STORMWATER MANAGEMENT PLANNING

A BEST PRACTICE BY THE NATIONAL GUIDE TO SUSTAINABLE MUNICIPAL INFRASTRUCTURE

National Guide to Sustainable Municipal Infrastructure
Guide national pour des infrastructures municipales durables

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Stormwater Management Planning

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TABLE OF CONTENTS

FIGURES

INTRODUCTION

INFRAGUIDE – INNOVATIONS AND BEST PRACTICES

Why Canada Needs InfraGuide

Canadian municipalities spend $12 to $15 billion annually on infrastructure but it never seems to be enough. Existing infrastructure is aging while demand grows for more and better roads, and improved water and sewer systems. Municipalities must provide these services to satisfy higher standards for safety, health and environmental protection as well as population growth. The solution is to change the way we plan, design and manage infrastructure. Only by doing so can municipalities meet new demands within a fiscally responsible and environmentally sustainable framework, while preserving our quality of life.

This is what the National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices (InfraGuide) seeks to accomplish.

In 2001, the federal government, through its Infrastructure Canada Program (IC) and the National Research Council (NRC), joined forces with the Federation of Canadian Municipalities (FCM) to create the National Guide to Sustainable Municipal Infrastructure (InfraGuide). InfraGuide is both a new, national network of people and a growing collection of published best practice documents for use by decision makers and technical personnel in the public and private sectors. Based on Canadian experience and research, the reports set out the best practices to support sustainable municipal infrastructure decisions and actions in six key areas: municipal roads and sidewalks, potable water, storm and wastewater, decision making and investment planning, environmental protocols, and transit. The best practices are available on-line and in hard copy.

A Knowledge Network of Excellence

InfraGuide's creation is made possible through $12.5 million from Infrastructure Canada, in-kind contributions from various facets of the industry, technical resources, the collaborative effort of municipal practitioners, researchers and other experts, and a host of volunteers throughout the country. By gathering and synthesizing the best Canadian experience and knowledge, InfraGuide helps municipalities get the maximum return on every dollar they spend on infrastructure—while being mindful of the social and environmental implications of their decisions.

Volunteer technical committees and working groups—with the assistance of consultants and other stakeholders—are responsible for the research and publication of the best practices. This is a system of shared knowledge, shared responsibility and shared benefits. We urge you to become a part of the InfraGuide Network of Excellence. Whether you are a municipal plant operator, a planner or a municipal councillor, your input is critical to the quality of our work.

Please join us.

Contact InfraGuide toll-free at **1-866-330-3350** or visit our Web site at ***www.infraguide.ca*** for more information. We look forward to working with you.

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The dedication of individuals who volunteered their time and expertise in the interest of the *National Guide to Sustainable Municipal Infrastructure (InfraGuide)* is acknowledged and much appreciated.

This best practice was developed by stakeholders from Canadian municipalities and specialists from across Canada, based on information from a scan of municipal practices and an extensive literature review. The following members of the Technical Committee provided guidance and direction in the development of this best practice. They were assisted by InfraGuide Directorate staff and Delcan Corporation.

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EXECUTIVE SUMMARY

The first drainage systems were installed in early Canadian cities at the end of the 19th century, with the main objectives typically being efficient drainage and flood protection within urban areas, and often conveyance of sanitary sewage to the nearest waterbody. Today, a more comprehensive and integrated stormwater management planning process is in place in many municipalities across Canada. The objectives of the process are to accommodate land development and population growth and protect property and natural resources. The increased emphasis on protecting natural resources is the main difference between the traditional approach and the integrated approach. The integrated approach is presented in this document as the best practice.

To apply the best practice, a good understanding of the hydrologic cycle is essential. The following assumptions are basic to this approach:

- Stormwater is viewed as a resource to be protected because of its importance to the natural environment;
- The complete spectrum of rainfall events has to be taken into account, again because of its importance to natural ecology and impacts on built environment; and
- Practices are put in place such that the behaviour of the natural hydrologic cycle is unaltered to the greatest extent feasible, thus reducing flood impacts and maintaining the natural base flows in rivers and streams and recharges to groundwater.

While it is recognized that bringing a watershed or part of a watershed back to its original condition is infeasible, mitigating degradation of the overall resource is an important consideration. In some cases, enhancing the resource by correcting past actions may also be considered where financial, technical and political factors allow.

The document outlines some guiding principles that should be used in implementing stormwater management planning. Among the principles presented are:

- **Sustainability** which recognizes the necessity to balance the economic, social and environmental needs and to protect resources for future generations, when planning, constructing and operating infrastructure;
- **Hierarchical Planning Approach** which requires planning for stormwater management to be carried out firstly at the watershed level, and thereafter proceeding down in increasing detail to the individual site level;
- **Public Consultation** which assumes that all affected stakeholders are consulted and given the opportunity to provide input to decisions; and

- **Adaptive Management** which recognizes we are dealing with very complex natural and man-made systems whose responses are not fully predictable with the currently available science-based tools. Best practice therefore requires designing facilities and processes on the basis of best available data, ongoing monitoring and data collection, and revisiting decisions to produce improved facility and process designs.

A framework for stormwater management planning is presented. It uses the guiding principles developed and issues identified as important in a survey of municipal engineers and administrators to build the planning framework. This entails four planning levels:

- Watershed
- Subwatershed
- Neighbourhood
- Site

For each planning level the intent, features, and typical key stakeholders involved in preparing the planning documents are presented. Practical limitations to the framework are also identified.

A key success factor in stormwater management planning is recognizing the importance of the linkages to land use planning. In ***Section 3*** of the best practice, these linkages are illustrated.

1. GENERAL

1.1. INTRODUCTION

This best practice is one of a number of best practices being developed under the auspices of the National Guide to Sustainable Municipal Infrastructure. These best practices are directed at the administrators, planners, designers and operators of municipal infrastructure and are meant to provide a road map to the best available knowledge and solutions for addressing issues related to infrastructure.

The subject of this best practice is "Stormwater Management Planning". Managing stormwater effectively is one of the challenges facing local and other levels of government charged with the responsibility for land use planning. As our society evolves, so does our approach to stormwater management. In the early days of urbanization in Canada, management of stormwater consisted of measures to:

- Control flooding and the resulting property damages; and
- Maintain streets so that traffic could still flow.

Generally at that time effective stormwater management was seen only as measures that conveyed runoff as quickly as possible to nearby streams and rivers. Today, the deficiencies of the "remove and convey" approach have become evident, and stormwater is increasingly seen as a resource that is vital to the protection of aquatic resources and wildlife habitat and to the overall enhancement of our quality of life.

1.2. PURPOSE AND SCOPE

The purpose of this best practice is to provide the intended users with guidance for the planning and review of stormwater management practices within their jurisdictions. The guidance provided is based on a survey of relevant practices across Canada and of the challenges faced by municipal managers in implementing stormwater management planning. The best practices presented have been seen to be successful and reliable in meeting the objective of the stakeholders involved. Stormwater planning and design practices vary widely across Canada because of the varied climate, geology and urbanization history across the country. For this reason, while the Best Practice provides effective guidance on the topic, users should exercise judgement and flexibility in interpreting the recommended practices, particularly where they related to specific site conditions and designs.

The scope of this best practice is limited to stormwater management **planning** and will not provide recommended practices for implementing stormwater management designs or **best management practices**. It will, however, bridge the gap between a **policy** as developed and agreed by elected officials and the development and approval of **planning documents** necessary for guiding developers and land use planners in managing stormwater. It will also explain how these stormwater management plans relate to the municipal land use planning process. However, the scope of the document is restricted to planning. It does not provide guidance for selecting analytical models, determining water quality criteria, controlling erosion or establishing engineering standards for siting and designing facilities.

1.3. How to Use This Document

The contents of this document should be applied with a clear understanding and appreciation that the practices and methodologies contained in the document are intended to provide guidance towards achievement of the best practice in stormwater management planning. If these practices are followed, the municipality can feel assured it will have adopted an innovative and progressive approach to stormwater management and the natural water-based resources within its boundaries are being protected for enjoyment by this and future generations.

The General section provides the general setting within which the best practice is being prepared, the context within which the finished document should be used, and the scope limitations that will apply.

Section 2 — Rationale outlines the evolution of stormwater management planning in Canada and describes the concepts that form the framework for effective stormwater management planning. It also lists the benefits these concepts will bring to the municipality.

Section 3 — Implementing Stormwater Management Planning discusses the guiding principles on which the best practice are based. Also described are planning issues that may be specific to municipalities. Most importantly, the planning framework that constitutes the best practice is developed.

Applications and limitations to the best practice are described in Section 4. Also described here is the need for ongoing monitoring. Potential research needs also are identified.

The final section describes measures that can be used to evaluate on an ongoing basis the effectiveness of elements of the best practice.

1.4. General Health and Safety

Health and safety procedures are not a focus of this best practice since it deals with a planning topic. Issues such as use of hazardous materials, working in hazardous areas, and the need to adhere to occupational health and safety standards are better covered in the best practices that deal with design and operational aspects of municipal infrastructure.

Several actual and potential public health and safety issues are related to stormwater management, and these should be taken into account at planning stage. Foremost among these is the potential for stormwater management facility design to create conditions that harbour and promote pathogens and the resulting dangers to public health. For instance, drains and stagnant water must be considered in developing the stormwater management plans in regard to the habitat they can create for mosquitoes and the pathogens they can harbour.

Poor planning of stormwater management facilities can result in:

- Increases in risk of drowning (particularly to children swimming in detention ponds;
- Increased traffic hazards due to flooding; and,
- Increased health risks from swimming/wading in contaminated water.

1.5. GLOSSARY

Adaptive Management — A management approach that recognizes we are dealing with very complex natural and man-made systems whose responses are not fully predictable using currently available science-based tools. In adaptive management, we design systems on the basis of the best available data, monitor, and on the basis of monitoring data improve the system designs if the original objectives are not met.

Combined Sewer — A collection system designed to convey stormwater and sanitary flows in a single pipe.

Detention — Temporary storage of runoff with the goal of controlling peak discharge and/or providing gravity settling of pollutants.

Development Cost Charges — Costs charged to owners/developers for the pre-building of infrastructure to service their lands.

Ecological Footprint — A way of determining relative consumption for the purposes of educating people about resource use. It approximates the amount of imagined productive land it takes to sustain a person or group of persons based on their use of energy, food, and other consumables.

Ecology — The science dealing with the relationships among organisms and with their surrounding environment.

Groundwater Recharge — The element of the hydrologic cycle where precipitation percolates through the ground surface and subsurface soil layers and reaches the saturated zone.

Hierarchical Planning — In the context of stormwater management planning, examining the impacts of development first at a larger watershed level and then at a subwatershed and site level.

Hydrologic Cycle — The continuous circulation of water between the oceans, atmosphere and land.

Integrated Stormwater Management — An approach to stormwater management that integrates the land use planning, engineering, and environmental science functions with the goal of protecting property and wildlife habitat while accommodating land development.

Neighbourhood — In the context of this document, an area where the planned development requires infrastructure to service several owners and sub-areas. This infrastructure is typically planned and supplied by the municipality.

Site — In the context of this document, an area to be developed which is controlled by one owner. Infrastructure is typically planned and supplied by this owner.

Stormwater Management — The planning, design and implementation of systems that mitigate and control the impacts of man-made changes to the runoff and other components of the hydrologic cycle. Stormwater management is better known as “rainwater management” in much of the world.

Stream Buffer — An area on either side of a stream retained in its natural state.

Subwatershed — A part of a larger watershed which also drains to one point.

Sustainability — In general terms, sustainability refers to conditions that meet current needs without compromising the needs of future generations, taking into consideration the environmental, social, and economic factors together (WCED, 1987). The terms “sustainability” and “sustainable development” have varying interpretations, depending on the perceptions, values, priorities, and perspective of individuals and organizations.

Watershed — An area for which all precipitation drains to one point or outlet.

2. RATIONALE

2.1. BACKGROUND

Stormwater is the component of rainfall that stays on the surface (ponding) or flows to receiving water bodies. It is the component of rainfall that traditionally has to be managed to prevent flooding and erosion, particularly when land development results in vegetation and topsoil being replaced with roads and buildings. When this happens, the natural water balance is altered. Clearing forested lands and developing them for residential housing or commercial buildings brings about an extreme alteration that can cause the runoff volume to increase by up to 500%.

Stormwater management has evolved constantly since the first sewer networks were installed in early Canadian cities at the end of the 19th century. With the increasing urbanization of the post-war era, urban drainage became more sophisticated with distinct preferences for piped systems. In the 1960s came the recognition of the value of a major/minor conveyance system, with the minor systems designed to convey in pipes the stormwater from fairly frequent events, typically up to and including the 1-in-10 (1:10) year event. The major (overland) systems were designed to convey the more infrequent events (up to 1: 200 year storm) without damage to property or people. Design criteria varied and continue to vary across the country. For instance, in Québec, designers most frequently use a 1:2 or a 1:5 year event for minor system design and a 1:100 for the major system. Embedded in the design basis of these conveyance systems was the objective of removing the runoff as quickly as possible without damage to properties being serviced and to downstream properties. Regrettably, the latter part of the objective was frequently not met, and the courts of North America were the frequent arbiters in cases where upstream development was alleged to cause downstream damage.

Detention ponds were a widely used innovation of the 1970s and 1980s. These wet or dry ponds were seen as providing solutions to the problems associated with increased peak flows from development areas. They were designed to store runoff from major storms and protect downstream properties. Facilities were designed to cope with infrequent storms, store large quantities of runoff, and release these quantities in a controlled way so that the capacities of natural and man-made conveyance systems were not exceeded. Often detention ponds did not reduce flooding problems and sometimes exacerbated low baseflows and habitat degradation. Sophisticated computer programs became available for hydraulic and hydrologic modelling of the systems. While these ponds were initially seen and marketed as attractive and aesthetic additions to a development, they frequently became maintenance burdens for the municipalities who assumed responsibility for them. Potential for drowning, habitat that promotes and harbours pathogens, and habitat that promotes mosquito breeding are additional considerations.

Today, ***Integrated Stormwater Management*** has gained widespread acceptance by local governments, environmental agencies, and developers, and is considered state-of-the-art for purposes of this best practice. It is a comprehensive approach to stormwater management planning where the word "integrated" is meant to convey an approach which accommodates land development and population growth while protecting property and natural resources. The need for such an approach arose out of the obvious deficiencies inherent in the practices of the 1970s and 1980s. These past practices focused on the fast conveyance of extreme storms and often created substantial erosion, degradation, and flooding in receiving streams.

Some of the features that differentiate integrated stormwater management planning from the traditional approach are:

- Stormwater is viewed as a resource to be protected because it is important for:
  - Fish, other aquatic species and wildlife;
  - Groundwater recharge to maintain base flow in streams;
  - Water supply; and,
  - Aesthetic and recreational use.

  To effectively plan with this feature in mind, the engineering, environmental science, and planning disciplines need to be involved.

- A complete spectrum of rainfall events has to be designed for, not merely the infrequent major storms. It is understood that the natural ecology is the product of and dependent on the **average** more that the **extreme** conditions. Therefore, the total rainfall pattern and inventory over a site or catchment has to be considered and peak flows, runoff volumes, and other characteristics should be maintained as close as possible to original conditions.
- The importance of maintaining base flows in rivers and streams is recognized.
- The importance of considering the capacity of receiving water bodies to assimilate the projected flows.
- The importance of planning at all levels—watershed, subwatershed, neighbourhood, and site—is recognized, and a critical component of this planning is effective public and stakeholder consultation.

In most cases, it is recognized that bringing a watershed or part of a watershed back to its original condition may be infeasible. However, preventing degradation of the overall resource is important and, where technically and financially feasible, enhancing the resource by mitigating past actions should be considered.

2.2. STORMWATER MANAGEMENT PLANNING

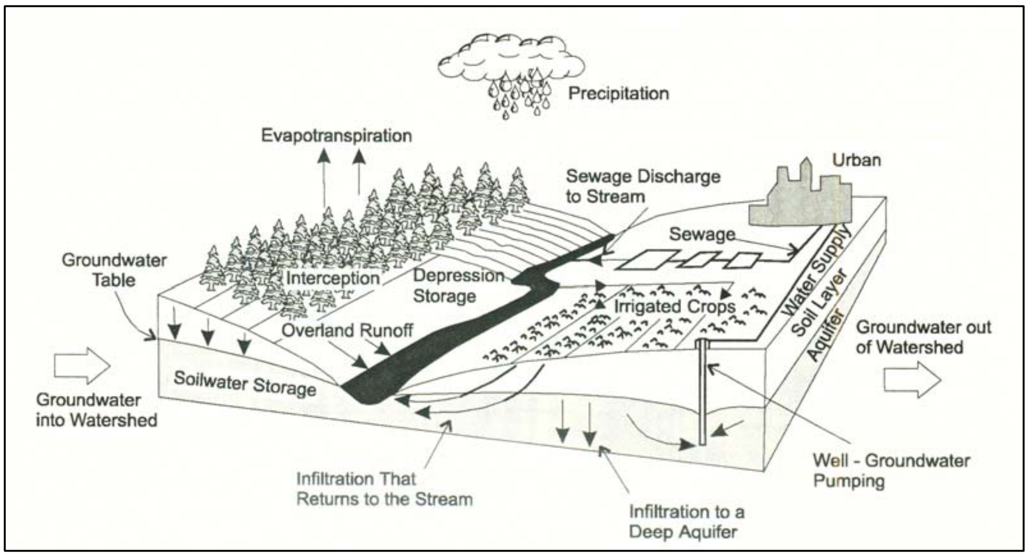
In the document, planning is defined as the bridge between the **policies** agreed at a political level and the **designs** and **field practices** proposed and implemented by development proponents and their advisors.

Understanding the hydrologic cycle is a crucial aspect of stormwater management planning, particularly in the integrated approach. In addition, the relationships between municipal land use planning and stormwater management planning are essential to preparing effective stormwater management documents and implementing facilities that function as planned.

2.2.1. HYDROLOGIC CYCLE

The hydrologic cycle describes the continuous circulation of water between the oceans, atmosphere and land. The main elements of the cycle are depicted in **Figure 2–1** as it relates to stormwater management planning ***(Ref 2)***.

Figure 2–1: Hydrologic Cycle



Important elements of the cycle impacted by human activities (agriculture, urbanization, and industrialization) are:

Evapotranspiration: Development of a forested area (0% imperviousness) for typical industrial/ commercial purposes (70% imperviousness) will reduce the amount of water evapotranspired by over 50%.

Overland Runoff: Development of raw land without mitigation for changes involved can increase total runoff by up to 500%. Water quality impacts are well documented.

Groundwater Table: Increased runoff resulting in reduced infiltration which in turn reduces groundwater table levels. This can impact water supplies for population centres, agriculture, and base flow contributions to streams**.**

Agriculture: Impact of irrigation and fertilizers on surface and groundwater is a major concern, particularly in flat areas such as the Fraser Valley in British Columbia. Implications of agricultural activity on water supplies, particularly for shallow groundwater, are highlighted by the Walkerton potable water crisis. Additional concerns are present if biosolids applied to agricultural land as soils amendment.

Sewage Discharge: Point-source contamination at treatment plant outfall is a serious concern for owners of treatment plants and regulators. Combined sewer system will periodically discharge untreated sewage at overflow locations. Stormwater point-source and non-point-source discharges are currently a significant contributor to contamination of receiving waters. Effective stormwater management planning will need to examine feasible ways to reduce this contribution.

2.2.2. Land Use Planning

Efforts to mitigate the impacts of urbanization has led to the integrated approach to stormwater management. In the context of municipal land use planning, the major challenge facing municipal administrators and planners is to facilitate development, be it residential, commercial, industrial or institutional, while avoiding flooding, erosion, and water quality degradation caused by stormwater **and** preserving the natural environment. For this reason, stormwater management planning and land use planning are closely linked. It is essential that the stormwater management planning documents, described more fully in ***Section 3***, account for the cumulative effects of development and provide relevant information to enable timely and appropriate decisions related to land use planning. The documents should be consistent with the municipal land use planning documents and provide direction to development proponents on how to meet the stormwater management objectives agreed during development of the documents.

2.3. Benefits

The benefits of stormwater management planning as an essential component of municipal land use planning and development cannot be over-emphasized. Many older urban areas in Canadian cities and towns have been developed without effective stormwater management and continue to suffer the related property and ecological impacts. Local governments have been held liable for downstream damage due to upstream development. Federal and provincial legislation provide local governments with the authority to plan, regulate and approve land use changes. With that authority comes the responsibility for protecting stakeholders' rights and the environment.

The benefits of adopting this best practice and the related guiding principles inherent in the best practice are:

- Acceptance and buy-in by stakeholders, including relevant agencies, resulting in compliance with applicable legislation and faster project approvals;
- Protection and improvement of water quality and aquatic and wildlife habitat;
- Effective flood, erosion and sediment control, during and after implementation of stormwater management measures and facilities;
- Maintenance of stream base flows and groundwater recharge systems; and
- Improved coordination between municipalities and other levels of governments, and between groups/departments within individual municipalities.

3. IMPLEMENTATION

3.1 STORMWATER MANAGEMENT PLANNING

The trend toward increased urbanization is continuing. With it comes the expectation on the part of the public that the available land will be developed with the following two interrelated objectives being met:

- Achieving developments that meet our current needs for housing, schools and other facilities; and
- Maintaining our natural resources for us and future generations to enjoy.

Ongoing and historical concerns regarding stormwater runoff on the part of stakeholders in the development process led to a renewed interest in how we deal with stormwater, since it is a vital link in the conservation and enhancement of terrestrial and aquatic resources. Surveys carried out across Canada for the purpose of this best practice indicate a worsening in the quality of the water bodies receiving stormwater discharges and a worsening in the quality and quantity of habitat for aquatic and terrestrial wildlife. The survey also pointed toward a growing interest in more effective stormwater management at all levels of governments.

3.2 GUIDING PRINCIPLES

The collective experience of planners, designers and operators of municipal infrastructure has resulted in the following guiding principles becoming the basis of best practice in stormwater management planning.

3.2.1 SUSTAINABILITY

As the title to the document of which this best practice is part indicates, **Sustainability** is rapidly becoming a key driver and focus of infrastructure planning. While the word “sustainability” means different things to different people, in the context of stormwater infrastructure emphasis is placed on the following features of sustainable development:

- Recognition of the need to reduce the “ecological footprint” in land development;
- Balancing the economic, environmental and social needs in planning constructing and operating infrastructure, i.e. the “triple bottom line” concept; and
- Commitment to preserving and where possible enhancing our natural resources, both local and global, for future generations.

Global sustainability issues such as energy use and greenhouse gas emissions will also need to be considered by infrastructure planners. While these issues are "global", the impacts are an accumulation of the impacts of "local" activities. Stormwater management facilities can influence the levels of greenhouse gas generated in the way they are designed, constructed and operated. Climate change resulting from global warming or other causes should also be a consideration in stormwater management planning.

3.2.2 Hierarchical Planning Approach

This guiding principle reflects the importance of a watershed as the basis for stormwater management planning. A watershed is an area which drains to a single point and can be a large part of a province or a smaller area which is only a fraction of a municipality's land base. The important feature of the principle is that stormwater management planning is carried out in a hierarchical fashion. This is accomplished by first examining impacts at the watershed level, then proceeding to an ever-increasing level of detail to subwatershed, neighbourhood and finally to a site level. Later in the best practice, more details will be given on the objectives and activities at each of the planning levels.

Key elements of this principle are:

- Recognition that watersheds, being natural drainage systems, are the appropriate level at which effective stormwater planning begins;
- Actual stormwater management facilities are implemented at the neighbourhood level (by the municipality) or site level (by the owner) to facilitate residential, commercial, industrial and institutional development;
- Intermediate levels of stormwater management planning may be required to bridge the largest planning level (watershed) and the smallest (neighbourhood and site); and
- Stormwater management planning is closely linked with resource, land use and community planning.

This last element is essential since it establishes the linkage and inter-dependence of community planning with stormwater management planning at all levels. At the higher level (watershed) it typically requires the cooperation of several municipalities and incorporation into their official planning documents of the decisions arrived at and recommended in the watershed plan.

3.2.3 Public Consultation

Public consultation is now considered an essential component of effective planning of municipal infrastructure. All stakeholders, from interested individuals to advocacy groups and affected landowners, need to be given the opportunity to become informed about and provide input to plans. This guiding principle is a direct result of our democratic process where stakeholders are informed and empowered by their rights as ultimate decision-makers at the ballot box. As a result, elected officials require public consultation before making a decision.

Several benefits can result from an effective public consultation program. Among them are a worthwhile sounding board for strategy and plans, early buy-in to approach, and smoother implementation. Public involvement can also result in assistance in getting detailed and up-to-date ecological data and in implementing monitoring programs.

3.2.4 PROPERTY OWNERSHIP

The three guiding principles described above are relatively new features in planning municipal infrastructure. In contrast, property ownership and the rights it confers have been enshrined in our legal system for centuries. All planning decisions related to land use and stormwater management are likely to be affected by ownership patterns. Development of urban and suburban land depends to a great extent on how successful development proponents can acquire and assemble the relevant parcels.

Key elements of this principle from a stormwater management planning viewpoint are:

- Lack of cooperation from individual owners in regard to proposed stormwater management plans can delay or compromise the most effective options.
- Expropriation of needed land is always an option for a municipality. However, laws related to expropriation recognize ownership rights and provide owners with a relatively high level of protection.
- On-lot stormwater management options, particularly in developed areas, are limited by owners' rights. This applies to Best Management Practices (BMPs) such as downspout disconnection, on-lot grading, and other source control measures.

3.2.5 INTEGRATED PLANNING APPROACH

The term integrated stormwater management planning has come to signify a multi-disciplinary approach to planning stormwater infrastructure. In contrast, "traditional" stormwater management tended to be uni-disciplinary and focused on the fast conveyance of extreme storms. Modern day planning requires a much higher degree of interdisciplinary interaction between land-use planners, engineers, landscape architects, and environmental scientists.

Key components of this principle are:

- By linking stream corridor impacts to catchment land use, it seeks to protect property from flooding and protect aquatic and terrestrial habitat from degradation;
- It will recognize that the natural system is dependent on the full spectrum of rainfall events and will seek to mimic to the greatest extent possible natural system behaviour at all levels from watershed scale down to individual site; and

- To apply the principle effectively, it acknowledges expertise in environmental and land use planning, aquatic and terrestrial ecologies, water chemistry, in addition to the more traditional disciplines of municipal engineering and surface and sub-surface water resources, are required.

3.2.6 Adaptive Management

In adaptive management existing knowledge is used to produce the best available plans and designs. These are then monitored with respect to predicted outcomes and objectives, and the monitoring data is analyzed to produce improvements in the system if the original objectives are not met.

The principle of adaptive management is important in integrated stormwater management planning for several reasons. Among them are:

- We are dealing with complex natural systems where the scientific data to link cause and effect is still evolving.
- Science-based decision-making tools are still being developed. While experience is providing us with useful guidance (e.g. ecological effects result when the ratio of impervious area to total area exceeds 10%), more data needs to be collected and analyzed to determine the effects of variables such as climate, geography, species, etc.
- Innovative technologies such as advanced supervisory control and data acquisition (SCADA) systems are now available to record, transmit, store and analyze data from stormwater systems. Solutions to complex problems which were not possible up to recent times are now possible and feasible using information technology.

Adaptive management should apply to all facets of stormwater management planning. The benefits are a continual improvement in quality and quantity of data available and therefore increased opportunities to arrive at science-based decisions. Recent solutions can be tested based on actual data and improved solutions developed based on data analysis.

3.2.7 Financial Viability

Modern stormwater facilities require significant capital investment and ongoing operations and maintenance efforts. Facilities need to be viewed on a lifecycle basis where funding for preventive and emergency events need to be available. Financial viability implies:

- Adequate funding is available for design and construction of the facilities;
- No deficiencies or flaws are evident when responsibility for the facilities are assumed by the operations and maintenance department of the municipality; and
- Sources of funding to adequately operate, maintain and ultimately replace the facilities at the end of their useful life are available.

Funding mechanisms could be federal/provincial infrastructure funding, municipal tax revenue, development cost charges, or a stormwater utility. A positive trend in recent years is using a stormwater utility. A utility is an attractive means of:

- Assigning costs to actual beneficiaries;
- Applying the principles of full cost accounting to the stormwater system; and
- Educating the public on the costs and benefits of stormwater management.

3.3 Planning Issues Specific to Municipality

Canada has a diversity of climates, geographies and other characteristics. Stormwater management planning has to take these different conditions into account. In interviews and surveys across the country, the following issues were highlighted with respect to their influence on planning:

3.3.1 Land Use

Many municipalities have significant rural land bases undeveloped and in many cases still utilized for agriculture. Annexation policies frequently promote this. Other municipalities have been effectively fully developed for a long time, and development opportunities are now restricted to infilling and redevelopment. There are challenges associated with each condition.

Agricultural land use presents municipalities with particular challenges. Typically, the most fertile land is in the floodplain. Settlers, by building dykes for flood protection and clearing land for tilling, have already altered the natural landscape enormously. Roadside and other ditches replaced natural drainage patterns.

Since farms are typically in the lower areas, increased flow from higher-level developed lands will contribute to land drainage problems. Drainage criteria for agricultural land are different from developed land. Impacts are dependent on time of year and the particular crop being cultivated. The City of Surrey in British Columbia has systematically addressed the issues related to lowland drainage for agricultural purposes (*City of Surrey, 1997)*.

Infill developments are typically carried out in areas developed under traditional stormwater management practices. As noted earlier, these practices resulted in the destruction of much of the natural resources associated with natural creeks, forests etc. In many cases, creeks became the routes for storm or combined sewers. In such cases, management of infill development should focus firstly on mitigating resource degradation by applying the practices appropriate to the individual sites being developed. In some cases, reversal of previous damaging decisions is being considered, such as “daylighting” of creeks, removal of river dams no longer in use, and habitat restoration.

3.3.2 GEOLOGY

Local and regional geology have a major impact on the hydrologic cycle. Some areas in their natural condition have impervious clay, silt, and bedrock layers which prevent groundwater recharge directly to subsurface aquifers. In the natural environment this results in ponding of fields, evaporation, shallow soil storage and runoff. In the natural rainforest prevalent in British Columbia approximately 50% of rainfall typically infiltrates and 50% is evapotranspired. Strategies for dealing with these variations need to be in place.

3.3.3 HYDROLOGY

Rainfall characteristics and seasonal patterns differ from area to area in Canada. As stated previously, the aquatic and terrestrial life systems are formed and sustained by precipitation (and other climatic conditions) over geological time. It is therefore important to compile rainfall and snowfall data from available stations to establish these patterns and use them to control the impact of land use changes on the hydrologic cycle. Analytical tools are now available to assist engineers in designing stormwater systems that:

- **Capture** the rainfall from the frequent smaller events and restore it to the natural predevelopment pathways in the hydrologic cycle;
- **Detain** rainfall from the medium size events with facilities that provide storage and the capability to release it to the sewer system or natural environment, again at the natural predevelopment level; and
- **Convey** the rainfall from the infrequent events; say 1:100 or 1:200 year events, minimizing damage to persons or property.

3.3.4 CONSTRUCTION PHASE STORMWATER

Surveys conducted for the purpose of this best practice pointed to construction sediment released during urban development activities being a significant proportion of total contaminants transported by stormwater. These contaminants are typically sediments transported to the receiving streams and storm sewers. During construction, runoff flows over areas stripped of cover and topsoil. It erodes the soil and conveys enormous quantities of sediment to locations where the velocity is reduced and the sediment settles out.

Municipalities should make detailed plans for sedimentation and erosion control during construction a requirement for project approval.

3.3.5 LEGISLATION

Legislation governing stormwater and the level of which it is enforced vary across the country. Legislation can be federal, provincial or municipal (bylaws).

Knowledge of the legislation and the agencies charged with its administration is an important consideration in stormwater management planning.

One of the most powerful laws that are relevant to stormwater management planning is the Federal Fisheries Act. This legislation prohibits "the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where the deleterious substance may enter any such water".

3.4 PLANNING FRAMEWORK

This subsection will develop the best practice framework for stormwater management planning based on the guiding principles and planning issues identified in previous subsections. The best practice will provide practical guidance on a framework and procedures that have been found to be effective in jurisdictions where they were established. It should be stated, however, that the state-of-the-art of stormwater management is constantly and rapidly evolving. Changes to best practices will therefore continue on an ongoing basis. With these improvements comes the need to constantly review and modify our approaches.

3.4.1 PLANNING FRAMEWORK DETAILS

The framework presented in the following paragraphs is a structure on which to build a state-of-the-art stormwater management planning process. It will recommend planning documents of various levels of detail and processes by which they become accepted references within the community. It may not suit the requirements of every municipality since requirements vary depending on size, climate, land use etc. Certain documents that cover the intent and contain the recommendations may already exist, and documents may be called different names since terminology varies widely.

In **Subsection 3.1** is described the principle of hierarchical planning as it applies to stormwater management. It results in considering watersheds as the natural and logical boundary for stormwater management planning, and in proposing the need for four levels of stormwater management planning:

- Watershed
- Subwatershed
- Neighbourhood
- Site

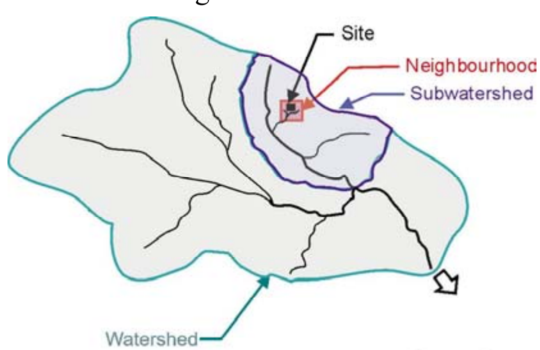


FIGURE 3.1
Stormwater Management Planning
Watershed, Subwatershed, Neighbourhood, Site Levels

A graphical representation of the above four levels of planning is illustrated in **Figure 3–1**. The intent is that the technical evaluations, field assessments, public consultations and other activities will lead to an agreed plan at each level. **Figure 3–2** presents a schematic of the framework and indicates the principal features of the plan along with the key stakeholders providing input and approvals.

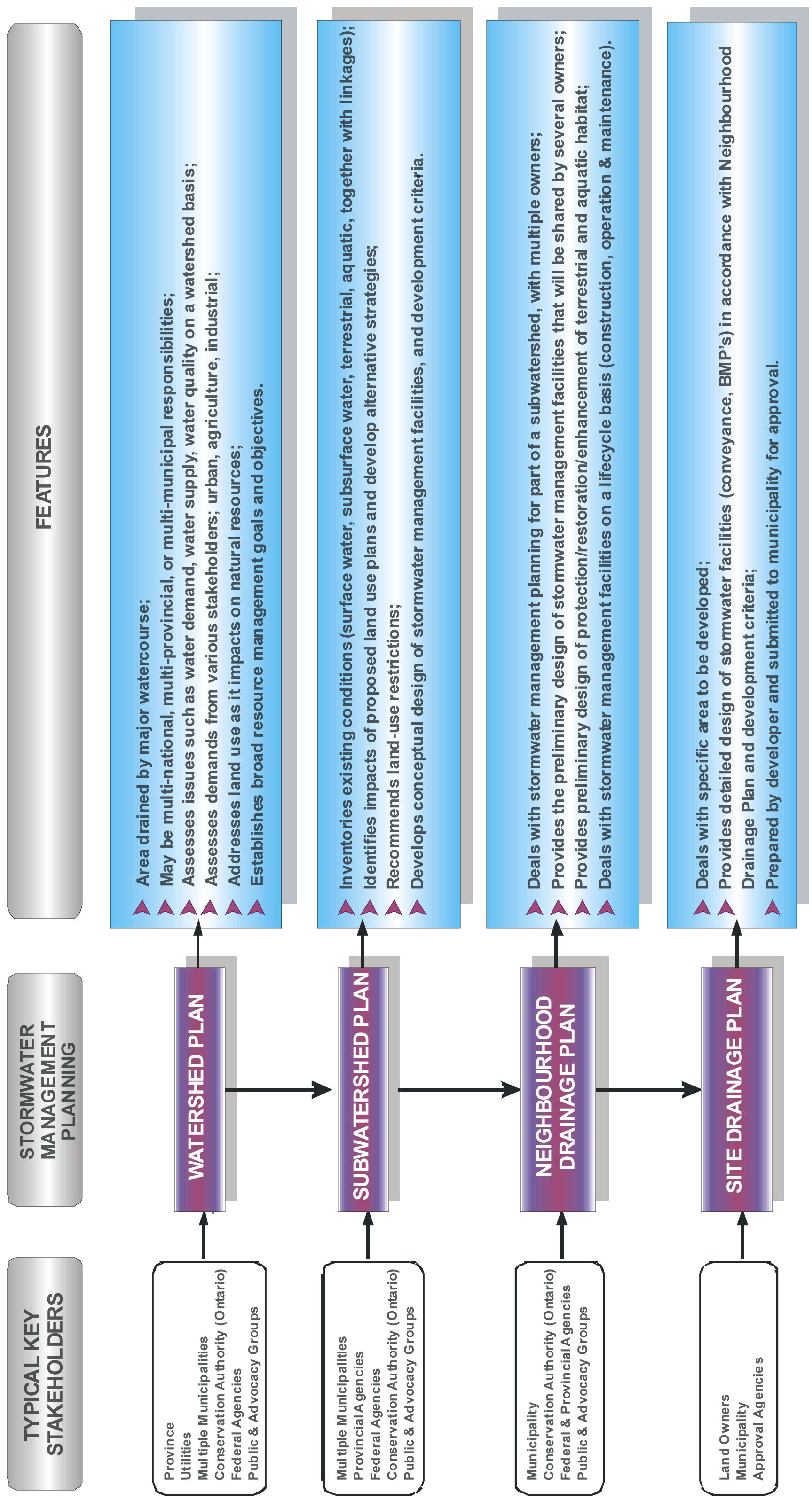


Figure 3–2: Planning Framework

Watershed Plan

The **Watershed Plan** is the highest level planning document.

Intent

The intent is to prepare a strategic plan that will allow development to occur while protecting or enhancing the natural ecosystems. Development could include urbanization, energy and resource development, crop irrigation (agriculture), or other industries that have a significant demand and/or impact on water in the watershed. The plan has goals and objectives together with actions necessary to meet them. The watershed plan will not contain the level of detail needed for design. It will be an "umbrella" document under which the subsequent plans will be prepared and should include vision, principles, and objectives.

Features

Features of a watershed plan are:

- It will cover an area drained by a major river, often greater than 1,000 km^2 (but may be much smaller if a large number of issues and stakeholders are involved);
- It will typically be a provincial, multi-municipality responsibility. In Ontario, the responsibility belongs to the Conservation Authorities. In other provinces, the regional level of government (between the municipality and the provincial government) may undertake the work;
- It assesses issues such as water demand, water supply, and water quality on a watershed basis. The demand from various stakeholders (rural, suburban, urban, industrial, power generation) is evaluated; and
- It addresses land use as it impacts on natural resources and describes the cumulative impacts associated with the developments (existing and proposed);

It establishes broad resource management goals and objectives which lower level plans will have to accept.

The technical disciplines required to develop a typical watershed plan are:

- Surface water hydrology;
- Subsurface hydrology and hydrogeology;
- Water quality;
- River engineering;
- Aquatic and terrestrial resource expertise; and
- Land use planning.

Key Stakeholders

Key stakeholders that should be engaged and invited to provide input are:

- Provincial and Federal departments/agencies, municipalities, and regional governments (in Ontario, Conservative Authorities);
- Energy and resource utilities, irrigation districts, industries, and farmer associations; and
- Elected officials, advocacy groups, and interested members of the public;

Subwatershed Plan

The **Subwatershed Plan** addresses stormwater management in a portion of a large watershed which typically will be a tributary of a major river. The subwatershed is also a watershed on its own right since all rainfall drains to a point, generally where it meets the main channel of the larger watershed. The subwatershed could be any size, but is typically between 10 and 200 km^2. The subwatershed plan could also be the first document produced. This will occur where developments in the subwatershed are relatively independent of those in the overall watershed and where there are few interrelated issues to be resolved at a larger watershed level.

Intent

The intent of the subwatershed plan is to establish a more detailed integrated stormwater management plan that will meet the goals and objectives established at a watershed level and further defined during the studies and public consultations for this plan.

Features

- It involves more intense participation by the agencies having jurisdiction and other stakeholders;
- It entails collecting the necessary background information related to the watershed. It also entails studies that typically will include some or all of the following, depending on how much information is already available:
  - Surface water resources;
  - Groundwater;
  - Water quality;
  - Inventory of aquatic and terrestrial resources; and
  - River and stream engineering.
- It will establish the linkages between the different resources so that the key elements which need to be protected can be identified;

- Developing the plan involves presenting the inter-relationships between the resources to the stakeholders so that goals and objectives for the plan can be established;
- It will consider alternative subwatershed management strategies and offer appropriate consultation with stakeholders to select a preferred strategy based on environmental, economics and social criteria; and
- It will recommend land use constraints, develop conceptual designs of stormwater management systems, and present development criteria and targets.

The technical disciplines required for developing a subwatershed plan are as for a watershed plan with the addition of:

- Urban hydrology/drainage engineering/computer modeling; and
- Stormwater management system design.

Key Stakeholders

Key stakeholders are as for the watershed plan. The level of interaction with stakeholders is significantly greater than that for a watershed pan due to decisions being made and number of stakeholders directly impacted. Group facilitation skills are needed in managing stakeholder input.

Neighbourhood Drainage Plan

The **Neighbourhood Drainage Plan** is the level of planning which provides for the area being considered the optimal drainage system in conformance with the plans for the watershed or subwatershed of which it is a part. The area covered by the neighbourhood drainage plan will typically be a part of a subwatershed for which a subwatershed plan has been prepared. Hydrologically it may be a watershed by itself; more likely the boundaries of the neighbourhood will be determined by other factors such as land use zoning, development pressures, ownership etc.

Intent

The intent is to develop the drainage plan for the area being considered, including the preliminary design of the stormwater management systems so that development can proceed in conformance with the subwatershed plan and applicable land use documents.

Features

- It typically deals with an area of one square kilometre, which has multiple owners and is part of a subwatershed for which a plan has been completed;
- It entails the preparation of a plan which details environmental conditions, establishes preferred strategy, and presents the findings and implementation plan/schedule;

- It will include preliminary designs for enhancement/restoration measures; location, sizing and preliminary designs of stormwater management facilities; and funding responsibilities for construction, operations and maintenance; and
- The development of the plan may be undertaken and funded by private developers with large land holdings within the plan boundaries.

The technical disciplines required for developing a neighbourhood drainage plan are as for the subwatershed with the addition of:

- Municipal engineering;
- Hydraulic design;
- Land use planning; and
- Geotechnical and environmental engineering.

Key Stakeholders

As for the Subwatershed Plan, with reduced interest for rural and agricultural interests.

Site Drainage Plan

The **Site Drainage Plan** generally provides details of proposed environmental and stormwater facilities for part of a neighbourhood for which a neighbourhood drainage plan has been prepared. It is a detailed design and is usually submitted with site servicing plans and site grading and erosion control plans. It is typically the responsibility of and funded by the owner/developer.

Features

- It deals with a specific area to be developed in accordance with land use planning documents, and the applicable subwatershed and neighbourhood plans;
- It provides detailed design of stormwater management facilities (detention, conveyance, BMP's); and
- It is typically prepared by the developer and submitted to the municipality and applicable approval agencies for approval.

Technical skills required are those related to detailed design and contract document preparation.

Key Stakeholders

Only the landowners, municipality, and relevant approval agencies are likely involved at this level. It is possible that affected neighbours may be involved.

3.4.2 Plan Staging

Many municipalities have developed a staged, sequential approach to plan preparation and implementation. This approach is presented as a best practice for stormwater management planning since it embodies many of the guiding principles outlined in this section and has been found to be successful in meeting planning objectives. It is graphically depicted in **Figure 3–3** following:

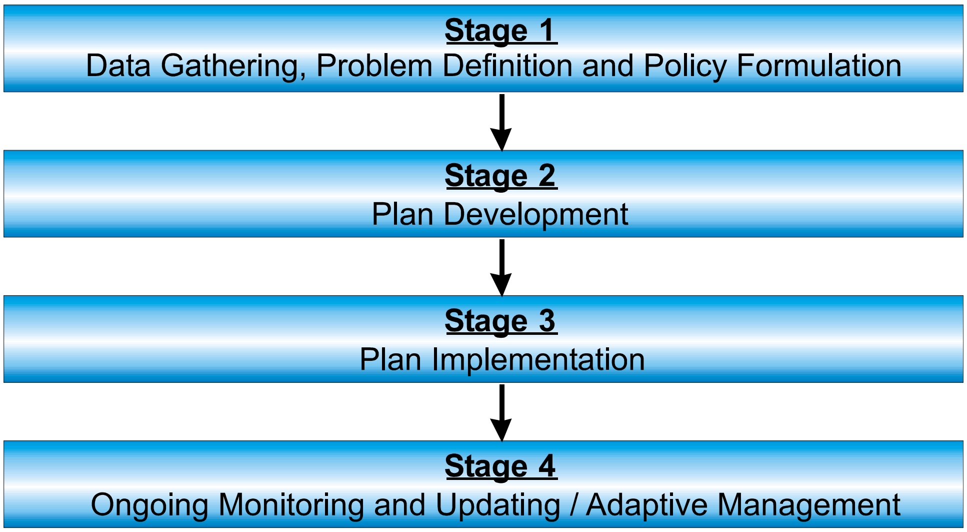


Figure 3–3: Staging of Stormwater Management Plans

The staging can be applied to all four levels of plan. Different plans will have varying levels of effort and emphasis at the different stages. Stage 4, embodying the principle of adaptive management, is important for all levels.

3.4.3 Practical Limitations

While the framework presented in this section represents the state-of-the-art and should be adopted where political and jurisdictional circumstances permit, there will be occasions when use of the full framework will not be feasible. Under some circumstances, it will not be possible or practical to prepare a watershed plan. A subwatershed plan and a neighbourhood drainage plan may sometimes be fused together in one document to meet the planning objectives. This can still be best practice as long as the plans are prepared with awareness of the guiding principles noted earlier. Of particular significance is the hierarchical approach which recognizes that stormwater management planning should, where feasible, begin at watershed level and proceed in increasing detail down to the actual drainage facilities constructed at site level.

International and inter-provincial watersheds may have complex planning challenges and require special considerations.

3.4.4 LINKAGE WITH LAND USE PLANNING

There is a general recognition that a more holistic approach is required to mitigate the impacts of urbanization. This is reflected in the official community planning documents which are prepared by municipalities under the enabling provincial legislation. In these documents are laid out the fundamental philosophy and principles which become the basis for the policies and practices governing the future growth of the community. Among the fundamental principles typically seen in the official community plans are:

- Protection of private property rights;
- Protection and enhancement of the environment; and
- Protection of surface water and groundwater quality and quantity.

These are closely related to and provide the momentum for integrated stormwater management. **Figure 3–4** summarizes the inter-relationship between municipal land use and stormwater management planning processes. Municipalities differ significantly on how they present land use planning documents, so the terminology used in **Figure 3–4** is arbitrary.

Given that extensive political and stakeholder involvement is necessary in developing and approving the land use documents, it is essential that the linkages to the stormwater management plans are recognized. **Figure 3–4** shows the linkage generally in both directions highlighting the “living” nature of these documents and the ongoing requirements to update them.

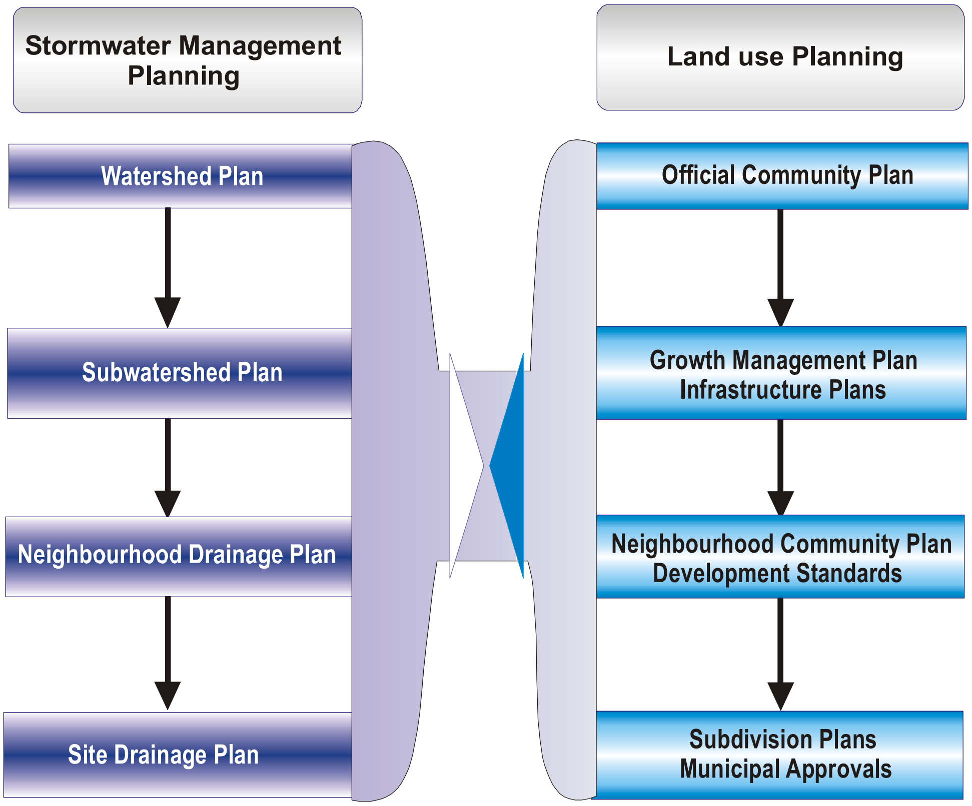


Figure 3-4: Stormwater Management Planning – Municipal Land Use Planning Linkage

4. APPLICATIONS & LIMITATIONS

4.1 APPLICATIONS

The guiding principles and planning framework presented in this best practice apply to all levels and areas. They are particularly relevant to high growth municipalities where natural and agricultural landscapes are being converted to developed subdivisions for residential, institutional and/or industrial purposes. As a best practice, the document applies equally to large and small municipalities across Canada.

Potential applications are as follows:

- By **higher level governments** (provincial, regional) to demonstrate the appropriate planning approach to municipalities in developing watersheds, within their jurisdiction;
- By **municipalities** to use as a guideline in developing their stormwater management planning documents and tools, thus ensuring they are in accordance with accepted best practice; and
- By the **public** and **other stakeholders** to ensure that planning within their municipality is in accordance with accepted best practice.

4.2 LIMITATIONS

The best practice proposes planning at four levels, watershed, subwatershed, neighbourhood and site. It proposes developing planning and engineering documents in increasing detail from the watershed plan down to individual site drainage plan. This template may be difficult to apply in all cases. The corresponding land use documents may not be available or may be in preparation. Action may be necessary on a priority basis to resolve a current drainage issue. Infill development may be so small compared to an already developed catchment that a site drainage plan is all that may be required. In any case, all the guiding principles noted in the best practice will still apply and the best available information should be used.

The best practice generally assumes the availability of corresponding land use planning documents to guide and provide input into the stormwater management planning documents. The land use planning documents will in turn be influenced by the recommendations and the implementation plan and schedule appearing in the stormwater management documents.

4.3 MONITORING

Integrated stormwater management is an evolving science. In seeking to protect environmental resources while facilitating land development and population growth, it has developed systems and designs such as BMPs with limited monitoring data to confirm long term performance.

Monitoring is necessary to confirm the effectiveness of stormwater management systems. Monitoring and reporting of results are important for the following parameters:

- Water Quality
- Watercourse Flow and Morphology Change
- Stream Health
- Costs

In relation to costs, best practices as outlined usually cost more initially than traditional practices where design of efficient conveyance systems was the priority. To comply with the principles of sustainability and financial viability, the increased costs at every stage of implementation should be monitored and reported to all stakeholders. Increased costs are incurred at planning stage (for public consultation, for instance), design and construction (more complicated system to control quality and quantity), and operations and maintenance. Adequate funding sources should be in place to finance these costs, particularly the ongoing operations and maintenance costs.

Funding mechanisms should be stable and funding levels related to expected costs for repair and replacements of components. High costs and the value of assigning the costs to operations related to specific facilities have led many municipalities to establish drainage utilities. Though relatively complicated to establish, experience with utilities where established is generally positive.

It should be stated, in discussing costs, that the full lifecycle costs of **not** implementing stormwater planning as outlined in this Best Practice may be more than the additional costs resulting from outdated practices.

4.4 RESEARCH NEEDS

Research should be an integral part of stormwater management planning and implementation because the many of the methodologies and systems are still evolving and are unproven. Research needs are categorized as follows:

- Water quality improvements.
- Costs, particularly operations and maintenance costs on a lifecycle basis.
- Understanding of the impacts of the full spectrum of rainfall events on hydrology and ecology of catchments.
- Impacts of human health.

The quantified long term performance of stormwater management practices for improving water quality is still uncertain. Research and post-construction performance monitoring of factors that impact water quality performance are needed in the following:

- Stormwater ponds and wetlands;
- Infiltration practices;
- Swales; and
- Catch basin inserts.

Regarding infiltration practices and measures, short and long-term infiltration rates for basins and trenches need further research. Achievement of rates assumed during design should be confirmed where possible by demonstration projects.

Many municipalities have concerns related to ongoing maintenance of stormwater management facilities. Emphasis is being placed on site-level practices such as green roofs, local storage, and mechanical/hydrodynamic structures. Although long used as standard designs in other parts of the world, confidence in their sustained performance, especially winter performance in cold climates, is just beginning to build in Canada. Case studies and research into the lifecycle performance would enable planners, designers, and operators to meet the O&M requirements using the appropriate resources.

Mention has already been made of the role of stormwater in providing habitat for mosquitoes and pathogens harboured by them. The West Nile Virus has been present in many provinces for several years. Initial research indicates that properly designed and maintained facilities should not result in increased mosquito problems, but further research into the possible relationship between mosquito problems and stormwater design practices is warranted.

5. EVALUATION

Evaluation of the results of applying the best practices outlined in this document is significantly impacted by the following:

- It is a planning-level best practice and therefore implementation entails several stages of planning/engineering/construction between the activity covered by their document and fully operational stormwater management facilities.
- As described earlier in the document, one of the guiding principles espoused in the best practice is adaptive management. This principle entails continuous evaluation of the designed systems to collect data and use that data to improve the designs.

The monitoring programs proposed to collect this data are outlined in **Section 4.3: Monitoring**. Effectiveness of the best practices in meeting the objectives of an integrated stormwater management plan should be evaluated every five (5) years; this is typically the frequency at which planning documents are revisited and updated.

Appendix A: CASE STUDIES

CASE STUDY 1: CITY OF CHILLIWACK, BRITISH COLUMBIA

Background

The City of Chilliwack, a municipality at the eastern end of the Fraser Valley in British Columbia, is one of the early adapters of the integrated Stormwater management planning approach. This municipal administration recognized at the outset the need to balance growth and development and protection of the natural environment. The City has grown from 59,000 to 75,000 people in the last ten years. Having adopted an integrated stormwater management policy, the municipality developed a planning manual through an inter-departmental and inter-agency process that included stakeholder participation.

Key Elements

Chilliwack's approach incorporates all of the guiding principles presented in this best practice, and has followed through with implementation in actual development projects. Its overall goal for the stormwater management program is to "implement integrated stormwater management that maintains or restores the water balance and water quality characteristics of a healthy watershed, manages flooding and geotechnical risks to protect life and property, and improves fish habitat values over time". It seeks to manage development to maintain stormwater characteristics that "emulate" the pre-development natural watershed.

Drainage system criteria include:

- Capturing the first 30mm of rainfall (per day) and restoring it to natural hydrologic pathways by promoting infiltration, evapotranspiration or rainwater re-use.
- Detaining the next 30mm of rainfall per day and releasing it to drainage system or watercourses at the natural predevelopment rates.
- Ensuring the stormwater facilities plan can safety convey storms greater a 60mm (up to a 1:100 year storm).
- To meet these targets, municipal and consultant teams have developed innovative practices. Examples of these are:
- Hydrologic and geotechnical evaluations to map the pre-development water balance;
- Soakaways in each lot;
- Infiltration pits at each catch basin;
- Perforated pipe as storm sewers, where geotechnical conditions support it;
- Combined detention and infiltration basins, again where geotechnical conditions support it.

In embracing the principle of adaptive management, the municipality, often in cooperation with other agencies interested in promoting integrated stormwater management, have underway several multi-year monitoring programs.

CASE STUDY 2: CITY OF TORONTO, WET WEATHER FLOW MASTER PLAN

In 1997, the City of Toronto initiated the development of a Wet Weather Flow Management Master Plan (WWFMMP) to address the impacts of wet weather flow. Instead of focusing on site specific wet weather flow issues, the plan development considered the whole natural hydrologic cycle within the context of watershed management and ecosystem protection.

The Master Plan was developed following the planning principles of the Province of Ontario's Environmental Assessment Act incorporating broad public consultation at key decision points. The master planning process was defined by four steps:

- **Step 1** – Data gathering, problem definition and policy formulation;
- **Step 2** – Development of the Wet Weather Flow Management Master Plan;
- **Step 3** – Implementation of the Master Plan; and
- **Step 4** – Ongoing monitoring and updating of the Master Plan.

Step 1 of the Master Planning Process included a synthesis of background information based on previous initiatives and current practices, found both nationally and internationally; identification of wet weather flow (WWF) impacts; the consolidation of existing legislation, policies and guidelines relative to WWF and the preparation of a draft Wet Weather Flow Management Policy Paper.

A new philosophy adopted for the development of the Master Plan emphasised control of rainwater where it falls to minimise the amount of stormwater runoff generated from a site. Following the runoff pathways from lot level to receiving waters, a hierarchy of management practices and controls were developed, starting with at source controls (lot level), followed by conveyance system controls, and then end-of-pipe controls.

Step 2 of the master planning process, initiated in 2000, involved developing the Wet Weather Flow Management Master Plan which was completed in 2003. Development of the WWFMMP included establishing targets, filling data gaps, development and assessment of strategies for controlling wet weather flow impacts and preparation of an implementation plan. Concurrent with the development of the WWFMMP, a Wet Weather Flow Management Policy and a funding mechanism to support implementation of the Plan were also developed. The Master Plan development focused on the 640 km^2 area contained within the City of Toronto boundaries. However, the study extended to include the six major watersheds of the Rouge River, Highland Creek, Don River, Humber River, Mimico Creek, Etobicoke Creek and the lake-based watersheds draining directly to Lake Ontario representing an area of about 2,100 km^2 (Figure A–1). Only one watershed, Highland Creek, is completely contained within the City boundaries, while the remaining five watersheds extend beyond the City's borders.

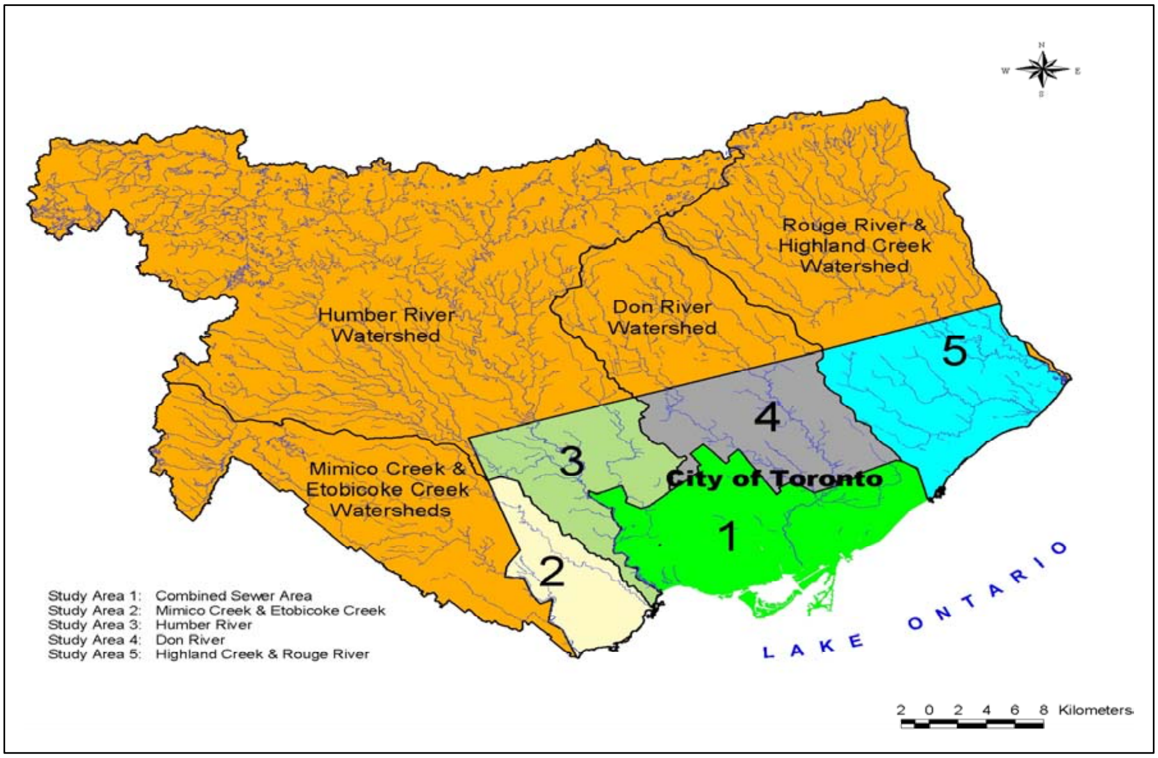


Figure A–1: Study Area

CASE STUDY 3: VILLE DE QUÉBEC COMBINED SEWER OVERFLOW CONTROL SYSTEM

In 1998 the Communauté urbaine de Québec (CUQ) embarked on a $190 million program to control the extent and frequency of overflow in its combined sewer system. Prior to the program, there were:

- 50 combined sewer overflow locations on the system;
- 52 overflow incidents to the St. Lawrence river and tributaries per year on average; and
- 3,600,000 cubic metres discharged per year on average.

Figure A–2 shows the elements of the program. The design of the program was based on the following principles:

- Maximizing the use existing system facilities;
- Implementing a real time control with an optimal global predictive (OGP-RTC) system to optimize this use; and
- Monitoring and optimizing the performance of the program before investing in expensive off-line storage facilities.

A pilot scheme of OGP-RTC has been implemented in the western part of the city to test the system and verify the performance.

Results of the program are as follows:

- 42% reduction in overflow events;
- 80% reduction in overflow volumes; and
- Effectiveness of the OGP-RTC in CSO control confirmed.

Based on these results, in March 2002, Ville de Québec (after amalgamation of surrounding municipalities) started the implementation of Phase 1 of the CSO control program with the construction of seven (7) off-line storage facilities for a budget of $45 million. Furthermore, Ville de Québec has also carried out the preliminary design for the storage facilities for Phases 2 and 3, estimated to cost more than $80 million.

Eventually, the CSO control program will reduce the CSO events on the system from an annual rate of 52 events to 2 or 4. This level of CSO is considered within the assimilative capacity of receiving water bodies.

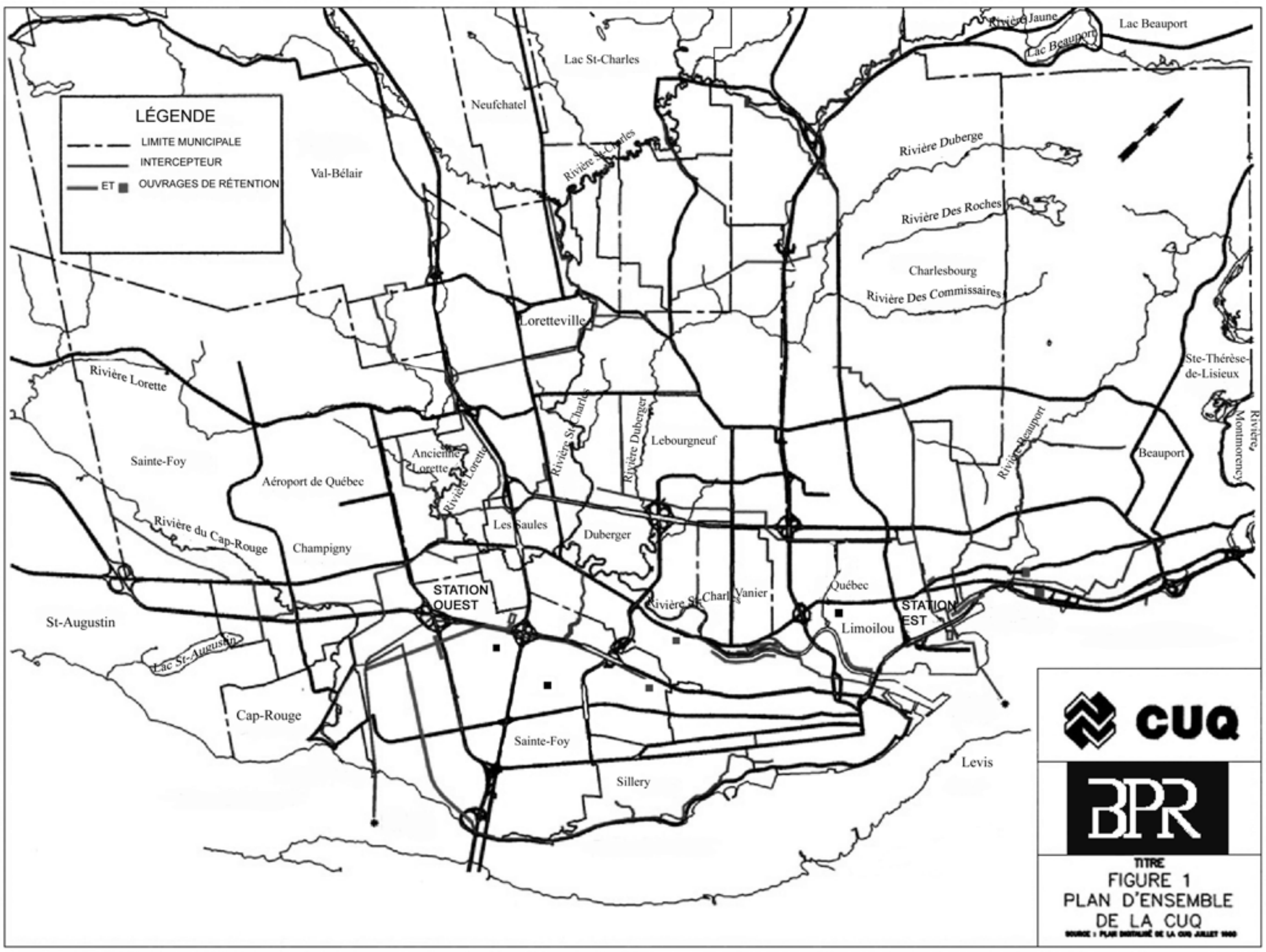


Figure A–2: Elements of the Program

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