysis begins by defining benefits that accrue with a set of common GI practices: tree planting, infiltration practices, permeable pavement, water harvesting, and green roofs. Each practice suggests input units as the basis for benefit calculations and explores variables that affect the accumulation of benefits and scales at which the benefit occurs. In the paper, Wise et al. (2010) reviewed current methods, tools, and case studies of valuation of the economic and social benefits produced by GI practices, particularly as applied to urban settings. For specific devices, it documented the value of this equipment.

There are multiple methods used to estimate dollar measures of economic values associated with ecosystems. King and Mazzotta (2000) from the University of Maryland developed one such approach for evaluating ecosystems. They outlined eight different methods to measure the cost of projects, namely:

1. Market Price Method: This method estimates economic values for ecosystem products or services that are bought and sold in commercial markets.
2. Productivity Method: This method estimates economic values for ecosystem products or services that contribute to the production of commercially marketed goods.
3. Hedonic Pricing Method: This method estimates economic values for ecosystem or environmental services that directly affect market prices of other goods. This is applied commonly to variations in housing prices that reflect the value of local environmental attributes.
4. Travel Cost Method: This method estimates economic values associated with ecosystems or sites that are used for recreation. It assumes that the value of a site is reflected in how much people are willing to pay to travel to visit the site.

5. Damage Cost Avoided, Replacement Cost, and Substitute Cost Methods: These methods estimate economic values based on costs of avoided damages resulting from lost ecosystem services, costs of replacing ecosystem services, or costs of providing substitute services.
6. Contingent Valuation Method: This method estimates economic values for virtually any ecosystem or environmental service. It is the most widely used method for estimating non-use or "passive use" values. This method asks people to state their willingness to pay for specific environmental services based on a hypothetical scenario.
7. Contingent Choice Method: This method estimates economic values for virtually any ecosystem or environmental service based on asking people to make trade-offs among sets of ecosystem or environmental services or characteristics. This method does not ask for willingness to pay because this is inferred from trade-offs that include cost as an attribute.
8. Benefit Transfer Method (BTM): This method estimates economic values by transferring existing benefit estimates from studies already completed for another location or issue.

The parallel evaluation between CI and GI needs to be improved. Incorporating the value of benefits in evaluations will improve investment decision making by comparing GI and CI costs. The difficulty lies in integrating the valuation of these multiple benefits, in quantifying benefits that may not be easily monetized, and in bringing recognition of these values into the infrastructure investment decisions by developers, communities, and agencies (Wise et al., 2010). Kesten, Thériault and Des Rosiers (2006) showed in their studies that the environmental dimension plays an important role in the spatial structure of residential house prices.

In 2011, Robert Hill published an OECD paper on hedonic methods. The hedonic approach aims to explain property prices on the basis of their physical and neighborhood-related characteristics (Des Rosiers, Thériault, & Villemeuve, 1999). House prices as a function of a vector of characteristics are particularly useful for this purpose. In his report, Hill considers some of the developments in the hedonic methodology, applied in a housing context, that have occurred in the past three decades. It is often difficult to see how these indexes relate to each other. For this reason, the paper attempts to impose some structure on the literature by developing taxonomy of hedonic methods, and then demonstrates how existing methods fit into this taxonomy (Hill, 2011). Hill presents and explores modeling methods to predict house prices.

A hedonic model develops the price of a product using a vector of characteristics. The hedonic equation is a reduced-form equation that is determined by the interaction of supply and demand. The hedonic method is used for two main purposes. The first purpose is to quality adjust the observed prices on the left-hand side of the hedonic equation to allow for the construction of a quality-adjusted price index. The second purpose is to obtain estimates of what people are willing to pay (Hill, 2011). The time-dummy method is the original hedonic method. It typically uses the semi-log functional form as a standard semi-log formulation.

That approach is a calculation method provided to specialists. Even so, few tools are available to compare different types of development. In 2008, the Canada Mortgage and Housing Corporation (CMHC) created the *Life Cycle Costing Tool for Community Infrastructure Planning* to allow users to estimate the major costs of community development and to compare alternative development scenarios. The tool is geared toward estimating planning level costs and revenues associated with the residential component of a development.

In 1996, the Asian Development Bank published *Economic Evaluation of Environmental Impacts: A Workbook* (Bando, Raucher, Lohami, & Owens, 1996). The book provides a set of working tools to incorporate environmental costs and benefits within project analysis. Today, the workbook is still accurate because it emphasizes evaluation and not the nuances of environmental economic analysis.

As stated previously, the CNT (2009b) published details of the GVC and the benefits of GI. CNT reviewed current methods to evaluate the economic and social benefits produced by GI practices.

Another tool is the Environmental Valuation Reference Inventory™ (EVRI):

> EVRI is a searchable storehouse of empirical studies on the economic value of environmental benefits and human health effects. It has been developed as a tool to help policy analysts use the benefits transfer approach. Using the EVRI to do a benefits transfer is an alternative to doing new valuation research.
>
> Environment Canada has developed the EVRI in collaboration with a number of international experts and organizations. Especially noteworthy is the collaboration with staff from the United States Environmental Protection Agency, Office of Water (Environment Canada, 2006).

Other scientific methods are available. In 2010, Robert Mavsar, a senior researcher at the European Forest Institute, proposed a review of the BTM. In his presentation, Mavsar proposed simple functions to calculate benefit transfer. These functions involve nit value transfer with income adjustment to adjust the benefit estimate at the policy site.

In the present study, the hedonic price method (HPM), BTM, and meta-analysis are the preferred methods used to evaluate the project. The HPM is appropriate in the housing market because it expresses preferences and willingness to pay a price. The price of a property is determined by the characteristics of the house. The HPM is used to estimate the extent to which each factor affects the price. In the present case, building with GI should be beneficial to the housing project. The benefit may be demonstrated by an increase in hedonic price value. For this reason, this method of valuation is very effective in demonstrating the benefit of GI to customers who are searching for a better quality of life (Hill, 2011). The exchange value of ecosystem services is the trading ratio for the required services. When services are directly tradable in normal markets, the price is the exchange value. The exchange-based, welfare value of natural goods or services is its market price net of the cost of bringing that service to market. When there are no explicit markets for services, we must resort to more indirect means of assessing economic values (Farber et al., 2002). Using the CNT calculator required identifying a city close to Vaudreuil-Dorion with the same climatic conditions. Malone is the nearest city with similar characteristics and it was selected for the BTM.

The concept of ecosystem service value serves as a useful guide to assess the compromise between the society and the rest of nature while improving human welfare in a sustainable way. Although winning situations for human activities in the environment may exist, they are hard to find in the ecological and economic system of our world (Farber et al, 2002). During municipal planning to choose infrastructure investments, the limit of financial resources appears as a constraint to sustainable development. However, there is evidence that sustainable technologies can be applied, and can provide services at lower costs and in some cases, allow lower than conventional approaches capital investments.

> The use of GI can result in a number of financial, environmental, and social benefits. Communities throughout the United States are beginning to recognize these benefits and have become increasingly interested in implementing GI-based approaches. However, because LID and GI have not yet been implemented on a wide scale, a number of uncertainties surround the implementation of these approaches in comparison with traditional or grey infrastructure. Adoption of GI practices has been hindered by concerns that implementing GI programs will increase costs or not adequately protect property or the environment (US EPA 2013)

The introduction of green infrastructure involves the use of landscaping to provide alternative infrastructure at the metropolitan or regional level. Considering the novelty of these systems, two types of approaches are used. First, the identification of the resources of nature related to consumption units of the society; Second, economic valuation is based on the theory of public goods, a mode of thinking that explains behaviors surrounding the use and exchange of non-market goods and services. (Wolf, 2008)

This assumption guides the progressive steps of this study. First, a synthesis was proposed to define a start-up point to work from a white page when defining a solution to create a new development. Decision makers ask the question: is there a benefit and what are the costs in selecting a new approach? Therefore, in the municipal context, the second part of the study is to answer that question. In the next chapter (Chapter 3), development of a new framework provides an improved method for structuring a green project. In Chapter 4, that new framework is applied to a new project and the revenues and expenses are determined to answer the question.

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Connecting Statement to Chapter 3

Chapter 1 presented the situation of GI on different continents and mainly highlighted the difference between the European and American concepts of GI. Findings showed that there is room for an integrated concept linking the two approaches. There is also interest in defining a framework to start a GI project.

Chapter 2 reviewed the literature to find existing frameworks related to GI and green scenarios' development. This also showed that there is a need to compare the cost between CI and GI. This chapter was published in the *European Journal of Sustainable Development* as "An Integrated Framework for the Development of Green Infrastructure: A Literature Review" (doi: 10.14207/ejsd.2013.v2n3p1; http://www.ecsdev.org/images/V2N3/beauchamp%201-24.pdf).

Chapter 3 presents the newly developed concept of integrated GI—IWCA—and a new framework to start a GI project. This chapter was presented as a proceeding and a poster at the Montreal 2011 conference on ecocities (9th Ecocity World Summit, August 22, 2011). A short version of this chapter was published by Ecocity Builders in 2013 (http://www.ecocitybuilders.org/wp-content/uploads/2013/10/Beauchamp-Shaping.pdf).

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Chapter 3: An Integrated Framework for the Development of Green Infrastructure: A Case Study in Qujing, China

AN INTEGRATED FRAMEWORK FOR THE DEVELOPMENT OF GREEN INFRASTRUCTURE: A CASE STUDY IN QUJING, CHINA

Abstract

Green infrastructure (GI) has emerged as an active term of reference in project development planning. A review of the GI research literature reveals an absence of an integrated framework to assist organizations in planning start-ups of new green development projects involving storm water, wastewater, and water supply. This study attempts to bridge this gap by developing and then assessing a new integrated framework. Different approaches were evaluated to provide an entry point to new development conceptualization for the design of infrastructure such as roads, water supply, drainage, and wastewater collection that are to be constructed using a green and integrated approach. These approaches were drawn from different groups such as the Environmental Protection Agency (EPA), the Low Impact Development Center and various US states and Canadian provinces. Based on this analysis, we selected four approaches and compared them in terms of usefulness in developing a new integrated framework: low impact development (LID) (Maryland Department of Environmental Resources), the EPA Water Quality Scorecard, Leadership in Energy and Environmental Design (LEED) (US Green Building Council), and the BC Guidebook (Government of British Columbia, Ministry of Environment). From this comparison, we created a new integrated framework.

This new integrated framework was then tested in a study case in Qujing, China, where it was shown that all of the components of GI can be integrated into one approach. We found that the new integrated approach was very effective in conceptualizing the project and in producing an optimized master plan. Nevertheless, one finding in implementing the master plan was that the best urban planning was not a guarantee of success. Indeed, the lack of organization of construction led to a work stoppage midway through realization. This allowed us to add an important element to our framework: capacity building of managers and other key stakeholders involved in the project.

Key words: framework, green infrastructure, integrated approach

3.1 Introduction

A multidisciplinary team of professionals developed this project to create an agro-food park in Qujing City in China. The basic concept was to develop an industrial high-technology park for the processing of specialized products. The Client requested that various components be included in the project such as a demonstration component, a horticultural component, and a housing project. The Designer's team suggested that a green design component be included in the project, which the Client accepted. To address all the uncertainties, a philosophy of adaptive management (AM) was chosen to manage the project.

The present study's first objective was to explore the use of fully integrated green infrastructure (GI) in the engineering design of a biophilic development incorporating sustainability principles. To achieve the desired teamwork, a clear sequence of tasks must define the workflow. A review of the literature led to the identification of several different approaches, from which four were selected, improved, and then employed to build a ready-to-use framework of sequenced tasks. These tasks included all components of water management (precipitation and drainage, water supply, and wastewater). A case study in China employed in testing this framework demonstrated that all GI components could be integrated into one approach. While the structuring of an integrated water-centric development (IWCD) approach was found to be applicable to a wide range of projects, appropriate capacity building was critical for its success.

Today, "green" is becoming a politically correct word to identify sustainability. Householders can create their own green projects just by adding solar panels to their houses. This is a green action. The concept here is larger and encompasses neighborhood development or housing, or industrial development – green infrastructure.

3.1.1 Green Infrastructure

According to Benedict and McMahon (2006):

> Green infrastructure (GI) means different things to different people, depending on the context in which the term is used. There are two definitions of GI. Some people refer to trees in urban areas as GI because of the "green" benefits they provide, while others use GI to refer to engineered structures (such as water treatment facilities or green roofs) that are designed to be environmentally friendly. Page 1

In the 1970s, Benedict and McMahon began working in the conservation movement. Originally, conservation organizations worked to protect individual parcels of land (Benedict & McMahon, 2002). At that time, they realized that networks of open space should be protected. This was the beginning of the new concept of GI in the USA.

Here, infrastructure is understood as the underlying foundation on which the growth of a community depends. As explained by Davies, McGloin, MacFarlane, and Roe (2006), "GI is the physical environment within, and between, our cities, towns, and villages. It is a network of multifunctional open spaces, including formal parks, gardens, woodlands, green corridors, waterways, street trees, and open countryside." Typically, the European concept of GI includes the network of green routes and hubs that preserve animal and plant biodiversity (Murphy, 2009). This is in contrast to the American concept of GI, which views it is as the network of structures that supports urban and rural development, built with the idea of protecting the natural habitat and reducing the impact of development (United States Environmental Protection Agency [USEPA], 2009a) This concept focuses on introducing green facilities such as parks, gardens, trees, and swales into the city's infrastructure. It also involves designing green and integrating low impact development (LID) techniques (Weinstein, 2008).

The North American concept of GI originated in the US in the 1990s. Initially, it referred to the planning for land development that ensured the low impact of storm water management on the environment. Various global organizations have expanded this definition to include the engineering of systems to have less impact on our environment and to be more efficient in the use of resources. Today, the concept is more extensive and integrates the European concept of hubs and links. In Europe, as early as 1996, the concept of sustainability was proposed to assist local authorities and practitioners in designing urban infrastructure. In addition, in the 1990s, the European Science Foundation proposed the concept of best practices in sustainable urban infrastructure (SUI). In Asia, the concept of GI involves the introduction of parks and gardens into large existing cities. The concept differs depending on the demographics and the age of existing urban infrastructure and housing. For example, in Singapore, the concept has been extended to recycling water because of shortages in the water supply. The World Bank has highlighted three cases of "ecocities" in China—QuingDao, Dongtan, and Tianjin—and is promoting the concept in Asia (Suzuki, Dastur, Moffatt, Yabuki, & Maruyama, 2010).

In summary, there are two routes to define GI: (1) the European concept of hubs and links to which the Conservation Fund (2013) adheres, defining GI as the interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; (2) the US Environmental Protection Agency (US EPA) concept of underlying infrastructure to be designed with respect for the environment. There is a need to define a third concept, which would be an integrated concept. This new definition should unite both concepts in such a way that the natural environment becomes the driver in designing infrastructure. It appears that the experience of nature in cities is integral to human health, well-being and quality of life (Wolf, 2003):

> Infrastructure systems dependably deliver diverse products and services. Green infrastructure should include ergonomics, thus delivering social and environmental services. Ergonomics of the city can expand the impact and appeal of green infrastructure. Page 4.

3.1.2 Green Project

A green project is a sustainable development action. It may refer to a single action, such as installing solar panels on a building. In addition, a green development project may refer to a multi-action implementation in a large-scale agglomeration. To certify green projects, the United States Green Building Council (USGBC) has developed a registration approach known as Leadership in Energy and Environmental Design (LEED). The aim of this approach is to focus more holistically on buildings as a source of multiple environmental effects. For example, buildings offer impressive opportunities for pollution abatement (Enkvist, Nauclér, & Rosander, 2007). Promoting green buildings conserves energy and water, reduces greenhouse gas emissions, and provides state-of-the-art, modern facilities for office and residential use (Tolley & Shaikh, 2010).

3.1.3 Green Development

Green development is a broader concept. Green development involves green space management that conserves natural ecosystem functions and provides associated benefits to ecosystems, including the human population (Benedict & McMahon, 2002). This type of development includes the construction or conservation of hubs and links. Hubs can include green hubs such as forests or lakes or functional hubs with housing, commercial, or institutional functions. Roads and pedestrian alleys are urban links; these may or may not be green. Conservation corridors, greenways, and greenbelts provide links between green hubs. Green development needs GI, and green links are essential to preserve green hubs. The concept of Water Sensitive Urban Design (WSUD), another GI approach developed in Australia, is based on formulating development plans that incorporate an integrated approach to the management of the urban water cycle. In relation to storm water management, WSUD involves a proactive process recognizing the opportunities for urban design, landscape architecture, and storm water management infrastructure to be intrinsically linked (Wong, 2006).

There has been increasing public and government interest in establishing green technologies in project development because of their demonstrated environmental benefits (Barlow, 2011). Many cities in the US and Canada have adopted a green policy. Large cities such as New York, Boston, Toronto, and Vancouver have developed environmental guidelines to promote green buildings. However, despite the increasing acceptance of green development concepts around the world, there have been very few examples of green development in China.

One of the major barriers to an increase in the implementation of green projects and green development around the world is the absence of suitable frameworks under which to initiate such projects. Of the frameworks that do exist, some, such as LID and LEED, do not cover wastewater treatment, water filtration, water supply, or water balance. Therefore, this research proposes a new integrated framework that includes all components of water management in GI in an integrated manner.

Adaptive Management (AM) as a concept has been designed primarily to support managers in dealing with highly connected systems (Medema & Jeffrey, 2005). This method has been introduced in this research. AM can be defined more generally as a systematic process for continually improving management policies and practices by learning from the outcomes of implemented management strategies (Pahl-Wostl, Schmidt, Rizzoli, & Jakeman, 2004). It emphasizes the need to consider complexity in resources management and to develop appropriate methods for different situations (Pahl-Wostl et al., 2004). In the case study related here, many workshops with stakeholders and four study tours played a crucial role in orienting decision making by integrating AM into the process. Accordingly, AM is the method used to elaborate the new concept of an integrated framework. The next section presents the framework.

3.2 Development of a New Integrated Framework

3.2.1 Existing Frameworks

Different approaches and frameworks were evaluated in this research to provide an entry point to new development conceptualization for the design of GI. In 2006, COST Action C8 edited a synthesis of theories, methods, and tools to assess SUI (Lahti, Calderon, Jones, Rijsberman, & Stuip, 2006). However, there are no "road maps" to initiate integrated green development projects. Most published papers found in the literature focus on individual aspects of green development. For example, Tzoulas et al. (2007) formulated a conceptual framework of associations between urban green space, ecosystems, and human health. Benedict and McMahon (2006) focused on land conservation, and explored how to face the challenge brought about by population growth; they proposed building conservation networks that link land for nature and people. McDonald, Allen, Benedict, & Connor (2005), also proposed a framework based on a landscape approach. Other examples include Mavsar (2010), who explored the integration of forests and GI; Amati and Taylor (2010), who studied greenbelts; and Lehmann (2010), who explored the principles of green urbanism. Douglas Farr presented the principles of sustainable urbanism in 2008. The latest development concept is Smart Growth. Smart Growth is a collection of land-use and development principles that aim to enhance our quality of life, preserve the natural environment, and save money over time (CaGBC, 2013).

Landscape architects, urbanists, and engineers are confronted with the concept of integration. In the research literature, Tress, Tress and Fry (2005) found many different terms used to describe integrative research concepts, including terms such as interdisciplinarity and transdisciplinarity as well as other forms of disciplinary interactions. In landscape research, various experts have advocated the application of integrative approaches for solving the pressing problems of landscape change and development. Because this study is oriented toward engineering development in GI, we find that this concept of integration is fundamental to achieving good performance in designing GI. A holistic theory of landscapes should become an integral part of the conceptual foundation of goal-oriented and mission-driven landscape ecology. This can be achieved through the help of innovative transdisciplinary approaches and research methods, and close cooperation with landscape ecologists and ecologically oriented scientists from relevant social sciences, the humanities and arts, and the professionals involved in all phases of land-use decisions (Naveh, 2000). Because of the various aspects in a landscape (components, processes, and relations), landscape ecology should be regarded as a multidisciplinary—or better, a transdisciplinary—science, in which different views and approaches are involved in a holistic manner. The principle of complementarity is helpful for understanding the character of landscape ecology. The holistic approach in the context of human–nature relations is the challenge of modern landscape ecology regarding the background of increasing environmental problems and the discussions about sustainability (Bastian, 2001). This statement principle has been incorporated into the new proposed framework for starting a GI project.

3.2.2 Selection of Frameworks for Analysis

There are many frameworks to describe project development but only a few of these address project start-up. Sarté (2010) identified systems and design philosophies that are often used: (1) LEED rating system, (2) Building Research Establishment Environmental Assessment Method (BREEAM), (3) net-zero energy development, (4) regenerative development, (5) permaculture, (6) light imprint, (7) SmartCode, (8) Living Building Challenge, (9) Rocky Mountain Institute's urban framework, (10) Melbourne Principles for Sustainable Cities, (11) One Planet Living's 10 principles, (12) the American Institute of Architects (AIA) Committee on the Environment's (COTE) 10 measures of sustainable design, and (13) the American Society of Landscape Architects (ASLA) Sustainable Sites Initiative benchmarks and performance guidelines.

Following an extensive literature review, approaches from one US state, the US National EPA, one non-government organization (NGO), and one Canadian province were selected for further investigation. Maryland's LID approach was chosen from among the US states because it was the first state to develop a strategy to implement LID techniques.

The EPA's Water Quality Scorecard was selected because the EPA is the American reference to assess environmental impacts. The USGBC's LEED is an internationally recognized green building certification system and, for this reason, it was selected as the NGO approach for further examination. Finally, British Columbia's (BC's) "guidebook" approach was selected from among the Canadian provinces because, since 2000, BC has been a proactive Canadian province in the implementation of environmental planning (BC Water & Waste Association [BCWWA] et al., 2010). BC now has extensive experience implementing GI designs (Rutherford, 2007). Environmental issues have been prominent in the public and political discourse in BC longer than anywhere else in Canada, dating back to regional planning efforts in the 1960s and continuing through the regional growth management plans of the 1990s and 2000s in the province's larger agglomerations (Tomalty, 2007). In May 2010, CaGBC announced that Smart Growth BC, its programs and brand have been acquired to ensure the ongoing legacy of a very successful provincial program:

> The announcement was the beginning of a national approach to supporting a Smart Growth Canada Program that combines the provincial success of Smart Growth BC with the national network of CaGBC. Smart Growth BC has helped the Province to lead Canada in the adoption of better urban development practices and will now be a significant component to support smart growth from coast to coast by the CaGBC. http://www.cagbc.org/Content/NavigationMenu/Programs/SmartGrowth/default.htm

3.2.3 Description of the Chosen Framework

The four selected approaches were compared in terms of their usefulness for the development of a new framework to integrate GI development. Because the four approaches are structured in steps, with each comprising a different number of steps, it was decided that comparing these steps would be the most effective means of comparison. Three of the four approaches are water-centric approaches, whereas LEED Neighborhood Development (LEED-ND) is focused more on urban planning. The LID approach of the Maryland Department of Environmental Resources (MDER) consists of five steps: site planning, hydrologic analysis, integrated management practices (IMPs), erosion and sediment control, and the establishment of a public outreach program (Prince George's County, Maryland Department of Environmental Resources [PGMDER], 1999). The EPA offers a six-step scorecard approach for initiating projects. The steps are: review the scorecard; review various sections; collect existing ordinances and policies that will provide the necessary references; coordinate between appropriate agencies or departments to complete the scorecard; identify specific policy questions; and identify short-, medium-, and long-term goals (US EPA, 2009b). The USGBC's LEED-ND suggests a three-step approach, which involves site analysis and programming, preliminary planning, and final design and public outreach (United States Green Building Council [USGBC], 2010). Finally, the BC Guidebook for storm water management proposes a seven-step approach: secure political interest and support, frame watershed problems, develop objectives and alternative scenarios, collect meaningful data and refine scenarios, evaluate, develop an implementation program, and refine through AM (British Columbia Ministry of Environment, 2005). After performing an extensive analysis, a six-step integrated framework was developed in this research, comprising an inventory, hydrological and hydraulic assessment, integrated water resources management (IWRM), land planning, consultation, and a master plan. In general, the GI concept should integrate the conservation of nature with the design of infrastructure. An integrated approach to GI should also plan for and manage the complete cycle of water within a "green environment." The proposed framework involves integrating natural resources and water management into the GI concept (see Figure 3.1). It also integrates a closed cycle of water, including LID components, water sensitive urban design (WSUD) components, best management practice components, and aspects of IWRM. IWRM is a process that promotes the coordinated development and management of water, land, and related resources, to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (Global Water Partnership, 2003). The selection of the different phases of the proposed integrated framework is described in more detail in the following section. Subsequent to that, a description of the implementation of the proposed integrated framework in the Qujing Agro-Park in Yunnan Province, China, is presented.

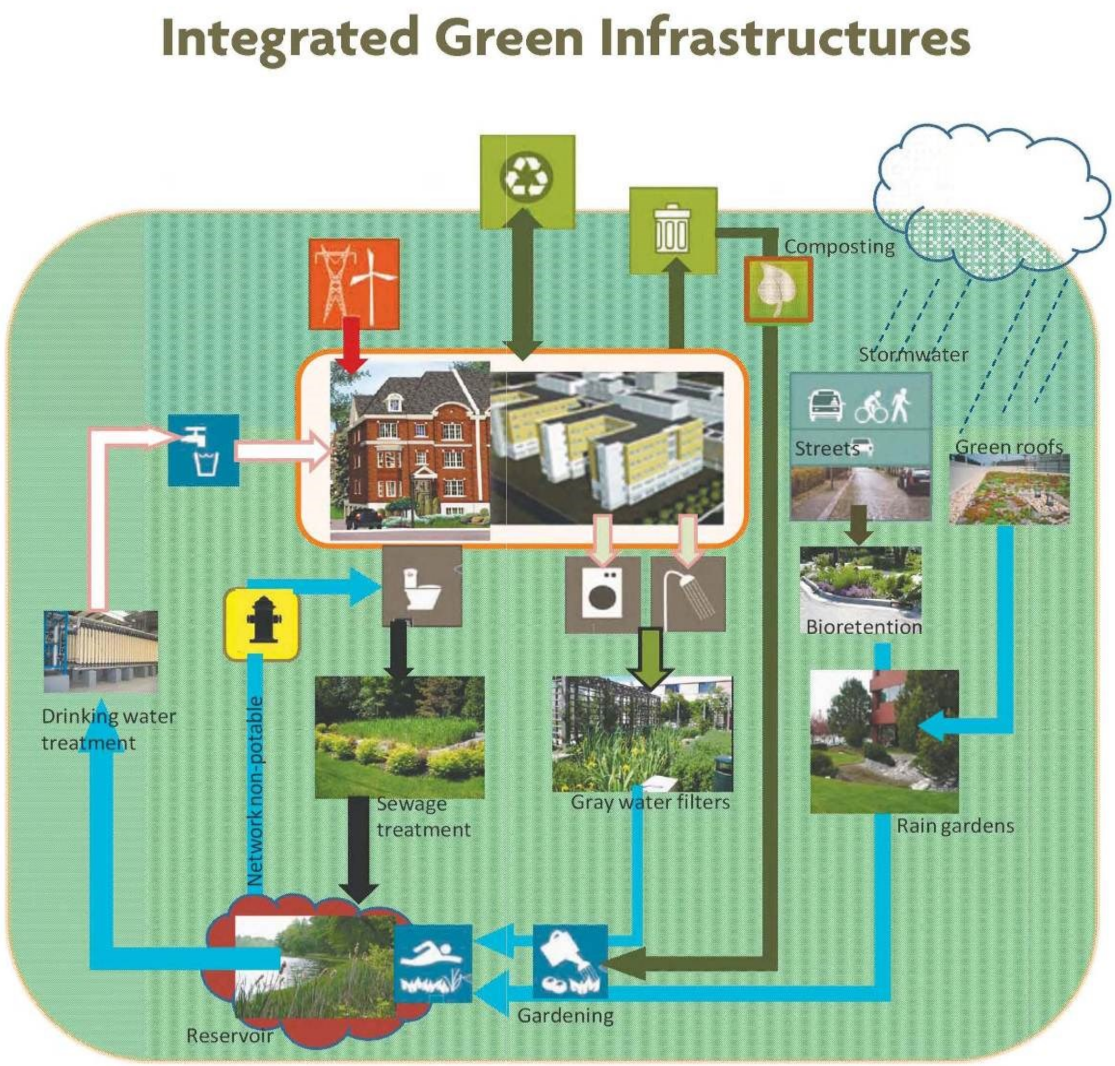

Figure 3.1: Integrated Green Concept

Table 3.1 focuses on the main characteristics of each selected framework. The existing frameworks are prepared to respond to a specific topic. Originally, LID was proposed to solve storm water management problems. It did not address IWRM issues except for one component. The Water Quality Scoreboard addresses a municipality's need to organize the start-up of a green project. It focuses on institutional organization. LEED is a certification for green projects. The LEED-ND addresses the designing of new developments, but it does not consider principles of IWRM. The BC Guidebook was originally prepared to manage storm water problems. In its second edition, the guidebook focused on IWRM, but the proposed framework is more of a guideline for policy makers and institutional management. The book largely covers storm water management practices. The four approaches are presented in Table 3.1 along with their main characteristics.

Table 3.1: Differentiation among Approaches

Approaches	Focus	Strength	Weakness
LID	Storm management	Hydraulic analysis	No water supply No wastewater No urban planning
Water Quality Scorecard (EPA)	Institutional organization	Policy issue	No water supply No wastewater
LEED (USGBC)	Urban planning	Land planning Standards	No storm management No water supply No wastewater
BC Guidebook	Storm management institutional policy	Watershed management	No water supply No wastewater

Most frameworks are designed to satisfy specific needs of public servants or specific needs of designated professionals such as engineers, urban planners, architects, or landscape architects. As an example, the Québec Ministry of Sustainable Development, Environment and Park (MDDEP) adopted a new guide (2011) for managing storm water. This approach proposes introducing LID techniques for managing storm water and pipe sizing. There is no consideration for planning other components of urban planning and other components of infrastructure planning. There is a separate and specific approach for guiding the design of water supply facilities and a specific approach for designing small or large wastewater treatment facilities, but there is no framework for integrating storm water, water supply, and wastewater with urban planning when creating a new urban development. Any Smart Growth development should be planned with this new approach: imitating nature, water should be a central element of a new concept. A strong interaction exists between each of these elements. Drinking water will finish as wastewater, and rainwater will finish in a lake or a river. Policy making is not an issue for designers; it is more of a municipal concern. In many cases, policies have already been defined and have become an existing parameter.

The new framework proposes integrating the European concept of natural hubs and links with the American concept of GI. It also extends the storm water management infrastructure approach with the idea of a looping water cycle so that reuse of wastewater and storm water is maximized. The basic idea is to mimic nature and reuse water. In the context of a soft water shortage in the world, mainly in developing countries, maximizing water conservation, natural storage, and water reuse will address this problem. To develop a new urban project, it is proposed that the concept be studied and developed in six steps:

1. Prepare an inventory to characterize the site and understand stakeholders' needs.
2. Study the hydrology and conduct a hydraulic assessment to understand the natural flow of water.
3. Propose IMP to introduce the new concept of a closed loop.
4. Develop land planning to mimic nature.
5. Prepare a consultation to review the stakeholders' needs already identified in Step 1.
6. Propose a master plan to define an initial solution in designing the project.

3.2.4 Selection of Phases in the Integrated Framework

The requirements of each of the selected approaches at each step are outlined below. By presenting the approaches in this way, similarities and differences become evident. Further, the steps of the proposed framework can be presented in contrast to the steps of the existing frameworks. In Table 3.2, these frameworks are presented in tabular form to demonstrate further the similarities and differences between them and the proposed framework.

3.2.4.1 First Step: Inventory and First Consultation

The MDER, in its application of LID, suggests starting with site planning. This includes using hydrology as the integrating framework, micromanagement, controlling storm water at the source, using simplistic, non-structural methods, and creating a multifunctional landscape (PGMDER, 1999). However, the EPA proposes structuring the team and finding resources to start the project, whereas the LEED approach begins with "site analysis and programming, including property selection, stakeholder identification, information gathering, environmental review, conceptual planning, and development programming" (USGBC, 2009). The BC Guidebook emphasizes the need to secure political interest and support, define a guiding philosophy, formulate supporting policies, and establish design criteria to achieve policies at the initial stage of a green project (British Columbia Ministry of Environment, 2005) (see Table 3.2).

After comparing the above first steps in the different methodologies, it was determined that, although it is important to assemble the project team, the first step should be the preparation of an inventory. Examining the site is critical for acquiring basic information on topography, hydrology, demography, ecology, and social, economic, governance, and political issues. During this process, it is necessary to hold a meeting with the various authorities, stakeholders, and agencies to obtain information (see Table 3.2). At this step, the stakeholders' needs should be well identified so that a first consultation will be achieved. It can be observed that AM principles are applied in the first step of the proposed framework. Consultation with stakeholders is a determinant to understanding their needs.

3.2.4.2 Second Step: Hydrology and Hydraulics of the Watershed

For the second step, LID proposes a hydrologic analysis. The EPA's Water Quality Scorecard proposes that the appropriate staff convene to review various sections of the tool, and to work together to ensure that updates and changes are made to codes, policies, and internal processes. LEED requires a preliminary planning stage to plan for land use, transportation networks, and major facilities, as well as public outreach and the refinement of plans. Finally, the BC Guidebook suggests the framing of watershed problems (see Table 3.2). The proposed integrated framework is geared toward a new concept of infrastructure design projects, in which the infrastructure will implement water cycles that mimic natural processes. First, as a foundation of the framework, an understanding of the natural hydrology of the development area must be established. Detailed hydrological and hydraulic assessment will be carried out as the process of design development progresses, since this is one of the key elements in structuring land use, transportation planning, and substructure planning (see Table 3.2).

Therefore, the proposed integrated framework has as its second step a detailed hydrological and hydraulic assessment aimed at developing a better understanding of the watershed because this is one of the key elements in structuring land use, transportation planning, and substructure planning (see Table 3.2 and Figure 3.1).

3.2.4.3 Third Step: Integrated Management Practices

For the third step, LID introduces IMPs, which integrate the site with the natural environment and eliminate the need for large centralized parcels of land to control end-of-pipe runoff. The EPA's Water Quality Scorecard recommends collecting existing ordinances and policies to provide the necessary references, whereas LEED groups all other activities, including the final design of the public outreach, the preparation of the final site plan, infrastructure, and building design, and the acquisition of construction permits. The BC Guidebook develops objectives and alternative scenarios in their third step (see Table 3.2). We argue that, at this stage, it is important to introduce IMPs from an IWRM perspective into the scenarios. The proposed integrated framework also introduces water supply and wastewater treatment into scenarios of management of storm water and recommends that water be recycled (see Table 3.2).

3.2.4.4 Fourth Step: Land Planning

In the fourth step, LID evaluates erosion and sediment control considerations. The EPA uses a scorecard approach, in which they suggest coordinating the appropriate agencies or departments to complete the scorecard. The BC Guidebook collects meaningful data and refines scenarios at this stage (see Table 3.2). With the information already gathered, it is necessary for the project team to prepare the land planning. This activity should be performed efficiently, with the team working in one space. The working sessions are critical to the ongoing process of change. Urban planners can then issue the preliminary documents to be submitted during a consultation process. Therefore, in the fourth step, the proposed integrated approach proposes land planning (see Table 3.2).

3.2.4.5 Fifth Step: Further Consultation

In the fifth step, LID prepares a public outreach program, the EPA identifies specific policy questions that should be prioritized for immediate revision or update, and the BC Guidebook evaluates alternatives and develops component plans (see Table 3.2). The proposed integrated framework recommends consultation with developers, landowners, public officials, and other key stakeholders following land planning (see Table 3.2). As soon as the first draft of the land-use plan is released, feedback from key stakeholders, developers, and landowners is required to complete the next step, which is the master plan. This consultation is feedback to the first step—inventory of the stakeholders' needs.

3.2.4.6 Sixth Step: Master Planning

In step six, the EPA identifies short-, medium-, and long-term goals and strategies for revising local policies to better support GI, whereas the BC Guidebook requires the development of an implementation program. The proposed integrated framework introduces the development of an integrated master plan as the final step, followed by design, implementation, evaluation, and updating (see Table 3.2). The master plan must address all of the key problems that were identified in the earlier steps. The master plan includes an implementation plan that also involves a description of the evaluation and updating mechanisms that will be implemented (see Table 3.2). With seven steps, the BC Guidebook proposes AM to adjust and refine the concept as its last step (see Table 3.2). It is proposed that AM be included in this sixth step as part of the master planning process.

Table 3.2: The Five Approaches to Developing Green Infrastructure

Step	LID (MDER)	Water Quality Scorecard (EPA)	LEED (USGBC)	BC Guidebook	Proposed Approach (IWCA)
1	Site planning: hydrology as the integrating framework, micromanagement, controlling storm water at the source, using simple non-structural methods, and creating a multifunctional landscape	Review the scorecard to identify which agencies, departments, or personnel are required	Site analysis and programming: property selection, stakeholder identification, information gathering, environmental review, conceptual planning, and development programming	Secure political interest and support, define a guiding philosophy, formulate supporting policies, and establish design criteria	Prepare an inventory: topography, hydrology, demography, ecology, social, economic, governance, and political issues, and meet with relevant departmental authorities and stakeholders to identify their needs
2	Hydrologic analysis	Convene appropriate staff to review various sections of the tool, and work together to ensure that updates and changes to codes, policies, and internal processes are done	Preliminary planning: planning of land use, transportation networks, and major facilities, public outreach and refinement of plans	Frame the watershed problems and opportunities	Perform hydrological and hydraulic assessment to understand the watershed
3	IMPs: integrate the lot with the natural environment and eliminate the need for large centralized parcels of land to control end-of-pipe runoff	Collect existing ordinances and policies that will be necessary references	Final design: public outreach, preparation of final site plan, infrastructure design and building designs, and acquisition of construction permit	Develop objectives and alternative scenarios	Introduce IMPs, introduce water supply and wastewater treatment into scenarios of management
4	Evaluate erosion and sediment control considerations	Coordinate between appropriate agencies or departments to complete the scorecard		Collect meaningful data and refine scenarios	Prepare land planning
5	Prepare a public outreach program	Identify specific policy questions that should be prioritized for immediate revision or update		Evaluate alternatives and develop component plans	Consult again with developers, landowners, and public and give feedback
6		Identify short-, medium-, and long-term goals and strategies for revising local policies		Develop an implementation program	Develop a master plan to guide design, implementation, and monitoring
7				Refine through adaptive management	

3.2.5 The Proposed Integrated Framework

In the last column of Table 3.2 is our proposal for a new integrated framework for planning integrated GI project development and for managing GI design including storm water, wastewater, and water supply. To achieve green development, land planners, architects, engineers, biologists, ecologists, sociologists, economists, managers, and citizens must be involved as an integral part of the team in planning the project. AM appears to offer a solution to the management gridlock caused by increasing complexity and uncertainty (Allan & Curtis, 2005); therefore, it is a central element of the proposed approach. An outline of the proposed six-step integrated framework is described below.

3.2.5.1 Inventory

The first step is to understand the site, define the current situation, and make a first consultation with the stakeholders. This is done by visiting the site, noting observations to determine the general topography of the site, and meeting individually with the stakeholders. In addition, an inventory of the ecosystem should be made, identifying green hubs, rivers, wetlands, and creeks, and qualifying them. A review and analysis of all available data and information, including economic and sociologic data, demography, topography, climatology, hydrology, hydrogeology, water quality, level of services, and water consumption by user groups in the surrounding area must also be conducted. Accurate knowledge of the existing situation will help to optimize and define the most appropriate alternatives. Basic data on the following topics are required:

- demography: present and past populations, population distribution and growth rate, and existing demographic studies;
- environmental survey;
- topography and hydrography: topographic maps, identification of main waterways, and hydrologic parameters (imperviousness, area, and land use);
- existing infrastructure: information on present and planned water supply and drainage/sewer networks, sanitation, and developments in the infrastructure;

- water resources: characterization of existing and proposed water source quality and quantity, and the importance of groundwater and/or surface water;
- norms and standards: water quality and environmental norms and standards;
- major water consumers and polluters: identification of existing and future major water consumers and polluters such as industries, towns and urban centers, public institutions, hospitals, and schools;
- town planning and development projections: present and projected land use, aerial photographs, existing related maps and studies, projected major development sectors, and master plans;
- precipitation: recorded rain data and existing hydrographs;
- key social, economic and political issues; and
- capacity building issues.

The consultation process starts with this activity by meeting each group of stakeholders through interviews. Stakeholders are informed about the management plan, are asked their opinions, and are asked to provide data regarding their knowledge of the region. Their needs are identified and are matched to define a green concept of the project. From this first round of consultation, goals and policy context are identified.

3.2.5.2 Hydrology and Hydraulic Assessment

In planning for GI development, the natural habitat can be mimicked in the design of new infrastructure. For this reason, it is necessary to define watershed and microwatershed areas, storm issues, modeling techniques, and water quality objectives. Further, runoff volume, peak runoff, frequency, and water quality control must be defined, and a macro hydrologic analysis must be performed. It may also be necessary to model the hydraulics of the river and catchment. The intent of this proposed step is illustrated by this description relating to the Maryland approach:

> The traditional approach to site drainage is reversed to mimic the natural drainage functions. Instead of rapidly and efficiently draining the site, low-impact development relies on various planning tools and control practices to

> preserve the natural hydrologic functions of the site. The essential existing hydrologic functions of the site and its functions must be maintained. The application of low-impact development techniques results in the creation of a hydrological functional landscape; the use of distributed micromanagement practices, impact minimization, and reduced effective imperviousness allowing maintenance of infiltration capacity, storage, and longer time of concentration. Integration of hydrology into the site planning process begins by identifying and preserving sensitive areas that affect the hydrology, including streams and their buffers, floodplains, wetlands, steep slopes, high-permeability soils, and woodland conservation zones (PGMDER, 1999).

3.2.5.3 Integrated Management Practices

LID is a multi-barrier approach that uses features at the lot, neighborhood, and watershed levels to maintain the on-site water balance (Gyurek, 2009). It was determined that the proposed framework must integrate this multi-barrier approach to reduce the water footprint in the development. This involves:

> designing strategies to provide quantity and quality control and enhancement of groundwater recharge (through infiltration of runoff into the soil), retention or detention of runoff for permanent storage or for later release, and pollutant settling and entrapment (by conveying runoff slowly through vegetated swales and buffer strips or small wetlands) (Gyurek, 2009).

In addition, “multiple uses of landscaped areas must also be considered as well as water balance analysis with consideration of domestic water streams (water demand and wastewater discharge)” (Gyurek, 2009). To achieve sustainable development, we must manage our most vital natural resource, water, in an integrated manner, or precisely through IWRM (Rahaman & Varis, 2005). Through these methods, it is possible to integrate water treatment, water supply, and wastewater treatment.

A multi-barrier approach also requires the assessment of the availability and potential of surface and groundwater sources—and the existing or potential pollution of such sources—as well as the gauging of any pollution control requirements for the protection of surface and groundwater supplies (Gyurek, 2009). The quality and quantity of each potential source must be examined, and the needs of each potential user must be analyzed using the projected population and per capita demand factors based on existing usage levels and national standards and regulations. The proposed integrated framework is different from LID, in that LID only deals with storm water management. The proposed framework integrates water supply and wastewater treatment into the chain by defining a core, such as a lake or a new reservoir, as the center of micromanagement. Cities manage water at a large scale, drawing water from a lake or river and discharging polluted water, which may have had limited treatment, back into the river. The proposed approach attempts to manage water within a closed loop (see Figure 3.2), avoiding the loss of clean water, or the discharging of polluted water into the core water source. However, to achieve this, new standards for water quality are required.

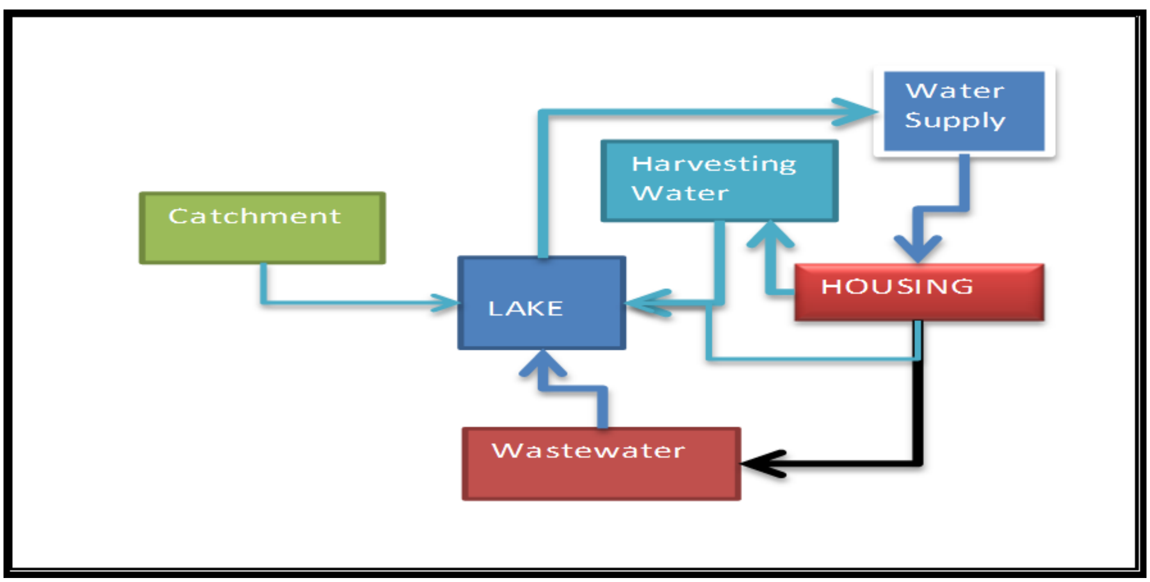

Figure 3.2: Water Infrastructure Closed Loop Concept

In the proposed approach, all LID features are introduced to maximize water quality. The concept includes features such as rain gardens, bioretention, and bioswales. To integrate all systems, it is necessary to create a lake or a reservoir on-site and to link all parts of the system with that water body as the core. In contrast to the LID concept, which focuses on rainwater, the proposed concept integrates water supply, wastewater, and storm water management. The system operates as a closed loop, as shown in Figure 3.2. Rain is captured and treated at the source; it then flows to the reservoir or is reused at the source. A filtration plant acts as a dam and receives water from the lake. The water distribution system is split into potable and non-potable water. Wastewater, split into black and gray water, is treated on-site, after which it flows to the reservoir.

3.2.5.4 Land Planning

At this stage, a site analysis and programming should be performed by identifying the owners and stakeholders, and preparing a conceptual planning and development program. This planning entails initial planning of land uses, transportation networks, and major facilities. This activity is completed by a team including various professionals such as land planners, architects, landscape architects, engineers, environmentalists, biologists, sociologists, and economists. The details of the land use will have been defined by the hydraulic assessment of the site.

3.2.5.5 Consultation

For the purpose of consultation, a public information program that involves developers, city planners, and other key stakeholders should be prepared and implementation announcements to the public made through newspapers and other media. This information should contain a description of the project and its components, and a schedule of its implementation. A letter describing the purpose, content, and schedule of the master plan should be developed and distributed at this stage, along with information for affected people about their rights and responsibilities and legal options. Information distribution or dissemination will also be in the form of a public information booklet. This document should be prepared by the city, province, state, or country, in conjunction with the project planners, and then distributed to all affected owners and stakeholders. Meetings also need to be organized to consult with relevant stakeholders again.

3.2.5.6 Master Plan

To prepare the urban and infrastructure master plan, a feasibility study, including a general review of existing studies, site surveys, and an examination of the design criteria, must be conducted. Alternatives are examined under technical, financial, economic, environmental, and social considerations, and basic summary design and preliminary cost estimations are carried out for each alternative. Next, comparative social, economic, and technical analyses of scenarios lead to the initial selection of a preferred solution. Finally, an initial implementation action plan and a monitoring plan must be developed to describe the project and optimal solutions in terms of costs, scheduling, funding, and adherence to the principles of sustainability. Figure 3.3 represents the initial model of the framework.

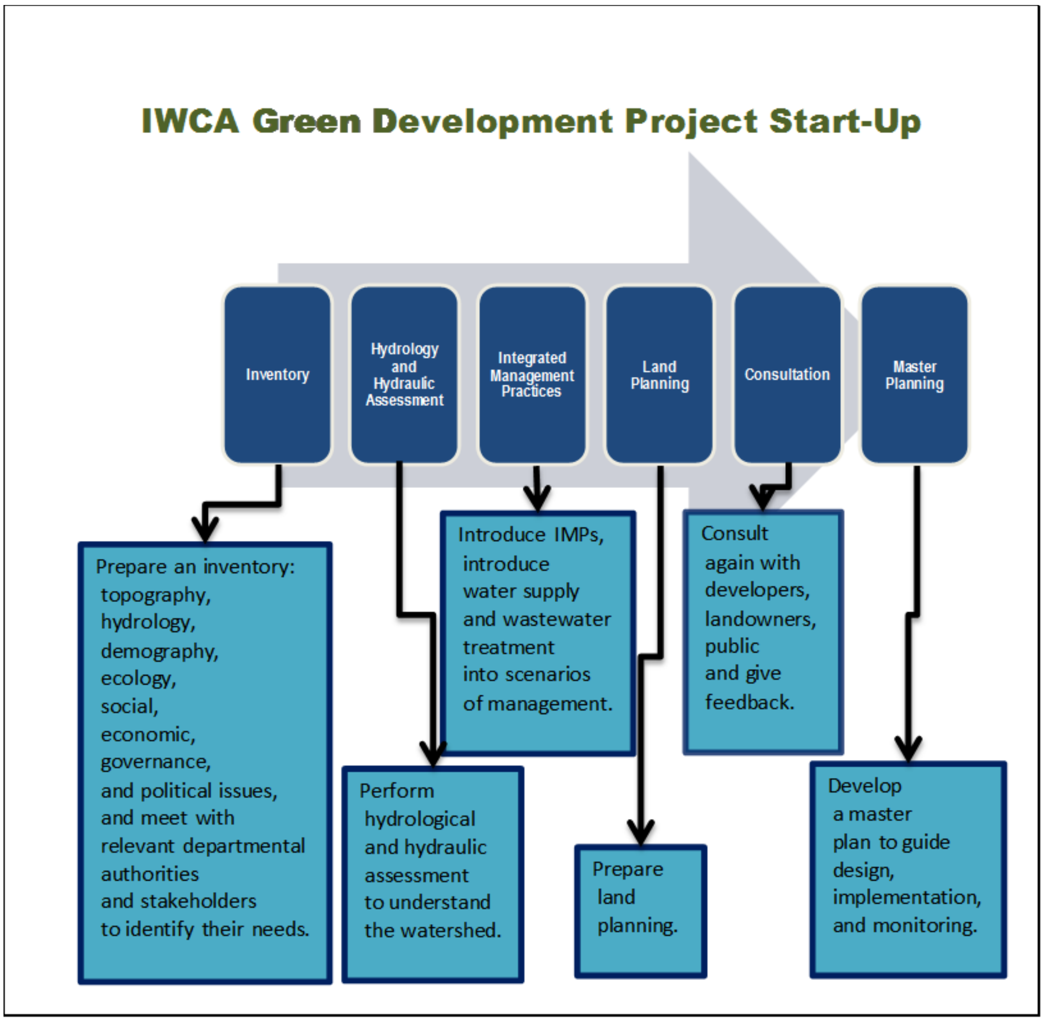

Figure 3.3: IWCA Start-Up Framework

3.3 Case Study: Qujing, China

3.3.1 Overview

In 2008, the Government of Yunnan Province entered into discussion with Constellation Monde Inc. (a Canadian company) to develop the Qujing Agro-Park in China. The integrated plan (based on the proposed integrated framework outlined in this paper) was developed in 2009, and construction started in May 2010. As of September 2011, the project was about 40 percent complete. This section of the paper describes the preliminary design of the project, as well as the master plan that was released in May 2009. An outline of the application of the proposed integrated framework in Qujing, China, is shown in Figure 3.4.

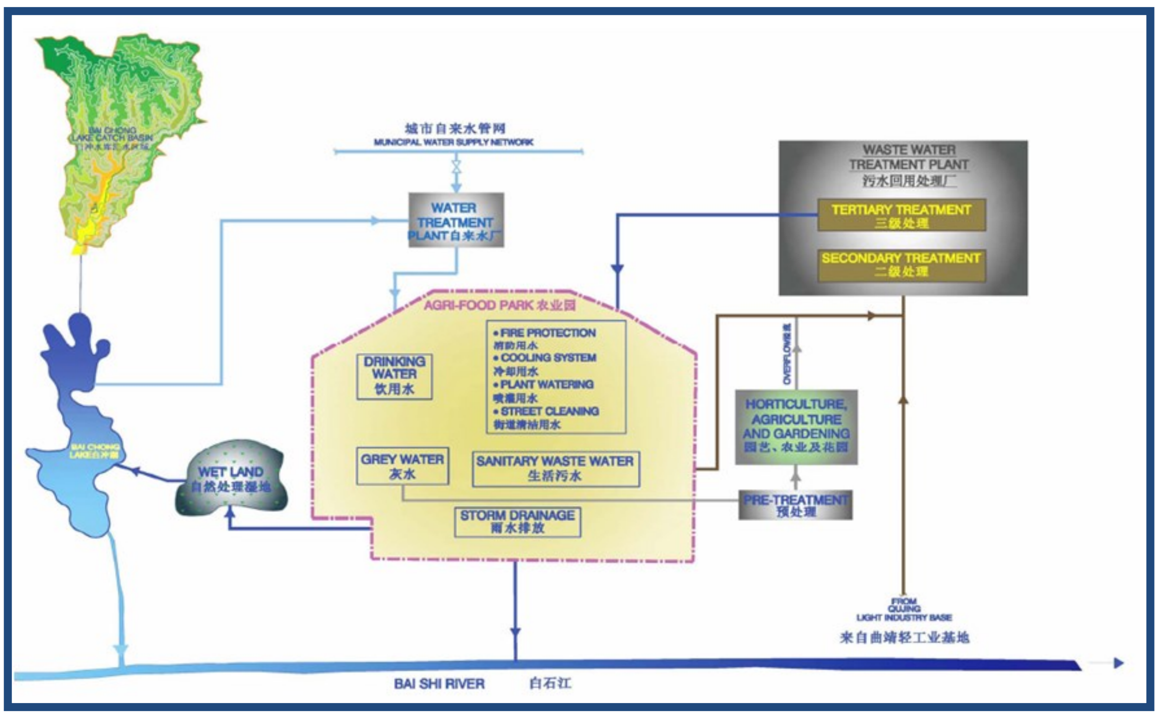

Figure 3.4: Integrated Approach in the Qujing Project (adapted from Les Consultants LBCD, 2009)

3.3.2 Background

Since 1980, Yunnan Province and Qujing Municipality in China have been experiencing rapid urbanization, industrialization, and income growth. The economy, traditionally based on agriculture and natural mineral resources, has moved increasingly toward industrial development as the population has grown, although agriculture remains important, with the production of rice and tobacco predominating.

The modernization of Chinese agriculture is one of the major challenges the People's Republic of China (PRC) is facing. The contribution of foreign technology and the presence of high-tech companies are some of the ways that have been chosen by the PRC to achieve this objective. Further, the PRC is providing training for managers, agronomists, and local technicians working in agriculture and the processing industries. To provide the facilities for this training, it was decided that an Agro-Food Techno-Park (AFTP) would be built in the Qujing Municipality. Constellation Monde Inc., a Canadian company from Montreal, and the province of Yunnan have a long history of collaboration. Therefore, Constellation Monde Inc. was awarded the contract to design and construct the AFTP. The AFTP will involve several high-tech agro-companies and provide a center for training and education, acting as a window for agro-business for Yunnan province and other areas. The AFTP's 300-hectare (ha) project site is located on the northern outskirts of the Qujing Light Industry Base. Qujing is a large city located in the northeastern region of the province of Yunnan in the southeast of China (see Figure 3.5).

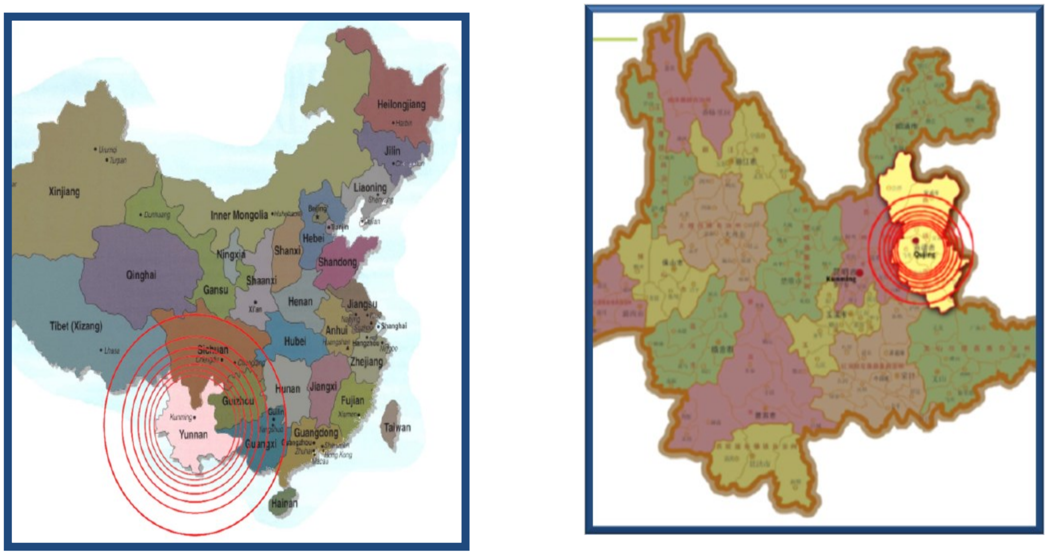

Figure 3.5: a) Yunnan Province, PRC; b) Qujing Municipality, Yunnan Province

3.3.3 Application of the Proposed Framework to the Qujing Case Study in China

3.3.3.1 Inventory

Quality baseline data are the foundation of a successful project. Therefore, senior engineers, biologists, environmentalists, geographers, botanists and agronomists (identified as the Engineering Group), architects, and landscape architects completed two data collection missions in Qujing. The first mission took place between August 11 and 17, 2008. The activities included visiting the site and meeting with decision makers from the Qujing Municipal Government and Constellation Monde Inc. (the Developer). During the first assignment, the Engineering Group obtained a better understanding of the needs of the clients, established communication channels with the clients, and received baseline information. The second data collection mission took place between September 30 and October 11, 2008. The objective of that mission was to complete the baseline data collection. The mission activities and information obtained were compiled into a multiple activity report, and included a survey of the site and surrounding area (see Figure 3.6), water and sediment sampling, bathymetrical measuring of the Bai Chong Reservoir, soil sampling of the site, and a description of the visits to relevant municipal departments, public service providers, and institutes (Data Collection Report LBCD, 2008).

Figure 3.6: Qujing Agro-Food Techno-Park Original Site

The engineering group visited 23 municipal departments, public service providers, and institutes. Table 3.3 presents stakeholders visited.

Table 3.3: Stakeholders

1. Qujing Water Supply and Sewage Collection Company 2. Qujing Environment Monitoring Station 3. Department of Agriculture of Qujing City 4. Department of Water Resources of Qujing City 5. Department of Forests of Qujing City 6. Bureau of Meteorology of Qujing City 7. Qujing Solid Waste Management Center 8. Department of Domestic Waste Management and Collection of Qilin District 9. Department of Transport of Qujing City 10. Qujing Economical-Technological Development Zone, Division of Urban Planning 11. Department of Hydrology of Qujing City 12. Department of Land Use of Qujing City, Division of Economic-Technological Development Zone 13. Department of Urban Construction of Qujing City	14. Qujing Urban Planning Bureau 15. Qujing Survey Management Station 16. Department of Water Resources of Qilin District 17. West Town (Xicheng) Community of Qilin District 18. Department of Forests of Qilin District 19. Qujing Electrical Power Supply Bureau 20. Department of Earthquakes of Qujing City 21. Yunnan Geology and Mineral Resources Exploration Bureau, Division 1 (Qujing) 22. China Telecom, Qujing Branch 23. Yunnan Forest Ecology Engineering and Planning Institute

Two senior engineers met separately with senior representatives of each department. They presented the basic concept of the project and discussed it with them to learn their concerns and understand their needs. A month later, a meeting was organized to meet all stakeholders together. One senior officer of each department presented his or her department's suggestions to improve the project. These were taken into account in a review of the project. Many suggestions were related to protection of environment, management of solid waste and shortage of water. There was a concern about the management of the Bai Chong water reservoir.

The activities were coordinated by Mr. Jinlin Chen, Vice Director of the Department of Foreign Investment, and Mr. Yi Wan, Secretary of Vice Mayor Zhou. Through these visits, we obtained valuable baseline information for the Agri-Food park project. The documents obtained are listed in Table 3.4.

Table 3.4: List of Documents Received

Description		Format	Notes
1.	Qujing urban master plan	Hard copy	Prior to mission no. 1
2	Summary of geographical distribution of population	Hard copy	Mission no. 1
3.	Qujing light industry base master plan	Hard copy + pdf	Mission no. 1
4.	Plan of topography of the Agri-Food park	Auto Cad	Mission no. 1
5.	Satellite image of Qujing City	JPEG	Mission no. 2
6.	Description of Baichong Reservoir	Hard copy	Mission no. 1
7.	Report of water quality analysis of Bai Chong Reservoir	Hard copy	Mission no. 1
8.	Master plan of land use (Part)	AutoCad	Mission no. 2
9.	Construction drawings of roads surrounding the Agri-Food park - Rui He West road - He Xing road	AutoCad	Mission no. 2
10.	Annual average meteorological data from Zhangyi station	Hard copy	Mission no. 1
11.	Historical meteorological data of Qujing	ASCI files	Mission no. 2
12.	Qujing water resources protection planning	Hard copy	Mission no. 2
13.	Qujing municipal regulation on water conservation and water resources protection	Pdf	Mission no. 1
14.	Summary of hydro-geological conditions of Qujing area	Word + MapGis	Mission no. 2
15.	Study report on Qilin district forest resources planning (version for approval)	Hard copy	Mission no. 2
16.	Summary of forest cover on the Agri-Food park	Hard copy	Mission no. 1
17.	Summary of baseline condition of West town community	Hard copy	Mission no. 2
18.	Summary of soil condition of Qujing City	Hard copy	Mission no. 1

Description		Format	Notes
19.	Summary of utilization of fertilizers on the Agri-Food park site	Hard copy	Mission no. 2
20.	Summary of utilization of pesticides on the Agri-Food park site	Word	Mission no. 2
21.	Summary of water and wastewater infrastructure of Qujing City	Hard copy	Mission no. 1
22.	Summary of Qujing water distribution network	Hard copy	Mission no. 2
23.	Plan of Qujing water distribution network	AutoCad	Mission no. 1
24.	Report of analysis of distributed water (WTP no. 2)	Hard copy	Mission no. 2
25.	Measurement of water distribution network pressure at the outlet of WTP no. 2 (13–18 July, 2008)	Hard copy	Mission no. 2
26.	Proposed solution for water supply to Hua Tai automotive town	Hard copy	Mission no. 2
27.	Proposed solution for water supply to Westmont Xiong Ye pharmaceutical plant	Hard copy	Mission no. 2
28.	Qujing central area solid waste management infrastructure master plan (2007–2020)	Hard copy	Mission no. 2
29.	Qujing urban integrated transport planning	Hard copy + pdf	Mission no. 2
30.	Technical standards for highway engineering	Hard copy	Mission no. 1
31.	Traffic counts at Qujing toll stations (Nov. 2007–Sept. 2008)	Hard copy	Mission no. 2
32.	Qujing electrical power distribution networks master plan	Electronic (pdf)	Mission no. 2
33.	Summary of existing electrical power supply installations near the Agri-Food park	Hard copy	Mission no. 1
34.	Control objectives for pollutants discharge from the Agri-Food park	Hard copy	Mission no. 1
35.	Standards for surface water quality (GB3838-2002)	Hard copy	Mission no. 1
36.	Standards for groundwater quality (GB/T14848-93)	Hard copy	Mission no. 1
37.	Standards for drinking water quality (GB5749-2006)	Hard copy	Mission no. 1
38.	Water quality standards for drinking water sources (CJ3020-93)	Hard copy	Internet
39.	Standards for wastewater discharge (GB8978-1996)	Hard copy	Mission no. 1
40.	Standards for industrial waste storage and disposal (GB18599-2001)	Hard copy	Mission no. 1
41.	Standards for air quality (GB3095-1996)	Hard copy	Mission no. 1
42.	Standards for air pollution control (GB16297-1996)	Hard copy	Mission no. 1
43.	Standards for noise level (GB3096-93)	Hard copy	Mission no. 2

3.3.3.2 Hydrology and Hydraulic Assessment

3.3.3.2.1 Storm Water System

The catchment basin of the Bai Chong Reservoir has a total surface area of 800 ha (see Figure 3.7). Only 15 percent (123 ha) of the catchment basin is located in the Techno-Park. The rest is situated outside of the park, to the north. The catchment includes small hamlets in the mountains. A complete ecological survey of the hamlets was conducted, including meeting villagers, determining potential pollution sources, and identifying flora and fauna. Each river branch was examined.

3.3.3.2.2 Meteorological Conditions

Qujing City is located close to the Tropic of Cancer and has a subtropical monsoonal climate, with the hottest days occurring in July, and the coldest in January. Because of its 3,300-meter-altitude difference, climate types ranging from lower subtropical to northern temperate can be found in the city. The main climatic information within the project area is described in Table 3.5.

Table 3.5: Main Climatic Information within the Project Area

Average annual temperature (Celsius)	Highest temperature (Celsius)	Lowest temperature (Celsius)	Precipitation (mm)	Sunshine (hours)
14.4	33.2	–9.2	985.9	1,917.4

Source: Meteorological Statistics of Zhanyi Meteorological Station (1971–2000), Qujing Meteorological Bureau, August 2008

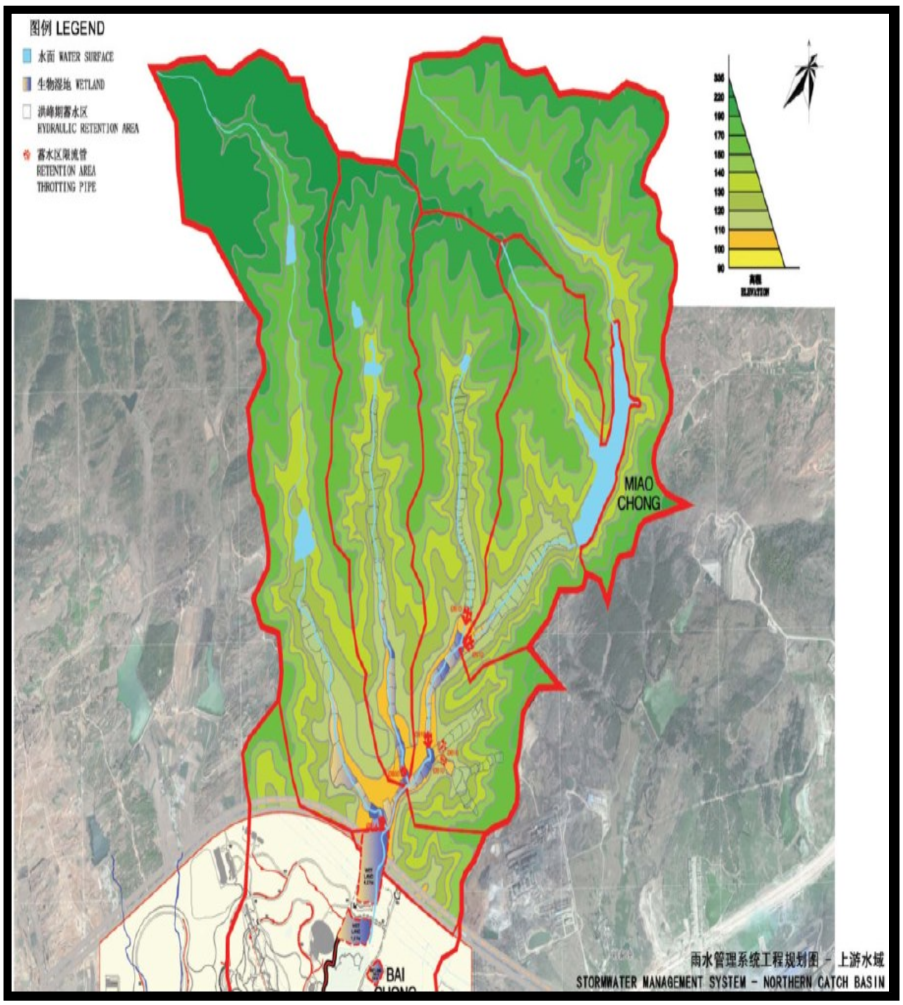

Figure 3.7: Agro-Park Upstream Watershed

3.3.2.3 Precipitation

The average annual rainfall accumulation in the area is 985.9 millimeters (mm). The distribution of rainfall over time is uneven. About 90 percent of the total annual precipitation occurs from May through November, whereas the winter months receive only 10 percent. The distribution of daily rainfall events also shows great variation. The maximum daily rainfall event was recorded on June 3, 1967, with a rainfall of 155.1 mm. In this project, 24-hour design storms using the Qujing intensity-duration-frequency equation were calculated. In the past 50 years, two storm events have exceeded the 100-year storm measurement: June 3, 1967, and July 7, 1976 (Qujing Meteorological Bureau, August 2008).

3.3.4 Integrated Management Practices

3.3.4.1 Ecological Treatment of Water

Upon completion of the project, the Bai Chong Reservoir will receive inflow from three sources: (1) runoff from the catchment basin, (2) direct rainfall, and (3) inflow from the wastewater treatment plant (WWTP). Runoff from the catchment basins and the inflow from the WWTP tertiary effluent will be treated. Following LID criteria, different types of infrastructure are proposed to protect the reservoir from undesirable elements that could accompany its influents. Wetlands and bioswales are two types of biological infrastructure that will be used to filter and treat water inflows ecologically. Bioswales also act as a channeling network for urban runoff drainage control. One of the components in the reservoir water balance equation is the inflow coming from the catchment basin runoff. Before entering the reservoir, that important inflow must be adequately treated. Even if erosion control infrastructure is built upstream, water flow might carry undesirable elements. The proposed wetland treatment includes pollutant removal, reduction of suspended solids, and nutrient extraction. Storm-water-constructed wetlands are included in the plan because of the improvement in downstream water quality, settlement of particulate pollutants, biological uptake of pollutants by wetland plants, flood and flow attenuation, and relatively low maintenance costs (Oberts, 2001).

Wetland designs depend on the quantity of water to be treated and the nature of the pollutants and charges to be removed. Many configurations can be built to maximize this. For the Bai Chong Reservoir runoff inflows, different types of constructed wetlands are needed, depending on the flow quantity and quality they have to treat. A major storm water wetland will be created to treat the northern catchment basin runoff, and minor storm water wetland systems will be created to complete the Techno-Park area water runoff treatment.

3.3.4.2 Requirements for Wastewater

The PRC has established environmental quality standards for water, air, soil, and waste (Ministry of Environmental Protection of the People's Republic of China, & General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China [MEP & GAQSIQ], 2002). The Qujing Municipal Environmental Protection Bureau stipulated the pollutant emission standards to be applied for the proposed project. The effluent from the Bai Chong Reservoir drains to the Baishi River, two km south of the project site; it must meet Class IV surface water quality standards. Because the water from the WWTP will be recirculated in the Bai Chong Reservoir, the quality standards for the effluent from the WWTP have to meet Class I quality standards for surface water (MEP & GAQSIQ, 2002). The lake will be filled by rainwater and reused water. Domestic wastewater will be separated into two streams: gray water and black water. For potable water, a water treatment plant (WTP) will be installed at the discharge of the lake. The WTP will be used exclusively for potable water. A non-potable water network will also be installed. The network will be supplied by the WWTP tertiary effluent. The network will distribute water for non-potable purposes, such as for use in the park, and for services such as fire protection, plant watering, street cleaning, toilet flushing, and industrial cooling.

3.3.4.3 Water Balance Analysis for the Bai Chong Reservoir

As part of this project, the water level in the Bai Chong Reservoir will be raised by two meters. The reservoir, in its current state, is heavily contaminated. The restoration of the reservoir requires that the reservoir be emptied and a one-meter layer of soil, consisting mainly of sediment, be removed from the bottom of the reservoir. Further, the reservoir needs to be excavated to a total water depth of 15 meters to maintain biodiversity. To calculate the time needed to refill the reservoir and to determine whether the reservoir has a sufficient inflow volume to be sustainable as a source of potable water, a water balance analysis was performed.

The Bai Chong Reservoir water balance equation comprises the following components: water gains, which comprise runoff from the catchment basin, direct rainfall over the reservoir, and inflow from the WWTP tertiary effluent; and water losses, which comprise discharge, water uses, evaporation, and seepage. Because of the limited available data, a simplified water balance analysis was performed. The analysis used the meteorological data recorded at Zhang Yi Station and Xiao Xiang Reservoir, and was performed on monthly rainfalls under two climatic conditions: average year and dry year (P = 90%). This analysis was performed at two stages of the development: reservoir refill stage (lake will be empty) and normal operation stage at Phase I of the project development. The evaporation rate from the reservoir was assumed to be constant and equal to P = 75 percent, with a return period of 1.33 years. The amount of seepage and infiltration from the groundwater is negligible and the water demand for irrigation is entirely supplied by upstream reservoirs. This means that the runoff from the sub-catchment basin upstream of the reservoirs does not contribute to the refilling of the Bai Chong Reservoir. The surface area of the effective tributary catchment basin is 521 ha. The surface area of the reservoir is 18.6 ha. During the normal operational stage, there will be a constant inflow from the WWTP tertiary effluent, and a constant draw by the WTP. The constant inflow from the WWTP is 5,000 cubic meters per day (m^3/d) in Phase I and 16,150 m^3/d in Phase II. The constant draw from the WTP is 6,150 m^3/d in Phase I and 10,000 m^3/d in Phase II. During the normal operational stage, the water level in the reservoir will be maintained at a constant level, when possible. The results of the water balance analysis of the Bai Chong Reservoir for the refill stage are summarized in Table 3.6.

Table 3.6: Summary of Water Balance Analysis—Fill-Up for Phase I

Water Volume	Unit	Climatic Condition	
		Average year	Dry year
Gains	(m^3/yr)	1,921,000	781,000
Losses	(m^3/yr)	–161,318	–161,000
Balance	(m^3/yr)	1,760,000	620,000

After restoration, the water volume of the Bai Chong Reservoir was estimated to be 1,200,000 m^3. In an average year, the reservoir will receive 1,921,000 m^3 of water from surface runoff and direct rainfall over the reservoir, but will experience a loss of 161,000 m^3 due to evaporation. There will be a net annual surplus of 1,760,000 m^3 of water. We conclude that, in an average year, there will be enough water volume to fill up the reservoir. However, in a dry year, the surface runoff and direct rainfall to the reservoir will be only 781,000 m^3. With evaporation assumed to remain at a constant level of 161,000 m^3 per year, the net annual surplus will be only 620,000 m^3, which is insufficient to fill up the reservoir. The gap will be filled by recycling water from the WWTP.

It should be noted that the region's rainfall exhibits a significant monthly variation. Only 10 percent of the annual rainfall falls in the dry months (December–April). During the dry months, the water losses from the reservoir exceed the gains. Therefore, the water budget runs at a deficit. Another related issue is water quality. A wetland treatment system will be installed immediately upstream of the reservoir to ensure that all surface runoff to the reservoir meets the water quality objectives. Further, water quality management of the Bai Chong Lake and its water sources will be partially handled by constructed filter marshes.

3.3.4.4 Main Filter Marsh

The objective of the main constructed filter marsh will be to treat water coming from the northern watershed naturally. Because this is the principal source of water for the reservoir, it is important to control the water quality before it enters the reservoir. The design criteria of the filter marsh must be determined according to the quality and the quantity of the water to be treated and the amount of space available. The water sampling survey conducted on October 7, 2008, determined the concentration of elements in the upstream river entering from the northern watershed. The sampling results revealed that the river carries a normal daily load of suspended solids (21, 24, and 53 milligrams per liter [mg/L]), a high load of total fecal coliforms (3,500, 16,000, and 16,000 colony forming units per liter [CFU/L]), medium total phosphorus (0.027, 0.040, and 0.040 mg/L), and medium total nitrogen (0.357, 0.406, and 0.435 mg/L) concentrations. The planned constructed wetland (filter marsh) will decrease these loads to ensure good water quality. The combined wetland system of the main filter marsh is expected to remove elements in the following proportions: suspended solids, 80 percent; total phosphorus, 60 percent; total nitrogen, 30 percent; fecal coliforms, 70 percent; and heavy metals, 50 percent.

3.3.5 Land Planning

Four professional teams were involved in the development of the Techno-Park: Les Consultants LBCD Inc. was mandated to prepare the infrastructure master plan, and to conduct an initial environmental evaluation (IEE); Williams Asselin Ackaoui Inc. (WAA) was responsible for landscaping; Les Architectes Corriveau et Girard provided the building designs; and the consultant Design+Communication Inc. provided the site and exhibit interpretation plan. All the professionals worked in cooperation and agreed to respect the proposed approach as well as design the land use to mimic the natural site.

The AFTP will include the following buildings: an administration and information building, an earth sciences and plant protection building, a quality control building, a branding and marketing building, an agri-food and environment technologies building, a visitor services building, a greeting building, an industrial crops building with a one-ha greenhouse, a horticulture and fish farming building with a two-ha greenhouse, several industrial buildings for animal and plant processing, a cow-farm-equipment maintenance garage and workshop, a meteorology station, a traditional Chinese village as a tourist attraction, a hotel, a low-density residential area, and a high-density residential area, a WTP, a WWTP, and a composting site (Yunnan International Agri-Food Techno-Park [Qujing] Conceptual Design drawings).

The required infrastructure also includes road networks, a drinking water distribution network, a non-potable water distribution network, a sewage network and pumping stations, a gray water and storm water treatment system, storm water management facilities, a solid waste collection system, a geothermal system, an electrical power supply and street lighting, and public parking.

3.3.6 Consultation

The city of Qujing created a steering committee that consisted of two vice mayors, two representatives of the Developer, as well as the General Manager and the Assistant General Manager of the Qujing Industrial Park to participate in the development of the project. The committee met with the professional teams and Constellation Monde Inc. every two months. All departmental groups and stakeholders were involved in the consultation process.

Zhang Yunlong summarized the final comments on a review meeting as this:

> More than 30 offices and firms have met in recent weeks to develop and study the various concepts presented to develop the Technoparc. After review and discussion on the overall project, the jury believes that the project is positive and achievable. All responded favorably to the project. The file is well documented. The following are highlighted: 1. Appropriate planning and zoning; 2. Modern concept; 3. Objective of the project clear. The issues have

been well addressed; 4. Standard sustainable development of very high level; It is concluded that this project has no negative impact on the environment. This project will give a boost to the entire industrial park. The project is therefore, in principle, accepted by Chinese experts. In order to refine the concept, the panel proposes: 1) Ensure proper planning of the main entrance, and coordination with urban planning provided therein; 2) That all works are planned to be well aligned; 3) Further studies on the Lake Baichong are needed; 4) Assess the environmental impact of industries to adjacent park; 5) Study must be carried out for the specific choice of the route of the railway; 6) Assure that the design work of various works is performed in accordance with Chinese law.

3.3.7 Master Plan

The master plan included the proposed infrastructure to be installed in the 300-ha Techno-Park as outlined in Section 3.3.4. Interventions to enhance water quality will take place in the whole catchment area of the Bai Chong Reservoir. Therefore, for the purpose of the IEE and the Bai Chong Reservoir rehabilitation and storm water management project, the study area had to cover the total area of the AFTP (300 ha) and the catchment area of the Bai Chong Reservoir (681 ha). The infrastructure master plan was produced by the engineering group, based on the findings of the landscape architects and other stakeholders using the proposed integrated framework. Figure 3.8 provides an illustration of the landscaping master plan produced by WAA, and Figure 3.9 depicts the water supply master plan. The urban planning includes a residential development on the east side, agricultural activities on the north side, buildings for agro-food production on the west and south boundary limits, and greenhouses, a public market, and a traditional village in the center. The lake is central to the development. It is dammed by a filtration plant, and there are two distribution networks of water supply: one for raw water and one for potable water.

Figure 3.8: Landscape Master Plan (WAA, 2009)

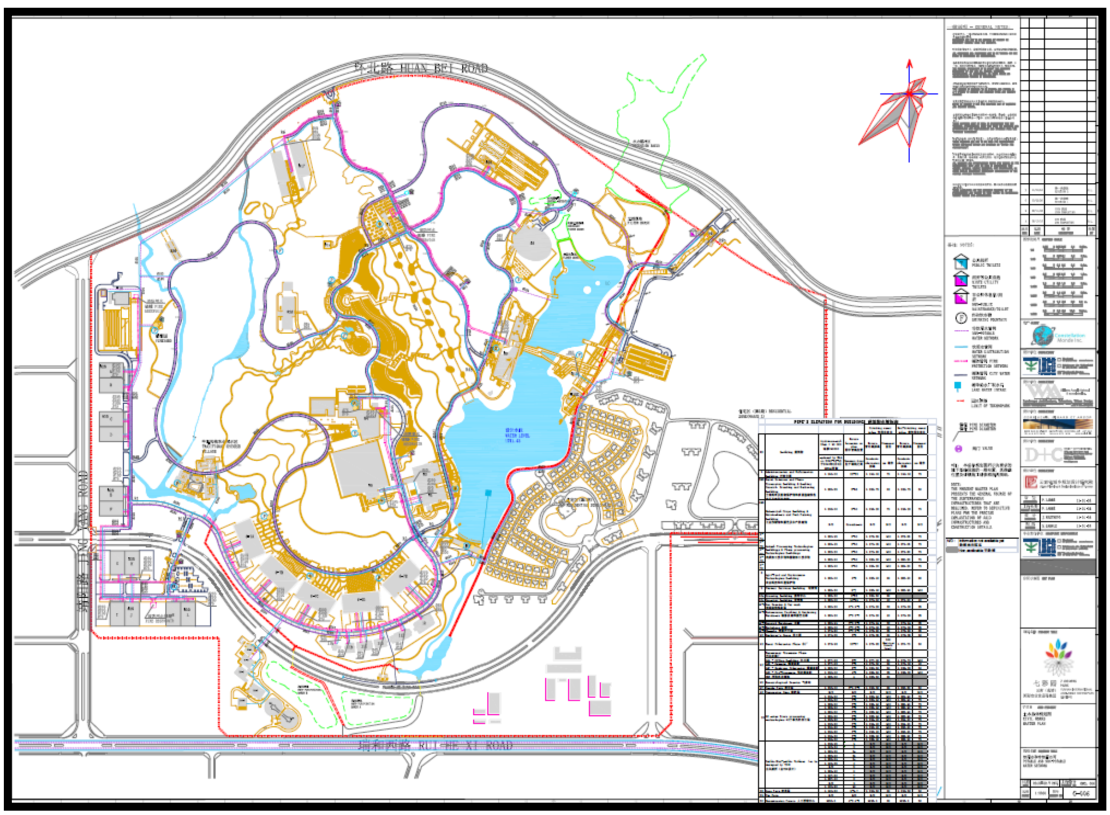

Figure 3.9: Water Supply Master Plan (Les Consultants LBCD Inc., 2009)

3.4 Discussion

3.4.1 Delay of Implementation

Even if the best master plan and the best design are performed, the implementation may encounter some pitfalls. In November 2011, the project was stopped for restructuring. Concrete and steel structures of most buildings had been erected. The lake had been dammed and excavated to 20 meters. A diversion channel had been built. Major roads had been completed. Then, the municipality asked Constellations Monde to propose an improvement to the ownership of the project. For that reason, the project was halted to review different aspects of project implementation. The major problem was found to be the institutional organization structure of the project. The capacity building of the local team was too weak to manage this project. A group of 60 employees was appointed to the construction management team. Three contractors, with 600 employees, were building the foundations and structures. Practically no one had experience with construction of large facilities. Seven international specialists were on-site to support them, but this was not sufficient. Communication between headquarters and the international specialists was very poor, and the responsibility of the project headquarters was not defined adequately.

The main causes of delay and the main cause of inefficacy in managing this project have been identified. The most important causes were: (1) improper planning by the project management unit (PMU), (2) PMU's poor site management, (3) inadequate contractor experience, (4) inadequate client finance and payments to complete work, (5) problems finding experienced subcontractors, (6) shortage of materials due to lack of construction market knowledge, (7) inadequate labor supply, (8) improper equipment availability, (9) lack of communication between parties. The main effects of the delay were: (1) time overrun, (2) cost overrun, and (3) some investors abandoned the implementation of their project in the park.

Sambasivan and Soon (2006) studied the problem of delays in the construction industry in Malaysia. They revealed that this is a global phenomenon. They identified the delay factors and their effect on project completion. Their study takes an integrated approach and attempts to analyze the impact of specific causes on specific effects. Many of their findings and those of previous studies are repeated in the Qujing Project. These causes are presented here and are findings of the Qujing experience.

Project management unit had improper planning. The PMU produced a nonpractical work program at the initial planning stage. This failure was interrelated with a lack of systematic site management and inadequate PMU experience with regard to the projects. Improper planning at the initial stages of a project is manifested throughout the project and caused delays at various stages.

Project management had poor site management. The PMU's poor site management was one of the most significant causes in the construction delays. Our observations indicate that the PMU and local contractors faced deficiencies in site planning, implementation, and controls. The poor site management resulted in delays and caused a negative effect on the overall work progress.

Inadequate contractor experience. Inadequate contractor experience was obvious on-site, and this could be linked to the contract-awarding procedure by which most projects were awarded to the well-known bidders in the city. These contractors with inadequate experience could not plan and manage the project properly.

Client's finance and payments for completed work was an issue. Payments to contractors were delayed for many months. The contractors found it difficult to bear the daily construction expenses when payments were delayed. Employees were not paid. Contractors could not keep sufficient employees on-site. Work progress was delayed owing to the late payments from the clients because there was inadequate cash flow to support construction expenses.

Finding contractors was difficult. In this project, there are many subcontractors working under main contractors. If the subcontractor is capable, the project can be completed on time as planned. In the present case, the project was delayed because the subcontractors underperformed owing to their inadequate experience or capability. This originated from the absence of qualified subcontractors in the region.

There was a shortage in material supply. This project was designed with high-tech materials. Shortages of adequate product in the region caused major delays in the project. This was also related to the inexperience of contractors in such a project.

There was a shortage of labor supply. The absence of quality and quantity of labor supply affected the project. Most workers were agriculturists. The low quality and productivity of these workers affected the project's progress and efficiency.

Equipment availability was deficient. Most of the contractors did not own the equipment that was required for the construction work. They rented the equipment, when possible. They proposed modifications to the design because they could not obtain the required equipment. This lack of equipment caused the progress of the project to be delayed.

Lack of communication between parties was an issue. Because of the many parties involved in the project (client, PMU, consultant, contractor, and subcontractors), communication between the parties was crucial for its success. There was an absence of structured communication channels in the project. Canadian companies performed the original design, and a Chinese company completed the final design to adapt it to Chinese requirements. There was difficulty explaining the solution proposed to solve the problem. In this case, two languages (Chinese and English) were used, and translation increased the communication difficulties. Problems like this with communication can lead to severe misunderstanding and, consequently, delays in the execution of the project.

3.4.2 Project Analysis

3.4.2.1 GI Elements

The master planning identified geographical and temporal parameters to be incorporated in the design criteria. The plan joined the two concepts of GI. From visits on-site, all hubs were identified and landscape architects proposed a continuous linkage system including greenbelts, greenways, ecobelts, conservation corridors, wetlands, and filter marsh. The water system is managed in a closed loop. The constructed reservoir is dammed with a filtration plant distributing two types of water: raw water and potable water. Capture of contaminated or wastewater is done by three different systems: gray water, black water, and storm water. Black water is reclaimed to be treated by a sophisticated tertiary treatment including reverse osmosis and ozonation. Gray water was treated by rain gardens. The storm water is treated with bioswales, bioretention, and filter marsh. All components of GI were introduced to manage infrastructure design. Each building has green building components such as solar panels, geothermic, solar walls, natural ventilation, green roofs, and natural light.

3.4.2.2 Integration

The master plan was coordinated with other sectors to accommodate future needs. The master plan integrated an analysis of functional protection elements of the landscape.

Although the project had the support of the city, the provincial government and the federal government, it is not clear if existing policies were coordinated with the needs of this particular project. One of the issues was to match existing regulations with this new GI project. Chinese building codes have not been adapted to incorporate green measures in buildings. Although the city had adopted a decree to authorize the project, the authorities of municipal departments required justifications to approve the design, and some green measures had to be removed from the project because they did not comply with local regulations.

In the province of Yunnan, there is no provincial or regional plan to guide introduction of such projects. The goals, strategy, and guide plan were presented to the Governor of the province, who had to approve them.

Consultation with stakeholders was done through direct meetings with small groups before designing the first elements of the plan. At the preliminary phase, three different meetings with all city departments were held to approve different phases of the project. An advisory committee was created to provide leadership in the project development.

Preparation of the master plan was performed by a diversity of professionals in many disciplines and representing multiple sectors: architects, landscape architects, engineers, biologists, environmentalists, botanists, sociologists, and communication specialists were working together to develop the final concept. Consultation among a diversity of professionals was done through monthly meetings.

The process of consultation did not permit the inclusion of an “adequate” public engagement process that provided stakeholders with ample opportunities to weigh in on the plan development. No NGOs, land trusts, or other conservation organizations were found to be engaged in the plan development. Nevertheless, provincial, county, and local governments did engage in the plan development.

3.4.2.3 Conservation Vision

The master plan was led by goals to protect ecological processes and functions. An environmental impact assessment was performed. The plan included some elements to protect working land. It included mitigation measures related to hazard waste management and for watershed protection. The master plan included goals for open space and its associated human benefits. It included goals for the preservation of cultural and historic resources. The project in itself is an ecotourism project including economic development activities that utilize conservation as a demonstration element.

As a negative element, during the construction, there was no control on construction companies to ensure they respected the mitigation measures. The authorities showed no willingness to preserve the environment.

3.4.2.4 Network Design Criteria

The master plan included a comprehensive assessment of landscapes and landscape features within plan parameters including biological, hydrological, geological, and human needs components. The plan included spatially explicit data sets that contain attribute information for landscape features. The network design included criteria for hubs and corridors incorporating ecological thresholds and other conservation parameters. Ecologists, environmentalists, and biologists were involved in producing the network design criteria based on current biological and ecological theories and best practices. The landscape architects assessed the conservation values for a range of spatial scales, including smaller parcel-level analysis. The final network design resulted in an ecologically connected framework. The network design incorporated a diversity of land uses including housing, industrial, and traditional agriculture activities.

3.4.2.5 Missing Elements

The master plan did not include a decision-support tool, but the plan allowed the incorporation of new data. The plan identified available mechanisms and tools for land protection, but the urban planning department did not want to include them in the regulations. The plan did not provide useful and effective ways to integrate the GI network implementation efforts into city regulations, planning, and capital improvement programs because the city deciders did not want to address this issue. Conservation funding opportunities were not found. The plan did not document strategies for leveraging existing funding sources to generate new sources of financing. The plan proposed an implementation strategy for the city, but no department was identified to manage it. The plan identified priorities for implementation, but the PMU was not interested. A PMU was created to coordinate and oversee implementation efforts.

Nevertheless, the personnel selected to do this had no relevant skills and no skill transfer program was adopted.

The plan identified necessary stewardship and management activities to restore, monitor, and maintain GI network resources over time, but there was no interest in these kinds of activity by public deciders, even though the deciders outlined a marketing and public outreach strategy to garner further support for the plan's goal. The plan defined development opportunities within the context of the GI network, and the plan identified a range of land uses to buffer priority protection areas from current development, but the authorities were not interested and changed it. The plan did not present a comprehensive strategy for funding the project.

3.4.2.6 Completion of the Project

The huge volume and complexity of subprojects in Qujing Agro-Park's construction project resulted in a major challenge, but provided many opportunities to various companies in the Qujing construction industry. Nevertheless, local companies did not succeed in meeting the challenge. The project was delayed for one year and was still not completed at the end of 2012. Currently, one industrial building is completed and the construction of two buildings started in November 2012. Over 30 buildings in the housing sector are completed. When reorganizing, the private sector became involved in financing the housing development. The industrial sector was granted by the city of Qujing and the private sector invested in the construction. Public infrastructures were funded by the city and granted by the provincial and federal government.

3.4.3 Capacity Building

As stated, one of the major issues to emerge in this project was the absence of capacity building. To save money, at the beginning of the project, the Client argued that they did not need support to analyze the organization and that they already had a strong construction team to manage the project. The delay of two years to complete the project indicated that this factor failed to be understood. In the inventory phase of a project, to ensure successful achievement, it is important to measure the capacity building of the organization and propose a skill transfer program.

In a situation such as this, the training program may be prepared with a Systems Approach to Training (SAT). SAT represents a proven training approach that is at the base of most training methodologies. SAT is the planned grouping and sequencing of training preparation and delivery activities, and commonly consists of five phases: (1) analysis phase, (2) evaluation phase, (3) training phase, (4) conduct phase, and (5) validation phase.

SAT has been used successfully to seek solutions to problems within complex operating environments. It is essentially a logical process or a way of viewing problems and their solutions in systems terms. It is a methodology applied to solving problems in the training domain. In simple terms, SAT involves defining the problem, clarifying the problem, and establishing the desired objectives. The approach also includes analyzing the problem, and identifying alternative solutions and means of achieving the objectives. It also involves selecting the optimum solution, developing the most appropriate or practicable of the means identified, and then implementing the solution and observing the results. Finally, it entails evaluating the results, determining the effectiveness of the solution, and feeding back results for improvement, as necessary.

As a systematic process of interdependent phases and activities, SAT results in cost-effective training that directly supports performance. The main objective of skill transfer is to strengthen the PMU's engineering and technical capacity and to assist the PMU in developing engineering skills and competency in project administration through an on-the-job training program.

3.4.4 Final Implementation

Achieving a GI project is not always possible. The design is a major undertaking, but the implementation can create great uncertainty and may require even greater efforts.

The introduction of new technologies has led to much resistance in the Qujing Project. Chinese engineers are used to working from schematics and preset techniques. The calculations are often made from tables. The new green techniques need trials and tests, which reduces the confidence of the Designer in the effectiveness of the project's implementation. That new techniques of ecological design have not been tested and have created great uncertainty among Chinese designers. Calculations require more time because they have to be more detailed. In a context such as China, this uncertainty is magnified because all designs of highways, roads, and streets are standardized in design manuals. For example, culverts for storm water are all standard. In major centers such as Beijing, Shanghai, and Xiang, engineers are bolder and can propose new techniques. Outside major centers, resistance to change is very high, and this was the case in Qujing; all new proposed technologies had to be demonstrated and explained to the technical authorities. Officers from several departments of the city of Qujing discussed new proposals and required that provincial and national authorizations be obtained.

The second difficulty was the ability to manage such a project and to implement new technologies. Institutional support was not adequate. The lack of expertise in construction management delayed the project to the degree that it was stopped for more than two years. The lesson we drew from this experience is that a training program must accompany the introduction of new approaches.

3.5 Conclusion

3.5.1 The Framework and Case Study

To fill the gap caused by a lack of integrated frameworks incorporating wastewater treatment, water filtration, and water supply, this research developed and introduced a new framework integrating all of the components of water management in GI. This framework was then applied to a case study in Qujing AFTP in China. The resulting project's conceptual design is based around a constructed lake, acting as the "heart" of a closed loop. Water is split into different components for specific uses, and then, after usage, wastewater is rejected separately according to the type of contamination. Storm water is managed with the LID concept. The system of treating water copies nature by incorporating natural features such a rain gardens, bioretention, bioswales, and wetlands. The lake is designed as a large reservoir to secure the water supply. The wastewater treatment system has two components: one with sophisticated high-tech treatment for black water, including two barriers of disinfection, and the other one for gray water and rainwater at a microlevel, with natural features such as infiltration beds and wetlands. The project plan was developed and implemented following the main principles of both IWRM and AM.

The realization of this project gave us the opportunity to develop a new management framework for the implementation of GI in a new development. The new model proposes integrating the European concept of natural hubs and links with the American concept of GI. It also extends the storm water management infrastructure approach with the idea of a looping water cycle so that reuse of wastewater and storm water is maximized. The basic idea is to mimic nature and reuse water. In the context of the soft water shortage, mainly in developing countries, maximizing water conservation, natural storage, and water reuse will address this problem. In developing a new urban project, it is proposed that the concept be studied and developed in six steps:

1. Prepare inventory to take a picture of the site and understand stakeholders' needs.
2. Study the hydrology and conduct a hydraulic assessment to understand the natural flow of water.
3. Propose IMP to introduce the new concept of a closed loop.

4. Develop land planning to mimic nature.
5. Prepare a consultation to review the stakeholders' needs already identified in step 1.
6. Propose a master plan to define an initial solution in designing the project.

This project is an example of a totally integrated GI project. Although the implementation has been postponed, in the end, the project will be totally or partially completed. The cost of two versions of the project was evaluated at the start. Table 3.7 presents a comparison of the costs of the two options and shows that, in this case study, the cost of the GI approach was 15 percent higher than the conventional infrastructure approach.

Table 3.7: Cost Evaluation

	QUJING GI ($)	Conventional Design ($)
WATER RESERVOIR RESTORATION	**14,179,000**	**14,179,000**
WATER FILTRATION PLANT	**24,000,000**	**24,000,000**
WASTEWATER TREATMENT PLANT	**85,138,000**	**67,100,000**
Pumping and maintenance	9,000,000	9 000,000
Pretreatment	4,200,000	4,200,000
SBR	20,000,000	20,000,000
Ultrafiltration	11,600,000	11,600,000
Reverse osmosis	22,200,000	–
Sludge treatment	14,300,000	14,300,000
Extra for gray water treatment	–	8,000,000
GRAY WATER TREATMENTS and reuse	**200,000**	–
STORMWATER TREATMENT	**12,200,000**	–
Bioretention; bioswales	2,200,000	–
Main filter marsh	1,700,000	–
Secondary filter marsh	450,000	–
TOTAL	**121,538,000**	**105,279,000**

3.5.2 Further Research

The closed concept could be studied further using a central closed reservoir to capture the water. Risk analysis suggests that water coming from wastewater might be contaminated. However, despite decontamination of recycled water being compulsory, this issue is not well documented and needs further research.

In addition, although the integrated framework that is proposed in this paper does not include capacity building, further research could focus on including specific capacity-building activities in the project plan. Low levels of human and institutional capacity in the case study area became a problem during the construction phase of the AFTP. Because of this issue, the project was delayed and, so far, less than 50 percent of the project has been completed, despite the estimated project completion date having passed. Currently, the construction management team is being reorganized to address issues of capacity building. The original financial planning proposed that the city fund the project. With reorganization, the private sector will complete the project and it will lose its demonstration and education aspects.

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Connecting Statement to Chapter 4

In Chapter 3, the new concept of integrated GI, IWCA, was developed with a new framework proposed for starting a GI project.

The findings of Chapter 3 were applied in preparing a feasibility study of a new project in Vaudreuil-Dorion. The analysis of this new project was structured using the newly proposed framework. However, the city officers of Vaudreuil-Dorion asked the question, "how much will a green project cost and is there a payback on such a project?"

The main idea of Chapter 4 is to demonstrate that there is a return on investment and an economic justification in designing "green" instead of designing "conventional." To promote the introduction of GI instead of standard design, developers and municipal decision makers must be convinced that there is an economic justification for choosing GI.

Thus, as presented in Chapter 4, two versions of the same project were designed in detail—green and conventional—with the same framework analysis.

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Chapter 4: Costs and Benefits in Housing Development

This chapter is presented as published.

Additional discussion to clarify objectives and findings is presented in Chapter 5.

Different Methods to Assess Green Infrastructure Costs and Benefits in Housing Development Projects

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A Water-Centric Approach to Develop Green Infrastructure: Framework and Cost

Abstract

Given the general lack of empirical data for evaluating green infrastructure (GI) in housing development projects, this study analyzed the costs and anticipated benefits of a GI housing project development in the city of Vaudreuil-Dorion, Quebec, Canada, including roads, drainage, water supply, and wastewater. The concept of managing storm water, wastewater, and water supply connected to a constructed lake within a closed loop has not previously been evaluated in detail. This study evaluated the economic costs and benefits of the investment in dollar terms using three methods of calculation: (1) the Center for Neighborhood Technology National Green Values™ Calculator, (2) the Canada Mortgage and Housing Corporation's Life Cycle Costing Tool, and (3) cost-benefit analysis. The findings of this study indicate that a GI project can provide significant economic and environmental benefits to cities.

Key words: green infrastructure, hedonic price, benefit transfer method

4.1 Introduction

There is increasing public and government interest in establishing green technologies in project development, because of their demonstrable environmental benefits (United States Environmental Protection Agency, 2009). Despite their potential as a climate change adaptation and mitigation tool and their widespread use in Europe and the US, there are very few examples of green development in eastern Canada. Further, even though there is increasing interest in sustainability in many locations and demonstrated capacity for urban design solutions, cities today are having difficulty investing in systems that are long term and ecologically sound (Suzuki, Dastur, Moffatt, Yabuki, & Maruyama, 2010). One of the major barriers to increasing the prevalence of extensive green projects is the lack of scientific data available to evaluate their applicability in local conditions. A second barrier is the absence of comparable costs for developing a project with a "green approach." However, it has been suggested that green infrastructure (GI) can accomplish many of the same goals as hard-engineered infrastructure at a lower cost (Hansen, 2010) and that an integrated GI approach to housing development can deliver economic and environmental benefits as well as significant cost savings for municipal infrastructure (Wise et al., 2010).

The terms "value system," "value," and "evaluation" have a range of meanings in different disciplines. "Value system" refers to norms and precepts that guide human judgment and action (Farber, Costanza, & Wilson, 2002). The term "value" means the contribution of an action or object to user-specified goals, objectives, or conditions (Costanza, 2001). In the current context, "ecosystem evaluation" is the process of expressing a value for ecosystem goods or services to provide the opportunity for scientific observation and measurement (Farber et al., 2002). In the specific case of housing development, "value" means willingness to pay a sum to acquire a house. "Benefit" refers to tax revenue for the municipalities and improvement value to the environment.

Infrastructure investments have brought GI and low impact development (LID) practices into cities' municipal infrastructure investment strategies. The difficulty lies in integrating the evaluation of multiple benefits, quantifying benefits that may not be easily monetized, and bringing recognition of these values into infrastructure investment decisions by developers, communities, and agencies (Wise et al., 2010). When services are directly tradable in normal markets, the price is the exchange value. When there are no explicit markets for services, we must resort to a more indirect means of assessing economic values (Farber et al., 2002). In the context of municipal planning and infrastructure investment, the prudent application of limited financial resources may appear at first as a constraint to sustainable development. However, there is growing evidence that strategies and technologies that are supportive of sustainability are possible and relevant, and that they provide services at lower costs, and even at lower capital investment, than conventional approaches (Centre for Sustainable Community Development, 2004).

The city of Vaudreuil-Dorion, Quebec, Canada, has decided to introduce green concepts into new housing development projects to attract new stakeholders. To determine how GI compares with conventional infrastructure (CI) in the suburban context, this study evaluated the construction cost of infrastructure such as roads, drainage, water supply, and sewerage facilities in a new housing development in Vaudreuil-Dorion. Housing is an extreme example of a differentiated product, in the sense that every house is different, in terms of both its physical characteristics and its location (Hill, 2011). A green environment may increase house value by five to 25 percent.

The hedonic price method (HPM) is used to value ecosystems or ecosystem services that directly affect market prices (King & Mazzotta, 2000). Hedonic price models have commonly been used to estimate house prices and property values (Limsombunchai, Gan, & Minso, 2004). In France, Cavailhès (2007) established a hedonic price for scenery. The results of another study confirmed the positive amenity effect of proximate urban green spaces on house prices in Jinan City, China (Kong, Yin, & Nakagoshi, 2006). In another study, green space amenity variables that were statistically significant at the five percent level included the size–distance index of forest scenery and accessibility to park and plaza green space types (Kong et al., 2006). In the Regional County Municipality (MRC) of Vaudreuil-Soulanges, where Vaudreuil-Dorion is located, the development of projects in different cities has demonstrated the attraction of buying a house in a green environment. Saint-Lazare, which has a naturally greener environment than Vaudreuil-Dorion, has a housing evaluation per inhabitant that is 27 percent higher than that of Vaudreuil-Dorion. These figures are supported by the following case study.

4.2 Literature Review

The economic dimension of value is only one of the many relevant factors that make humans value ecosystems (Villa, Ceroni, & Krivov, 2007). Traditional valuation techniques, such as cost-benefit analysis and contingent valuation, may not be adequate for valuing the ecological and social functions of urban green spaces, which is required to strengthen their role in the decision-making process within local communities (James et al., 2009).

In 2011, Hill published a paper for the Organisation for Economic Co-operation and Development on hedonic methods. House prices as a function of a vector of characteristics were deemed particularly useful for this purpose. In his report, Hill considered some of the developments in hedonic methodology as applied in a housing context that have occurred in the past three decades. Hill mainly presented and explored modeling methods to predict house prices. It is often difficult to see how hedonic methodology indexes relate to each other. For this reason, Hill attempted to impose some structure on the literature by developing a taxonomy of hedonic methods, and demonstrated how existing methods fit into this taxonomy.

There are many methods used to estimate dollar measures of economic values associated with ecosystems. King and Mazzotta (2000) developed an approach to evaluating ecosystems in general and, specifically, in the housing market. They outlined eight different methods to measure the cost of projects in their publication: market price method; productivity method; hedonic pricing method; travel cost method; damage cost avoided, replacement cost, and substitute cost methods; contingent valuation method; contingent choice method; and benefit transfer method (BTM).

In the context of housing development, the HPM and BTM are more relevant for identifying benefits because willingness to pay can be quantified; therefore, this study will refer to these methods. Traditional house price prediction is based on cost and sale price comparison that is lacking in accepted standards and a certification process (Limsombunchai et al., 2004).

There are few tools available for comparing construction costs in different types of housing development. In 2008, the Canada Mortgage and Housing Corporation (CMHC) created the Life Cycle Costing Tool (LCCT) for community infrastructure planning to allow users to estimate the major costs of community development and to compare alternative development scenarios. The tool is geared toward estimating planning level costs and revenues associated with the residential component of a development (Pollard, 2008). In 1996, the Asian Development Bank published *Economic Evaluation of Environmental Impacts: A Workbook* (Bando, Raucher, Lohami, & Owens, 1996). The book provides a set of working tools to incorporate environmental costs and benefits within project analysis. Today, the workbook is still considered current because it emphasizes evaluation of environmental economic analysis. In 2009, the Center for Neighborhood Technology (CNT) produced the National Green Values™ Calculator (GVC) and published the detailed benefits of GI. The CNT reviewed current methods of evaluating the economic and social benefits of GI practices (Center for Neighborhood Technology [CNT], 2009a).

Another tool is the Environmental Valuation Reference Inventory™ (EVRI), which is a searchable storehouse of empirical studies on the economic value of environmental benefits and human health effects. The EVRI has been developed as a tool to help policy analysts use the benefits transfer approach, as an alternative to conducting new valuation research (Environment Canada, 2006). The EVRI can provide indicators for evaluating environmental benefits. Environment Canada developed the EVRI in collaboration with a number of international experts and organizations, particularly the Office of Water, United States Environmental Protection Agency.

Foster, Lowe, and Winkelman (2011) proposed an evaluation of all feature benefits. The value of GI actions is calculated by comparison with the cost of hard infrastructure alternatives, the value of avoided damages, or market preferences that enhance value (such as property value). GI benefits can generally be divided into five categories of environmental protection: (1) land value, (2) quality of life, (3) public health, (4) hazard mitigation, and (5) regulatory compliance (Foster et al., 2011).

In 2005, Wachter used the New Kensington Greening Program to model the economic benefits of place-based investment strategies. The potential benefits of these investments can be identified by measuring the additional value that people place on living in neighborhoods where such investments have been made (Wachter, 2005). Wachter employed hedonic regression techniques in her study. The study found that vacant land improvements result in surrounding house value increases of as much as 30 percent, and new tree plantings increase surrounding house values by approximately 10 percent. In the New Kensington area, this translates to a US$4 million gain in property value through tree planting, and a US$12 million gain through lot improvements. The direct and indirect effects of greening on the city's property tax base are likely to contribute to the overall fiscal health of the city of Philadelphia (Wachter, 2005).

In the housing context, a distinction can be drawn between omitted variables that relate to the physical characteristics of a dwelling and those that relate to its location. Many characteristics may appear in hedonic regressions for housing, such as square footage, land area, bedrooms, garages, and swimming pools (Hill, 2011). In the current study, these parameters do not need to be considered, because the focus is on willingness to live in a green development. In 2005, Bourassa, Cantoni, and Hoesli used a sample of sales transactions from Auckland, New Zealand, to demonstrate that housing submarkets defined as small geographical areas have more practical utility than submarkets defined without regard to spatial contiguity. Moreover, submarkets matter in a way that underscores the value of the practical knowledge of appraisers (Bourassa, Hoesli, & Peng, 2003). Not only do submarkets matter, but geography also makes a difference. The sale price is approximately 10 percent higher when there is a water view (Bourassa et al., 2005). The quality of the neighborhood is very important, and higher quality is associated with higher prices. A property with high-quality neighboring properties would be valued, on average, 38 percent higher than the same property with poor-quality neighbors (Bourassa et al., 2003).

Hill (2011) explored modeling methods to predict house prices. King and Mazzotta (2000) surveyed multiple methods to estimate dollar measures of economic values associated with ecosystems. Wachter (2005) modeled the economic benefits of place-based investment strategies. The tools commonly preferred in the literature to compare housing development are the LCCT and GVC. In the context of housing development, the HPM and BTM are relevant and needed for measuring benefits and increases in property value.

4.3 Methodology

The management of storm water, wastewater, and water supply connected to a constructed lake in a housing development is a relatively new concept that has not received much attention in the past. The Vaudreuil-Dorion 540 Development Project is in the preliminary phase of project preparation, and is conceptualized here with a new framework. The proposal is currently at the stage of investigation.

This study addresses hard costs and house values. The economic analysis was of a quantitative type, and the economic evaluation used was the rapid analytic method, including the BTM and HPM. The basic analytical framework considered a preliminary design of infrastructure components, comparing the CI and GI approach. Three methods of evaluation were used: the LCCT, the CNT calculator, and economic analysis. Hard costs were determined first, and then the HPM and BTM were used to determine the value of the housing properties.

The HPM is a "revealed preference" method of valuation because it infers the value of environmental features from the prices of traded goods (Gundimeda, 2007). It is applicable in those cases in which the price of a good is directly influenced by environmental factors (Alberini, 2004). The HPM of environmental valuation uses surrogate markets for placing a value on environmental quality, and the HPM relies on information provided by households when they make location decisions (Gundimeda, 2007).

The HPM is appropriate in the housing market because it expresses preferences and willingness to pay a price. The price of a property is determined by the characteristics of the house. The HPM is used to estimate the extent to which each factor affects the price. In the present case, building with GI should be beneficial to the housing project. The benefit may be demonstrated by an increase in hedonic price value. For this reason, this method of valuation is very effective in demonstrating the benefit of GI to customers who are searching for a better quality of life (Hill, 2011). According to the literature, GI design should increase house prices by five to 25 percent (Bourassa et al., 2005; Wachter, 2005) because householders are willing to pay more for a green environment. This estimation is tested in this study.

The BTM is an alternative method of obtaining non-market values. It is used to assign monetary values to non-market goods. This approach is often applied to evaluate the environmental impact of a project: "It involves 'transferring' values that have already been estimated for a similar good or service from another location to the current location. The approach is useful because surveys are costly in terms of time and money" (United Nations Economic and Social Commission for Asia and the Pacific, 2011). The use of the BTM as an alternative valuation method has some advantages. From a practical perspective, the BTM has the advantage of reducing both time and financial resources that are needed to develop separate evaluations for each individual policy decision (Eshet, Baron, & Shechter, 2007). BTMs apply valuation results produced in prior research to a new context, and conserve time and resources by obviating the need to carry out an original study (Jenkins & Kramer, 2008; Plummer, 2009). For this reason, the BTM was also selected to evaluate costs in this proposed case. In this study, the BTM was used as a complementary method to demonstrate benefits and estimate costs. Unit costs from other completed projects were used in the comparison and valuation of the Vaudreuil-Dorion project site infrastructure costs. As an example of BTM in this specific study, the CNT calculator estimates costs only in US cities. Nevertheless, the conditions described in the US cities near the Canadian border can be considered similar to the Canadian context. To use the CNT calculator in Canada, a similar city must be selected in the US, and then the results for that city can be transferred to the designated city in Canada. This is what was done in this study for Vaudreuil-Dorion.

A third method, the LCCT, was used to correlate results. Meta-analysis is a general term for any methodology that summarizes results from several studies. In the case of environmental benefit transfer, benefit estimates gathered from several studies serve as the dependent variable in regression analysis, and the characteristics of the individual studies serve as the independent variables (Dumas, Schuhmann, & Whitehead, 2005). The present study combines different methods to calculate prices and costs.

Economic evaluation is different from financial analysis, which is concerned with a project's return on investment or its profits and losses. Financial analysis of projects relates to the costs, revenues, and payments of a financial measure in market price. In contrast, economic evaluations are based on the project's costs and benefits to the economy as a whole, measured in economic values (Bando et al., 1996). The present study develops an economic analysis.

Beauchamp, Adamowski, and Beauséjour (2011) presented a paper to structure the development of a new green development project. The authors used a new framework to design the proposed project. The framework includes six steps: (1) inventory, (2) hydrological and hydraulic assessment, (3) integrated water resources management, (4) land planning, (5) consultation, and (6) master plan (Beauchamp et al., 2011). This methodology can be applied in a housing development project. In the next section, this approach will be applied to the Vaudreuil-Dorion housing project, and the described valuation methodology will be applied to calculate the costs and benefits of the project. It should be noted that the first author of this paper is a senior Vice President at exp, the engineering consulting firm that was involved in the preliminary study of the Vaudreuil-Dorion housing development project. The first author of this paper was involved in all aspects of the design of this proposal and, therefore, all the calculations and design considerations and specifications presented in this paper are the outcome of the work conducted by the first author**.**

4.4 Case Study: Vaudreuil-Dorion 540 Development Project

The city of Vaudreuil-Dorion is a suburban neighborhood of Montreal in the province of Quebec, Canada. Its population has grown from 5,000 in 1982 to 31,471 in 2011. The existing master plan was designed to service 35,000 residents. The city of Vaudreuil-Dorion is evaluating the feasibility of creating a new development covering a 600-hectare (ha) area in an underdeveloped sector. This project gives the city an opportunity to plan an ecosustainable development close to the urban perimeter of the city and to protect the city's greenbelt. Because the city's existing infrastructure was not designed to handle the extra demand generated by new development, a new master plan must be developed to provide services such as roads, drainage, water supply, and wastewater collection to housing and institutional development in this area. Incorporating GI practices at the scale of the municipal neighborhood and site could protect the environment and avoid flood problems in the sector. Figure 4.1 shows the site to be developed. The existing residential area of the city is located between highways 40, 20, and 540, and the Lake of Two Mountains.

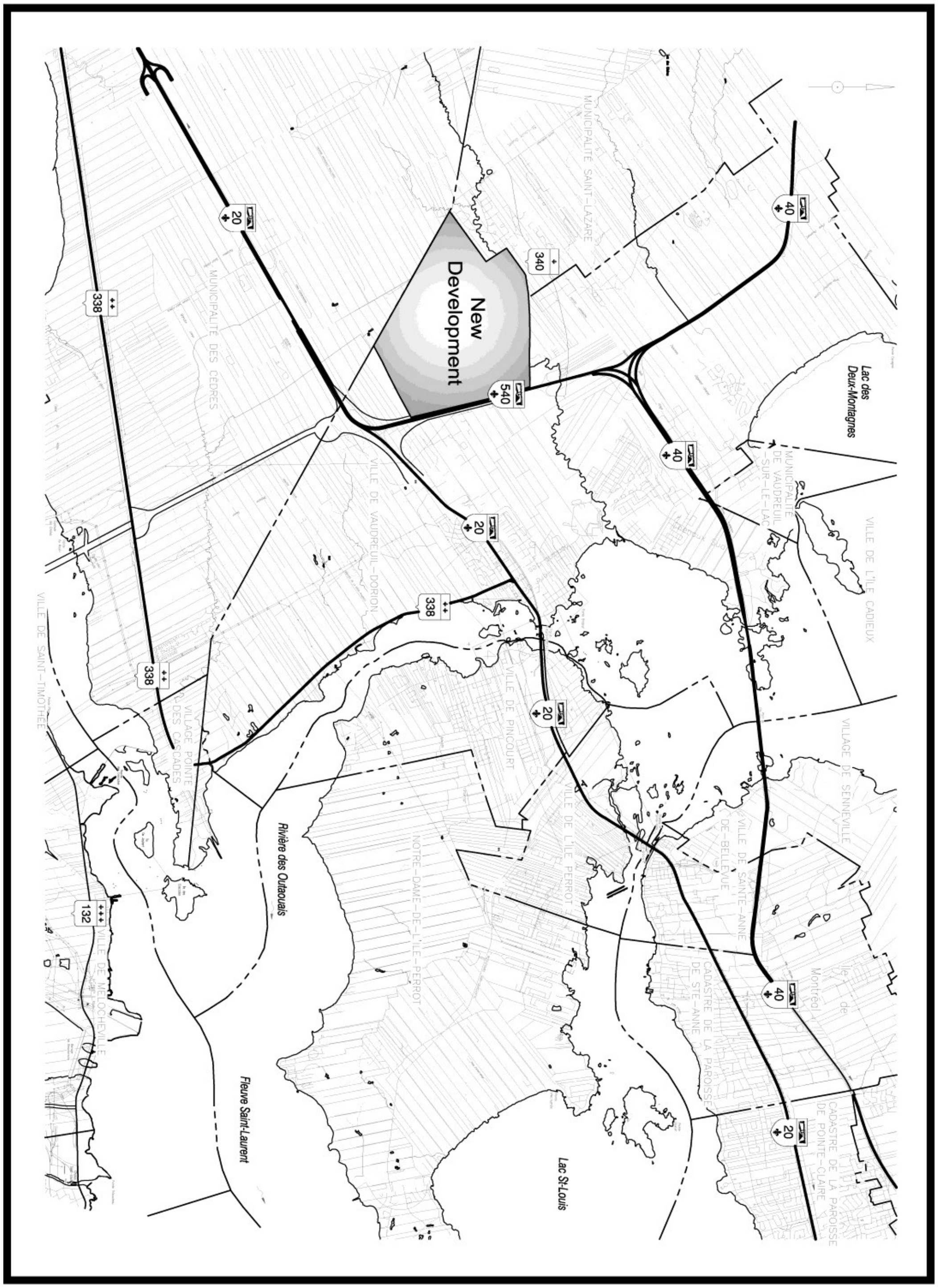

Figure 4.1: New Development Site

The potential new development is located southwest of highway 540 between the railroad and highway 20 (see Figure 4.1).

The population of the MRC of Vaudreuil-Soulanges is projected to grow to 270,000 in the next 20 years, meaning that a new institutional pole will be needed to service the region. Vaudreuil-Dorion wishes to develop this institutional pole and welcome 10,000 new residents to live in the sector. The principles of sustainability, environmental protection, and ecological balance will be highly valued in the development of this project. Vaudreuil-Dorion proposed a “green development,” which is a broader concept than GI. Green development involves green space management that conserves natural ecosystem functions and provides associated benefits to ecosystems, including humans. It involves hubs and links. There are green hubs, such as forests and lakes; functional hubs, such as housing; as well as commercial and institutional hubs. Roads and pedestrian alleys are urban links; these may or may not be green. Conservation corridors, greenways, and greenbelts provide links between green hubs. Green development needs GI, and green links are essential to preserve green hubs.

This concept has been applied to the design of this project. Figure 4.2 shows the actual situation in combination with the proposed scheme, which respects existing links and hubs.

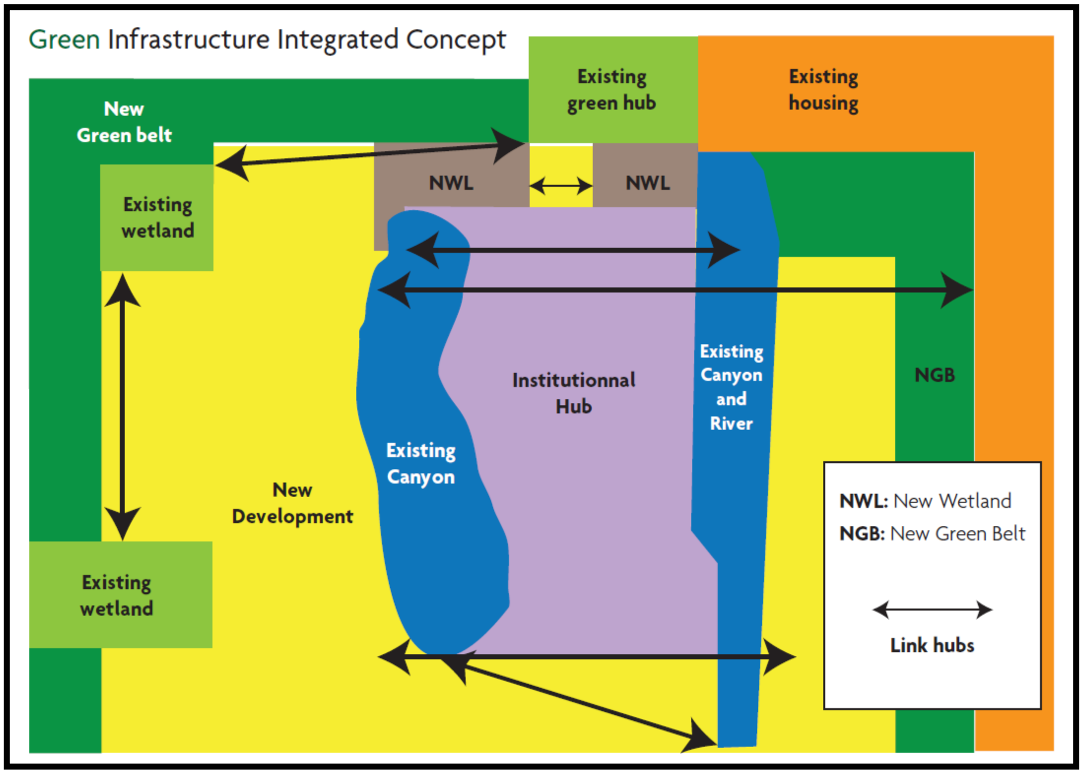

Figure 4.2: Hubs and Links in the Vaudreuil-Dorion 540 Development Project

4.5 Project Framework

The following sections describe the proposed housing project with reference to the framework proposed by Beauchamp et al. (2011). The six components are summarized below.

4.5.1 Inventory

Following the site inspection and inventory, poles and hubs are shown in a schematic (see Figure 4.2). The main function of the future development is the institutional function, which is central to the development. Other functions are housing and commercial services. The hubs in the area include a river, two existing wetlands, a forest, and a creek.

The topography shows two small canyons, one for the river crossing the development and the other where the creek is flowing. The site forms a large catchment area flowing into the river and there are three sub-catchments on the site. Available topography is not detailed, although it does show principal levels. Existing hubs and proposed functions are represented. Links between proposed functions and existing hubs were created. Existing wetlands and green space are to be preserved and linked, creating a greenbelt around the project. A new lake would be built to become the core node of the water management cycle.

4.5.2 Hydrology and Hydraulic Assessment

The study area is a sub-catchment basin of the Quinchien River. The entire catchment area of the Quinchien River covers 2,846 ha across three municipalities: Vaudreuil-Dorion, Saint-Lazare, and Les Cèdres. An extensive hydraulic study of the river was completed in 2007, identifying a risk of flooding in downtown Vaudreuil-Dorion. One of the solutions proposed was to create a retention basin. The retention basin could be incorporated into the present project. In this case study, the SWWM5 model was used to develop hydrographs of the sub-catchment areas. The WinTR-20 model of the US Department of Agriculture was used to calculate open-ditch runoff, and the HEC-RAS model of the Hydrologic Engineering Center of the US Army Corps of Engineers was used to perform river hydraulic calculations under various conditions. In this study, the Type II synthetic rainfall pattern developed by US Soil Conservation Services was used to develop synthetic design storms based on data from the Sainte-Anne-de-Bellevue meteorological center from 1963 to 1990.

4.5.3 Integrated Management Practices

The sustainable management of water is one of the key challenges in the development. The planning and design of water management infrastructure should respect the Leadership in Energy and Environmental Design (LEED) criteria if the Developer wants to qualify for the program and then integrate LID techniques into the approach. In this study, it is proposed that the project be taken a step further than the LID standards: the domestic water in the project will form a closed circuit, and none will be rejected from the project.

The principle of the design of housing services will include water use reduction, consumption at source reduction, water-efficient landscaping, use of non-potable water, innovative wastewater technologies, and storm water management. Integrated water resource management (IWRM) is a strategy that integrates all facets of the water cycle, including points of consumption and discharge, water supply (potable and non-potable), sewage, and storm water management. The conceptual IWRM model developed for this project is shown in Figure 4.3.

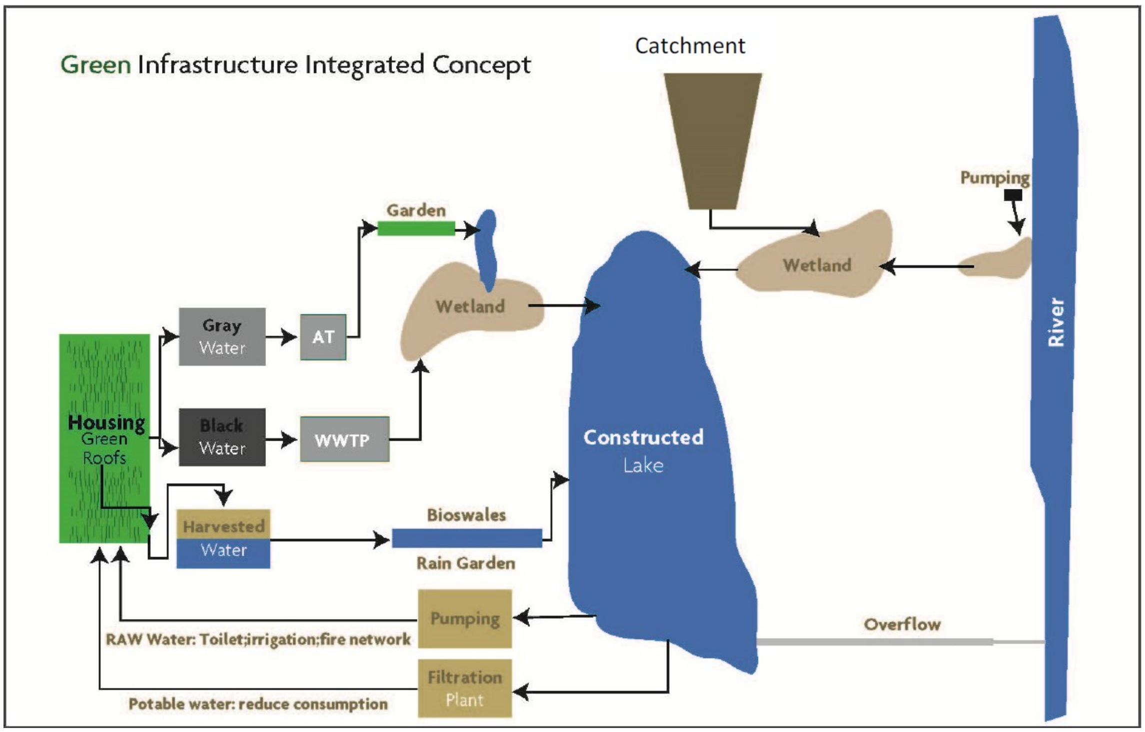

Figure 4.3: Integrated Approach for the Vaudreuil-Dorion 540 Development Project

The conceptual IWRM model includes the following features. All infrastructure services for housing will be integrated in a new concept, in which water consideration drives other elements of the design such as roads, bridges, and landscape. As a measure of water use reduction, the domestic water demand is separated into two groups: potable water and non-potable water (water required for fire protection, watering of plants, street cleaning, and toilet flushing is categorized as non-potable). Separating non-potable from potable water reduces the capital and operational costs of the wastewater treatment plant (WWTP).

Domestic wastewater will be separated into two streams: gray water and black water. Gray water is wastewater generated from domestic processes such as dish washing, laundry, and bathing. Wastewater from toilets is categorized as black water. The main difference between gray water and black water is the organic loading. Black water has a much higher organic loading than gray water. By keeping gray water separate from black water, gray water can be readily treated by natural ecological treatment systems. This leads to a reduction in the capital and operational costs of the WWTP.

Upon completion of the project, a reservoir (lake) will receive inflow from three sources: (1) runoff from the catchment basin, (2) direct rainfall, and (3) inflow from the wastewater reuse facilities. Runoff from the catchment basins and the inflow from the wastewater reuse facility need to be adequately treated. Here, attention is directed to protecting the water quality of the lake. Following the LID criteria, the proposed infrastructure aims to protect the reservoir from undesirable elements that could be introduced from the influents. Wetlands and bioswales are two types of biological infrastructure that can be used to filter and treat water inflows ecologically. Bioswales act as a channeling network for urban runoff drainage control, collecting runoff during rainfall. One of the components in the reservoir water balance equation is the inflow coming from the catchment basin’s runoff. Before entering the reservoir, this important inflow must be adequately treated, which can be achieved by passing it through wetland.

For the management of storm water, LID techniques will be used to create a treatment system. Peak storm water flow from the catchment area will be attenuated by three types of infrastructure: (1) green roofs, (2) rain gardens, and (3) LID techniques, including bioswales and wetlands in the project site.

4.5.4 Land Planning

At this stage, an initial conceptual plan of land uses is proposed for evaluation and consultation. While maintaining more than 40 percent green space, the project could support a population equivalent to 34,000 people at maturity of the institutional pole. Of these, 16,000 would be inhabitants and 18,000 would be in the workforce.

The type of land use was studied by the MRC of Vaudreuil-Soulanges to preserve the natural habitat. A study was prepared by the urban planning firm Sotar to determine the location of a new hospital. Table 4.1 shows the maximum population that the sector can accommodate. However, environmental studies will reduce these figures upon completion of the land protection plan. For the purposes of the present study, the preliminary design has been calculated for a maximum of 13,600 inhabitants.

Table 4.1: Maximum Land-Use Distribution

Type		Density	Area	Population
		pers/ha	ha	
Commercial		261.1	32.91	7,417
Institutional		138.5	84.99	11,768
Residential			251.46	15,959
	Condos	140.8	51	7,260
	Townhouses	60.7	60	3,640
	Houses 1st buy	43.9	69	3,016
	Houses luxury	28.7	71	2,044
Green space		41%	260.74	
Total			630.1	

4.5.5 Consultation

The City of Vaudreuil-Dorion and the MRC initiated a series of consultations with stakeholders, including developers, the Union des Producteurs Agricoles (UPA; Union of Farmers), and five governmental ministries (health, environment, municipal, tourism, and agriculture) (see Figure 4.4). From these consultations, a preliminary master plan is proposed (for study only).

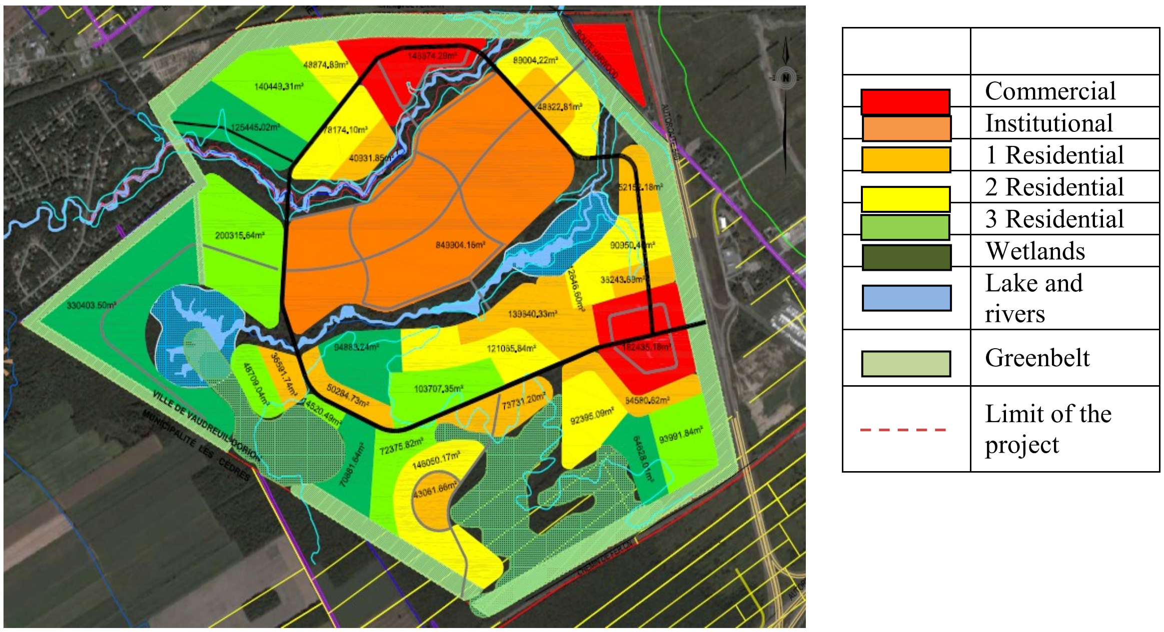

Figure 4.4: Land-Use Proposal for Consultation Purposes (MRC VS)

4.5.6 Master Plan

Two proposals were prepared for consideration: one using a standard development approach and the other using a green development approach. The proposals have not yet been accepted. Figures 4.5 and 4.6 present the two options in terms of land use and road distribution. For the standard approach, streets are larger and longer, and housing is more spread out. For the green approach, density is increased and green space is maximized; streets are narrower and shorter and land use is reduced when using a green development approach. The green approach differs from the conventional scheme which has more roads and is less dense. Using the green approach, housing buildings are grouped around green space, such as rain gardens (or bioretention areas), retention ponds, green alleys, and urban forestry.

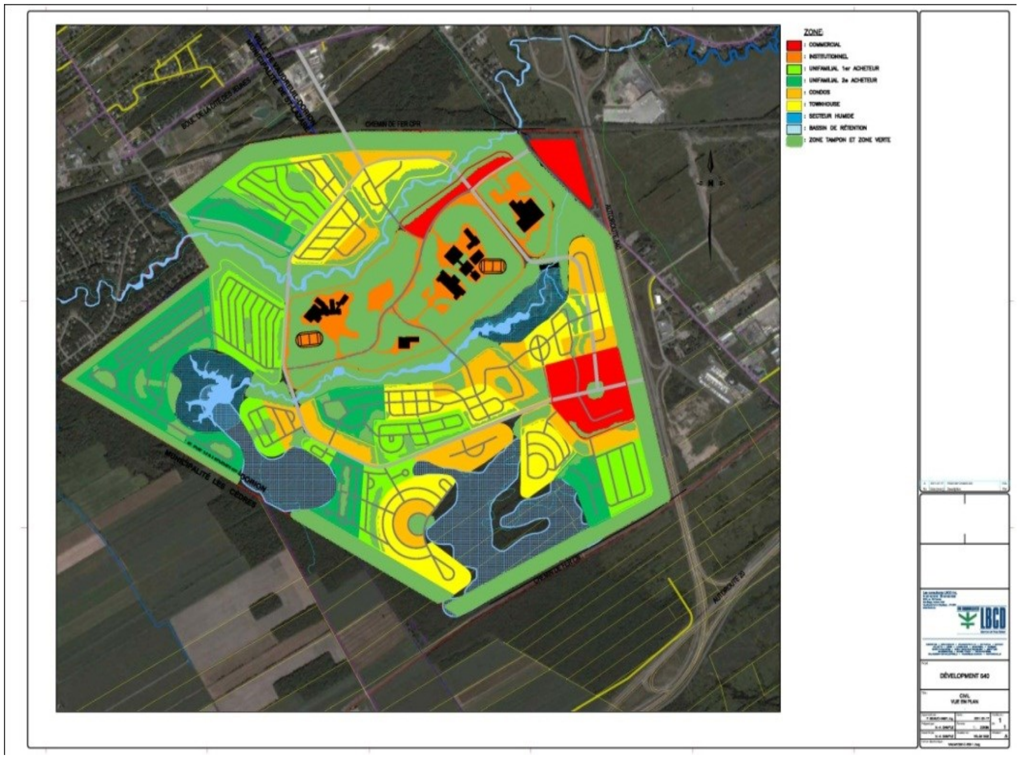

Figure 4.5: Road Distribution for Standard Design

Figure 4.6: Road Distribution for a Green Design

4.6 Project Evaluation

This section summarizes the data and technical characteristics of the project. Table 4.2 shows the characteristics of the project, comparing the CI and GI designs. The description and evaluation by unit cost is then calculated and presented for each scheme. Currencies are in Canadian dollars (which were close to US dollars in value in 2011).

Table 4.2: Project Description

Design Criteria		Conventional Design	Green Infrastructure
Water supply	Sourcing	Municipal	Constructed lake
	Treatment	Conventional	Membranes
	Pumping	2 km	100 m
	Storage	6,000 m^3	3,000 m^3
	Distribution	From city network	From filtration plant
	Non-potable supply	None	One pipe
	Potable supply	One pipe	One pipe
	Fire protection	Minimum 250 mm	Direct pipe from lake
Storm water	Surface reception flow	Storm drains	Green roofs
	Conveyance	Pipes	Bioswales
	Retention/detention	25 L/s/ha	Rain gardens
	Treatment	None	Wetlands
	Discharge	River	Lake
Wastewater	Conveyance	Pumping and pipes	Small pipes and swales
	Treatment	Conventional plant	Septic tanks and wetlands
	Discharge	River	Constructed lake
	Biosolids management	Mechanization	Mechanization
	Site level treatment	None	Yes
Transportation	Roads	11 and 9 m	9 and 7 m
	Sidewalks	Conventional	Integrated in design
	Pathways	None	Integrated in design
	Parking facilities	Conventional	Infiltration material

4.6.1 Infrastructure in the Conventional Development Scheme

The infrastructure in the conventional development scheme includes a road network, a water distribution network, a sewage collection network, and a storm water collection network. The existing municipal water treatment plant (WTP), supplies potable water. However, to cater for increased demand, the plant capacity needs to be increased. Therefore, a new WTP would be constructed for the new development. The capacity and cost of the infrastructure were evaluated, and are discussed below.

4.6.1.1 Road Network

The road network would consist of 54 kilometers (km) of paved roads, including a beltway that links all the subsectors, a principal road that passes through the central institutional and commercial zone, and local roads in the residential zone. The cost for the construction of paved roads is estimated to be $54,000,000. Paved roads occupy a total area of 505,500 square meters (m^2), representing eight percent of the total development area. This would cause a significant increase in peak surface runoff.

4.6.1.2 Water Distribution Network and Water Supply

Water main pipes are to be installed along all roads, forming a looped water distribution network. The total length of water pipes is 50 km, and pipe diameters range from 150 to 300 millimeters (mm). The water distribution network will not only provide water for domestic consumption but also provide it for fire protection, plant watering, street cleaning, and various other public uses. The total clean water demand of the development is estimated to be 13,000 cubic meters per day (m^3/d). The source of water supply is the existing municipal WTP. This water distribution network would be connected to the existing municipal network via 2 km of 400-mm water main pipes. A booster pumping station will be required to ensure adequate pressure in the water distribution network. The existing municipal WTP needs to be expanded to satisfy the additional demand from the development. The total hard costs of the water works, including the booster pumping station, the distribution network, and the transfer pipe, is estimated to be $10,828,000 and the cost for increasing the municipal WTP capacity is estimated at $5,000,000—bringing the total cost for the proposed conventional water supply network to $15,828,000.

4.6.1.3 Sewer Networks

The wastewater collection network consists of 53 km of gravity sewer pipes, ranging from 200 to 350 mm in diameter. There are three main collectors: (1) the north collector, located along the north bank of Quinchien River, which collects wastewater from subsectors 1,100, 1,200, 1,300, 1,400, and 1,500; (2) the central collector, which is located along the principal road and collects wastewater from subsectors 2,100 and 2,200, as well as from the institutional and commercial zones; and (3) the south collector, which is located along the southern beltway and collects wastewater from subsectors 3,100, 3,200, 3,300, 3,400, 4,100, 4,200, 4,300, 4,400, and 4,500. The cost for installing these sewer networks is estimated to be $8,113,000. This estimate includes an allowance for five small lifting stations.

The storm water sewer network consists of several subnetworks, each having its proper outfall to either the Quinchien River or the creek. The network pipes have been designed to cope with one-in-five-year storms. An MRC regulation requires a runoff control of 25 L/sec/ha, necessitating a retention basin. Pipe diameters range from 350 to 2,700 mm. The total cost for installing the sewer pipes is estimated to be $30,500,000.

4.6.1.4 Wastewater Treatment Plant

The wastewater discharge from the new development is estimated to be 10,500 m^3/d. The city's existing WWTP, located some 4 km away from the development site, is not able to accept this additional load. It is proposed to construct a new WWTP with a 10,500 m^3/d capacity on the site of the new development. The plant will be located on Route Harwood, near the entrance to the development zone. The plant includes pre-treatment, a micro filter membrane bioreactor, tertiary treatment, ultraviolet treatment, and sludge treatment. The cost for the construction of the new WWTP is estimated to be $16,150,000.

4.6.2 Infrastructure in the Green Development Scheme

In the green development scheme, water supply is carried by two separate networks: one for potable water and the other for non-potable water. The source of the potable water supply is a new WTP. The source of the non-potable water supply is a pumping station drawing water in the lake. Domestic wastewater is separated into two streams at source: black water and gray water. Black water is sent to the new wastewater reuse plant for treatment and reuse. Gray water is treated at source with ecological systems, as mentioned in Section 4.5.3. Surface runoff is treated by bioswales and other LID techniques before being discharged into the environment. The entire water system forms a closed circuit, in that the WTP draws raw water from the lake to produce potable water, and the lake is in turn replenished by the effluent of the wastewater reuse plant. Part of the wastewater reuse plant effluent is directly reused for non-potable purposes. It is clear that more pipes will be needed for a green development.

4.6.2.1 Road Network

The road network in the green development scheme has been planned with a reduced paved road surface to conserve green space. The network would consist of 45 km of paved roads covering 365,000 m^2, which represents 5.8 percent of the total development area. The main structure of the network is similar to that of the conventional development scheme, with a beltway that links all the subsectors, a principal road that passes through the central institutional and commercial zone, and local roads in the residential zone. The cost for the construction of paved roads is estimated to be $35,000,000.

4.6.2.2 Water Distribution Networks and Water Supply

The installation of two separate water supply networks is proposed: one for potable water and another for non-potable water (see Figure 4.7). The water main pipes of the two networks would run in parallel, along all roads. The total pipe length of each network would be 41.8 km. The pipe diameters range from 150 to 200 mm for potable water, and from 150 to 250 millimeters for non-potable water. The total cost for constructing the two networks is estimated to be $12,300,000.

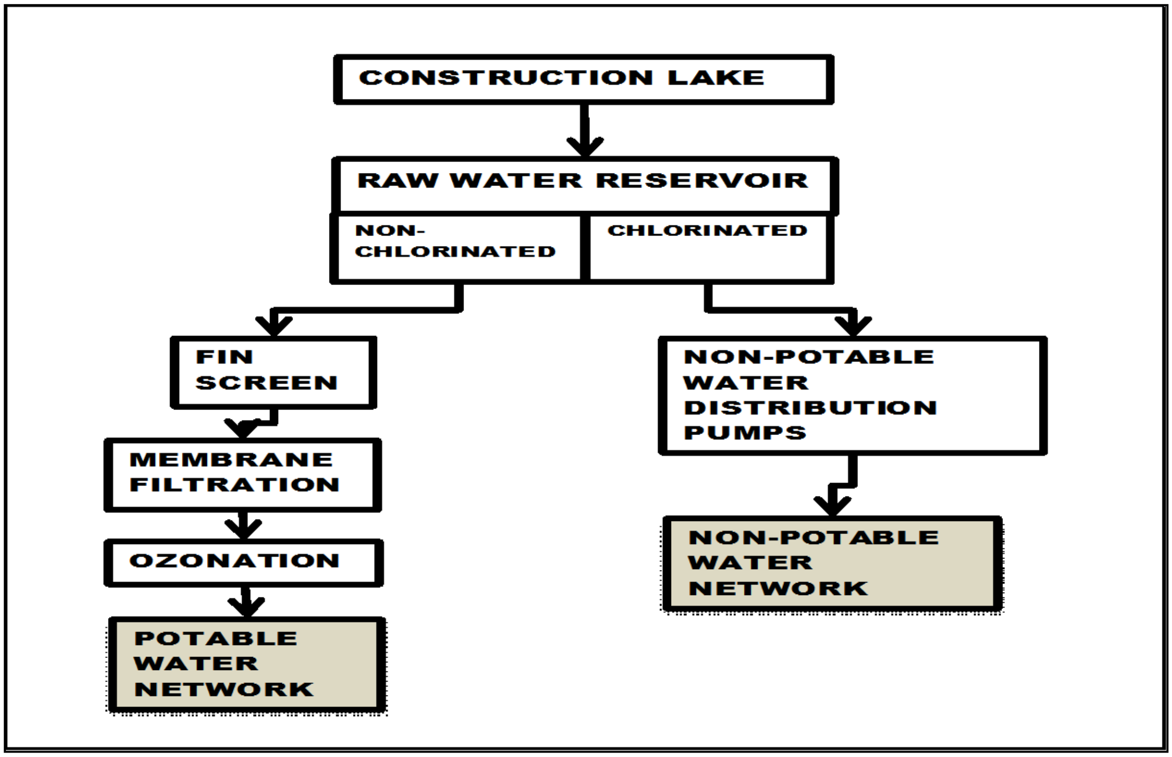

Figure 4.7: Water Distribution Networks

The potable water demand of the development is estimated to be 7,800 m^3/d, and the non-potable water demand is estimated at 5,200 m^3/d. The new WTP would be located near the constructed lake. The estimated cost for the construction of the plant is $7,223,000, bringing the total cost for the construction of the water supply networks using GI to $19,523,000.

4.6.2.3 Black Water Collection and Treatment

By separating black water and gray water at source, the black water flow to be carried by the sewer network is reduced. Black water represents about 40 percent of total domestic wastewater. The total black water flow from the development is estimated to be 4,150 m^3/d. Following the preliminary examination of the topography of the site, the installation of three separate networks is proposed. (1) The northern network will service subsectors 1,100, 1,200, 1,300, 1,400, and 1,500 (from which the average black water flow is estimated to be 490 m^3/d). (2) The central network will collect wastewater from subsectors 2,100 and 2,200, as well as from the institutional and commercial zones, with an estimated average black water flow of 1,900 m^3/d. (3) The southern network will collect wastewater from subsectors 3,100, 3,200, 3,300, 3,400, 4,100, 4,200, 4,300, 4,400, and 4,500. The estimated average flow from these is estimated to be 1,760 m^3/d. The approximate length of sewer pipe required for all three networks is 53 km. The pipe diameters range from 200 to 350 mm. The cost for installing the sewer networks is estimated to be $6,858,000, including an allowance for five small lifting stations.

Three WWTPs could be constructed, one for each black water network. The plants would use Ecophyltre, a green wastewater treatment technology (see Figure 4.8). Table 4.3 provides a summary of the proposed plants and their costs. Alternatively, the construction of a centralized plant, with the same processes as a conventional plant, plus the addition of membranes and reverse osmosis, would be $17,539,000 and still permit the recycling of water as non-potable water.

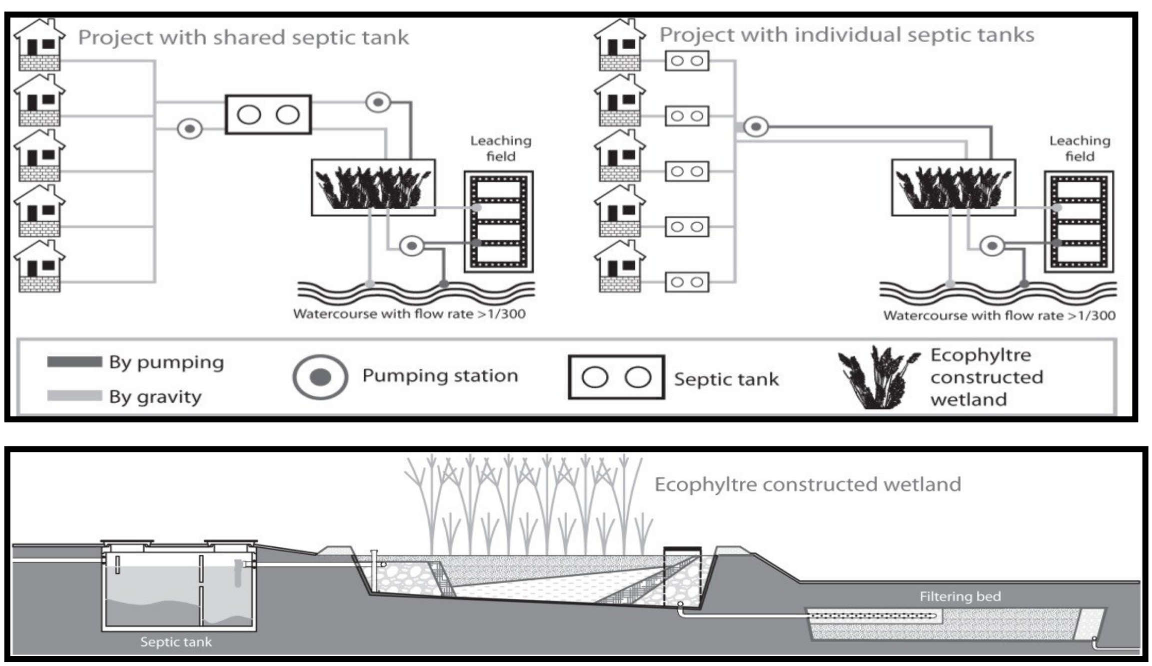

Figure 4.8: Ecophyltre: The Installation of Small Wetlands (HG Environnement, Blainville, PQ, CAN)

Table 4.3: Wastewater Treatment Plant Costs

Description	Northern Network	Central Network	Southern Network	Total
Average flow	490 m3/d	1,900 m3/d	1,760 m3/d	4,150 m3/d
Surface area	185 m x 60 m	360 m x 120 m	335 m x 120 m	94,500 m2
Discharge	To Qinchien River	To wetland	To wetland	n/a
Cost	$3,283,000	$12,783,600	$11,792,000	$27,856,600

4.6.2.4 Gray Water Collection and Treatment

Gray water will be treated at source at the household level using an ecological system, consisting of a septic tank followed by a vertical-flow planted filter (VFPF). The treated effluent will then be discharged into the storm water network. For the purpose of the present study, the estimated cost is based on a typical system of 1.2 m^3/d capacity, which includes a septic tank of 1.8 m^3, a VFPF of 8 m^2, and 25 m of 100-mm diameter discharge pipe. To treat 6,226 m^3/d of gray water, 5,188 equivalent typical systems would be required. The total cost for constructing gray water collection and treatment systems is estimated to be $23,128,000.

4.6.2.5 Storm Water Management Works

In the green development scheme, the main infrastructure of storm water management is bioswales and wetlands. The green roofs and rain gardens, although an integrated part of the storm water management strategy, will be implemented at household level and are excluded from the infrastructure cost. These costs constitute developer costs. The storm water collection and conveyance network consists of 36.2 km of bioswales and two constructed wetlands of 20 ha and 12 ha, respectively. The total cost for constructing the bioswales and wetlands is estimated to be $13,060,000.

4.6.3 Cost Summary of Two Schemes of Housing Infrastructure

In the previous section, all schemes and costs were described for the two approaches, CI and GI. Costing has been evaluated from the 2011 **exp** International Services database for unit price. Table 4.4 provides a cost summary for each option, CI and GI. The first part of the table shows public investment for housing and institutional pole infrastructure services; the second part indicates the investment required from developers or stakeholders.

Table 4.4 also illustrates the baseline of cost evaluation for all infrastructure required to serve the proposed housing development. The cost of public infrastructure is $21,078 per house unit for conventional design and $19,475 per house unit for green design. However, the developer will have to invest an additional $10,084 per house unit to reach the goals of GI. Using this method of evaluation, the investment is 29 percent higher for a green option. Nevertheless, public investment for GI is lower than for CI.

Table 4.4: Cost of Projects from Detailed Unit Price Calculation

Public Infrastructure	**Conventional ($)**	**Green Development ($)**
Roads network	54,000,000	35,000,000
Water distribution network		
- Potable water	10,828,000	5,851,000
- Non-potable water	n/a	6,462,000
Water treatment plant	5,000,000	7,223,000
Sanitary (black water) sewer networks	8,113,000	6,858,000
Wastewater treatment plants	16,151,000	17,539,468
Gray water treatment system	n/a	23,128,000
Storm water sewer networks	30,500,000	13,060,000
Subtotal	124,592,000	115,121,468
Extra Developer Costs for Green Option		
Green roof		42,600,000
Filter box + rain garden		17,000,000
Subtotal		59,600,000
TOTAL		
Total	124,592,000	174,721,468
Cost/unit without cost at lot level	21,078	19,475
Cost/unit with green cost at lot level	21,078	29,559

4.6.3.1 Center for Neighborhood Technology National Green ValuesTM Calculator

The second method used to compare costs between CI and GI was the GVC. The parameters of the project were entered into this software, which was developed by the CNT (2009b). The simulation calculates the cost of each alternative (conventional and green) for storm water LID design. However, the calculator does not include water supply or wastewater infrastructure cost. The GVC calculates the annual precipitation depth and cost price for an LID project in any site in the US. Therefore, in this case study, the BTM was considered appropriate to determine the value for Vaudreuil-Dorion from another site in the US. The city of Malone, located in the north of New York State, 55 km south of Vaudreuil-Dorion, was chosen for this purpose because its weather conditions are similar to those of Vaudreuil-Dorion, and the characteristics of the site are appropriate for the BTM. The RSMeans Building Construction Cost Database and RSMeans Site Work and Landscape Cost Database were used by the GVC for referencing unit costs.

Table 4.5 shows a total investment per house for public infrastructure in housing and local owners' investment of US$20,290.15 for CI, compared with US$26,649.03 for GI. This calculation indicates that each house unit would need 24 percent more investment for a green option.

Table 4.5: CNT Calculator

Storm Water LID Costs	**Public Construction Cost ($)**		
Infrastructure	Conventional	Green	Difference
Concrete sidewalk	921,225.00	921,225.00	–
Curbs and gutters	3,055,320.00	1,330,337.00	1,724,983.00
Street	24,541,747.00	17,901,415.00	6,640,332.00
Parking lot	132,240.00	–	132,240.00
Conventional storm water storage	20,012,656.00	2,636,073.00	17,376,583.00
Permeable pavement, Porous asphalt	–	735,440.00	(735,440.00)
Turf	11,331,881.00	11,536,751.00	(204,870.00)

Rain garden	–	413,000.00	(413,000.00)
Roadside swales	–	5,999,940.00	(5,999,940.00)
Swales in parking lot	–	2,100,000.00	(2,100,000.00)
Planter box	–	792,000.00	(792,000.00)
Additional soil	–	19,980,000.00	(19,980,000.00)
Subtotal	59,995,069.00	62,875,301.00	(2,880,232.00)
Standard roof	59,940,000.00	29,970,000.00	29,970,000.00
Green roof	–	62,937,000.00	(62,937,000.00)
Subtotal	59,940,000.00	62,875,301.00	(2,880,232.00)
TOTAL	119,935,069.00	157,522,305.00	(37,587,232.00)
5,911 units	Conventional/unit	Green/unit	
Infrastructure	10,149.73	10,637.02	(487.28)
Owners at lot level	10,140.42	16,012.01	(5,871.60)
TOTAL	20,290.15	26,649.03	(6,358.88)

4.6.3.2 Life Cycle Costing Tool

The LCCT was the third method used for calculation for comparing the CI with GI. The CMHC developed this tool to help users explore and compare the costs of different forms of development and community planning alternatives that could help contribute to more sustainable development (Pollard, 2008). The tool is capable of providing planning level cost and revenue estimates only. However, the tool does not calculate all green costs at lot level. Basic project data were introduced into the costing tool. Table 4.6 provides the results.

The tool includes costing variables to allow for the estimation of costs for the following major categories: hard infrastructure, municipal services, private user costs, and external costs. In this case study, items retained for comparison were roads, sewers, storm water facilities, and management services. The tool revealed that the cost of infrastructure for each housing unit is CAD$20,993 for CI and CAD$23,525 for GI. Using this method, the investment differential is 11 percent more for a green option.

Table 4.6: Life Cycle Cost Calculator

Life Cycle Costing Tool		Conventional Development ($)	Green Development ($)
Hard infrastructure	Local roads	63,435,397	51,023,386
	Regional roads	1,226,480	566,927
	Water distribution and water treatment	11,700,000	9,300,000
	Sanitary sewers and wastewater treatment	12,630,000	10,150,000
	Storm sewers and water management	35,100,000	28,910,000
Green infrastructure items			39,112,360
TOTAL		124,091,878	139,062,673
	Cost/unit	20,993	23,526

4.7 Project Value and Benefits

This section will evaluate direct benefits to the city. The Greater Montréal Real Estate Board (GMREB) is a non-profit organization that brings together most of the real estate brokers who work in the Greater Montreal area. The GMREB publishes statistics on housing prices. In December 2010, the median price of a single-family home in Greater Montreal was $262,000; this was an increase of nine percent compared with December 2009. The median price of condominiums also increased by nine percent to $218,000 over this period, while that of duplexes increased by 10 percent to reach $385,000 (Ménard, 2011).

As discussed in Section 4.2, studies show that buyers are willing to pay between five and 38 percent more to buy a house in a quality neighborhood. EQuilibrium™ is a national sustainable housing initiative created and led by the CMHC. It strives to balance the demands of housing needs with those of the natural environment (Pollard, 2008). In 2009, the CMHC carried out market research with Canadians who were expecting to buy a home in the next five years. According to the findings, 90 percent of respondents were interested in this green initiative, citing concern for the environment as the reason for their interest. The majority recognized the need for this type of housing, with about half willing to pay an additional $5,000 to $25,000 (and an additional 15 percent willing to pay more than $25,000) for an EQuilibrium home, with the expectation that the savings from reduced energy costs would offset the initial extra expense over a reasonable period (Canada Mortgage and Housing Corporation [CMHC], 2010).

Once the structures and their interconnections are defined, performance standards can be developed; existing performance standards for urban green are broad-brush, such as acres of open space per resident or canopy cover percentages (Wolf, 2003). There have been numerous studies on land use and the green environment. Des Rosiers, Thériault, Kestens, and Villeneuve (2002) demonstrated that house prices in Quebec City increase by 0.2 percent for each percent of trees on the land and an attractive landscape increases the house value by 7.7 percent. Kestens, Thériault, and Des Rosiers (2006) demonstrated the positive value of greening within 40 meters of housing. In Michigan, Thorsnes (2002) demonstrated that houses near forests were valued between 19 and 35 percent higher than similar houses in non-forested areas. Hobden, Laughton, and Morgan (2004) found that, in the suburbs of Vancouver, corridors to parks increased house values by 6.9 percent and green pedestrian walkways increased property value by 11 percent. In France, Cavailhès (2007) determined that green outlooks have the effect of increasing house prices by between one and five percent.

To quantify the hypothesis that property value increases in a green environment, six cities in the MRC of Vaudreuil-Soulanges were chosen. The canopy cover percentage was evaluated and compared with their municipal housing evaluation. Using the Ministère des Affaires municipales, des Régions et de l'Occupation du territoire (MAMROT, 2011) database, Table 4.7 shows an evaluation of property in the housing sector for six cities: Ville de l'Ile-Perrot, Notre-Dame de L'Ile-Perrot (NDIP), Pincourt, Vaudreuil-Dorion, Hudson, and Saint-Lazare. Three of these cities were greener than Vaudreuil-Dorion: NDIP, Saint-Lazare, and Hudson. For these cities, housing evaluations per inhabitant were 15, 27, and 100 percent higher, respectively, than for Vaudreuil-Dorion.

Table 4.7: Housing Evaluation in Six Vaudreuil-Soulanges Cities

	A	B	C	D	E	F
	Municipality	Population	Total Housing Evaluation	Evaluation per Habitant ($)	Ratio	Forest Canopy
			$	C/B	D/D4	%
1	L'Ile-Perrot	10,515	749,239,482	71,254,35	0.86	16
2	ND-de-l'Île-Perrot	10,564	1,007,255,704	95,347,95	1.15	29
3	Pincourt	13,679	1,123,409,805	82,126,60	0.99	17
4	Vaudreuil-Dorion	31,461	2,599,697,064	82,632,37	1.00	26
5	Hudson	4,954	823,222,050	166,173,20	2.01	39
6	Saint-Lazare	18,922	1,987,503,965	105,036,68	1.27	40

As discussed in Section 4.2, a green approach increases the hedonic value of property. From the comparison presented in Table 4.7, it can be observed that 15 percent is a conservative value for the hedonic increase value in the proposed housing project due to willingness to pay for houses in a green neighborhood, as shown in Vaudreuil-Soulanges. This corresponds with the value showing a difference between the Vaudreuil-Dorion and NDIP housing evaluation; therefore, this study proposes a hedonic value of 15 percent more for a house in a green development. It is noted that it could be more (27 percent), as in Saint-Lazare, where the forest environment is predominant. The percentage of forest coverage can be determined by measuring the canopy of each city from an aerial view. There is a linear regression between property value and canopy size.

In Table 4.8, house values are calculated for the proposed project using conventional housing prices, with a hedonic increase in value of 15 percent. Column A shows the number of total units of each type in the proposed development; B, the unit price as per Greater Montreal statistics in 2010 from the GMREB; C, the total evaluation for a CI project; D, the hedonic value; and E, the total value of housing in a GI project. The total increase in value for the municipal housing project would be CAD$202,902,000 for a GI scheme. The results shown in Table 4.8 were used to determine the potential additional tax revenue for the city (shown in Table 4.9). In Table 4.9, 2011 tax rates were multiplied by the new building value and compared with tax revenue from houses being constructed in a conventional scheme. Tax revenue increases by $1,458,115.68 per year for a green development. The city would collect $245.35 of extra tax per house unit per year from a project built using GI.

Table 4.8: Green Building Evaluations for 540 Vaudreuil-Dorion Development

Building Value		Buildings	Buildings	+	Buildings
	A	B	C	D	E
		2010	100% evaluation	15%	100% evaluation
Type	Unit	Unit Price ($)	Total Conventional ($)	Hedonic Value ($)	Total Green ($)
Unifamilial	1,874	262,000	490,988,000	73,648,200	564,636,200
Townhouse	1,348	192,500	259,490,000	38,923,500	298,413,500
Condo	2,689	218,000	586,202,000	87,930,300	674,132,300
Commercial	32	500,000	16,000,000	2,400,000	18,400,000
Institutional	6	50,000,000	300,000,000	–	300,000,000
Total	5,949		1,652,680,000	202,902,000	1,855,582,000

Table 4.9: Proposed New Development Tax Revenue for the City

Building value	Infrastructure	Infrastructure	Taxation	Conventional	Green
	Conventional building values ($)	Green building values ($)	$ per $100 evaluation	Revenue for the city ($)	Revenue for the city ($)
			2011	per year	per year
Unifamilial	490,988,000.00	564,636,200.00	0.67	3,289,619.60	3,783,062.54
Townhouse	259,490,000.00	298,413,500.00	0.73	1,894,277.00	2,178,418.55
Condo	586,202,000.00	674,132,300.00	0.73	4,279,274.60	4,921,165.79
Commercial	16,000,000.00	18,400,000.00	1.61	257,600.00	296,240.00
Institutional	300,000,000.00	300,000,000.00	1.61	4,830,000.00	4,830,000.00
Total	1,652,680,000.00	1,855,582,000.00		14,550,771.20	16,008,886.88

4.8 Conclusion

Infrastructure costs for conventional design and green design were evaluated using three different methods for the proposed Vaudreuil-Dorion project. The total infrastructure cost for CI averages CAD$125,000,000 for the proposed project. The total infrastructure cost for GI could vary from CAD$140,000,000 to CAD$200,000,000, including investment at lot level. The public component of the GI investment could vary from CAD$100,000,000 to CAD$120,000,000. The minimum increase in value of the total property evaluation would be CAD$202,902,000 for a GI scheme in the Vaudreuil-Dorion project. The minimum extra taxes collected annually would be CAD$1,458,115.68 per year. In a new development, the evaluation of the hard costs of infrastructure shows that the public costs of the CI and GI designs are very close, if investment at lot level is excluded. According to the three different methods of calculation, GI design is determined to cost 29, 24, or 11 percent more, respectively, including householders' extra landscape investment at lot level, depending on the nature of the investment. However, the hedonic value of a house built in a GI scheme will increase by 15 to 27 percent. Therefore, the increase in value and the increase in cost are balanced.

This study does not address the environmental costs and benefits of the project, which may require further research. Nevertheless, using the CNT calculator, the environmental benefits of the project were evaluated at US$276,858 per year. This includes reduced air pollutants, carbon dioxide sequestration, the compensatory value of trees, groundwater replenishment, reduced energy use, and reduced treatment requirements. Another point of interest is the operating cost: the CNT calculator predicted an increase of US$216,979, excluding WTP or WWTP operating and maintenance costs. The third method, the LCCT, predicted an additional annual operating cost of CAD$278,367 for a green solution, compared with a conventional solution. These paradigms will require further research. Compared with conventional development practices, the implementation of sustainable devices for drainage, water supply, and sewerage reduces the need for infrastructure expansion and provides economic and environmental benefits.

The evaluation of green development projects is an economic concern for cities. This study analyzed the quantitative values and costs of a green development project in comparison with a conventional development project. In considering these two forms of development, city decision makers will have to answer two questions: (1) Are the benefits of the project greater than the cost to taxpayers? (2) Is city spending being managed in such a way as to maximize benefits? The value of each unit increases by CAD$34,100 for a green development. The hard infrastructure cost was evaluated at CAD$19,475 per unit and the extra cost of building green to be paid by the developer was evaluated at CAD$10,084 (at lot level), resulting in a total of CAD$29,557. Overall, the benefits exceed the costs. If the developer contributes to city infrastructure investment, the city will increase its revenue.

This study has demonstrated that the householders and the city will benefit by choosing a GI approach in the proposed project. The indicators also show that the environment may be protected by choosing this option.

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Chapter 5: Conclusion

5.1 Introduction

This study explored how to link the built infrastructure design approach to the European GI concept (the hub-and-connecting-link concept). Indeed, the proposal assumes that engineered infrastructures will be designed to support the greening process; this approach is identified as integrated GIs. The new GI proposal includes an integrated concept to respect ecology and mimic nature; water is a central element of this new approach. Taking a greener approach to infrastructure development mitigates the potential environmental impacts on the ecosystem.

In the first part, this study proposed to assist engineering organizations in planning the start-up of new projects within the green context. A clear sequence of tasks defines the workflow to lead the teamwork. Through the literature review, different approaches were identified and four were selected to build a ready-to-use framework of sequenced tasks, which includes all the components of water management (rain and drainage, water supply, and wastewater). It was found that MIWCA could apply to any project. Nevertheless, we found that without adequate capacity building, any project could fail.

In the second part of this study, the costs of designing green were compared with the cost of designing conventionally. The study demonstrated the economic benefits of the investment in dollar terms. Results show that an increase in the value of GI projects corresponds to an increase in the cost of constructing such a project. In this chapter, the two parts of the study are reviewed and discussed.

Two case studies were conducted to demonstrate the results of the thesis statements. One project, an industrial agro-park, was carried out in China. Currently, its construction has been postponed and it remains at a stage of 50 percent completion, but it should be completed in the coming years. The second case is a new development planned in the city of Vaudreuil-Dorion to implement a new institutional pole surrounded by a new ecocity. In these two cases, the principles of GI were applied to the design.

5.2 Green Concept

In 1992, the EU adopted legislation to protect natural habitats in all European countries. This directive completes a directive adopted in 1979 to protect birds. From these two directives, special protection zones were identified and a network was formed called Natura 2000. All European countries are required to implement and manage the Natura 2000 level. Thus, the concept of ecological linkages can be described as a European concept. In North America, a few municipalities have adopted this concept, but there are no such structural networks. Leaders in project development are municipalities and, currently in North America, many cities are focusing on introducing LID techniques to build their hard infrastructure, which is a direct action under the second definition of GI.

The European concept of GI includes the network of green routes and hubs that preserves animals and plant biodiversity. The American concept of GI views it as the network of structures that supports urban and rural development, built with the idea of protecting the natural habitat and reducing the impact of development. This concept focuses on introducing green facilities such as parks, gardens, trees, and swales into the city's infrastructure. It also involves designing green, and integrating LID techniques.

In general, the GI concept should present a framework for conservation and development. The term GI has multiple meanings as it relates to conservation efforts; the term GI refers to nature's life support system (Benedict & Bjornlund, 2002). In this study, a new green approach for new development has been defined. An integrated approach to GI should manage the complete cycle of water within the green environment. This concept proposes the integration of water management into the GI concept. The methodology integrates a closed cycle of water, including LID components, WSUD components, BMP components, water supply, sewerage, wastewater treatment, and aspects of IMPs.

5.3 Green Approaches

Most management approaches to starting development projects are focused on green principles of urban planning. Two groups of authors have specifically examined the engineering of GI: one book, *Sustainable Infrastructure* published in 2010, was written by S. B. Sarté (2010); another book, *Water Centric Sustainable Communities*, was published by Vladimir Novotny, Jack Ahern and Paul Brown in 2010.

Sarté offers several forms of guidance for project planning. He suggests creating a unique approach for each project by combining different philosophy or development frameworks. He identified 13 frameworks, the most popular of which are LEED and BREEAM, and four approaches for analyzing sustainable infrastructure. He suggested considering four existing frameworks when organizing green projects:

- **Framework 1: Pillars of Sustainability.** This approach presents an analysis based on five elements: water, energy, materials, ecology, and community. Analysis of the project is formatted in these terms and it is proposed to proceed with a development evolution of the design following five levels of progression.
- **Framework 2: The Scale-Density Framework**. This approach is defined in four words: water, wastewater, energy, and solid waste. The needs analysis is defined according to four levels: the city, the district, the block, and the building. The organization becomes a pyramidal structure and presents an overall picture of the final proposal.
- **Framework 3: The Transect.** This approach defines the territory into seven areas: T1 Natural, T2 Rural, T3 Suburban, T4 General Urban, T5 Urban Center T6 Urban Core, and SD Special District. The approach is a form of territorial organization to establish a balance between each of the zones and to identify needs. The overall plan is determined based on a progression from one area to another by introducing measures of sustainable development.
- **Framework 4: The Built Form-Ecology Framework.** This approach interconnects human actions with natural ecological systems. The method uses

> drivers to guide development. On the horizontal axis are biodiversity, water, air, land, and energy. The vertical axis is divided into three parts: habitation/settlement, industry/resource extraction, and recreation. The principle consists of establishing an equilibrium balancing all these elements according to the criteria in the appropriate box.

All of these approaches or development frameworks are elements of reflection appropriate to defining a development project and a sustainable strategy. However, none of them defines a formula to start up a project from scratch and to proceed to final detailed engineering. These frameworks are rhetoric guidelines to orient development. In this study, the aim was to create a practical approach to assembling the pillars of a new development. This does not exclude the use of these rhetorical frameworks to enhance the orientation and define goals.

In the second book, Ahern examines best practices for planning the urban environment in a sustainable manner. Ahern proposes placing water at the center of urban concerns.

The concept of ecosystem services now provides a powerful, broadly accepted, logical argument for the protection and responsible development of landscapes justified by the specific functions that landscapes provide, often with direct and measurable economic benefits for human beings (Ahern, 2010). Ahern proposed a six-step methodology: (1) ecosystem services: goals and assessments; (2) resilience factors; (3) resilience planning strategies; (4) develop scenarios; (5) urban resilience-sustainability plan; (6) plan implementation-adaptation. Two elements sought in this study are included in Ahern's approach: a way to start up a project and a water-centric approach. Nevertheless, it does not describe in detail what to do and how to do it. The new proposed framework in this study is focused on start-up of a new development project with a water-centric approach.

From the findings, four approaches were selected to use in developing a new start-up framework: Maryland's LID approach was chosen from among the US states because it was the first state to develop a strategy to implement LID techniques. The EPA's Water

Quality Scorecard was selected because the EPA is the American reference to assess environmental impacts. The USGBC's LEED is an internationally recognized green building certification system and, for this reason, it was selected as the NGO approach for further examination. Finally, BC's "guidebook" approach was selected from among the Canadian provinces because, since 2000, BC has been a proactive Canadian province in the implementation of environmental planning (BC Water & Waste Association (BCWWA) Water Sustainability Committee 2010).

5.4 The Proposed Integrated Framework

To achieve green development, land planners, architects, engineers, biologists, ecologists, sociologists, economists, managers, and citizens must be involved as an integral part of the team in planning the project. AM appears to offer a solution to the management gridlock caused by increasing complexity and uncertainty (Allan & Curtis, 2005); therefore, it is a central element of the proposed approach. An outline of the proposed six-step integrated framework is described below.

5.4.1 Inventory

The first step is to understand the site, define the current situation, and hold a first consultation with the stakeholders. This is done by visiting the site, noting observations to determine the general topography of the site, and meeting individually with the stakeholders. In addition, an inventory of the ecosystem should be made, identifying green hubs, rivers, wetlands, and creeks, and qualifying them. A review and analysis of all available data and information, including economic and sociological data, demography, topography, climatology, hydrology, hydrogeology, water quality, level of services, and water consumption by user groups in the surrounding area must also be conducted. Accurate knowledge of the existing situation will help to optimize and define the most appropriate alternative solutions. Basic data on the following topics are required:

- demography: present and past populations, population distribution and growth rate, and existing demographic studies;
- environmental survey;
- topography and hydrography: topographic maps, identification of main waterways, and hydrologic parameters (imperviousness, area, and land use);
- existing infrastructure: information on present and planned water supply and drainage/sewer networks, sanitation, and developments in the infrastructure;
- water resources: characterization of existing and proposed water source quality and quantity, and the importance of groundwater and/or surface water;
- norms and standards: water quality and environmental norms and standards;
- major water consumers and polluters: identification of existing and future major water consumers and polluters such as industries, towns and urban centers, public institutions, hospitals, and schools;
- town planning and development projections: present and projected land use, aerial photographs, existing related maps and studies, projected major development sectors, and master plans;
- precipitation: recorded rain data and existing hydrographs;
- key social, economic and political issues; and
- capacity building issues.

The consultation process starts with this activity, which involves meeting each group of stakeholders. The process is carried out through interviews. Stakeholders are informed about the management plan, are asked their opinion of it, and are asked to provide data and their knowledge of the region. Their needs are identified and are matched to define a green concept of the project. From this first round of consultation, goals and policy context are encompassed. As a lesson from the Qujing Project, evaluation of institutional capacity must be a permanent concern during the inventory phase. As observed, a lack of capacity building may cause a long delay in project completion as well as a failure in project financial performance.

5.4.2 Hydrology and Hydraulic Assessment

In planning for GI development, the natural habitat can be mimicked in the design of new infrastructure. For this reason, it is necessary to define watershed and micro-watershed areas, storm issues, modeling techniques, and water quality objectives. Further, runoff volume, peak runoff, frequency, and water quality control must be defined, and a macro hydrologic analysis must be performed. It may also be necessary to model the hydraulics of the river and catchment. The intent of this proposed step is illustrated by this description relating to the Maryland approach:

> The traditional approach to site drainage is reversed to mimic the natural drainage functions. Instead of rapidly and efficiently draining the site, low-impact development relies on various planning tools and control practices to preserve the natural hydrologic functions of the site. The essential existing hydrologic functions of the site and its functions must be maintained. The application of low-impact development techniques results in the creation of a hydrological functional landscape; the use of distributed micromanagement practices, impact minimization, and reduced effective imperviousness allowing maintenance of infiltration capacity, storage, and longer time of concentration. Integration of hydrology into the site planning process begins by identifying and preserving sensitive areas that affect the hydrology, including streams and their buffers, floodplains, wetlands, steep slopes, high-permeability soils, and woodland conservation zones. (Prince George's County Maryland Department of Environmental Resources, 2008)

5.4.3 Integrated Management Practices

LID is a multi-barrier approach that uses features at the lot, neighborhood, and watershed level to maintain the on-site water balance (Gyurek, 2009). It was determined that the proposed framework must integrate this multi-barrier approach to reduce the water footprint in the development. This involves:

> designing strategies to provide quantity and quality control and enhancement of groundwater recharge (through infiltration of runoff into the soil), retention or detention of runoff for permanent storage or for later release, and pollutant settling and entrapment (by conveying runoff slowly through vegetated swales and buffer strips or small wetlands). (Gyurek, 2009)

In addition, “multiple uses of landscaped areas must also be considered as well as water balance analysis with consideration of domestic water streams (water demand and wastewater discharge)” (Gyurek, 2009). To achieve sustainable development, we must manage our most vital natural resource, water, in an integrated manner, or precisely through IWRM (Rahaman & Varis, 2005). Through these methods, it is possible to integrate water treatment, water supply, and wastewater treatment.

A multi-barrier approach also requires the assessment of the availability and potential of surface and groundwater sources—and the existing or potential pollution of such sources—as well as the gauging of any pollution control requirements for the protection of surface and groundwater supplies (Gyurek, 2009). The quality and quantity of each potential source must be examined, and the needs of each potential user must be analyzed using the projected population and per capita demand factors based on existing usage levels and national standards and regulations. The proposed integrated framework is different from LID, in that LID only deals with storm water management. The proposed framework integrates water supply and wastewater treatment into the chain by defining a core, such as a lake or a new reservoir, as the center of micromanagement. Cities manage water at a large scale, drawing water from a lake or river and discharging polluted water, which may have had limited treatment, back into the river. The proposed approach attempts to manage water within a closed loop (see Figure 5.1), avoiding the loss of clean water, or the discharging of polluted water into the core water source. However, to achieve this, new standards for water quality are required.

In the proposed approach, all LID features are introduced to maximize water quality. The concept includes features such as rain gardens, bioretention, and bioswales. To integrate all systems, it is necessary to create a lake or a reservoir on-site and to link all parts of the system with that water body as the core. In contrast to the LID concept, which focuses on rainwater, the proposed concept integrates water supply, wastewater, and storm water management. The system operates as a closed loop, as shown in Figure 5.1. Rain is captured and treated at the source and flows to the reservoir or is reused at the source. A filtration plant acts as a dam and receives water from the lake. The water distribution system is split into potable and non-potable water. Wastewater is also split into black and gray water, which is treated on-site, after which it flows to the reservoir.

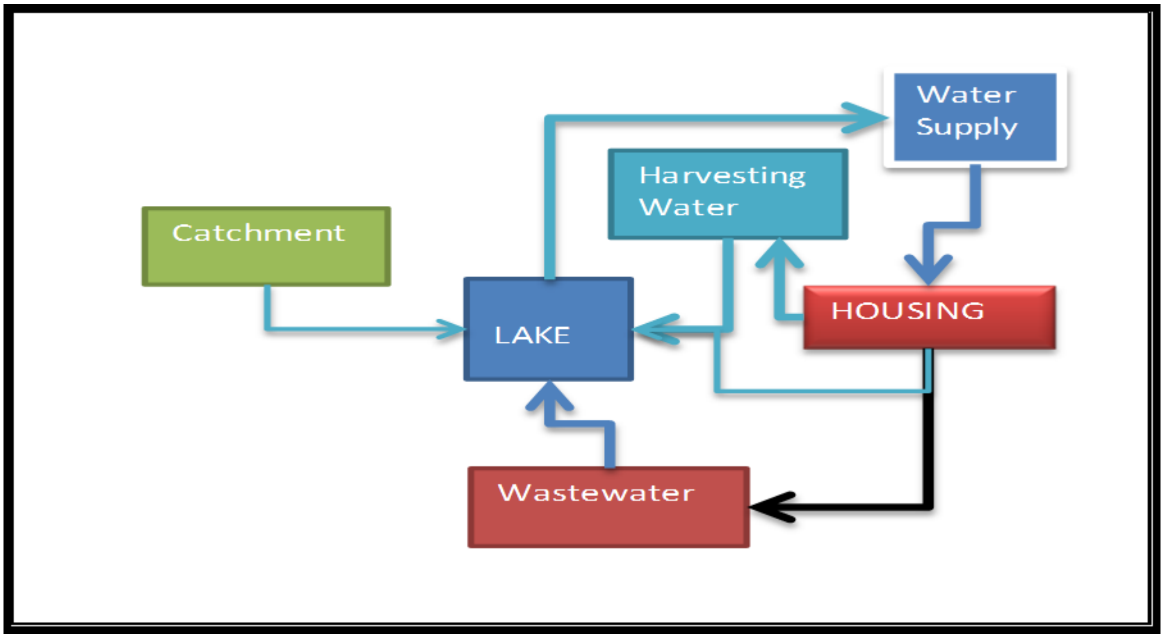

Figure 5.1: Water Infrastructure Closed Loop Concept

5.4.4 Land Planning

At this stage, a site analysis and programming should be performed by identifying the owners and stakeholders, and preparing a conceptual planning and development program. This planning entails initial planning of land uses, transportation networks, and major facilities. This activity is completed by a team including various professionals such as land planners, architects, landscape architects, engineers, environmentalists, biologists, sociologists, and economists. The details of the land use will have been defined by the hydraulic assessment of the site. At this step, other concepts of sustainability can be introduced such as transit-oriented development or transect, for example.

5.4.5 Consultation

For the purpose of consultation, a public information program that involves developers, city planners, and other key stakeholders should be prepared and implementation announcements to the public made through newspapers and other media. This information should contain a description of the project and its components, and a schedule of its implementation. A letter describing the purpose, content, and schedule of the master plan should be developed and distributed at this stage, along with information for affected people about their rights and responsibilities and legal options. Information distribution or dissemination will also be in the form of a public information booklet. This document should be prepared by the city, in conjunction with the project planners, and then distributed to all affected owners and stakeholders. Meetings also need to be organized to consult relevant stakeholders again.

5.4.6 Master Plan

To prepare the urban and infrastructure master plan, a feasibility study must be conducted, including a general review of existing studies and site surveys, and an examination of the design criteria. Alternatives are examined under technical, financial, economic, environmental, and social considerations, and basic summary design and preliminary cost estimations are carried out for each alternative. Next, comparative social, economic, and technical analyses of scenarios lead to the initial selection of a preferred solution. Finally, an initial implementation action plan and a monitoring plan must be developed to describe the project and optimal solutions in terms of costs, scheduling, funding, and adherence to the principles of sustainability.

5.5 Testing the Model

The proposed framework has been applied to two projects, one in China and one in Canada. The first project was completed to the construction phase (see Figure 5.2), and the second project remained at the stage of a feasibility study. During the first project in Qujing, several pitfalls were found, which resulted in a halt to construction before reaching 50 percent completion. The first observation is that the introduction of new technologies causes a great deal of resistance, especially with design engineers who are accustomed to working from schematics and techniques they use repeatedly. Calculations are often made from charts. These techniques are already proven and, therefore, provide the Designer with confidence regarding the effectiveness of project implementation and functioning facilities. New green design techniques are untested and require more verification. Calculations require more time because they must be more detailed. In a context such as China, this is even more relevant because all designs of highways, roads, and streets are standardized in manuals. For example, culverts for storm water are standardized. In the larger centers such as Beijing, Shanghai, and Xiang, engineers are bolder and propose new techniques. Outside the major centers, resistance to change is very high, and this was the case in Qujing. All new proposed technologies had to be demonstrated and explained, and required specific authorization. Several Qujing City department officers examined new proposals and, for specific cases, provincial and national authorizations had to be obtained.

Figure 5.2: Qujing Project under Construction

The second pitfall to be overcome was the lack of ability to build and implement new technologies. Capacity building was very limited and the emergence of new technologies caused a decline and a refusal to execute new concepts. In each case of a new concept being presented, the objectives should be explained in detail. Weak capacity building delayed the project to such an extent that it was stopped for two years subject to an administrative reorganization. The lesson drawn from this experience is that the introduction of new approaches must be accompanied by an institutional training program and a program to improve capacity building. Thus, it is proposed, in the final diagram representing the new management framework, an activity of institutional strengthening and improvement program of capacity building. Figure 5.3 illustrates the final proposal of the new framework.

The new framework should also include, as the first step, an assessment of the institutional capacity to manage such a project. The inventory step should involve conducting a diagnostic of the administration capacity in terms of organizational setup, work process, management information, and accounting systems to manage the project. In the new framework in figure 5.3, these new components are added.

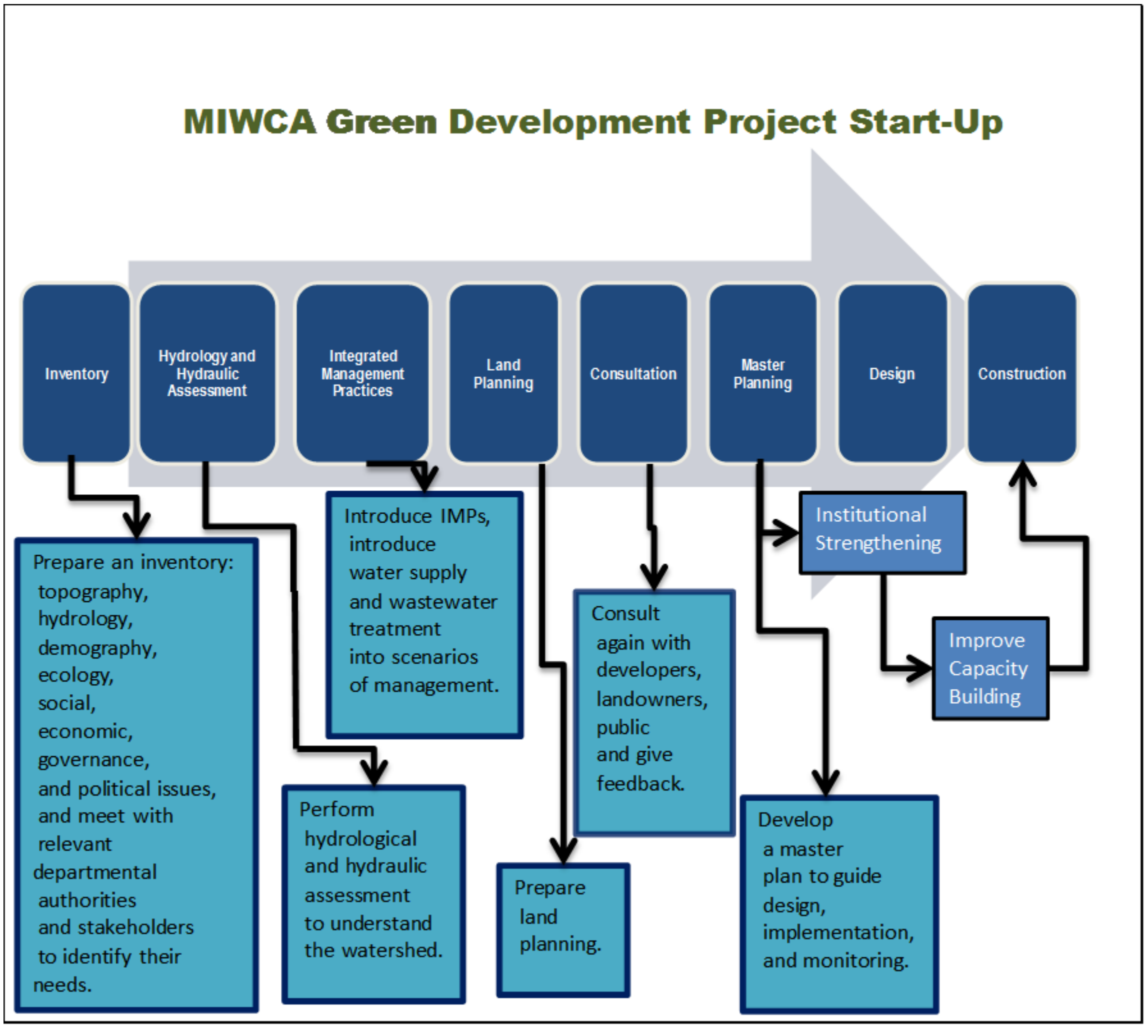

Figure 5.3: New Framework

To launch the project, the team should meet to develop a work plan. The plan will include a participatory agenda to be followed through the study and project implementation. The plan will be reviewed in light of the new proposed framework. According to the type of project, some outside parameters may be evaluated to arm the basic water-centric green approach so that all considerations will be addressed, such as transportation and energy. Then, as the project commences, the first required activity is the inception mission. This mission consists of a preliminary field visit by the team leader, and specialty leaders, to gain a general picture of the project. They will meet with all stakeholders in the project to assess available studies and plans, and they will prepare a final work plan to be approved by the authorities.

5.6 Revenues and Cost

The framework developed in Chapter 3 was systematically applied to build the concept of the new project presented in Chapter 4 (Vaudreuil-Dorion Institutional Pole). The basic analytical framework used for this study considered a preliminary design of an infrastructure component. The new project was designed in detail with CI and with GI. In the GI concept, principles of sustainability, environmental protection, and ecological balance are highly valued. Because the project is being built to create an institutional pole in the city, the basic working plan introduced the transit rhetoric into the concept. Creation of a lake is the heart of the project because all water will be harvested, recycled, and reused in a closed loop circuit. To evaluate the project, water supply including a filtration plant, wastewater including a WWTP, drainage and roads were included in the design and evaluation. In the GI option, facilities include water supply with potable water and raw water distribution network, filtration plant, two networks of wastewater, gray and black water, and low-cost sanitation including wetlands and local wastewater treatment facilities grouping multiple units.

Figure 5.4: Vaudreuil-Dorion Institutional Pole

Figure 5.4 represents a street pattern configuration for the GI scheme. Roads include drainage with retention, bioswales, and wetlands before the water flows into the lake. In this option (GI), investment is needed in each property to complete the design, such as green roofs, rain gardens, and bioretention.

Three methods for cost evaluation were considered:

1. economic analysis
2. the CNT calculator
3. the LCCT.

Revenues were calculated from municipal taxes. The HPM and BTM were used to determine the value of the housing properties. The Vaudreuil-Dorion taxation model was then applied to all properties in the development. Economic analysis is a standard method for evaluating any project. The two other methods are calculators that were developed in the US (CNT) and in Canada (the LCCT). Practitioners refer to these two methods for rapid determination of the value of a project.

5.6.1 Results

5.6.1.1 Costs

The total infrastructure cost for CI averaged $125,000,000 for the proposed project. The total infrastructure cost for GI could vary from $140,000,000 to $200,000,000, including investment at the lot level. The public component of the GI investment could vary from $100,000,000 to $125,000,000. Based only on public investment, GI is less costly than CI. This demonstrates that public administrations can save capital investment using GI. However, the investment needed at the lot level is at least 11 percent higher. This is compensated by a minimum increase in housing value of 15 percent.

All three methods of costing were considered to determine the accuracy of each method. Detailed cost analysis is the baseline method because it evaluates the detailed cost of each component of the project. The two other methods are used as tools for decision makers. They use software into which basic design information is fed. Table 5.1 summarizes the results of each method. For a CI concept, the results are nearly the same, within four percent precision. For a GI concept, the difference is larger: 10 percent for the CNT method and 20 percent for the LCCT method. Nevertheless, this is within the acceptable precision for a preliminary design. The larger deviation may be explained by the lack of updating of unit costs in the software. In addition, the cost for GI at the lot level is not completely detailed in methods 2 and 3. Nevertheless, as a quick tool to evaluate a basic concept, these two tools produce interesting results and do not require a complete detailed design to perform the evaluation.

Table 5.1: GI vs. CI Cost Comparison

	Conventional	Gap	Green	Green	Total Green	Gap
Method	Public municipal infrastructure (roads, drainage, water supply and sewerage)	%	Public municipal infrastructure (roads, drainage, water supply and sewerage)	Developer costs at lot level (green roof, rain garden, filter box)	Public investment + developer investment at lot level	%
1) Detailed Cost Analysis	$124,592,000	0	$115,121,468	$59,600,000	$174,721,468	
2) CNT Green Values Calculator	$119,935,069	4			$157,522,305	11
3) Life Cycle Cost Calculator	$124,091,878	0,4			$139,062,673	25

5.6.1.2 Revenues

In the proposed project, the minimum increased value of the total housing property in a green development could be $202,902,000 for the GI scheme (from $1,652,689,000 for CI to $1,885,582,000 for GI) , and annual extra fiscal taxes to be collected and related to this extra value could be $1,458,115 per year.

The hedonic property value of a house built under a GI scheme could be expected to increase by 15 to 27 percent. This was demonstrated by a simple test comparing canopy cover in six small municipalities of Vaudreuil-Soulanges MRC. The value of houses is directly linked to the number of trees in the city. Many other factors could be evaluated such as views of a lake. Many studies have demonstrated this kind of result for a green environment. Currently, the increase in property values within the Montreal region is based on speculative housing built in a green or blue surrounding. Many projects show a 100 percent increase in value two years after completion.

5.7 Contribution to Knowledge

This research was carried out to provide original contributions to knowledge in GI and sustainable public services.

The first contribution is the development of a new integrated concept and a framework for GI. There are two main concepts of GI: one is the link between ecological hubs and, the second involves a more sustainable substructure to serve the population with water, recycle wastewater, capture the rain, and provide the roads that link villages and cities, including internal services for these habitats. This study demonstrated that it is possible to develop a new concept including both existing concepts; this concept is named MIWCA. This concept proposes mimicking nature in designing public infrastructure, and respecting and linking ecological hubs using the public infrastructure. The concept proposes organizing the district plan around a lake or a reservoir as the central point, and creating it when it does not already exist. The concept proposes organizing urban planning that implement a water-recycling concept with rain and wastewater.

The second contribution is the development and application of a new framework for starting a green development project. This framework is also included in the MIWCA model. There is a multitude of specific frameworks for brainstorming about sustainable development that can contribute to a project's structure. This study proposes a systematic simple approach to organizing a green development project. It is a model for gathering a group of professionals in urban development such as architects, planners, engineers, landscape architects, biologists, sociologists, and ecologists to create a sustainable project.

The third contribution is an added understanding of the cost and value structure of GI. The study presents a comparative evaluation of developing a housing and institutional project using two approaches, one in a green context and one in a conventional context. The new framework was applied to developing two projects. For the second project, a feasibility study was conducted with a complete detailed design using both approaches, and the two were evaluated to compare costs and revenues in each situation. There are limited studies comparing these for a large-scale project such as the one proposed. This study proved that the public part of infrastructure is less costly using a green approach. However, at the house level, an extra investment of 15 percent is required, but this is compensated by more than 15 percent of increased value of the house by value added.

The study also compared the results of two software programs (the CNT GVC and the LCCT) to evaluate the level of investment for GI. After completing the detailed design of each alternative, a detailed cost analysis was performed and results were compared with the two other models. The cost analysis demonstrated the accuracy of the two software results.

5.8 Adversity, Uncertainty, and Proposed Action

In North America, many researchers have suggested that including the concept of GI in a development meets with variable success when it is implemented. In the beginning, Benedict and McMahon (2002) were discussing land preservation and a move to embrace the European concept of hubs and links. As indicated by Pauleit and al. (2011), in North America, cities are team leaders in managing infrastructures and they are facing many challenges by forgetting to incorporate hubs and links according to the ecological concept. For example, the city of Montreal has to replace 100-year-old infrastructure pipes, and policy makers are focusing only on socioeconomic principles and financial concerns. Nevertheless, the city has a greening program focusing on the canopy index. Montreal, with its many green spaces, is well placed in terms of the canopy index in comparison with other major North American cities, but only a few new projects have been accepted with a formal GI program. The concept of connecting ecological hubs has not been defined and LID techniques have not been adopted in a municipal regulation. It is obvious that municipal engineers are reluctant to introduce GI features in design because of the uncertainty of obtaining results. The Montreal Park Division has targeted the planting of 300,000 trees in the next 10 years, but the Public Works Department is not interested in the program. In contrast, the City of Toronto has a strong greening program supported by adapted regulations. However, Toronto has no plan to identify and connect ecological hubs. The program is focusing on green building and waterfront rehabilitation. New York, Chicago, and Boston are focusing on green building and require that new large buildings are certified LEED. Only the City of San Francisco has developed a green connection program with a citywide map of green connections, a design toolkit, conceptual street designs in six neighborhoods, and an implementation document. Most city projects in North America tentatively base their programs on the EPA definition of GI:

> Green infrastructure is an approach that communities can choose to maintain healthy waters, provide multiple environmental benefits and support sustainable communities. Unlike single-purpose gray stormwater infrastructure, which uses pipes to dispose of rainwater, green infrastructure uses vegetation and soil to manage rainwater where it falls. By weaving natural processes into the built environment, green infrastructure provides not only stormwater management, but also flood mitigation, air quality management, and much more. (http://www2.epa.gov/science-and-technology/land-waste-and-cleanup-science)

Currently in Vietnam, many cities are building new hard infrastructure funded by the World Bank and Asian Development Bank. None of the cities included a green perspective in their strategic sanitation plan, except Ninh Binh. The World Bank proposed an eco2 city program to Haiphong, Hue, and Ho Chi Minh City, and they picked up some elements of the program, mainly for transportation.

In China, the China Sustainable Transportation Center (CSTC) was founded by the Energy Foundation in 2005 in Beijing as a non-profit organization. CSTC is the technical center for the China Sustainable Cities Program under the Energy Foundation (http://www.chinastc.org/home).

The CSTC has engaged in:

1. urban planning and transportation pilot projects nationwide.
2. policy and standards research.
3. capacity building, such as training programs.

In China, there is a National Policy prepared by the National Development and Reform Commission (NDRC). Large cities have a rational program but programs have not yet been organized in small cities. Beijing has a program focusing on transportation. Air pollution and water pollution need to be addressed. Cities such as Kunming are addressing water contamination and trying to increase the green area. Nevertheless, a recent program to rationalize the car traffic problem by building large concrete infrastructures was conducted without proposing incorporation of green elements.

In 2003, the Planning Board of the Shanghai Municipal Government made a green map that focused on long-term sustainable planning and development:

> This green map is the framework for Shanghai's future ecological environment and social space. The future urban project will follow this green map and single case will be organized to comply with this map. Big events, like Expo 2010 Shanghai, provide more opportunities in this green urbanism process in multi scale and functions.
> (http://courses.umass.edu/greenurb/2007/he/index.htm) (Xiongfei He, 2013)

Waterfront rehabilitation and creation of new linear parks have been increasing biodiversity and creating green effective links between identified hubs, but this concept is not defined in the process.

In the province of Quebec, there is no plan to maintain and connect ecological links. From a practical point of view, linking the two concepts of GI could demonstrate their economic value and would give decision makers a strategic argument. Many neighborhood developers have found that new families are searching for a better environment for their family, and this new approach should be rationalized and regulated by Quebec municipalities.

5.9 Recommendations for Future Studies

Quebec is a Nordic region with severe winters that has used very few LID techniques to date. This can be explained by the fact that there is not much information regarding how freezing conditions can affect LID techniques. Therefore, municipal engineers have been reluctant in the past to use these known techniques. In fact, it was only in 2011 that the Ministry of Environment of Quebec adopted a design guide for green storm water management. Only a few years ago, analysts from the ministry prohibited the use of bioswales. Concerning the use of wetlands, there is high resistance to retaining this type of equipment to treat wastewater or rainwater. Quebec projects that integrate all elements of GI do not exist. Several projects are in the planning stages and others have introduced some elements of GI. As for the recycling and reuse of water, no projects have been built in Quebec.

It is important to complete an inventory of some of the projects carried out in Quebec even though the techniques used are sketchy or incomplete. It is important to know the costs and to establish their performance. The creation of a university chair to monitor these projects would reassure policy makers and encourage designers to use more of these techniques.

Regarding the reuse of wastewater, it is necessary to increase the level of knowledge because contamination remains a potential risk.

With regard to the storage of rainwater, melting water and recycled water, potential technical storage for a Nordic region needs to be analyzed. This question is all the more relevant because Quebec will be affected by climate change and it is necessary to prepare for other contingencies.

Finally, in northern regions, operating costs and environmental benefits involved in the use of green technology are not well documented and may require more research.

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