

## CONTENTS

<b>Section 4: Stormwater Management .....</b>	<b>1</b>
<i>Objective .....</i>	<i>1</i>
<i>Stormwater Management Objectives .....</i>	<i>2</i>
Volume Reduction Sizing Methodologies .....	6
<i>Stormwater Legislation and Regulation .....</i>	<i>8</i>
<i>Stormwater Management Planning .....</i>	<i>9</i>
Integrated Stormwater Management Planning .....	10
Planning .....	11
<i>Selection of Stormwater Management BMPs .....</i>	<i>13</i>
<i>Low Impact Development Practices .....</i>	<i>14</i>
<i>Stormwater Source Control Technologies .....</i>	<i>17</i>
<i>Stormwater Detention Systems .....</i>	<i>21</i>
Stormwater Detention Ponds .....	21
Detention Systems for Built-up Areas .....	23
<i>Infiltration Systems .....</i>	<i>24</i>
Application of Infiltration Systems .....	24
<i>Stormwater Runoff Water Quality .....</i>	<i>24</i>
Water Quality Best Management Practices .....	25
Guidelines for Implementation of Stormwater Water Quality Objectives .....	27
Construction Best Practices .....	27
Monitoring During Construction .....	28
Post-Construction Monitoring .....	29



## Section 4: Stormwater Management

The DFO/MOE goal for stormwater is to maintain, as closely as possible, the natural pre-development flow pattern and water quality in the receiving watercourse.



Stormwater management helps to preserve the diversity and productivity of natural streams. Mackay Creek, District of North Vancouver, B.C.

### **Objective**

The primary objective of these stormwater management guidelines is to prevent harmful impacts to water quality, fish and wildlife species, and habitats that result from the connection of stormwater management systems to local streams. The goal is to maintain, as closely as possible, the natural pre-development flow pattern and water quality in the receiving watercourse.

The clearing, grading and servicing of development sites alter the natural hydrology of the watershed. The increase in cleared and developed areas decreases the ponding, infiltration, evaporation and transpiration of precipitation that previously occurred in vegetative canopies and soil layers. Unaltered watersheds delay runoff reducing peak flows and volumes through natural retention and detention. The increase in imperviousness in developed areas and the rapid routing of stormwater through conventional drainage infrastructure decreases retention and infiltration of precipitation which increases surface runoff. As the surface runoff component increases so does the total runoff volume and with reduced detention and retention, this runoff can concentrate rapidly into significantly higher peak flows which when combined with increased runoff volumes, leads to longer periods of higher flows. Streams get flashier and faster.

This combination of hydrologic effects can initiate or accelerate channel and bank instability with negative impacts on fish and fish habitat. Increases in the magnitude and intensity of flows can lead to increased substrate embeddedness and loss of instream woody debris which provides complexity and cover for fish. The loss of infiltration and local groundwater recharge further reduces baseflows during natural low flow conditions reducing both the amount and quality of habitat available to fish during these critical periods. These flow-related impacts are often combined with:

- Decreased water quality resulting from pollutants and sediments introduced by the surface runoff.
- Loss of habitat related to channelization and enclosure of small streams.
- Destruction of wetlands, floodplains and related riparian areas through drainage and development.

These impacts are typical of a disturbed, urbanized watershed, and reduce the diversity and productivity of the aquatic habitats in the watershed. One of the most important factors governing stream ecology is hydrology. The cumulative hydrologic effects of increasing impervious area in a watershed in combination with loss of riparian corridor integrity will have an increasingly detrimental effect on stream ecology.

In summary, the known stormwater effects on fish and fish habitat resulting from urban development practices include combinations of:

**Hydrologic effects** – increases in magnitude and frequency of rainfall response. These result in flooding and erosion, decreased infiltration and stream baseflows which reduce stream depths thereby restricting fish movement, scour streambeds, deposit sediments in gravels and pools, reduce the quality of fish habitat, eliminate preferred invertebrate food sources, and increase water temperatures that can stress or kill salmonids and other cold-water species.

**Hydraulic effects** – high flood flows and water levels result in erosion of channels and higher sediment loads, scouring of streambanks and riparian areas, and destruction of natural spawning and rearing areas in stream riffles and pools.

**Water quality effects** – increased pollutant loading from developed areas includes higher sediment loads, higher water temperatures, and higher concentrations of wash-off pollution such as oil, heavy metals, particulates, fertilizers, pesticides and herbicides.

As stormwater management is a rapidly evolving science an adaptive approach to management is required. As research, implementation and assessment of new stormwater management practices and technologies progress, the objectives of these guidelines may also need to be revisited to reflect new knowledge and improve protection of fish and fish habitat.

## ***Stormwater Management Objectives***

Stormwater Management performance objectives are those that need to be achieved in the design of communities and construction of stormwater management works in order to reduce the potential for the harmful alteration, disruption or destruction (HADD) of fish habitat associated as required by the federal *Fisheries Act*.

Unmitigated development can have detrimental hydrologic, hydraulic and water quality impacts to receiving water courses.



Streambank scouring along Little Campbell River in Surrey, BC

Stormwater Management  
Criteria:

- Volume Reduction
- Water Quality Control
- Rate Control



A road-side rain garden like this one in Maple Ridge, BC can help to achieve the DFO/MOE Stormwater Management Criteria for Volume Reduction and Water Quality

The DFO/MOE Stormwater Management Objectives are threefold:

- Volume Reduction
- Water Quality Control
- Rate Control or Detention

They are discussed individually.

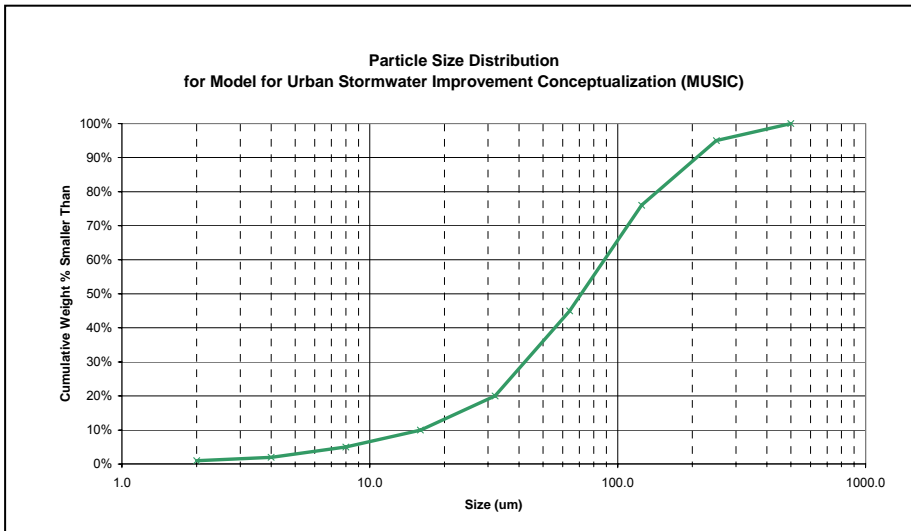
**Volume Reduction – Retain the 6-month, 24-hour post-development runoff volume on-site and infiltrate into the ground rather than conveying it offsite.** It has been shown that all the rainfall events up to and including the 6-month, 24-hour storm event are equivalent to 90% of the average annual historic rainfall volume. The rainfall depth of the 6-month, 24-hour storm may be estimated as 72-percent of the 2-year, 24-hour storm event rainfall depth. (Reference for the 6-month storm and 90-percent of the average annual historic rainfall may be found in Appendix 1-B of the [Stormwater Management Manual for Western Washington](#), February 2005).

The terms “retain” or “capture” are intended to prevent post-development rainfall runoff from directly traveling to the downstream receiving water. Water leaving through source control perforated drains, for example, cannot be included in volumetric reduction calculations. For source control measures, it can be assumed that the initial condition of the soil moisture for these calculations is dry.

**Water Quality Control – Maintain or improve the quality of runoff discharged to streams. Collect and treat the runoff volume from impervious areas for the 6-month, 24-hour precipitation event.** This is equivalent to 90% of the total annual rainfall. A continuous simulation model may be used to determine the required treatment volume, or the 6-month, 24-hour storm event may be used (72% of the 2-year, 24-hour rainfall depth).

Water quality treatment systems should be designed to remove 80-percent by mass of the inflow Total Suspended Solids (TSS), for particle sizes greater than 50  $\mu\text{m}$ , using the MUSIC (Model for Urban Stormwater Improvement Conceptualization) particle size distribution. Systems should not increase the runoff temperature above 15° C.

Figure 4.1 - Particle Size Distribution



The maximum TSS and turbidity concentrations for effluent discharges should comply with the requirements in Chapter 3 Erosion and Sediment Control. Runoff from the development site should contain less than 25 mg/L of suspended solids above the background levels of the receiving waters during normal dry weather and less than 75 mg/L above background levels during design storm events.

Receiving water quality (where monitored) should comply with the following Canadian Council of Ministers of the Environment (CCME) and [British Columbia Approved Water Quality Guidelines](#) for the protection of aquatic life:

Table 4.1 – Receiving Water Quality Guidelines for Protection of Aquatic Life

Measured Background TSS Concentration (mg/L)	Receiving water TSS Concentration (mg/L)	Measured Background Turbidity (NTU)	Receiving water Turbidity (NTU)
≤ 25 mg/L	<25 mg/L for 24 hours; < 5 mg/L for >24 hrs	≤ 8 NTU	<8 NTU in <24 hours; Mean of 2 NTU for > 24 hrs
Between 25 to 250 mg/L	<25 mg/L	Between 8 to 80 NTU	<8 NTU
≥ 250 mg/L	<10% over background	≥ 80 NTU	<10% over background

Canadian Council of Ministers of the Environment (CCME) and [British Columbia Approved Water Quality Guidelines](#) for the protection of aquatic life



Water Quality Plume



For discharge into a receiving watercourse, the Rate Control and Volume Reduction objectives must be achieved in addition to the Water Quality objectives and municipal criteria.



Detention Pond  
Overflow Weir, Sechelt



These parameters may be included in a monitoring plan developed to assess potential impacts of stormwater on receiving water quality. Water quality controls for a site may have various components because different types of impervious areas may, based on risk, need to be treated separately for maintenance of water quality. For example, if typical roof water is collected and conveyed separately from ground surface or pavement runoff, it would not generally require water quality treatment as it is simply rain water with atmospheric dust. There are exceptions such as galvanized metal roofs that can be contaminated with zinc which would require treatment.

Runoff from pavement on roads and parking lots, however, should be treated as it contains sediment, metals, oil/grease, and other contaminants. It should be noted that if a site meets the volumetric reduction criteria above, and the 6-month, 24-hour rainfall is retained or captured, many source controls also provide water quality treatment.

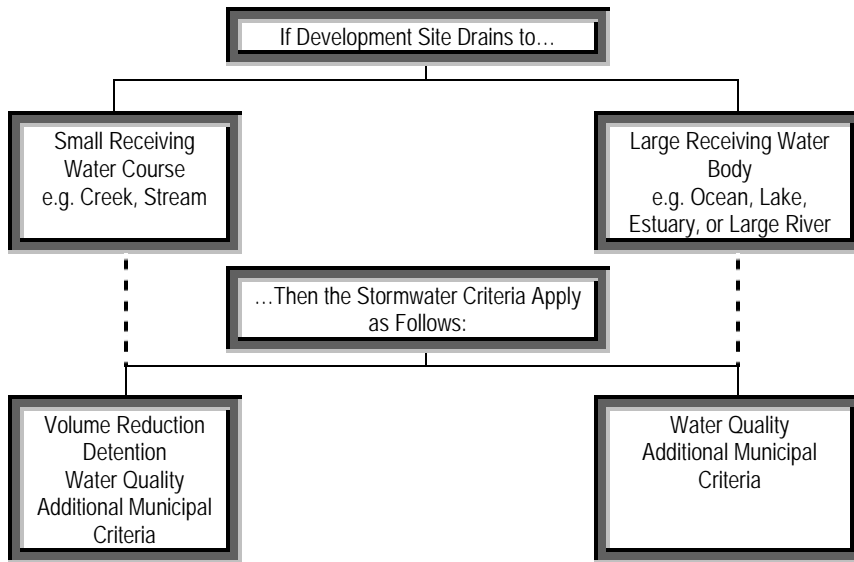
**Rate Control or Detention** – Reduce the peak runoff flow rates prior to discharge into receiving waters. **Reduce post-development flows (hydrograph volume, approximate shape and peak instantaneous rates) to pre-development levels for the 6-month, 2-year, and 5-year 24-hour precipitation events.** Pre-development is considered to be natural forested conditions, unless an alternate standard is developed during an ISMP watershed process. Unlike Volume Reduction measures, detention volumes should be calculated assuming wet antecedent moisture conditions. If pre-development discharge information is unavailable, a pre-development unit discharge of 4.0 L/s/ha may be assumed for the 6-month, 24-hour release rate.

### Application of Stormwater Guidelines

Figure 4.2 shows how the DFO/MOE Stormwater Guidelines may vary in application depending on whether the receiving water is a stream or a large water body.

If project proponents are not sure which stormwater guidelines apply, check with DFO or municipal environment staff.

Figure 4.2 - Application of DFO Stormwater Guidelines



In order to meet these objectives, planning for stormwater should be initiated at the earliest stage of community planning and site design. The desired objective of any stormwater management plan should be to maintain the pre-development flow patterns and volumes over the entire rainfall spectrum. Post-development flow patterns and volumes should strive to mimic pre-development conditions.

Alterations in stream hydrology are often compounded by stormwater management proposals to divert or re-locate flows through flow-splitting and inter-watershed stormwater connections. Proposals for large-scale diversions and/or disruptions of flows, including works that intercept baseflows and redirect flows from natural catchment areas, that can result in long term harmful impacts to fish and fish habitat will generally not be authorized under *the Fisheries Act*.

## Volume Reduction Sizing Methodologies

Designing to meet the volume reduction criterion may be approached in two ways, depending on the data available and the goals of the project site. Both methods should be implemented by Professional Engineers.

**Method 1: Discrete Design Storm Approach** - Use the design storm approach, i.e. the rainfall depth of the 6-month, 24-hour (72% of 2-year, 24-hour) storm event. This enables a calculation based on generally available climatic data (the 2-year, 24-hour rainfall depth), rather than requiring more complex data-gathering and analysis. Assume dry antecedent conditions for calculations. Where retention/infiltration of the 6-month, 24-hour storm is not possible, e.g. where there is bedrock with shallow overburden, an alternative capture criteria depth may be determined by using Method 2 described below.



Designing to meet the volume reduction criterion may be approached in two ways:

1. Discrete Design Storm Approach
2. Continuous Simulation Approach

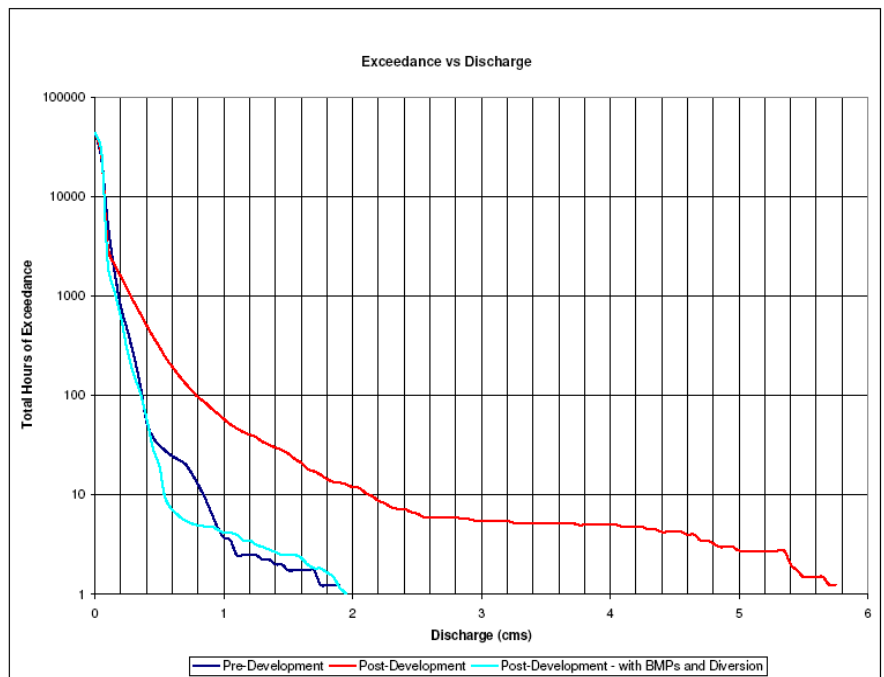


Flooding in North Vancouver

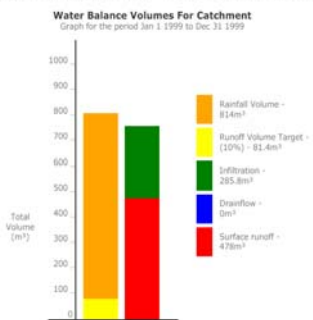
**Method 2: Continuous Simulation Approach** - Use a continuous simulation model to determine retention, detention and treatment volumes. Multi-year rainfall data is required, as well as knowledge of soil infiltration parameters for the project site and monthly evaporation values for the region. The goal of continuous simulation modeling is to generate exceedance duration curves showing the durations of flow levels for three cases: pre-development, fully developed watershed conditions with no mitigation, and fully developed watershed with volumetric reduction, rate control, and water quality control measures in place. Pre-development should be considered to be naturally forested conditions unless an alternate standard is identified as part of an ISMP.

To protect the current health of the watershed, mitigation measures should be designed such that the mitigation exceedance duration curve closely approximates the pre-development curve. It is possible that due to soil conditions, terrain slope, and other hydrologic factors, the exceedance duration analysis may result in a lesser volumetric and rate control design condition than Method 1. In this case Method 2 shall take precedence.

Figure 4.3 - Example of Exceedance Duration Curves



GVRD Source Control Research - B - Area with Infiltration Swale



Sample Results from the Water Balance Model showing rainfall and runoff volumes.

The [Water Balance Model powered by QUALHYMO](#) (WBM), available free on the national Water Balance Model website, is one tool for continuous simulation analysis. It may be particularly useful for sites in the Lower Mainland of BC as the model has rainfall and other data built into it for this region. Other models that can be used for continuous simulation are available commercially, such as XP-SWMM.

## Stormwater Legislation and Regulation

The federal regulatory basis for protection of fish and fish habitat is **Section 35(2) and Section 36 of the federal Fisheries Act (FA)**. Under Section 35, DFO has the responsibility to manage impacts to fish and fish habitat in order to prevent the Harmful Alteration, Disruption or Destruction (HADD) of fish habitat by direct or indirect means. Where a project includes unmitigated stormwater which will result in a hydrologic change to fish habitat or will be a direct discharge to fish habitat DFO must be notified and project specific information provided to determine the potential for a HADD. Where HADD's are unavoidable they must be authorized under Section 35(2) of the FA. **Section 36(3) of the Fisheries Act** prohibits the deposit of deleterious substances into waters frequented by fish. This section of the Act is administered by Environment Canada

This federal regulatory role is augmented by the **Canadian Environmental Assessment Act (CEAA)** which requires DFO to conduct environmental assessments of projects that require a federal authorization.

Under the federal **Species At Risk Act (SARA)** DFO is also the lead federal authority for the protection and recovery of aquatic species listed under the Act. Under SARA DFO is required to give special consideration to any project that may kill, harm or harass a species at risk, damage or destroy their residence or destroy any part of their critical habitat. **The department will typically not authorize activities that would result in the destruction of critical habitats for SARA listed species.**

In fulfilling its regulatory role, DFO also works in conjunction with provincial authorities, which also have regulatory roles in stormwater management under the provincial **Waste Management Act** and its associated Liquid Waste Management Regulations, as well as the **Water Act**. The latter will apply where stormwater management infrastructure is likely to result in a significant change to natural surface water drainage.

If a portion of a stormwater management plan includes in-stream works, removal of riparian vegetation or the creation of structural "footprints" within any part of a stream channel including the banks the project must be referred to both DFO for determination of a HADD and to MOE for a Water Act approval. Where works or structures are contemplated in navigable waters, there may also be an approval required from the Ministry of Transport under the federal **Navigable Waters Protection Act (NWPA)**.

Under the **Fisheries Act**, DFO has the responsibility to manage impacts to fish and fish habitat in order to prevent the Harmful Alteration, Disruption or Destruction (HADD) of fish habitat.



Salmon, one of the fish resources protected by DFO under the Fisheries Act (Source: file photo)

The ultimate responsibility for land drainage and stormwater management in developed and developing areas resides with local or municipal governments under the Local Government Act.

Stormwater management is an evolving discipline that requires an adaptive management approach to reflect new science and incorporate new tools and approaches.

Stormwater management planning is necessary on a variety of scales:

- Regional
- Watershed
- Neighbourhood
- Site

The ultimate responsibility for land drainage and stormwater management in developed and developing areas however, resides with local or municipal governments under the **Local Government Act**.

Local government responsibilities for drainage and their legislative authority to require integrated stormwater solutions have been summarized in the [Stormwater Planning Guidebook for British Columbia \(2002\)](#). For more information on local governments' roles and responsibilities regarding drainage and stormwater management please consult Chapter 1 Section 1.4 of this guide.

Stormwater management requires consideration of a variety of possible effects, above and beyond those related to fish or fish habitat. Stormwater management is also no longer just a function of local government or highway engineers, but is a shared responsibility with land use planners, developers, their agents and regulatory agencies and requires that stormwater management considerations be included in the earliest stages of development planning.

### ***Stormwater Management Planning***

Planning is the first and most critical step for ensuring that stormwater management standards can be met and fish and fish habitats are protected in the long-term. Stormwater management planning is necessary on a variety of scales, which can be classified into four main categories: Regional, Watershed, Neighbourhood, and Site. These different scales of planning represent corresponding levels of complexity in the analysis of stormwater issues and impacts. For individual development projects, it might be tempting to assume that site-level planning is all that would apply, but that is not the case. Subdivision development or block-scale re-developments, often require neighbourhood-scale planning efforts and consideration of watershed scale issues, best addressed in integrated watershed management plans, in order to minimize stormwater impacts.

In addition, whatever the size of the project, watershed- and/or regional-scale stormwater planning by a local or provincial authority may identify additional stormwater management requirements or constraints that affect projects located in these areas. Therefore stormwater planning for any individual project must be integrated with larger-scale planning efforts where these are occurring.

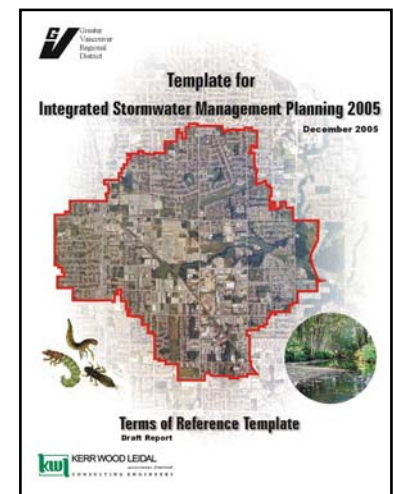
## Integrated Stormwater Management Planning

Some municipalities and regional governments have undertaken integrated watershed and neighbourhood-scale stormwater management planning. Integrated Stormwater Management Planning (ISMP) is a comprehensive watershed-based study or assessment that strives to balance land development with environmental protection. ISMPs that focus on both flood and environmental risks from stormwater create a broad context for identifying and addressing locally critical drainage and stormwater management issues as well as environmental protection. These plans often present approaches and mechanisms by which these collective goals can be achieved on a watershed-scale.

An ISMP has the specific goal of planning for development within a watershed while maintaining or improving overall watershed health. An ISMP will also identify areas where environmental or social benefits can be recognized and solutions to regional priorities, over and above meeting DFO/MOE stormwater criteria, may be achieved in the watershed. These opportunities once identified, may help offset constraints and limitations in other areas of the same watershed where limiting geology or other factors preclude attainment of the criteria at one location, but enable achievement of the criteria for the watershed as a whole. The Metro Vancouver has an online [ISMP Template](#) to help municipalities and consultants with developing and implementing ISMPs.

An ISMP will typically develop watershed-specific stormwater criteria which can be applied to subsequent development projects in the watershed. The ISMP criteria governs over the DFO/MOE stormwater criteria provided a “letter of endorsement” of the ISMP has been obtained from DFO. Where a Watershed Management Plan or an ISMP has been completed, the ISMP criteria generally govern over municipal criteria as well. The ISMP process may develop an alternate standard for a watershed based on existing developed conditions rather than natural forested conditions, so long as the exceedance duration analysis shows that creek erosion is minimized and ecological health is maintained or improved. An ISMP can be an invaluable resource for designing projects in a watershed and will often reduce the amount of new study and analysis necessary for a project or site-specific stormwater management plan.

ISMP is a comprehensive watershed-based study or assessment that strives to balance land development with environmental protection



ISMPs excel at finding solutions to difficult problems utilizing trading of benefits within the watershed



Aerial view of a preserved riparian strip along a creek in Abbotsford, BC

**A 'Design with Nature' approach to community design means...**



- Develop compact, complete communities
- Increase transportation options
- Reduce the loads on water, waste and energy systems
- Protect and restore urban 'green' space
- Strive for a lighter 'hydrologic footprint'
- Achieve higher levels of stream, wetland and lake protection

From *Beyond the Guidebook*  
(Source: [www.waterbucket.ca](http://www.waterbucket.ca))

For large-scale projects, where an ISMP does not exist, one may need to be developed for the project itself in order to properly identify, evaluate and mitigate the full range of impacts that could be associated with the project. However, watershed management plans and ISMPs are not the only means of guiding and informing stormwater planning and decision-making. For example, a local municipal drainage or stormwater management bylaw may be in place that specifies the stormwater requirements. If these are flood protection criteria only, then the DFO/MOE stormwater criteria should also be applied for environmental protection. For watersheds within the Metro Vancouver member municipalities, an ISMP is required under the terms of the Liquid Waste Management Plan.

**Planning**

Stormwater management planning is not just the immediate concern of current development projects. The planning process needs to consider past, (and anticipate future) development and stormwater issues in the watershed. This can influence the selection layering and sizing of BMPs required to achieve the desired stormwater management objectives. For example, a variety of individual developments in a watershed may independently apply for new stormwater outfalls to the nearest creek which will have significant and cumulative negative impacts to fish and fish habitat. The need for these may be reduced with good planning.

Similarly opportunities may exist to remediate historic drainage or environmental problems during redevelopment however in the absence of an integrated planning approach at the catchment or watershed scale the full range of opportunities cannot be arrayed and addressed in a comprehensive manner.

Stormwater management has advanced significantly in BC in the last decade as a result of improved science and an increasing body of knowledge. Stormwater management is an adaptive and evolving discipline which is constantly incorporating new tools and approaches that were first pioneered in the Pacific Northwest.

Stormwater management can be viewed as part of a much larger water management and urban land development issue. The way we develop our communities has significant implications for both stormwater generation and stormwater management. A key initiative of the province, "[The Water Sustainability Action Plan for British Columbia](#)" promotes a "water-centric" approach to community planning and development.

One of the initiatives under this Action Plan has as its goal the protection and restoration of the natural environment by improving the built environment. This initiative, known as the [Green Infrastructure Partnership](#), focuses on infrastructure practices that embody a ‘design with nature’ way of thinking and acting. This partnership is active in showcasing examples of communities throughout BC that have embraced Green Infrastructure principles in their design and development, and in the process has made BC a leader in natural systems approaches to stormwater management.

There are a variety of guides and a significant body of literature available to assist those involved in stormwater management planning. [Stormwater Planning: A Guidebook for British Columbia](#) - an informative guide developed by municipal, provincial and federal agencies is a key resource for those involved in developing stormwater management plans.

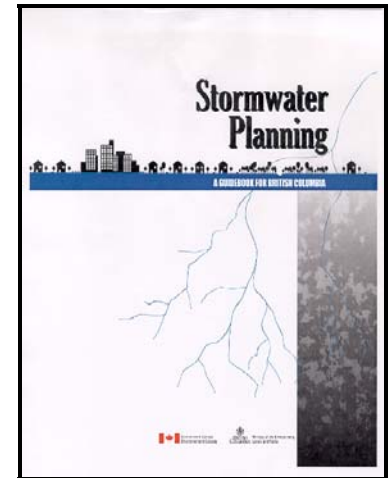
In addition to the Stormwater Planning Guide for BC, several excellent guides to Stormwater Management Best Practices and Stormwater Source Control Designs have been developed by the [Metro Vancouver](#) and are useful references for those involved in planning and designing stormwater management systems.

The extensive technical stormwater management and LID Manuals developed by the [Washington Department of Ecology](#) and the [Puget Sound Action Team](#) are also directly relevant to BC and are available on-line.

Readers are also referred to the resources section at the end of this chapter.

The key goal of the DFO/MOE stormwater criteria is to reduce the hydrologic footprint from land development and manage runoff associated with such developments such that fish habitats are not harmfully altered and deleterious substances are not discharged to fish bearing waters.

Table 4.3 summarizes the DFO/MOE Stormwater criteria and presents general categories of BMPs that can be used to meet the criteria.



BMPs include planning, design and site preparation considerations, mitigation technologies and an array of management approaches that can be used to address stormwater issues.

The preferred approach should always be to prevent, as much as possible, runoff generation by preserving the existing natural stormwater management capacity of the land.



An infiltration swale located near the parking area of Crown Park in Coquitlam BC.

Stormwater Source Control practices are intended to retain and capture rainfall runoff near the point where it is created and return it to natural hydrologic pathways.

**Table 4.2 – DFO Stormwater Criteria and Applicable Technologies**

Stormwater Criteria*		Stormwater Technologies/BMPs
<b>Volume Reduction</b>	Retain the - 6-month, 24-hour event or - 90% of annual rainfall	- Low Impact Development - Source controls
<b>Water Quality Treatment</b>	Collect and treat the - 6-month, 24-hour event or - 90% of annual rainfall	- Source controls including biofiltration - Constructed Wetlands - Oil and grit separators - Construction practices, e.g. sediment and erosion control - Settling and wet detention ponds - Operational BMPs such as street sweeping
<b>Detention</b>	Reduce post-development flows to pre-development levels for the - 6-month hydrograph - 2-year hydrograph - 5-year hydrograph	- On-site or regional detention facilities - Wet and dry ponds - Underground tanks, vaults - Infiltration

\*criteria shown are for the Discrete Design Storm Approach

Effective stormwater management relies on the use of Best Management Practices, (BMPs), which if followed, should achieve the stormwater management goals for the development while ensuring impacts to riparian and aquatic fish habitats are mitigated. BMPs range from planning, to design and site preparation, effect mitigation, best practicable technologies and operational practices.

### ***Selection of Stormwater Management BMPs***

In a developed or developing watershed, best practices to manage stormwater runoff are required to replace some of the natural hydrologic processes that existed prior to development. The intention of these BMPs and technologies is to mimic natural hydrographs, and maintain receiving water quality. They will not be able to replace the natural runoff flow retention and detention, or water quality buffering and sediment filtering characteristics of an undisturbed watershed. At best structural BMPs mitigate negative impacts while planning BMP's can help prevent effects and identify opportunities to remediate historic problems.

Certain BMPs provide hydrologic, hydraulic and water quality benefits and BMPs that can provide multiple benefits are generally preferred to minimize design requirements and costs for constructed facilities.

There is generally a greater ecological and often economic benefit from reducing stormwater discharges than there is for controlling and managing the resultant discharges. The preferred approach therefore should always be to prevent, as much as possible, runoff generation by preserving the existing natural infiltration and detention capacity of the land. Approaches such as Low Impact Development (LID) minimize the creation of impervious area and other land covers that increase runoff and deliver contaminants directly to watercourses. Retention of natural water storage and treatment features such as floodplains, wetlands and riparian forests is also a key element of LID.

The DFO/MOE stormwater guidelines, which focus on volume reduction, water quality treatment and runoff control, can be achieved at the site level through some combination of LID and source control strategies.

Source controls retain and capture runoff near the point where it is created and return it to natural hydrologic pathways via infiltration and evapotranspiration, or re-use at the source. Source controls create hydraulic disconnects that reduce the Effective Impervious Area (EIA) and consequently downstream hydrologic and hydraulic impacts. Stormwater re-use must be considered cautiously however, as it could interfere with preservation of stream baseflows.

Tables 4.4 and 4.5 in the following subsection illustrate some of the advantages and disadvantages of various stormwater management BMPs and technologies.

### ***Low Impact Development Practices***

Low Impact Development (LID) is a design with nature approach that reduces a development's ecological footprint. LID concepts embodied at the planning stage, often affords more opportunities to reduce the overall negative effects of development and reduce costs. Requirements for expensive traditional stormwater infrastructure may also be reduced as less runoff will be generated.

There are many BMPs commonly used in LID, however it is not always possible to incorporate all of them into a development, and even with adoption of all available LID options, there will still be changes to the hydrologic regime relative to the pre-development conditions and some additional measures or facilities will often be required. LID practices are most effective in mitigating adverse stormwater effects when used in combination with other BMPs, such as constructed source controls and detention. The Puget Sound Action Team's [LID Technical Guidance Manual](#) is an excellent resource for LID planning and design.



Low Impact Development (LID) measures are intended to minimize the creation of impervious area and other land covers that increase stormwater runoff.



Reduced road width in a development with flat curbs, Crown Street, Vancouver, BC



Pervious parking surface,  
Sechelt, BC



Reduced pavement in a  
residential lane (Source: file  
photo)

Several LID practices are described below. This is not an exhaustive list and proponents are encouraged to consult with qualified planning and engineering professionals and to refer to the resources in this chapter to gain a better understanding of the full array of LID BMPs available and to identify and select appropriate LID BMPs for individual projects.

**Reduced Road Widths** – Traditional road pavement widths may be larger than they need to be, particularly for streets that are residential access only, and not thoroughfares. Road widths can be narrowed to a minimum that allows necessary traffic flow, but that discourages excess traffic and excess speed, both of which are beneficial in a family- and pedestrian-oriented neighbourhood. Road widths do, however, need to meet the community’s needs for utility and emergency vehicle access and these requirements will often determine acceptable minimum road widths.

**Reduced Building Footprints** – Building footprints, and impervious roof area, may be reduced without compromising floor area by increasing building height.. This also allows greater flexibility to develop layouts that preserve naturally vegetated areas and provide space for infiltration facilities. Some relaxation of building height restrictions may be necessary to allow this type of design.

**Reduced Parking Standards** – Reducing the required number of parking spaces for a development reduces the impervious area and encourages pedestrian and public transit-friendly communities. Reducing the required parking spaces also reduces development costs.

**Limiting Surface Parking** – Limiting surface parking and restricting parking to below building roof areas, also directly reduces the impervious area in a development.

**Pervious Parking Surfaces** – Use of pervious paving materials rather than impervious concrete or asphalt can reduce the runoff generated from parking areas. Pervious materials may include gravel, reinforced turf, or engineered permeable pavements.

**Building Compact Communities** – A complete and compact development plan preserves more natural watershed features and significantly reduces imperviousness. In some cases, compact communities have up to 75% less roadway pavement per dwelling unit, and parking needs are reduced because local services are more accessible by pedestrians and via public transit.

**Preserving Naturally Significant Features** – Preservation of natural areas in a watershed is always an important consideration, which can provide recreational as well as environmental benefits but some natural areas perform special aquatic ecosystem functions and as such are vital to maintaining watershed health. These areas, which include riparian forests, wetlands, floodplains and natural infiltration depressions with highly permeable soils, are particularly important to inventory and protect from alteration.

These LID technologies are summarized in Table 4.3, below.

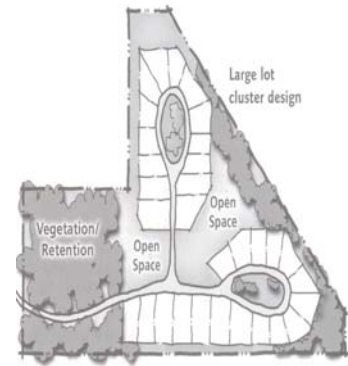
**Table 4.3 - Advantages and Disadvantages of LID BMPs**

BMP	Advantages	Disadvantages*
<b>Reduced Road Widths</b>	<ul style="list-style-type: none"> <li>- Reduces impervious area</li> <li>- Reduces motor vehicle speed</li> <li>- Improves pedestrian/bicycle safety</li> <li>- Allows more vegetative canopy coverage of paved area and reduces air temperatures</li> </ul>	<ul style="list-style-type: none"> <li>- may require evaluation of road width requirements for fire and emergency services</li> </ul>
<b>Reduced Building Footprint</b>	<ul style="list-style-type: none"> <li>- Reduces impervious area coverage</li> <li>- Increases flexibility to develop layouts that preserve naturally vegetated area</li> <li>- Provides space for infiltration facilities</li> </ul>	<ul style="list-style-type: none"> <li>- may require relaxation of building height restrictions</li> </ul>
<b>Reduced Parking Requirements</b>	<ul style="list-style-type: none"> <li>- Reduces impervious area</li> <li>- Promotes walking and transit use</li> <li>- Appropriate for low-income housing developments with fewer vehicles per household</li> <li>- Reduces parking-related development costs</li> </ul>	<ul style="list-style-type: none"> <li>- May not be accepted by suburban lifestyle oriented residents</li> <li>- May necessitate improvements to public transit</li> </ul>
<b>Limiting Surface Parking</b>	<ul style="list-style-type: none"> <li>- Reduces impervious area outside the building envelope</li> <li>- Greater opportunity to mitigate runoff from parkades using green roofs or rainwater reuse</li> </ul>	<ul style="list-style-type: none"> <li>- Generally only supported where land economics favour underground or rooftop parking or parkades over surface parking</li> </ul>
<b>Pervious Pavements</b>	<ul style="list-style-type: none"> <li>- Creates surface parking and driveways that produce less runoff</li> <li>- Often aesthetically more pleasing than solid pavements</li> </ul>	<ul style="list-style-type: none"> <li>- not practical for heavy vehicle use</li> <li>- requires more maintenance</li> <li>- not practical in cold climates</li> </ul>
<b>Building Compact Communities</b>	<ul style="list-style-type: none"> <li>- Preserves more natural areas for aesthetic &amp; environmental benefits</li> <li>- Reduces impervious coverage at the watershed scale</li> <li>- May reduce development costs</li> </ul>	<ul style="list-style-type: none"> <li>- Requires public education and familiarization for acceptance</li> </ul>
<b>Preserving Naturally Significant Features</b>	<ul style="list-style-type: none"> <li>- Preserves natural infiltration areas, and reduces flood risk</li> </ul>	<ul style="list-style-type: none"> <li>- Reduces the developable land area</li> </ul>

\* For LID planning, many of these disadvantages can be overcome by an initial effort to achieve planning approvals



Reinforced turf, used as a pervious residential road shoulder in Vancouver, BC



Example layout showing clustered lots to maximize preservation of natural areas (Source: LID Technical Guidance Manual, Puget Sound Action Team)

## Stormwater Source Control Technologies

Stormwater source controls reduce the runoff that is discharged to the stream network by managing the water balance at the site level. Source controls play a key role in achieving DFO/MOE Stormwater Criteria for volume reduction, water quality treatment, and runoff control and can be very effective at reducing runoff volumes and peak runoff rates from events smaller than the 6-month storm. Though they do provide some flow-detention benefits for the 2-year and 5-year storms, source controls have limited ability to reduce peak runoff rates from large storms in excess of the 6-month storm and must be designed with adequate overflow capacity. Additional stormwater infrastructure must be provided to safely convey stormwater offsite for the 5- to 200-year event, as required by municipal standards.

Several standard source control technologies are described below. This list is also not exhaustive and proponents are encouraged to consult qualified planning and engineering professionals, and refer to the resources listed at the end of the chapter, when selecting and applying source control BMPs to individual projects. The [Metro Vancouver Source Control Guidelines](#) is an excellent reference for source control BMP design advice.

**Absorbent Landscaping** – Natural topsoil is generally permeable. The vegetation on topsoil provides a layer of organic matter which is mixed into the soil by worms and micro-organisms, creating voids, which allow rain water to percolate through, and making the soil more structurally capable of providing storage in the void spaces when saturated.

Standard construction practice is often to strip the existing topsoil, compact or excavate a site surface to the desired grade, and then cover it with a thin layer of imported topsoil. Although lawns and other ornamental landscaping will establish a vegetated surface, both the original surface and subsurface flows and storage capacities have been altered and surface runoff will be increased. Instead of stripping and removing, original topsoil it should be replaced on the site and augmented with organic matter and sand to improve soil structure and increase macropore development.

To increase absorbency, surface soils should have a minimum organic content to facilitate plant growth and a soil depth sufficient to meet the 6-month rainfall capture target. Increased soil depths also provide retention for runoff from adjacent hard surfaces. Surface vegetation should include herbaceous groundcovers with a thickly matted rooting zone, deciduous trees, or evergreens.



Absorbent landscaping on a housing lot, Maple Ridge, BC



Roadside bio-retention facility, Maple Ridge, BC

Some maintenance over the long term is required for the absorbent landscape to continue to provide stormwater benefits. Maintenance activities may include replacing soils that have eroded and replanting dead or dying vegetation.

**Surface Infiltration Facilities** – Rainfall runoff is stored at or near the surface in a layer of absorbent soil, sand, gravel, or rock, and/or on the ground surface in a ponding area. The stored runoff that infiltrates into the soil becomes interflow and augments groundwater in the sub-surface.

Surface infiltration facilities can look like normal vegetated swales or ponds, and can be aesthetically landscaped and integrated into the design of open spaces. They include bioretention facilities and rain gardens. Both surface and sub-surface infiltration facilities can be effective at the lot level, as well as at the neighbourhood level, where individual lot sizes or layouts don't support on-lot facilities or where more permeable soils or groundwater recharge areas are located off-site. Surface infiltration facilities can, depending on their design, provide some level of water quality treatment as well.

Surface infiltration can be combined with detention, where the detention release rate allows sufficient time for infiltration through the pond. Infiltration facilities are highly dependent on the hydrologic properties of the sub-surface soils.

Surface infiltration can also be promoted by the used of permeable pavers or other pervious surfacing materials.

### Bio-Retention Facilities

If infiltration rates are low, such as is likely in clay and till soils, bio-retention facilities can be designed to store the volume reduction target in soil and rock trench voids and infiltrate it slowly over time.

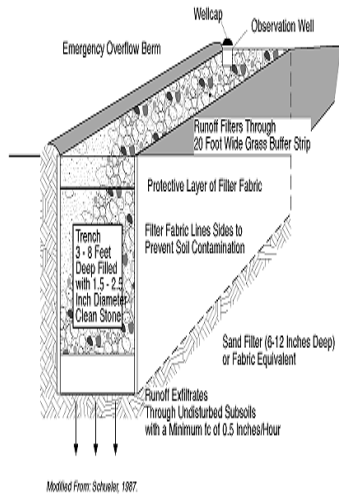
Where applicable, a retention facility may also be designed as a baseflow augmentation facility that retains the design capture volume in a tank or pond and releases it at baseflow rates. These rates are very low, and are based on measured summer baseflows in a watercourse divided by the contributing watershed area, and then applied to the area of the site contributing runoff. Baseflow augmentation facilities discharge the capture volume to the downstream stormwater system or watercourse at a maximum of the determined baseflow rates. Any volumes above the capture volume must be allowed to bypass the baseflow augmentation facility.



Bioswale for infiltration in Vancouver, BC



A roadside rain garden and reduced pavement width on SEA Street in Seattle, WA



Example of an infiltration trench (Source: [www.montgomerycountymd.gov](http://www.montgomerycountymd.gov))

Green Roof on the Vancouver Public Library, Vancouver, BC



Green roofs are the preferable source control in areas where ground surface controls are not possible.

**Sub-surface Infiltration Facilities** – A similar design process is used for sub-surface infiltration as for surface infiltration facilities. The main advantage of sub-surface facilities is that they often have vertical walls and do not require as much dedicated ground area, allowing them to be located beneath paved impervious areas.

Sub-surface facilities must be located at least 0.5 m above the level of the water table so that they can discharge through the sides and bottom of the structure and will not merely store infiltrated groundwater. Generally, the deeper an infiltration facility is located, the less-effective it will be. Subsurface infiltration facilities can be as simple as a trench filled with clean, free-draining rock that is protected from soil by a permeable membrane. There are numerous products available commercially for subsurface infiltration as well.

**Green Roofs** – Installing a green roof rather than a conventional impervious roof can significantly reduce the volume and rate of runoff from a building lot particularly for the smaller, more frequent storm events.

A green roof is essentially a roof with a layer of absorbent soil and vegetation on top of a drainage collection layer or system. Rainfall is absorbed or stored by the soil and vegetation for later evapotranspiration. The green roof has a limited storage capacity, so any excess rainfall percolates through and is collected by a drainage system. The excess rainfall is then routed to the ground for detention and conveyance.

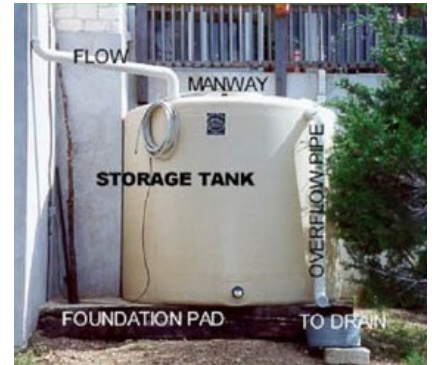
Green roofs are more expensive to build as they have structural costs as well as landscaping costs and do require maintenance to ensure their ongoing functionality. However, when compared with land costs for alternate facilities in high density urban areas, the costs for a green roof may be favourable. Green roofs also have other benefits, in addition to stormwater benefits, that can include heating or cooling cost savings by insulating the building, aesthetic benefits, air quality benefits, and reduced solar gain that decreases the urban heat island effect. Green roofs should only be designed and constructed by qualified professionals as structural engineering, building envelope and landscape design as well as stormwater engineering are all critical components. Green roofs are the preferable source control in areas where ground surface controls are not possible. For more information on green roofs readers are referred to the [Green Roofs for Healthy Cities](#) website.

**Rainwater Re-use** – Rainwater re-use is commonly afforded by residential rain barrels which are effectively retention facilities for roof runoff. Limitations of rain barrels are that rainfall is seldom a reliable source for water during the dryer seasons and rain barrels are often not large enough to store the 6-month capture target. The most significant reductions in runoff volume from re-use are achieved by capturing and re-using rainwater for indoor grey-water uses, or for commercial and industrial applications with high water consumption rates or where water supplies are limited. Recycling rainwater reduces demands from surface waters and reservoirs and can reduce supply infrastructure costs. Rainwater re-use can also be combined with infiltration facilities.

The advantages and disadvantages of each of the aforementioned Source Control technologies are summarized in Table 4.4, below.

**Table 4.4 - Advantages and Disadvantages of Source Control BMPs**

BMP	Advantages	Disadvantages
<b>Absorbent Landscaping</b>	<ul style="list-style-type: none"> <li>- Reduces runoff from landscaped areas</li> <li>- Captures and stores water from impervious runoff in the soil voids</li> <li>- Provides high infiltration rates and augments interflow</li> <li>- Promotes and maintains evapotranspiration capacity</li> </ul>	<ul style="list-style-type: none"> <li>- May require addition of organic material and physical processing to create desired soil characteristics</li> <li>- Avoid compacting subgrade during construction to as much as possible</li> </ul>
<b>Surface Infiltration Facilities</b>	<ul style="list-style-type: none"> <li>- Reduces runoff volume &amp; rates from impervious surfaces</li> <li>- May be aesthetically landscaped</li> <li>- When designed as a bio-retention facility, increases evapotranspiration</li> </ul>	<ul style="list-style-type: none"> <li>- Must be protected from siltation during and after construction,</li> <li>- Must be maintained to ensure continued functionality.</li> </ul>
<b>Subsurface Infiltration facilities</b>	<ul style="list-style-type: none"> <li>- Reduces runoff volume &amp; rates from impervious surfaces</li> <li>- May be located below driveways or paved areas, or combined with pervious pavements above</li> </ul>	<ul style="list-style-type: none"> <li>- Must be protected from siltation during construction</li> <li>- Must be located above groundwater table</li> </ul>
<b>Green Roofs</b>	<ul style="list-style-type: none"> <li>- Removes roof area from calculations to help achieve the rainfall capture target</li> <li>- Promotes evapotranspiration</li> <li>- Provides temperature moderation in hot and cold climates</li> <li>- Cheaper than land-intensive alternatives in high-density areas</li> </ul>	<ul style="list-style-type: none"> <li>- Requires maintenance</li> <li>- Less effective in very wet climates</li> <li>- Higher capital costs for construction relative to an ordinary roof structure</li> </ul>
<b>Rainwater Re-use</b>	<ul style="list-style-type: none"> <li>- Reduces roof runoff from entering stormwater system</li> <li>- Can reduce the amount and costs of water drawn from reservoirs</li> <li>- Beneficial where soils have low infiltration rates</li> </ul>	<ul style="list-style-type: none"> <li>- Best used for indoor grey water</li> <li>- Generally not adequate for irrigation in the dry season</li> <li>- Ensure watercourse baseflows are not negatively impacted</li> </ul>



A tank for collecting rainwater from a roof for re-use. (Source: file photo)



## Stormwater Detention Systems

The DFO/MOE stormwater detention objective is to limit the post-development runoff to the pre-development rate, volume, and approximate shape of the hydrograph for the 6-month/24-hour, 2-year/24-hour, and 5-year/24-hour storm events and to maintain, as closely as possible, the natural pre-development flow pattern in the receiving watercourse.

These detention levels have been adopted to address increases in impervious areas in developments and the environmental impacts (e.g. stream erosion, sedimentation; loss of riparian habitat, changes in stream morphology, etc.) that are occurring due to the more frequent, smaller storm events being rapidly conveyed off hard surfaces into fish bearing waters.

Detention requirements can be estimated by various methods including: rational method, SCS (U.S. Soil Conservation Service) unit hydrograph and level pool routing. The selection of the method of analysis depends on the size of development and type of information available, as well as the intended application of the results. Analyses should be done or reviewed and sealed by a Professional Engineer. Municipal design manuals usually outline the preferred methods required for specific circumstances. There are many computer software packages available that aid in the analysis and design of these facilities, especially in the design of larger, complex drainage and community detention systems.

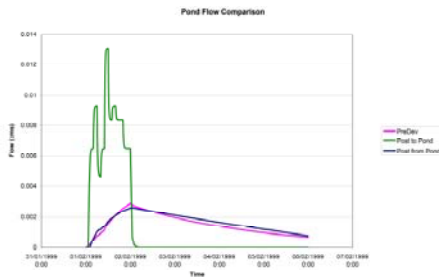
Many regional and municipal authorities have also established specific runoff and detention requirements. They can be combined with these detention criteria or take precedence where they exceed the environmental objectives of these guidelines.

Table 4.6 lists some of the advantages and disadvantages of several types of detention facilities.

### Stormwater Detention Ponds

There are several types of detention ponds whose functions are the same, but which differ in design and operation. Detention ponds generally provide temporary storage of runoff. The variation in pond type and operation allows the design to suit the size and type of development.

Example of Detention Pond design curves, showing the pre-development flow (pink),



post-development inflow to the pond (green), and pond outflow (blue) matching the pre-development hydrograph



Detention Pond Outlet, Sechtel

**Table 4.5 - Advantages and Disadvantages of Detention Technologies**

Technology	Advantages	Disadvantages
<b>Wet Ponds</b>	<ul style="list-style-type: none"> <li>- Provides good water quality treatment</li> <li>- Excellent sediment removal</li> <li>- Good for aesthetics / park values</li> <li>- Good for large detention volumes</li> <li>- Good peak rate control</li> </ul>	<ul style="list-style-type: none"> <li>- Large land area required</li> <li>- Greater storage volume than dry pond needed</li> <li>- Possible insect problems</li> <li>- Requires large contributing area to sustain wet pool</li> <li>- Increases water temperature</li> </ul>
<b>Dry Ponds</b>	<ul style="list-style-type: none"> <li>- Suitable for large detention volumes</li> <li>- Good for multiple use areas</li> <li>- Good peak rate control</li> <li>- Can be used in conjunction with infiltration although infiltration may clog over time</li> </ul>	<ul style="list-style-type: none"> <li>- Poor water quality treatment and sediment removal performance</li> <li>- Large land area required</li> <li>- Empty ponds can have poor aesthetics</li> </ul>
<b>Wet Tanks or Vault Detention</b>	<ul style="list-style-type: none"> <li>- Good multiple use if covered/buried</li> <li>- Good for building/rooftop runoff</li> <li>- Can be used close to structures/foundations</li> <li>- Good for built-up areas</li> </ul>	<ul style="list-style-type: none"> <li>- Cost prohibitive for large detention volumes</li> <li>- Inappropriate for inflows with high sediment loads</li> <li>- Requires maintenance/clean-out</li> </ul>
<b>Infiltration Systems</b>	<ul style="list-style-type: none"> <li>- Good water quality treatment possible if biofiltration is included</li> <li>- Excellent small storm retention</li> <li>- Excellent groundwater recharge to help sustain stream baseflows</li> <li>- Good peak rate control</li> <li>- Good for developments with no downstream drainage system</li> <li>- Good for clean inflows (i.e. rooftops)</li> </ul>	<ul style="list-style-type: none"> <li>- Not suitable for sediment-laden inflows</li> <li>- Inappropriate in areas of high groundwater</li> <li>- May require surface discharge</li> <li>- Generally not suitable for large detention volumes</li> <li>- Not for low permeability soils</li> </ul>
<b>Constructed Wetlands</b>	<ul style="list-style-type: none"> <li>- Excellent water quality buffering and volume reduction</li> <li>- Excellent sediment removal</li> <li>- Good for aesthetics / park values</li> <li>- Suitable for large runoff volumes</li> <li>- Good groundwater recharge</li> </ul>	<ul style="list-style-type: none"> <li>- Requires large area</li> <li>- High maintenance costs</li> <li>- Possible insect problems</li> <li>- Water quality treatment only</li> <li>- Detention capacity limited by vegetation health requirements</li> </ul>



Example of a wet detention pond (Source: file photo)



Example of a dry detention pond, WA

Dry ponds provide temporary detention by filling during storm events, and slowly releasing runoff at a predetermined rate until empty. Because of the temporary nature of the detention of the storm runoff, dry pond technology can be used in multi-use areas like playing fields, parking lots, and natural depressions.

Wet ponds maintain a minimum level of water at all times and provide detention by storing runoff above this level. They release flows at a predetermined rate down to the minimum water level and require a minimum contributing area to sustain the wet pool and prevent it from becoming stagnant. Wet ponds are a permanent structure which can be designed as an amenity or aesthetic water feature within a development.

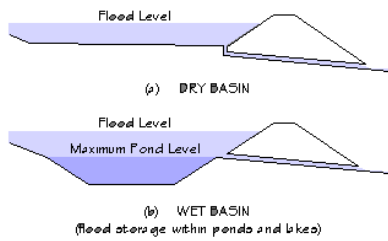
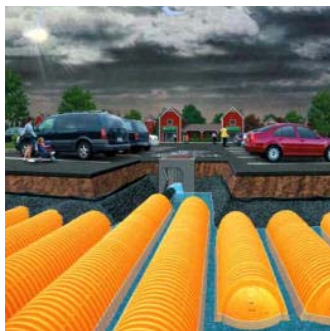


Illustration showing water levels in dry and wet detention ponds.

(Source: [www.water.gov.my](http://www.water.gov.my))

Parking lots, park areas and work yard areas may be used for temporary water detention to shallow depths.



Underground detention storage in prefabricated plastic chambers; this image shows a proprietary product from StormTech, LLC (<http://www.stormtech.com>)

Detention ponds remain after the development is complete, and must be protected and maintained on a regular basis. Detention ponds generally require a suitably sized area located at the lowest point in the development area. The number of ponds required is dependent on the area available for detention storage and the contributing catchment area. Various design guidelines are available, but in any given area there may be municipal guidelines for design of detention facilities, and the local design guidelines should be followed wherever possible. The [Metro Vancouver's Best Management Practices Guide for Stormwater](#) in particular has useful guidelines for design of detention facilities.

### Detention Systems for Built-up Areas

Detention facilities can also be designed to fit into existing developments where space is limited and construction of a conventional pond is not practical.

**Roof Top Detention** - The use of roof top storage should be considered for industrial, commercial and institutional buildings with flat roofs. Structural support is required and the appropriate building code requirements covering rain and snow loading must be followed (National Building Code, 1990, Part 4, Commentary 1). The release rate from the roof top should be controlled by a roof top device and overflow scuppers should be provided at the maximum operating water level.

**Parking Lot, Park Area and Work Yard Detention** - Parking lots, parks and work yards can be used for temporary water detention to shallow depths. Generally, the flooded area operates like a dry pond where the runoff rate is controlled by a valve or orifice located in an outlet pipe or manhole. The allowable ponding depth is a function of safety and convenience to users and should be designed accordingly. Flow control chambers should be used to control the water depth. Overflows to the storm drainage system, and/or a surface flood route, should be provided at the maximum operating level.

**Underground Detention Structures** - Underground detention can be incorporated into the design of stormwater systems by using oversized piping or off-line tanks controlled by a suitable device to limit outflow. Underground tanks, pipes or culverts can be used as detention storage facilities. All such underground facilities should have an access point for inspection and maintenance and should be designed by a Professional Engineer in accordance with local municipal requirements.

## Infiltration Systems

Stormwater infiltration systems can provide many benefits to urban streams. Infiltration systems can retain runoff, recharge groundwater and control peak flows. The soil, through which the stormwater runoff passes, also acts as a filter removing a large percentage of the common pollutants normally discharged to the stream or creek. Infiltration can recharge local groundwater which in turn feeds smaller streams and creeks through seepage. Groundwater which is slowly discharged back into streams and can constitute all or part of a stream's baseflow. This baseflow can be critical for fish and fish habitat during extended periods of little or no precipitation and runoff. It maintains preferred spawning conditions for several salmon species which key on groundwater seepage areas for spawning and egg incubation.

In areas with well-draining soils, stormwater runoff from a site can be collected and discharged into an infiltration system where there are no conventional stormwater removal systems, or infrastructure, which reduces the costs of providing offsite conveyance.

### Application of Infiltration Systems

Infiltration basins may be used as a method of stormwater detention only if required detention volumes are relatively small.

For larger applications, a series of infiltration basins may be necessary, each serving a small collection area. Using several galleries may reduce collection and piping costs normally associated with conventional stormwater systems.

Ponding and detention can also be incorporated into the design of the infiltration system. Conversely, infiltration can be used in combination with other detention technologies to provide retention of runoff.

### Stormwater Runoff Water Quality

Changes in land use, loss of natural biofiltration capacity, increases in impervious area, and pollutant laden runoff associated with urban development all contribute to reduced water quality which impacts fish and fish habitat. The DFO/MOE water quality stormwater runoff criteria were established to address specific legislative requirements. Under the federal *Fisheries Act* the discharge of deleterious substances into fish bearing waters is prohibited (see Appendix I for definitions of "deleterious substances").

Infiltration can provide recharge to the local area groundwater which in turn feeds smaller streams and creeks.



An infiltration gallery during installation at Turtle Mountain in the City of Vernon, BC.



Water Quality BMPs are physical, structural or management practices that reduce or prevent water quality degradation.

Without source control, runoff water quality is limited by the effectiveness of treatment technology.



Using source controls such as street sweeping and mandating lead free or alternative fuels can lead to better stormwater quality from city streets. (Source: Raincoast Applied Ecology)

Source controls for water quality are measures that are taken to prevent or reduce pollutants from encountering and combining with stormwater.

In addition, under the provincial Waste Management Act, Regional Districts are required to develop Liquid Waste Management Plans (LWMP's). In some jurisdictions such as Metro Vancouver the LWMP directs member municipalities to develop integrated stormwater management plans which address among other things water quality. The LWMP for Metro Vancouver also specifies that all watersheds within their jurisdiction should have ISMPs in place by 2014.

### Water Quality Best Management Practices

BMPs designed to capture and treat runoff need to be incorporated into stormwater management plans. The following provides a brief overview of stormwater management strategies that can be implemented as BMPs.

Water Quality BMPs are physical, structural or management practices that reduce or prevent water quality degradation. Many of these are the same as, or similar to those used for runoff volume reduction and rate control and but have ancillary benefits for water quality. Source control remains the key means of reducing introduction of toxic and hazardous materials or organic and inorganic contaminants, originating from land and water use or as a result of commercial or industrial spills. Without source control, runoff water quality is limited by the effectiveness of treatment technology.

### Water Quality Source Controls

Source controls for water quality are measures that are taken to prevent or reduce pollutants from encountering and combining with stormwater. Programs and alternatives focused on eliminating or reducing the use and release of pollutants (deleterious substances) and controlling and minimizing spills are examples of source controls. Such non-point-source pollution controls are key elements of any stormwater management plan. This includes examples such as: careful application and disposal of pesticides and herbicides, dog litter bylaws, street sweeping, and use of lead free or alternative vehicle fuels.

### Treatment Controls

Treatment controls on the other hand are point-source water quality management measures. They are generally constructed facilities and are often individual installations incorporated into the stormwater management infrastructure. They should be designed on a site-specific basis, after examining all alternative treatment technologies, and selecting the best available options based on cost and effectiveness. These controls should be designed and constructed by appropriately qualified environmental professionals.

## Water Quality Best Practical Technologies

Several technologies have the ability to provide both water quality benefits and runoff control. Water quality benefits are derived from contaminant removal mechanisms that use biological and physical processes. Runoff control is accomplished by improving stormwater detention and retention which reduces peak runoff discharge rates and volumes. The following are examples of stormwater treatment technologies that can be implemented as **best practical technologies** (BPTs) for both contaminant removal and runoff control. For more detail on the full array of BMPs and BPTs for water quality maintenance, refer to other resources such as [Stormwater Planning: A Guidebook for British Columbia](#), [Metro Vancouver guidance documents](#), [Stormwater Management Manual for Western Washington](#).

**Biofilters** - Biofilters are vegetated filter strips, swales and rain gardens that remove deleterious substances, notably particulate contaminants, though some combination of physical (e.g.: adsorption) and biological (biodegradation) removal mechanisms. Biofilter technology is suitable for sheet flow runoff, typical of large linear impervious developments like roadways and parking lots.

**Urban Forests and Leave Strips** - Depending on the extent of tree canopy and ground cover retained, runoff reduction and pollutant removal can be achieved by maintaining natural well functioning urban forested areas. The contaminant removal processes forests and natural vegetation provide include: filtration, adsorption, absorption, and biological uptake and conversion by plant life. Urban forests also provide habitat refuges for many species whose habitats have been fragmented while riparian leave strips along watercourses, provide critical fish and wildlife habitat.

**Infiltration Systems** - Infiltration systems generally require pre-treatment for water quality to prevent clogging and binding-off of the permeable materials and contamination of underlying aquifers. Physical removal of deleterious substances by filtration and adsorption, as well as conversion of soluble pollutants by bacteria, also occurs within the infiltrating soils.

**Constructed Wetlands** – Physical, biological and chemical processes combine in wetlands to remove contaminants and either surface or subsurface flow wetlands can be constructed specifically to treat stormwater runoff. Constructed wetlands also offer retention benefits and can create preferred habitats for aquatic and terrestrial wildlife species. **The use of existing natural wetlands to treat stormwater however is not an acceptable practice.**

Treatment controls are point-source water quality treatment facilities that are incorporated within the stormwater management infrastructure.

BPTs are technologies that provide for contaminant removal and treatment in a cost-effective manner.



Lost Lagoon – a constructed stormwater treatment wetland located in Stanley Park, Vancouver, BC – treats road runoff from the Stanley Park Causeway which handles 60,000 vehicles per day.



Example of a wet detention pond at SFU in Burnaby, BC



Installation of an oil and grit separator

(Source: file photo)

Clearing should only be undertaken immediately in advance of work

**Wet Detention Ponds** - Permanent wet ponds remove pollutants and other deleterious substances through physical processes such as sedimentation, filtration, absorption and adsorption and through biological mechanisms such as: uptake and conversion by plants, and microbial degradation. Wet ponds can also detain flows thereby contributing to rate control and volume reduction objectives. General design parameters need to include: vegetation types (floating, emergent and submergent vegetation), water depth and ponding area, and will often require consideration of detailed pond specific operational parameters.

**Oil and Grit Separators** – Oil and grit separators are suitable for spill control and removal of floatable petroleum-based contaminants as well as coarse grit and sediment from small areas, such as gas stations, automotive service areas and parking lots. Oil and grit separators have limited application in large-scale stormwater runoff applications, and should be limited to small area generation sites.

### Guidelines for Implementation of Stormwater Water Quality Objectives

1. Use a combination of best management practices (BMPs) and best practical technologies (BPTs) for stormwater runoff water quality control particularly where contaminated runoff will be generated and may be discharged to fish habitat
2. Use technologies that offer both physical and biological contaminant removal, in addition to detention and retention capacity to maximize benefits and reduce costs.

### Construction Best Practices

Construction Best Practices for instream stormwater management works include timing of the works to minimize impacts. Timing windows should be adhered to in order to minimize impacts to fish and wildlife and specifically to avoid sensitive periods for certain life history stages of fish (e.g.; adult spawning, egg and alevin intergravel incubation). Where information is available on critical life history stages and timing for any identified Species at Risk, these times should also be avoided. Clearing should only be undertaken immediately in advance of work, and only during vegetation clearing timing windows, where these have been identified for protection of nesting birds. To the extent possible, work should be restricted to cells and undertaken in a systematic manner to limit the area disturbed at any given time. Works should only be undertaken during favourable weather conditions and low water conditions.

Measures must be taken to prevent the release, from any work site, of silt, sediment, sediment-laden water, raw concrete, concrete leachate, or any other *deleterious substance* into any ditch, watercourse, stream, or storm sewer system. The work area should be isolated from flowing water as much as possible and diversions around the site should be provided for overland flow paths. Ensuring that all equipment used on-site is in good working order, and having a ready spill containment kit and staff trained in its use, are also critical measures.

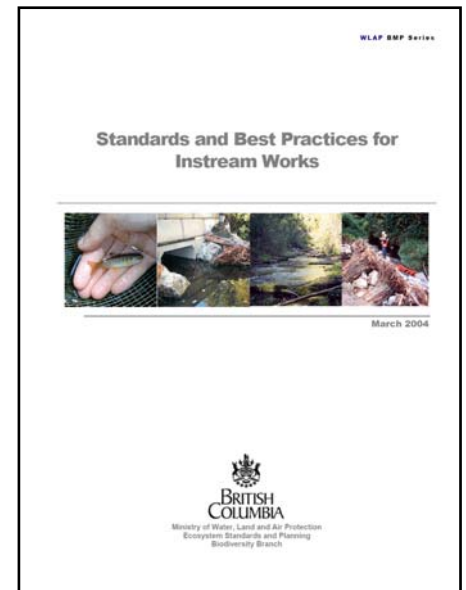
For further information on managing erosion and sediment discharges during construction, see the Erosion and Sediment Control section of these Land Development Guidelines and the [Standards and Best Practices for Instream Works](#).

## Monitoring During Construction

Construction activities should be monitored full-time during start-up and during any in-stream works or activity that will affect fish or fish habitats, and on a daily basis during any other construction activity until the completion of the project. The environmental monitor must be an independent and “appropriately qualified professional” as defined in the MOE [Standards and Practices for Instream Works Guidebook](#). The environmental monitor will be provided with written authority to modify or halt any construction activity if it is deemed necessary for the protection of fish and wildlife populations or their habitats. A sign listing the monitoring company’s name and phone number should be posted at the entrance to the site or in the immediate vicinity. Many municipalities have sediment and erosion control monitoring requirements for construction which will also need to be followed.

A pre-construction meeting between the environmental monitor and the contractor responsible for the work should be held on the site so that both parties begin the work with a common understanding of the mitigation best practices for the project. Within 60 days of the project’s completion, the environmental monitor should complete and submit at least one copy of a monitoring report to the work’s owner, DFO and the Ministry of Environment. The report should be consistent with the recommended standard format and content as shown in 8.2 of the [Standards and Best Practices for Instream Works Guidebook](#).

Measures should be taken to prevent release of silt, sediment, sediment-laden water, raw concrete, concrete leachate, or any other *deleterious substance* into any ditch, watercourse, stream, or storm sewer system from any works site.



Construction activities should be monitored full-time during start-up and during any in-stream works or activity that will affect fish or fish habitats

Stormwater management is an evolving science and data is required to support adaptive management and improvements to the stormwater tools currently available.



Overflow flow monitoring weir

## Post-Construction Monitoring

In some instances, post-construction monitoring will also be required. Such monitoring may be associated with a Water Act approval or a Federal Fisheries Act authorization. Where the proponent has recommended an atypical, innovative, or unique stormwater BMP, monitoring and evaluation will be essential. Stormwater management is an evolving science and data is required to support adaptive management and improvements to the stormwater tools currently available. Monitoring is also necessary in order to confirm the effectiveness of BMPs and BPTs employed.

Any stormwater management plan should be developed in consultation with the local government authority and a Professional Engineer who has stormwater experience. Data may be required on the watershed development conditions, local rainfall, storage depth, and the inflows and outflows from stormwater facilities. If a natural stream is part of the stormwater system, the stream water quality, flows, channel morphology and stream health should also be monitored. The objective of this monitoring is to collect actual rainfall and storm flow data related to the operation of the as-constructed drainage system, and to compare these with design objectives to assess whether further improvements or adjustments are required. The data should be reviewed and analyzed by an independent Professional Engineer who will provide reports to the owner, DFO and MOE, and the municipality on the effectiveness of the works in meeting the stormwater objectives.

## Resources

The March 2006 version of *Develop with Care* replaces the previous versions (June 2004 and April 2005) of *Environmental Best Management Practices for Urban and Rural Land Development in British Columbia*. This document is intended to assist people who are involved in planning, implementing, reviewing and/or approving land developments in British Columbia's urban and rural areas and is available at:

[http://www.env.gov.bc.ca/wld/documents/bmp/devwithcare2006/develop\\_with\\_care\\_intro.html](http://www.env.gov.bc.ca/wld/documents/bmp/devwithcare2006/develop_with_care_intro.html).

The BC Ministry of Water, Land and Air Protection's *Standards and Best Practices for Instream Works* (draft March 2004) contains guidance on the management of stormwater runoff. It is available at: <http://wlapwww.gov.bc.ca/sry/iswstdsbpsmarch2004.pdf>.

Metro Vancouver (previously the GVRD) has produced a number of useful documents relating to stormwater design and monitoring. Among them are the *Stormwater Management Best Practices Guide*, the *ISMP Template*, and the *Stormwater Source Control Design Guidelines*. These documents are available online at:

[http://www.gvrd.bc.ca/sewerage/stormwater\\_reports.htm](http://www.gvrd.bc.ca/sewerage/stormwater_reports.htm).

*Stormwater Planning: A Guidebook for British Columbia* (2002) is available at:

<http://www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html>.

Additional guidance on practices that balance development and ecological concerns is available in the Intergovernmental Water Sustainability Action Plan for British Columbia's *Beyond the Guidebook* document, available at:

<http://www.waterbucket.ca/rm/sites/wbcrm/documents/media/37.pdf>

For information on the Riparian Assessment Regulation readers are referred to the Riparian Assessment Regulation Website at:

[http://www.env.gov.bc.ca/habitat/fish\\_protection\\_act/riparian/riparian\\_areas.html](http://www.env.gov.bc.ca/habitat/fish_protection_act/riparian/riparian_areas.html)

The Provincial (BC) Water Act text can be found online at: [http://www.qp.gov.bc.ca/statreg/stat/W/96483\\_01.htm](http://www.qp.gov.bc.ca/statreg/stat/W/96483_01.htm) and other Water Act information is available at: <http://www.bcwatersheds.org/issues/water/bcgwlp/o36.shtml>

The text of the Provincial (BC) Fish Protection Act can be viewed online at: [http://www.qp.gov.bc.ca/statreg/stat/F/97021\\_01.htm](http://www.qp.gov.bc.ca/statreg/stat/F/97021_01.htm) and the Fish Protection Act Homepage may be found at: [http://www.env.gov.bc.ca/habitat/fish\\_protection\\_act/](http://www.env.gov.bc.ca/habitat/fish_protection_act/)

The Provincial Government has published the *British Columbia Approved Water Quality Guidelines* (August 2006) that establishes maximum allowable sediment loading for aquatic ecosystems at: [http://www.env.gov.bc.ca/wat/wq/BCguidelines/approv\\_wq\\_guide/approved.html](http://www.env.gov.bc.ca/wat/wq/BCguidelines/approv_wq_guide/approved.html)

The *Green Infrastructure Guide* developed by West Coast Environmental Law provides a readable overview of many of the goals and methods available for progressive stormwater management, as well as examples of various stormwater BMPs in use in B.C. The Guide may be downloaded from: <http://www.wcel.org/wcelpub/2007/14255.pdf>

The text of the Federal Fisheries Act can be viewed online at: <http://laws.justice.gc.ca/en/F-14/text.html>

The Canadian Environmental Assessment Act text can be viewed online at: <http://laws.justice.gc.ca/en/C-15.2/text.html>

For information on Species At Risk, including listed species, visit the SARA website at: [http://www.sararegistry.gc.ca/default\\_e.cfm](http://www.sararegistry.gc.ca/default_e.cfm)

The National Guide to Sustainable Municipal Infrastructure (InfraGuide), a Natural Resources Canada funded body, has a *Best Practices Guide for Stormwater Management Planning, Source and On-Site Controls for Municipal Drainage Systems*, as well as *Conveyance and End-of-Pipe Measures for Stormwater Control*, all available at:

[http://sustainablecommunities.fcm.ca/Infraguide/Storm\\_and\\_Water.asp](http://sustainablecommunities.fcm.ca/Infraguide/Storm_and_Water.asp)

An auxiliary tool to the stormwater planning guidebook is a runoff based simulation model – the Water Balance Model powered by QUALHYMO. The model is of use to developers, municipalities and engineers for conducting exceedance duration analyses and assessing runoff reductions associated with various low impact development measures. The model is available at:

<http://www.waterbalance.ca/waterbalance/home/wbnBCIndex.asp>

Washington State Department of Ecology has a number of on-line resources for stormwater management. One of the most comprehensive is the *Stormwater Management Manual for Western Washington*, in five volumes, available at:

<http://www.ecy.wa.gov/programs/wq/stormwater/manual.html>

The Puget Sound Action Team has an extensive list of Low Impact Development resources which are available on their website at:

[http://www.psparchives.com/our\\_work/stormwater/lid.htm](http://www.psparchives.com/our_work/stormwater/lid.htm)

The Puget Sound Action Team has also published its own *Low Impact Development Technical Guidance Manual for Puget Sound*, that can be found at:

[http://www.psparchives.com/publications/our\\_work/stormwater/lid/LID\\_manual2005.pdf](http://www.psparchives.com/publications/our_work/stormwater/lid/LID_manual2005.pdf)