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Sustainable Water and Stormwater Management

Sustainable Water and Stormwater Management

Presented By: CMHC International
c/o Canada Mortgage and Housing Corporation
700 Montreal Road
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Description: Provides an overview of site, neighborhood, and watershed water and stormwater management approaches and their relationship to sustainable community planning and green building design.

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Learning Objectives

At the end of this program, participants will be able to:

- recall the principles of ground and surface water supply, including methods of discharge, recharge and connectivity
- list, in order of usage amount, Canada’s water users
- compare and contrast a watershed management, sub-watershed management and stormwater management plan
- identify five principles of integrated stormwater management planning
- identify and describe five categories of residential water usage management
- list six strategies and 16 advantages of low impact development, and
- describe how building and site plan designs can relate to larger scale water management strategies.

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Columbia River, Washington State, U.S.A.

Why Study Water and Stormwater Management?

Relationship to Sustainable Planning Principles

In this section of the course, we'll take a look at the reasons that water management is essential and give some examples of how water management informs design at many levels. Water management relates to every sustainable planning principle.

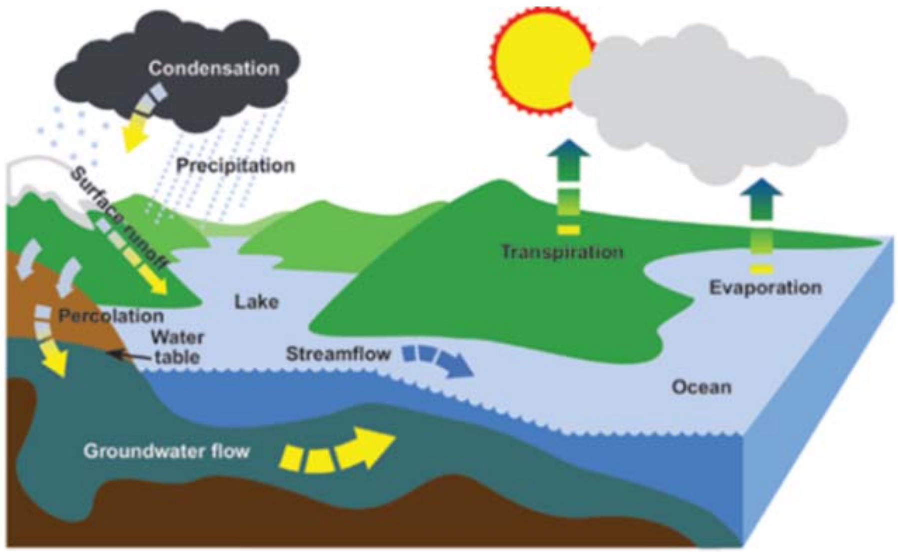
Planning Principle	Why Manage Water?
Complete and liveable communities	Water is both essential and pleasurable
Environmental protection	Water sources therefore must be protected
Energy and emissions reduction	Water requires considerable pumping and processing energy
Green, efficient resources	Water is a finite resource and must be used efficiently
Enhanced economic performance	Reducing the cost of processing water, flood damage, building and infrastructure deterioration and health care improves community economic performance
Sustainable community management and public education	Managing water resources and sharing conservation approaches is part of community management

The Hydrologic Cycle Informs Our Planning Decisions

Water, as described on the Environment Canada website, is “constant in quantity and continuously in motion.”

Because we have a constant amount of water and a rapidly increasing population, we must learn to use water more efficiently.

Because water is constantly in motion, we must develop communities where water will remain available.



Source: Environment Canada

The hydrologic cycle is an almost perfect water circulating system. Development patterns, if executed properly, can benefit from it—or conversely, if done poorly, will interfere with it.

Communities Are an Entity in the Ecosystem

Water does not recognize man-made boundaries and is constantly crossing them; many boundaries are set in the middle of water elements.

Water management, therefore, must be cooperatively integrated at a number of scales: countries, states, provinces, watersheds, regions, districts, communities, neighborhoods, sites, and buildings.

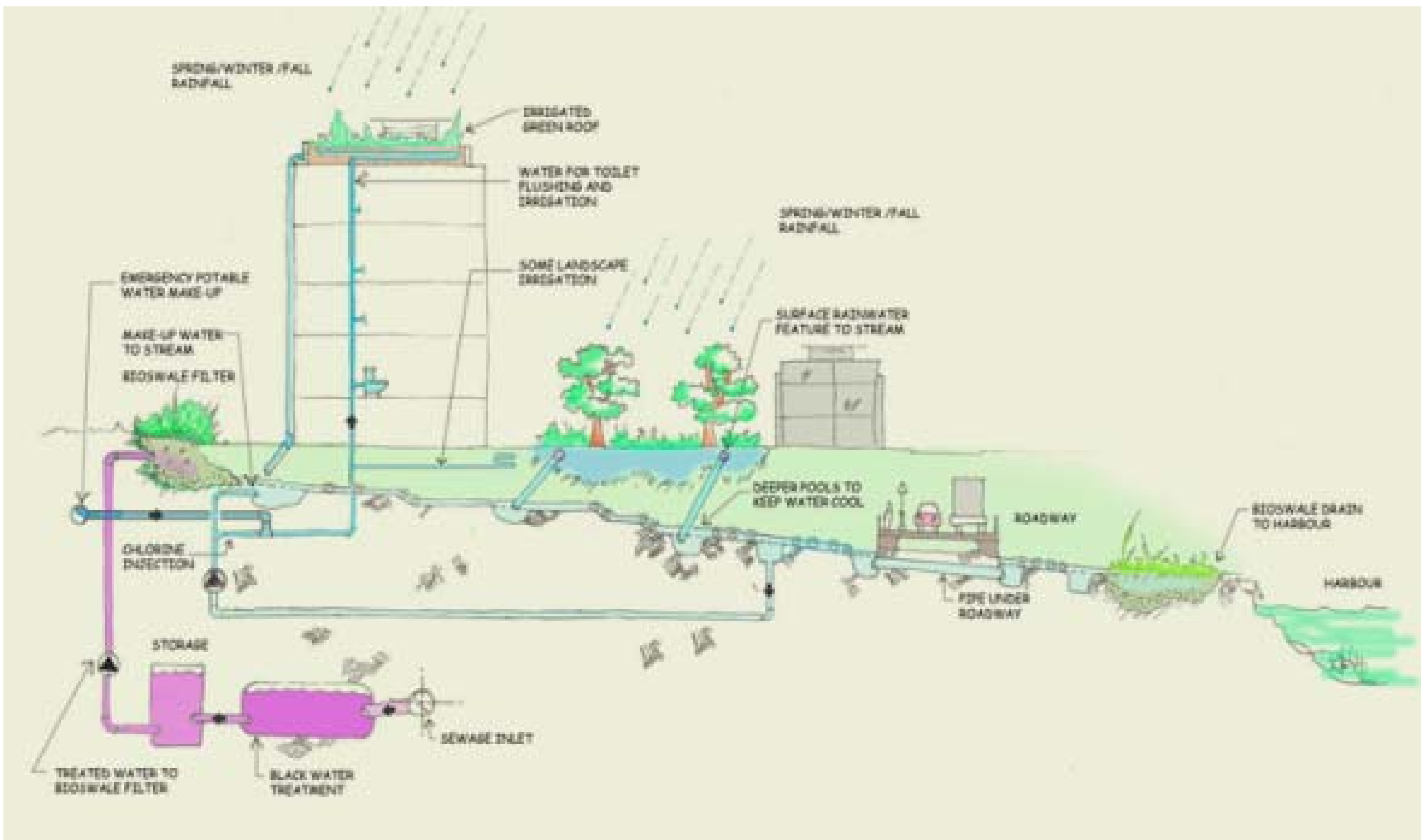
Managing, planning, and designing at each scale requires understanding the management strategies of every other scale.

Neighborhood: Design Tool

The stormwater management/reuse system at Dockside Green in Victoria, B.C. includes a surface feature which is used as a powerful site plan organizing element in this multi-building high-rise project.

Neighborhood: Designing with Natural Water Movement

The Dockside Green rainwater system shown on slide 11 in many ways mimics the natural hydrological cycle by capturing, polishing, and reusing stormwater before slowly releasing it to the ocean through the ground.



Regional: Water Quantity/Quality

The City of Toronto, in the province of Ontario, determined that to preserve its water quality and quantity it had to curtail further development on its large northern green belt area, one of its critical water sources.

Preventing development in this area meant a review of the city intensification policies and placed development pressures on nearby communities, who in turn had to review theirs.

Disruption of Natural Water Movement

Every time we use, interact with, or redirect water, we can affect the hydrologic cycle.

For instance, dam construction alters natural river flow significantly. The Colorado River, with the Glen Canyon Dam, the Hoover Dam and the Fleming Gorge Dam on the Green River (a tributary of the Colorado River), have resulted in a controlled flow regime whereby fluctuations in flow regime and peak flows have all but disappeared. Natural seasonal variation has been replaced by a nearly uniform flow regime.

Regulating flow in this manner allows for a predicable water supply for agriculture, power production and industry, etc., and also reduces the risk of flooding.

However, dams such as these not only disturb natural seasonal water fluctuation, but also have an effect on the river sediment transport, geomorphology, river ecology and riparian ecosystems; planning must include restoration of these ecosystem attributes.

Niger River, Mali

Hoover Dam, Nevada/Arizona

Effects of Increased Water Demand

Because the amount of water on earth never changes, worldwide water systems are under stress, due to human population growth and the exploitation of water resources to meet ever increasing water needs. In a 1999 report from the Asian Development Bank, a 17-percent increase in the number of countries facing water stress by 2025 is expected. This includes the U.S. The population of Texas, for example, is expected to increase 82% by 2050, and the Texas Water Development Board has issued $6B in bonds to fund new water infrastructure and conservation projects.

An increase in population size requires an increase in food production, and consequently an increase in water use/ demand for irrigated agriculture in especially arid and semi-arid regions of the world. It is expected that annual water use for agriculture will have to increase by 30 percent for crop production to double and meet global food requirements by 2025.

Disruption of Natural Water Movement

Las Vegas is a well-known and valuable example of disruption of natural water movement and increased water demand. Original settlers of Las Vegas located the town near springs in the desert. It has been able to grow to its present size through water piped from nearby Lake Mead since the 1930s. Despite a 30-foot rise in water level in the winter of 2011, Lake Mead is still well below water levels that would provide a sustainable water resource for Las Vegas.

Even with this increase of water level, water shortages are expected as soon as 2014, according to Bureau of Reclamation spokeswoman Rose Davis. (Source: Shine, Conor. "Lake Mead's water level rises 30 feet after wet winter." *Las Vegas Sun*, Aug. 17, 2011. http://www.lasvegassun.com/news/2011/aug/17/lake-meads-water-level-rises/)

Las Vegas now has to spend 3 billion dollars on even more piping far into the region, because it continues to grow while the water supply is shrinking. This situation affects not only the residents of Las Vegas, but also the natural balance for people and animals including ranchers and their stock.

Further Effects of Increased Water Demand

Along with increased population, economic and industrial expansion also puts a burden on water resources. These increasing trends in water consumption will have a tremendous impact on the sustainability of ecosystems throughout the world.

Given these facts, many organizations have recognized that sustainable water management should be a priority at all scales including the country, regional, watershed, community, neighborhood and building scales.

Community Planning Based on Water Demand

The community of Okotoks, Alberta (pop 25,000) based their sustainable community planning strategy around water demand management.

The town defined their growth limits, water usage allowances and overall planning strategy on the capacity of the adjacent Sheep River to sustain the provision of clean water without a loss in flow or necessity for expensive increased mechanical treatment.

Building Design Based on Stormwater Management

Not only does this affordable housing project capture and reuse its stormwater, but the water is used to grow food in a roof garden that is then used in the restaurant on the ground floor.

Occupants of the building are primarily service industry employees, so the restaurant serves as a training and job opportunity, as well.

60 Richmond St. E., Toronto

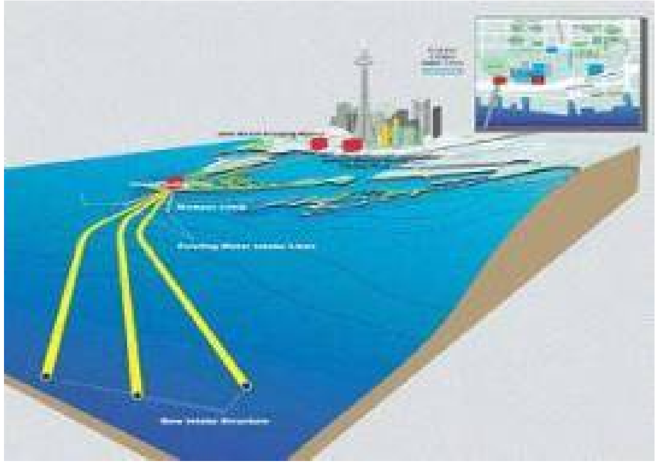
District Cooling Based on Water Management

Toronto, Ontario had serious issues with potable water supplies from the adjoining lake becoming clogged by Zebra mussels.

Private industry installed three huge intakes deep in the lake, where the water is 4 degrees C year-round and where Zebra mussels do not survive.

The water is so cold that it can chill the district cooling loop for dozens of major buildings, using a temperature exchanger as it passes through the pumping plant.

Selling this cooling is profitable to the installer, a cost saver to the many towers who use it and an overall benefit to the community due to reduced emissions and noise from turning off numerous cooling towers.



Project Designs Based on Water Management

The False Creek Village in Vancouver has an integrated stormwater and wastewater strategy incorporating roof gardens (1) to capture, polish, reuse and enjoy stormwater; constructed wetlands (2) to further polish it and provide habitat and recreational areas; foreshore restoration (3) to add more habitat and ensure site edge integrity; and heat recovery from the municipal wastewater plant (4) to heat the entire 20-building project.

This heat recovery also ensures that water enters the ocean at a temperature which does not adversely affect adjacent salmon spawning grounds.

Overuse of Water

In many regions of the world, a year-to-year decline in groundwater levels is observed due to over-exploitation.

For example, in the Baluchistan Province in Pakistan, groundwater use, for agriculture and domestic uses, has increased tremendously due to the large-scale development and operation of tubewells since the late 1980s.

This overuse of groundwater may lead to groundwater depletion, which requires a deeper well—in many parts of the world, well construction costs can be high.

Fetching water from a stream, Mauritania

Fleming Gorge Reservoir, U.S.A.

Effects of Overuse

Mexico City, originally an island in a lake, is now one of the largest cities in the world. This settlement, in addition to filling in the lake, also has overtaxed and drained the local water source so severely that the main cathedral is now leaning and sinking.

The city currently relies on one of the largest and most expensive pumping systems in the world to bring water from outlying areas.

Climate Change

Climate change is affecting rainfall patterns, snow and ice cover, and sea levels. It causes increases in extreme weather conditions, like heavy spring rains, heat waves and more frequent droughts. This directly impacts freshwater availability as icecaps and glacier melt mingle with seawater, and changing rainfall patterns reduce ground and surface water recharge in parts of the world. Decreased snow packs and subsequent runoff affects river hydrology patterns.

Effects of Climate Change

At the same time, land use activities such as agriculture, deforestation, and irrigation influence climate change. These activities impact the earth’s ability to absorb or reflect heat and light.

They also impact the natural soil coverage and natural water balance. Climate change has implications for water management planning and decision-making.

Natural Water Quality

Water contains naturally occurring substances—mainly bicarbonates, sulphates, sodium, chlorides, calcium, magnesium, and potassium. They are absorbed into surface and groundwater from:

- soil, geologic formations and terrain in a catchment area (river basin);
- surrounding vegetation and wildlife; precipitation and runoff from adjacent land; biological, physical and chemical processes in the water; and
- human activities in the region.

Human Impact on Natural Water Quality

Natural decomposition processes by micro-organisms are responsible for cleaning water from these naturally occurring substances. However, there are many toxic substances, most resulting from human activity, which are only partially or not at all decomposed by micro-organisms.

In Canada, the Great Lakes, the Fraser River, and the St. Lawrence River are, and continue to be, seriously contaminated by such toxic chemicals. (Environment Canada)

Source: Environment Canada http://www.ec.gc.ca/water/en/manage/qual/e_qual.htm

Human Impact on Natural Water Quality

Human induced toxic contamination of surface water and groundwater is caused by improper, unregulated disposal of toxic chemicals and residuals from numerous industries, including mining and agriculture.

Percolation of fertilizers and pesticide residuals are the main pollutants caused by agriculture. Incorrectly disposing of toxic cleaning products is the main cause of pollution at residences and industries. In addition, leaking and infiltration of pollutants at designated storage facilities cause groundwater contamination.

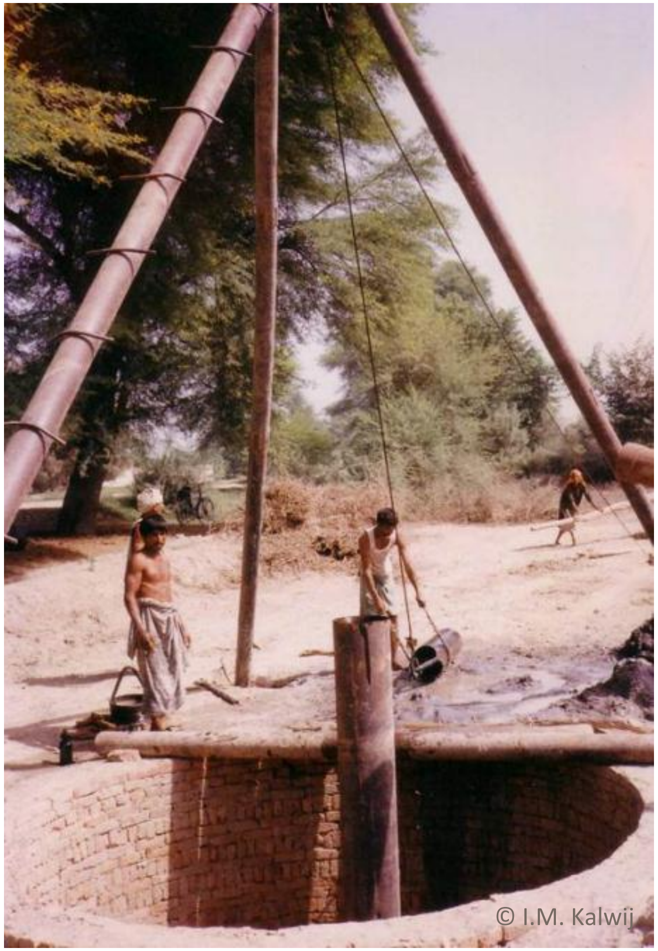
Among the offending compounds are nitrates, pesticides and herbicides used by the agricultural industry, solvents and chemicals used by industries and pharmaceuticals and endocrine disruptors. Still unknown is the cumulative effect of more than one of these compounds.

Groundwater Pollution and Prevention

The three keys to pollution prevention are proper construction, monitoring and public awareness. Proper construction/installation of septic systems, disposal facilities, wells and underground storage tanks can prevent malfunctioning and potential leakage.

Monitoring of potential sources of contamination (disposal sites, septic systems, disposal pits, underground storage tanks) for damage and leakage, and soil and water quality monitoring, are essential for early detection of leakage and contamination in an early stage.

Public awareness of the pollution risks of house and garden chemicals, the proper safe disposal of toxic chemicals, and use of non-toxic (cleaning) materials is needed.



Well construction, Pakistan

Columbia River, Washington State, U.S.A.

Understanding Water Sources and Supply

Water Resources

Although water covers nearly ¾ of the earth's surface, freshwater accounts for only 3% of this supply. We use this freshwater for drinking, for manufacturing products, to process raw materials, to transport people and goods, and to generate electricity. Almost every time we use water, we change it.

Water can change location and quality with use.

Source: USGS http://ga.water.usgs.gov/edu/watercycle.html

Water Supply

The earth's fixed amount of water is distributed widely and exists in various forms. It is available to us as both fresh and salt water. Sources of freshwater include glaciers, permanent snow cover; fresh surface water and groundwater; ground ice, permafrost; freshwater lakes; wetlands and marshes; rivers and streams; and atmospheric water vapor/precipitation. Saltwater sources are oceans and seas; salt lakes; and salt and brackish groundwater.

Most of the earth's freshwater is stored in icecaps and glaciers as seen in the diagram at right. About 30% of freshwater resources are underground in aquifers, and less than 1% of freshwater is surface water.

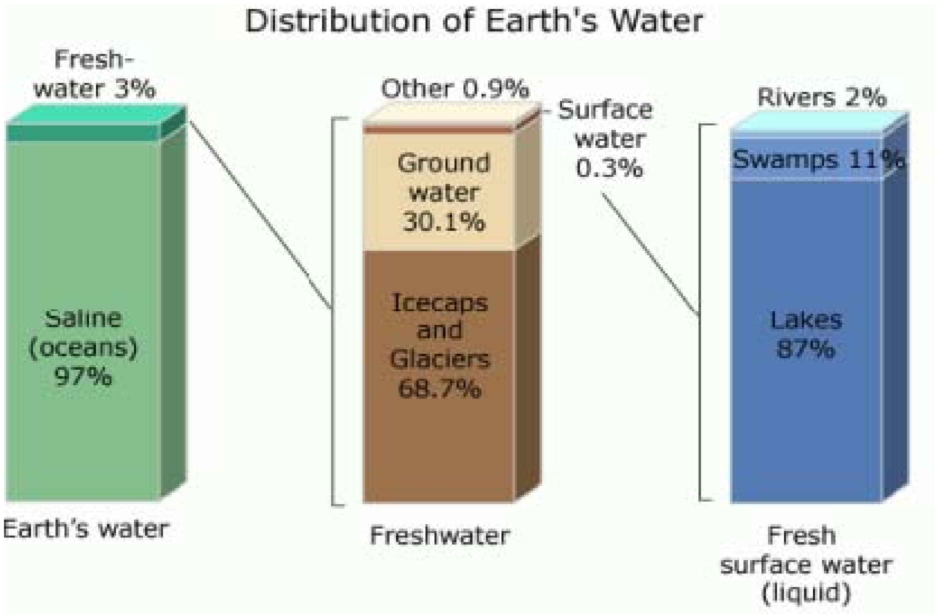


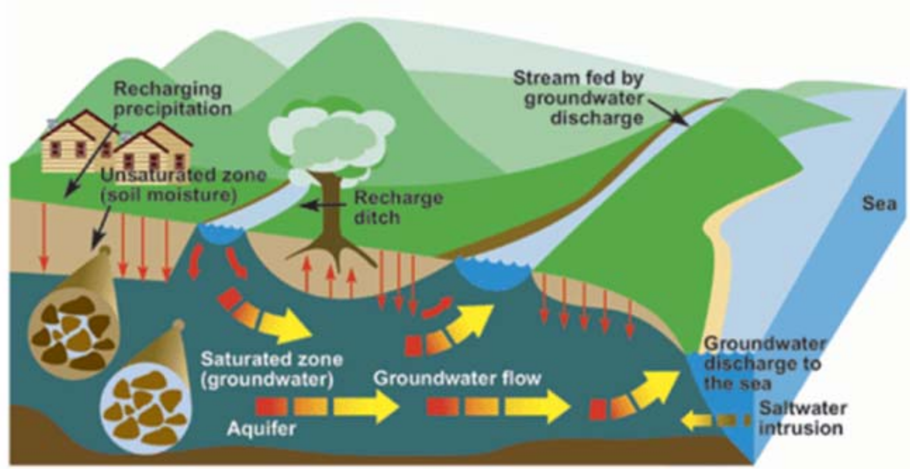
Image Source: USGS website http://ga.water.usgs.gov/edu/waterdistribution.html

Groundwater and Surface Water Supply

Although groundwater and surface water appear separate, they are interconnected through recharging and discharging processes.

Surface water infiltrates, moving into aquifers, recharging groundwater. Groundwater will discharge naturally to the surface via surface streams, rivers, lakes, and oceans. Groundwater is also discharged by human-induced activities such as pumping and mining.

Contaminating practices can affect the quality of surface and groundwater simultaneously and can travel great distances.



The water table is a line which demarcates saturated and unsaturated zones. A large continuous saturated zone is an aquifer, a water-bearing formation which can produce useful quantities of water.

Source: Environment Canada

Storm Event Recharge

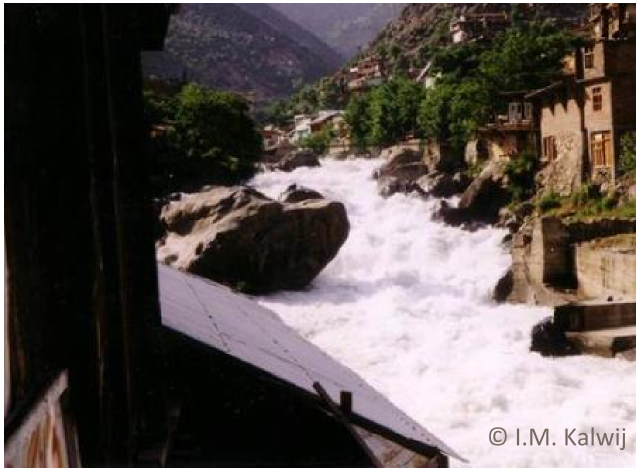
Recharging of water resources is essential to prevent depletion of water within a watershed. Storm events are part of the natural water balance. They bring high amounts of precipitation, recharging aquifers, rivers, lakes and reservoirs. Water is constantly on the move, and both groundwater and surface water levels will naturally vary depending on climate and season.

Surface Water Hydrology

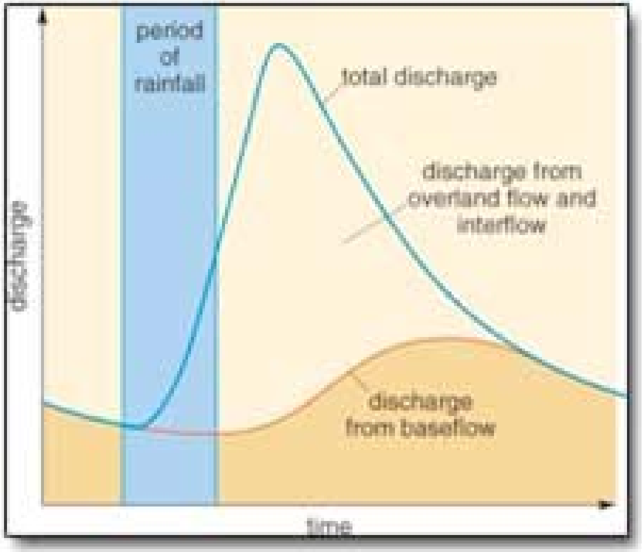
Surface water seasonal variability occurs in river flow and subsequently groundwater levels.

River flow is affected by the quantity of snowmelt and precipitation and runoff. The general trend is a peak flow in early spring, and lowest discharge at the end of the summer/early fall.

In a typical hydrograph for Canada (i.e. for a moderate climate), the peak flow occurs in late spring/early summer, mainly due to the melting of snow after the winter. In this type of climate, peak flow will vary year-to-year depending mainly on the amount of snow accumulated in the mountains during the preceding winter.



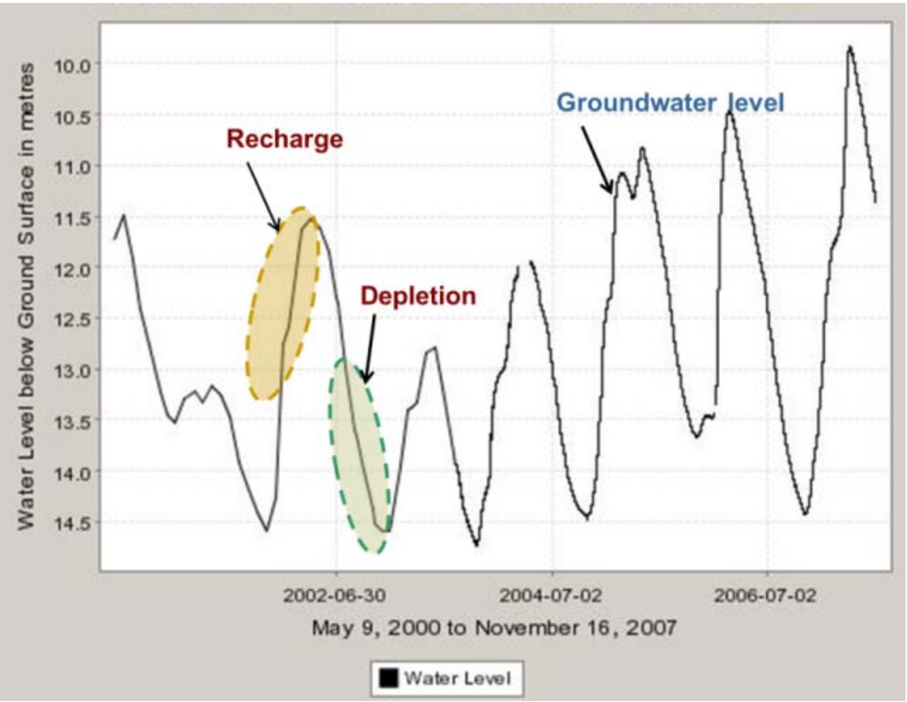
Swat River, Pakistan



Groundwater Hydrology

Groundwater levels rely on percolation and infiltration for recharge. Fluctuation in the groundwater level is a function of this discharge-recharge ratio. The illustration shows a typical trend in groundwater level fluctuation for a temperate climate. Groundwater recharge from late fall to early spring contributes to a rising trend in the groundwater level.

A declining trend in the groundwater table (i.e. increasing trend in groundwater level below the surface) generally starts from spring to fall. In this figure, the general yearly trend in groundwater level is variable.



The figure illustrates yearly and seasonal groundwater level fluctuations for Abbotsford in British Columbia, a moderate climate. (Source: B.C. Ministry of Environment)

Groundwater Extraction

Groundwater levels will also vary through groundwater extraction. Groundwater is generally accessed via:

- open or dug wells which retrieve water from below the water table
- shallow closed wells
- deep closed wells which are drilled into underground aquifers and are called artesian wells, or
- natural springs.

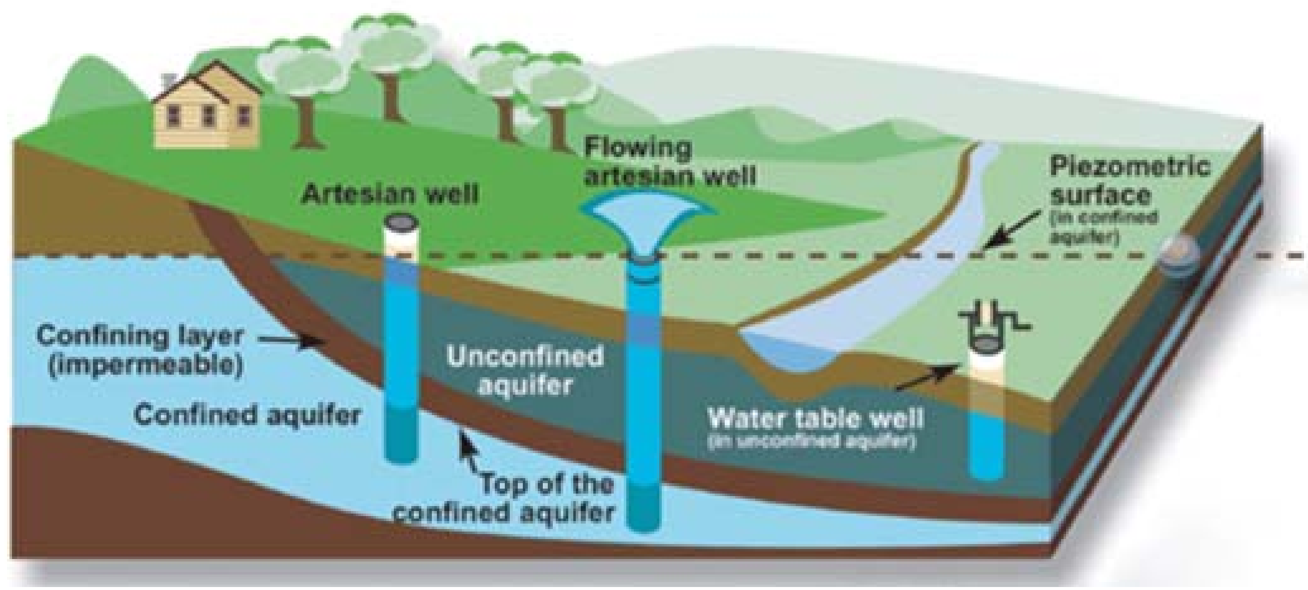


Image Source: Environment Canada

Groundwater Usage

Groundwater use has many advantages:

- Access to water when a public water system is not available
- Generally good quality water, especially from deeper aquifers (does not require treatment)
- Closed wells won't have any interaction between the water source and outside pollutants
- Generally guarantees a consistent / steady volume of water
- In many rural areas in developing countries, a public drinking water well also functions as a place for social gathering

"Tubewell" water use, Pakistan

Villagers fetching water from a deep dug well, Mauritania

Groundwater Quality

In many parts of the world, a properly constructed well can eliminate one of the biggest limitations to groundwater use: that is, potential contamination from outside sources, such as leakages from underground fuel tanks, sewer and septic systems; accidental releases and spills from industries; contaminated runoff or percolation; and abandoned contaminated wells.

Inspection of dug well, Mauritania

Surface Water Usage

In nations that have plenty of surface water, it is more often used than groundwater. In 2005, 80% of all freshwater in the U.S. came from surface water sources. This water is used for drinking water, irrigation and industrial uses. One advantage of surface water use is its easy accessibility by diverting water through channels or pipes from rivers, streams, lakes, and reservoirs.

Irrigated agriculture, Chile

Water Users and Standards

Water Users

If we know who uses water, we can better manage its use. For both groundwater and surface water, the main water users are:

- Hydroelectric generation
- Residential or domestic
- Commercial and institutional
- Flora and fauna
- Agricultural
- Industrial
- Recreational

The largest user of freshwater in the U.S. is the thermoelectric industry. This industry uses the water to cool electrical generating equipment. The second largest user of surface water is the agricultural sector, for irrigation of crops.

In many industrial and other uses water is discharged back to the system after its use, either treated or untreated. Therefore, actual water usage equals the water intake (i.e. water diverted) minus the water discharge.

Hydroelectric Plant, Aswan Dam, Egypt

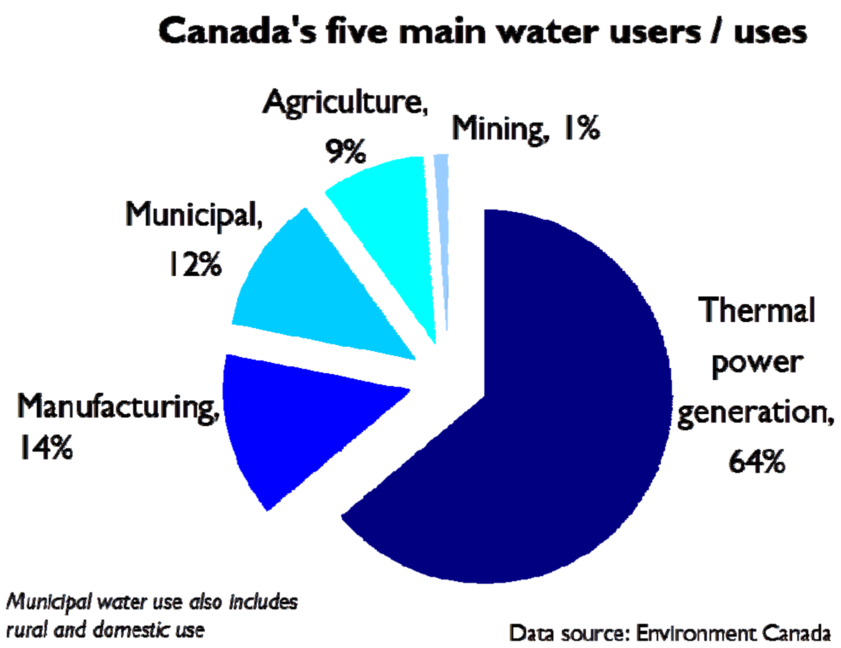
Rice fields, Laos

Water Users

For different countries or communities, the order and/or type of the largest water users can and most likely will be different. This depends on factors such as geography, climate, and economy.

In Canada, water use is divided as shown in the graph at right. This type of analysis helps decision makers and regulators to reach the main water users and jointly create conservation and management plans.

Data derived from a 1996 study from Environment Canada.



Water Use Standards

Global standards, national standards and municipal standards guide water management plans, and each different use requires a different water quality standard. Typically, water quality standards can be found for the following types of uses:

- Drinking water quality
- Agricultural water quality (Food and Agriculture Organization of the United Nations has developed water quality guidelines for agriculture)
- Industrial water quality
- River water quality
- Aquatic ecosystem water quality

Conversely, water quality can restrict water uses. For example, if river water does not meet the imposed water quality standards, it cannot be used for drinking water purposes, but it could perhaps still be used for irrigation purposes. Saline water cannot be used for irrigation purposes, but can still serve the aquatic ecosystem, serving as a resource for tourism and recreation.

National: Canadian Drinking Water Standards

In 1987, the Canadian Council of Ministers for the Environment (CCME) published the *Canadian Water Quality Guidelines*. This document provided national environmental quality guidelines for major water uses in Canada. Since its release, it has influenced the water quality measures in more than 45 countries. In April 1996, the CCME produced a second document, *Canadian Environmental Quality Guidelines*. This new document integrates national environmental quality guidelines for all environmental media including:

- water and sediment quality guidelines for the protection of aquatic life
- water quality guidelines for the protection of agricultural water uses
- tissue residue guidelines for the protection of wildlife consumers of aquatic biota, and
- soil quality guidelines for the protection of environmental and human health.

Canadian Environmental Quality Guidelines

These Canadian Standards are used to define the norms of acceptable quality and are intended to protect, sustain, and enhance the quality of the Canadian environment and its many beneficial uses.

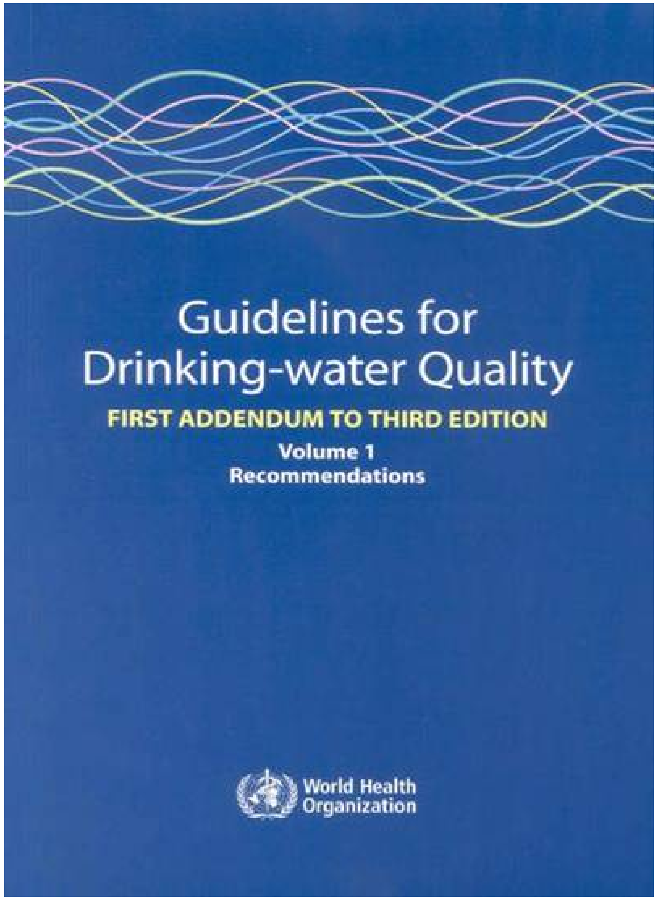
WHO: Drinking Water Quality Management

At a global level, the World Health Organization publishes a guideline for drinking water quality, saying:

"Drinking-water quality is an issue of concern for human health in developing and developed countries world-wide. The risks arise from infectious agents, toxic chemicals and radiological hazards. Experience highlights the value of **preventive management** approaches spanning from water resource to consumer."

WHO produces international norms, such as these on water quality and human health, in the form of guidelines that are used as the basis for regulation and standard setting, in developing and developed countries world-wide. Using this document, and supporting literature, countries can access a large pool of expertise, constantly under review, in informing their local regulations.

Source: http://www.who.int/water_sanitation_health/dwq/guidelines/en/index.html



Chilean water management: Junto de Vigilancia

Water Source Management

Water Governance and Management

Managing water sources and resources is not a simple task and has many challenges. Among them:

- Fragmentation of the regulations and powers: According to an IBM Innovation Outlook report, there are nearly 53,000 water agencies in the U.S. with no coordination between them.
- Management and communication of the information: Rarely is there sharing of collected data.
- Management of a dynamic and evolving resource.
- Managing safe, equal and reliable water supply.
- Water supply may come from long distances, multiple watersheds and multiple sources from within each of those watersheds, involving dealing with bureaucracy of different jurisdictions.

Multi Watershed Management

Later on in this course we will discuss watershed management plans. Although the watershed is an ideal management area since it has a natural definition of water flow, communities can use and manage multiple watersheds (Toronto has six) and multiple sources within each one (rivers and wells and lakes, etc.). In some cases like in Mexico, Las Vegas and Los Angeles, when pipes that access water run well beyond the urban area, they can also cross many watersheds to get to a water source; their use starts to affect watersheds they are not naturally part of.

Division of Responsibility

In Canada, the responsibility for water management is shared by the federal, provincial, and local governments, and in some instances, by the territories and by Aboriginal governments under self-government agreements. The higher authorities are primarily responsible for setting overall standards which then guide the other authorities in their more detailed planning based on local conditions.

At the federal level, Environment Canada administers acts and legislation pertaining to water management. For the most part, waters that lie solely within a province's boundaries fall within the constitutional authority of that province. Provincial legislative powers include, but are not restricted to, areas of flow regulation, authorization of water use development, water supply, pollution control, and thermal and hydroelectric power development. (Source: Environment Canada)

Local or municipal government manages the infrastructure related to: water treatment; water delivery; planning, financing; and controlling operations related to it. Local government follows the provincial or territorial water governance legislation.

The following case study for Oxford County illustrates one such local management plan.

Local Water Management Plan: Oxford County, Ontario

Oxford County is located in the heart of southwestern Ontario, and is 2050 square kilometers in area. Characterized by rolling hills and productive farmland, its primary activity is agriculture. Other activities that have the potential to influence water quality are aggregate extraction—with 40 percent of the province's limestone quarried here, manufacturing (mainly automotive), construction, small businesses, and highway maintenance.

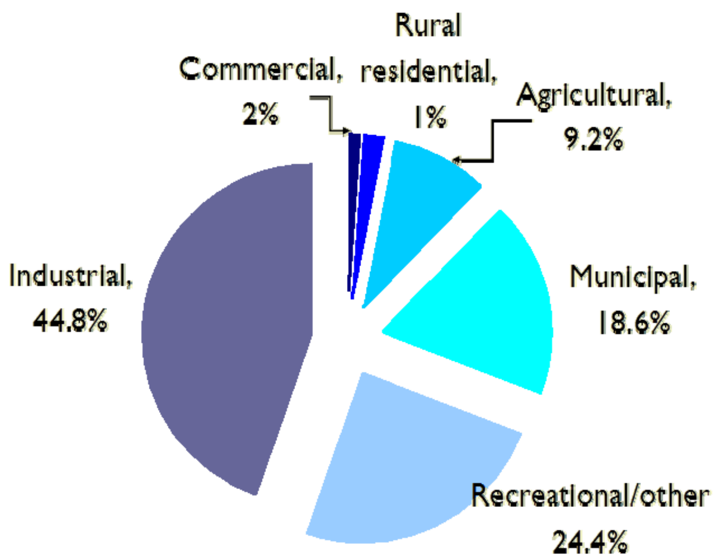
Oxford county uses solely groundwater and lies within the watersheds of four Conservation Authorities. All of the river systems drain into Lake Erie, either directly, or, in the case of the Thames River, via Lake St. Clair.

Source: http://www.ec.gc.ca/water/en/manage/qual/case/e_oxford.htm#5.2.6. This website discusses background information and details on Phase I and Phase II. Phase I was completed in 1999 and Phase II was completed in 2001.

Oxford County Groundwater Protection Plan

The estimated overall annual water use in the county is broken down as shown at right, where 1% equals approximately 0.8 million cubic metres (m3).

About 100,000 people obtain their drinking water in this area: 70,000 residents are on municipal water systems, and 30,000 have private wells. There are 83 municipal wells. Water services are funded through water rates. The average household income in Oxford County is $59,200.



This graph shows the estimated overall annual water use in the county.

Sources of potential water contaminants include agrochemicals and manure (especially from large livestock operations). Industrial leaks and spills, road salt, road spills, and previous and existing industrial land uses also pose a threat to source water quality.

Oxford County Groundwater Protection Plan

The Water Protection Committee adopted the mandate to identify existing and potential risks to the quality and quantity of the Oxford County water supply and to make recommendations to ensure the water supply.

Under this mandate, the following steps were set as priorities for groundwater protection:

- Define, identify, and map the areas requiring protection.
- Develop objectives and strategies for protecting these areas.
- Identify potential contaminants and land use practices that pose a high risk of contamination.
- Define permitted uses, restricted uses, and prohibited uses for each designated area requiring protection.
- Develop lot creation (growth management) policies for each designated area requiring protection.

Oxford County Groundwater Protection Plan

To support these steps, the County undertook two phases of a county-wide groundwater protection study. The first phase, completed in April 1999, assigned a relative risk rating to each of the County's 83 municipal supply wells. This analysis determined the level of risk of water quality degradation due to land uses within 500 metres of a well head.

Phase II was built on one of the protection strategies proposed in Phase I, which called for:

- definition of the groundwater resource, including development of well head protection areas and mapping of aquifers and assessment of their vulnerability
- community consultation and awareness
- identification of potential contaminant sources
- water quality monitoring and establishment of a baseline
- data management, and
- emergency preparedness and contingency plan.

Source: http://www.ec.gc.ca/water/en/manage/qual/case/e_oxford.htm#5.2.6. This website discusses background information and details on Phase I and Phase II. Phase I was completed in 1999 and Phase II was completed in 2001.

Oxford County Groundwater Protection Plan

The result is Oxford County's Groundwater Protection Strategy, designed to limit the risk of water supply contamination from historical, existing, or future land uses; to manage water quantities to ensure that the quantity used does not exceed recharge capacity; and to promote water conservation. It includes the following recommendations:

Land use restrictions:

Sensitive areas around municipal water supply wells and vulnerable aquifer areas were protected from potential water contamination by restricting land uses that pose a contaminant risk.

Water quantity protection policies:

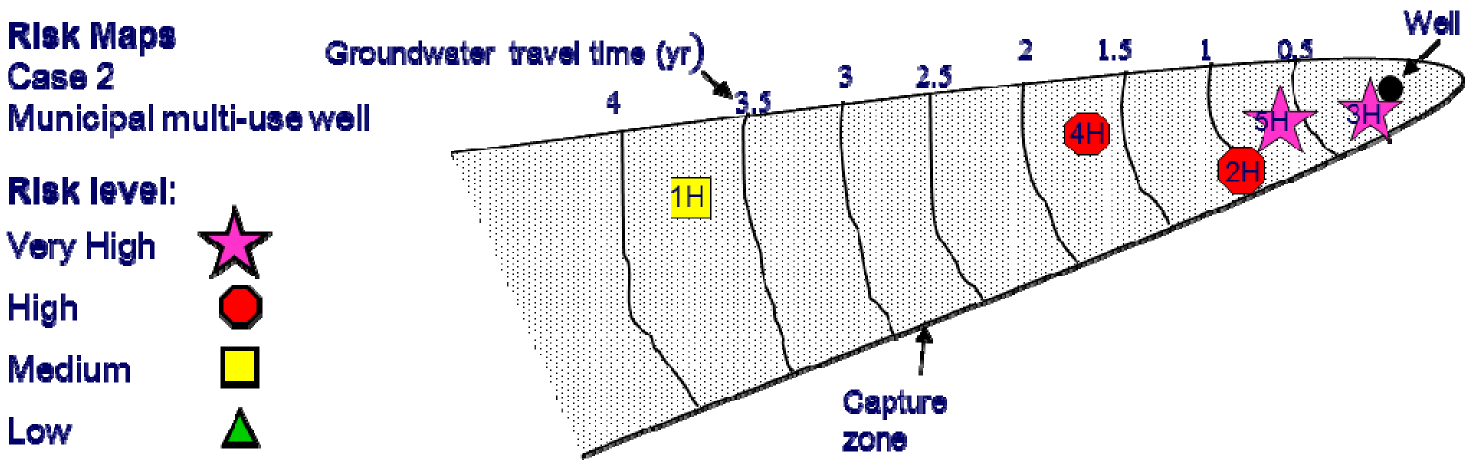
Water budgets and conservation plans were prepared as part of watershed planning initiatives.

Source: http://www.ec.gc.ca/water/en/manage/qual/case/e_oxford.htm#5.2.6. This website discusses background information and details on Phase I and Phase II. Phase I was completed in 1999 and Phase II was completed in 2001.

Oxford County Groundwater Protection Plan

Well head protection policies:

Well head protection focuses on areas adjacent to the public water supply wells, with generally more stringent controls closer to the well. When planning to protect aquifers and water supplies, a risk-based approach is recommended. It consists of a) understanding the capture zone of a well or water supply and b) estimating the risk of impact of potential contamination events based on their likelihood of exposure (low to very high) and the consequences of the hazard (low to very high).



Typical well head protection diagram

Source: http://www.ec.gc.ca/water/en/manage/qual/case/e_oxford.htm#5.2.6 . This website discusses background information and details on Phase I and Phase II. Phase I was completed in 1999 and Phase II was completed in 2001.

Oxford County Groundwater Protection Plan

Well head protection policies:

Wells were classified according to their importance to the municipal supply and the sensitivity of the well to surface activities within the 25-year capture area. Lands within the Well Head Protection Areas are now subject to certain prohibitions or additional requirements and restrictions, according to the relative risk.

Aquifer protection policies:

Aquifer protection is used to protect an entire aquifer, particularly those that are unconfined or shallow and overlain by permeable materials (Highly Vulnerable Aquifer).

Source: http://www.ec.gc.ca/water/en/manage/qual/case/e_oxford.htm#5.2.6 . This website discusses background information and details on Phase I and Phase II. Phase I was completed in 1999 and Phase II was completed in 2001.

Oxford County Groundwater Protection Plan

In a county whose water resources originate within four Conservation Authorities, a successful plan depended, to a great deal, on cooperation between these authorities. Other factors that contributed to the success of Oxford County's groundwater protection plan were:

- a high level of commitment on the part of county and municipal councils
- good support from the Provincial Government,
- a commitment to embedding groundwater protection in policy that balances this concern with development needs
- good technical support from consultants and in-house Geographical Information System staff
- a highly inclusive process with good community response
- data sharing (e.g., through the on-line Groundwater Navigator and Map Your Farm), and
- development of plans to target specific issues, such as the nitrate reduction strategy, the farm-level nutrient management strategy (supported by a high level of commitment on the part of producers), and the bio-solids management plan.

Quoted from: http://www.ec.gc.ca/water/en/manage/qual/case/e_oxford.htm#5.2.6 . This website discusses background information and details on Phase I and Phase II. Phase I was completed in 1999 and Phase II was completed in 2001.

Watershed Planning and Management

Watershed and Sub-watershed

The watershed is an area that drains all precipitation received as a runoff or base flow (groundwater sources) into a river and its tributaries, and may be separated from an adjacent watershed by a land ridge or divide. The watershed drainage area provides the natural boundary for managing human uses of the river and connected wetlands, woodlands, valley lands and floodplains. A sub-watershed is the land that drains to a tributary of a river.

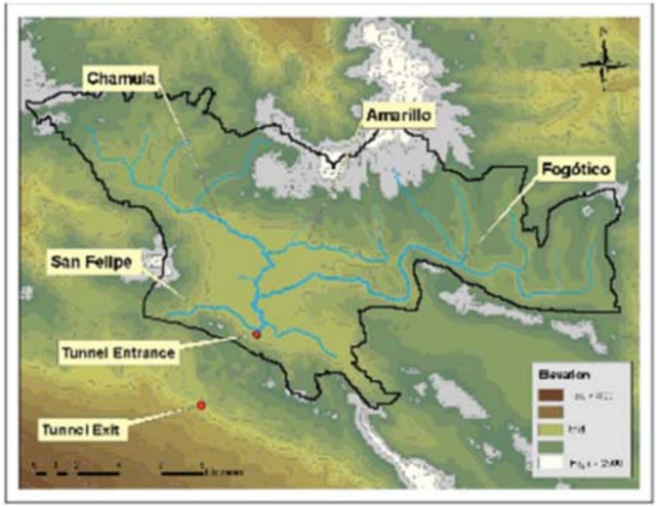
“Basin” is a term used interchangeably with “watershed.” It is used to describe lands which eventually descend to a river or a stream. From the highest point of land down to the stream bottom, all the surface land is considered part of a stream or river’s drainage. A sub-basin forms part of the basin.

Watershed Management

Effective water management combines large-scale environmental planning at the watershed level with smaller scale sub-watershed and stormwater management.

Watershed planning provides a framework to protect, maintain and restore a healthy natural watershed system, balancing environmental, social and economic needs. It requires ongoing collection and analysis of data and is complicated by wide-ranging interests, uses of water and the fact that watershed boundaries often cross jurisdictions.

The **watershed management plan** targets an entire drainage basin area, includes physical, chemical, and biological characteristics of the basin, defines existing and potential water uses and defines goals, objectives, methods, and technologies.



Watershed

Sub-watershed Management

The **sub-watershed plan** addresses stormwater management requirements on a sub-basin level. Information prescribed in the Watershed Management Plan is used to develop necessary sub-watershed stormwater controls such as infiltration, trenches, extended swales (low-lying land) or stormwater ponds. This planning level is at the same scale as the neighborhood plans, which provide more specific planning details such as land use and transportation corridors. Developing these two plans in an integrated manner will ensure the optimization of all resources within that sub-basin.

Source: http://www.ec.gc.ca/water/en/manage/floodgen/e_mngt.htm#stormwater

Multi Watershed Management

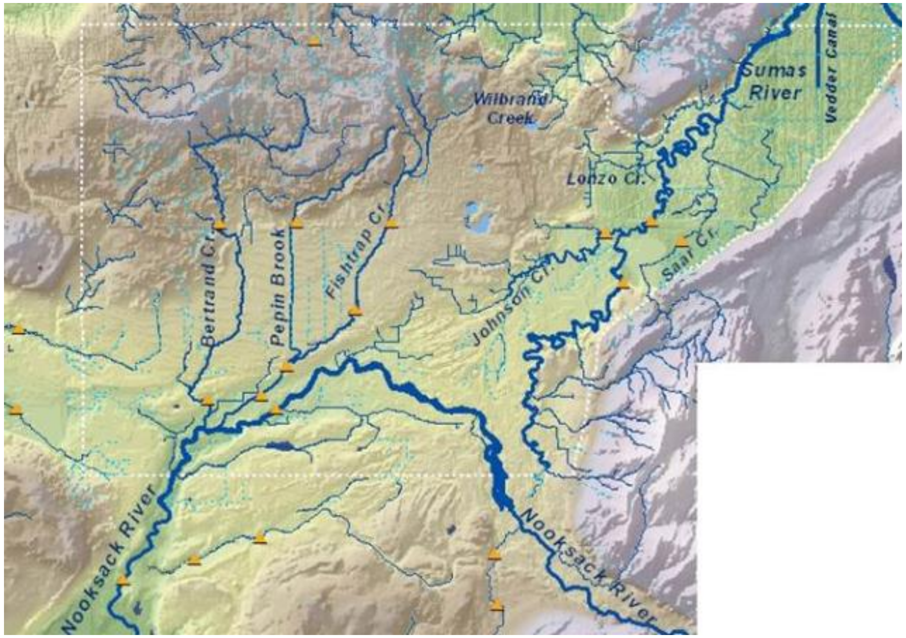
Although the watershed is an ideal management area since is has a natural definition of water flow, communities can use and manage multiple watersheds and multiple sources within each one (rivers and wells and lakes, etc.). In some cases like Las Vegas and Los Angeles, pipes providing water cross many watersheds to get to a water source; their use starts to affect watersheds they are not naturally part of.

Watershed Planning Tools: Maps

Data analysis for watershed planning incudes mapping. We'll take a look at three maps, each of which presents important data to watershed planning.

Surface water mapping:

Mapping the network of surface water allows us to see where water is present and how it moves at the surface, and how it is controlled by topography. Mapping the surface water network also provides information to allow us to define boundaries of watersheds.

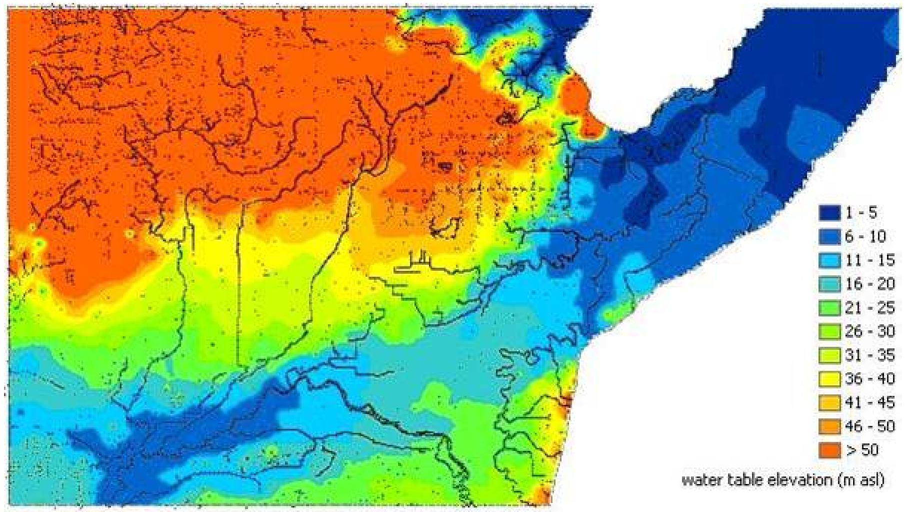


Watershed Planning Tools: Maps

Groundwater elevation mapping:

This map shows the elevation of groundwater in a regional aquifer. Groundwater flow direction can be inferred from this map, from the ridge of higher elevation in orange to the areas in blue where the groundwater elevations are the lowest.

Mapping aquifers is as important as mapping surface water in defining a watershed. By overlaying this map with a topographic map, it can clearly reveal where the rivers are being supplied by groundwater or, vice-versa, where the streams recharge the aquifers.



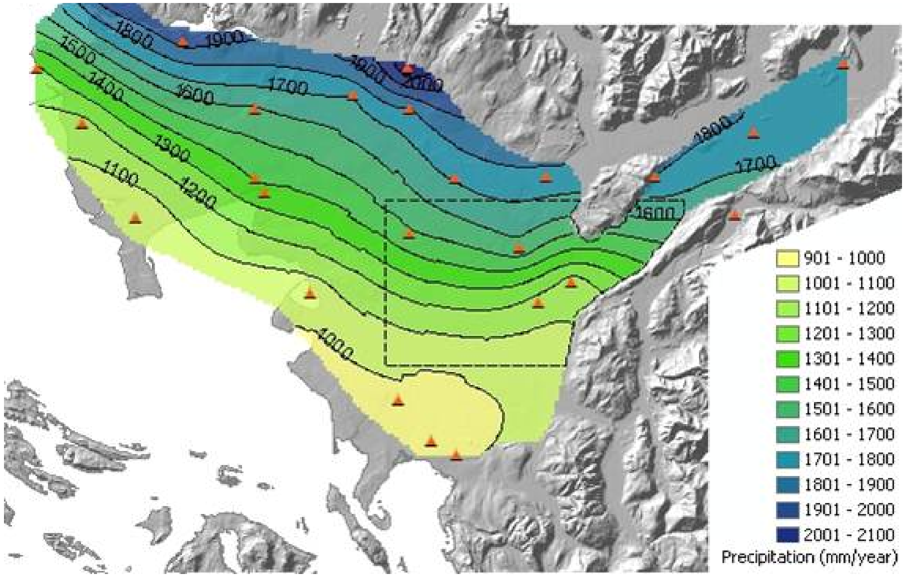
Watershed Planning Tools: Maps

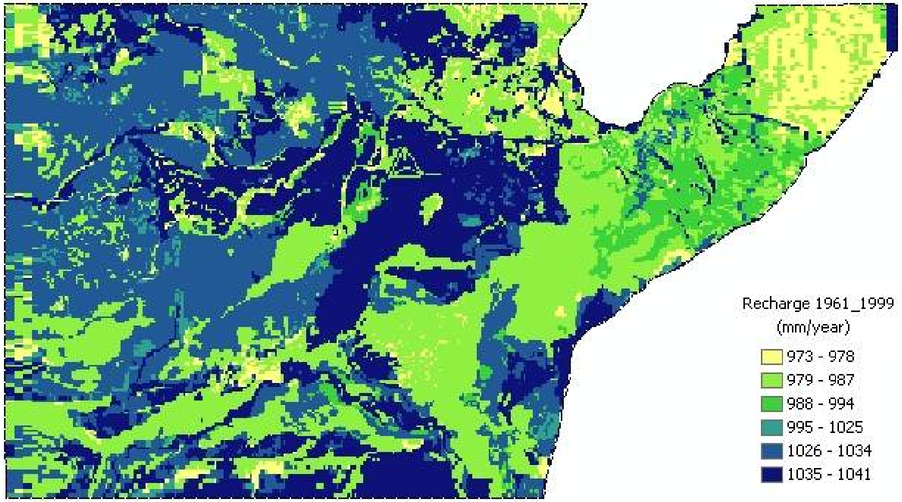
Precipitation and recharge mapping:

The base map shows the variation in annual precipitation ranges from near 1 m in yellow to 2 m in blue. Precipitation data was integrated with other information such as ground cover, evapotranspiration, and the soil vertical conductivity to estimate the annual recharge.

The annual recharge, lower map, is quite high for the study area, ranging between 970 mm (in yellow) and 1040 mm in blue.

Precipitation and recharge data are used to estimate the water balance and how much water reaches streams or aquifers over specific areas or regions.





Watershed Management: Groundwater Monitoring

Groundwater monitoring is an integral part of watershed management. This is done by monitoring the water in a series of monitoring wells. These wells are generally smaller in diameter than production wells and are only used for collecting data, for instance monitoring hydraulic head in the aquifer. They are used for evaluating:

- groundwater quality/early detection of contamination
- long-term water level trends
- aquifer recharge
- groundwater/surface water interaction
- impacts of climate fluctuations
- water conservation planning, and
- water conflicts and interferences.

Stormwater Management

Stormwater Management

Stormwater/runoff management focuses at a smaller scale on planning and consideration of minor and major drainage systems, the capture and direction of rainwater, and snowmelt and increase of recharge. It may also include runoff from human activities such as lawn watering, washing cars, and draining pools.

Traditionally, stormwater management dealt mainly with conveying the excess runoff through a drainage system to the nearest waterway. Today, stormwater management is evolving into comprehensive planning with multi-agency involvement. It integrates stormwater infrastructure planning with relevant municipal planning processes—such as Official Community Plans, land use plans, Neighborhood Concept Plans, recreation and parks plans, and even strategic transportation plans—to address impacts of rainwater on community values.

Such stormwater management planning is referred to as integrated stormwater management (ISWM) planning. The integrated management plan provides strategies to manage human activities within a watershed.

Principles of Integrated Stormwater Management

The Province of British Columbia has published a guidebook called *Stormwater Planning: A Guidebook for British Columbia*. This book presents a widely accepted framework for effective integrated stormwater management and contains some guiding principles for integrated stormwater management:

- Agree that stormwater is a resource:
  - Stormwater is no longer seen as just a drainage or flood management issue, but also a resource for:
    - Fish and other aquatic species
    - Groundwater recharge
    - Water supply
    - Aesthetic and recreational uses
- Design for the complete spectrum of rainfall events:
  - Rainfall capture for small storms
  - Runoff control for large storms
  - Flood risk management for extreme storms

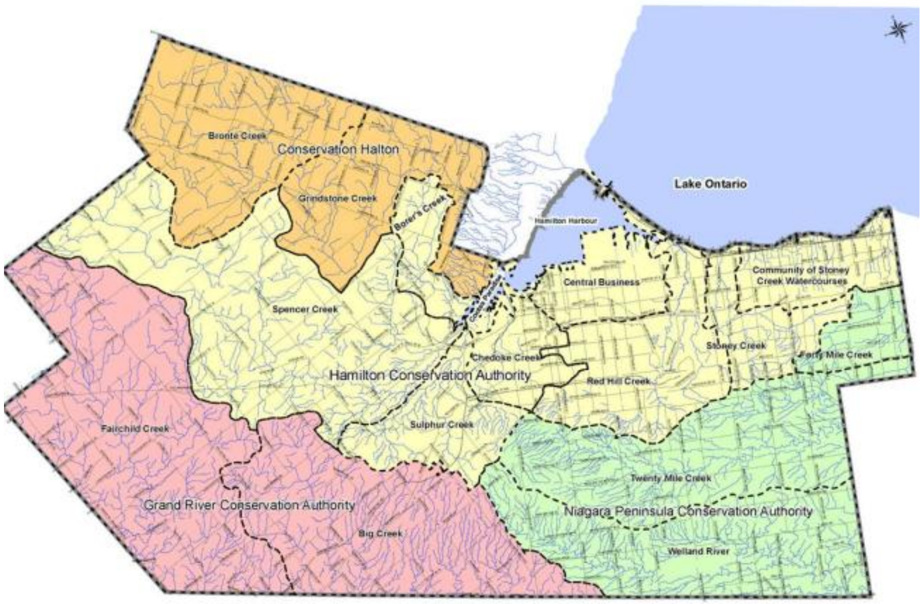
Quoted from: Ministry of Water, Land and Air, British Columbia (2002), *Stormwater Planning: A Guidebook for British Columbia.* Authors are: Kim A. Stephens (CH2M Hill Canada Ltd.), Patrick Graham (CH2M Hill Canada Ltd., and David Reid (Lanarc Consultants). Available at: http://env.gov.bc.ca/epd/mun-waste/waste-liquid/stormwater/

Principles of Integrated Stormwater Management

- Act on a priority basis in at-risk drainage catchments:
    - Priority action should be focused on at-risk drainage basins where there is both high pressure for land use change and a driver for action (a high-value ecological resource that is threatened, or an unacceptable drainage problem).
- Plan at regional, watershed, neighborhood and site scale:
    - Long-term planning at:
        - Regional and watershed levels: establish stormwater management objectives and priorities
        - Neighborhood level: integrate stormwater management objectives into community and neighborhood planning processes
        - Site level: implement site design practices that reduce the volume and rate of surface runoff and improve water quality
- Test solutions and reduce costs by adaptive management:
    - Performance targets and stormwater management practices should be optimized over time based on:
        - Monitoring the performance of demonstration projects
        - Strategic data collection and modeling

ISWM Plan: City of Hamilton, Ontario

In the next few slides, we look at how the city of Hamilton created a comprehensive stormwater (quantity/quality) management plan and determined best practice scenarios for their 15 watersheds. This Stormwater Master Plan is being integrated with the Transportation Master Plan and Water and Wastewater Master Plan, all of which will be the supporting documentation to the City's new Official Plan.



The figure is copied from the Executive Summary document of Stormwater Master Plan - Class EA Final Report, available at: http://www.hamilton.ca/CityDepartments/PublicWorks/Environment_Sustainable_Infrastructure/StrategicPlanning/StrategicEnvironmentalPlanningProjects/GRIDS/Stormwater+Management+Master+Plan.htm

ISWM Plan: City of Hamilton, Ontario

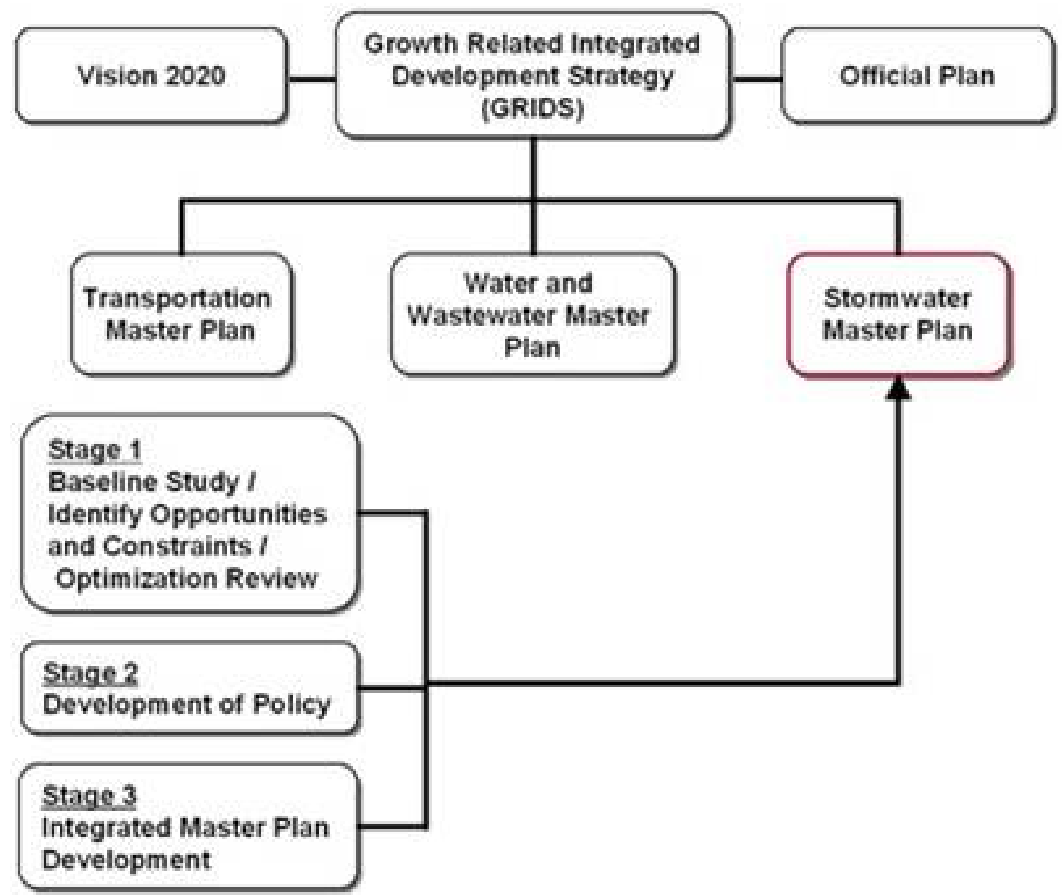
The Stormwater Master Plan process was undertaken as part of the City's long-term growth management strategic planning initiative called GRIDS (Growth Related Integrated Development Strategy). The principal objectives of the stormwater master plan are to:

- study and review existing storm sewer infrastructure and operating strategies to identify system upgrades
- establish appropriate stormwater management practices
- develop a stormwater quality management program for the City
- identify system requirements
- identify the preferred alternatives
- develop a recommended implementation program, and
- develop a monitoring plan.

Source: City of Hamilton's website: http://www.hamilton.ca/CityDepartments/PublicWorks/Environment_Sustainable_Infrastructure/StrategicPlanning/StrategicEnvironmentalPlanningProjects/GRIDS/Stormwater+Management+Master+Plan.htm

ISWM Plan: City of Hamilton, Ontario

The figure illustrates that the plan consisted of three stages. Further, the figure illustrates that the Stormwater Master Plan is being integrated with the Transportation Master Plan and Water and Wastewater Master Plan, all of which will be the supporting documentation to the City's new Official Plan.



Quoted from: City of Hamilton's website: http://www.hamilton.ca/CityDepartments/PublicWorks/Environment_Sustainable_Infrastructure/StrategicPlanning/StrategicEnvironmentalPlanningProjects/GRIDS/Stormwater+Management+Master+Plan.htm (flow chart copied from this website)

Hamilton: Alternative Strategies

A total of five alternative management strategies were assessed. They were:

Do Nothing Management Strategy

- This strategy, as the name suggests, would mean that no stormwater works are carried out in any of the existing urban or rural lands or within any proposed development or redevelopment areas. An assessment as to the impacts associated with the implementation of this strategy is required as part of undertaking a Municipal Class Environmental Assessment Study.

Business as Usual Management Strategy

- Stormwater management practices would only be implemented within proposed development or redevelopment areas. Typically, the proposed works would consist of stormwater management ponds, which are constructed to address issues related to flooding, erosion, and water quality. Conventional storm sewer systems would be installed and source control measures on private property would be limited to the majority of roof downspouts being discharged to the surface.

Comprehensive Urbanization Approach Management Strategy

- Consistent with the Business as Usual Management Strategy, stormwater management practices would be implemented within proposed development or redevelopment areas. In addition, alternative approaches on private property (source controls) and within the municipal right-of-way (conveyance controls) would be used in conjunction with a variety of end-of-pipe measures in order to comprehensively address impacts associated with development. Alternative development forms, which emphasize conservation and use of existing natural site features together with distributed, small-scale stormwater controls to more closely mimic natural hydrologic patterns, would also be considered.

Hamilton: Alternative Strategies

Business as Usual with Urban Retrofits Management Strategy

- This strategy is consistent with the Business as Usual Strategy in that conventional stormwater management practices would be implemented within proposed development or redevelopment areas. The Business as Usual Strategy would be augmented, however, by implementing a variety of source, conveyance, and end-of-pipe measures within existing urban areas.

Business as Usual with Rural Retrofits Management Strategy

- This strategy is consistent with the Business as Usual Strategy in that conventional stormwater management practices would be implemented within proposed development or redevelopment areas. The Business as Usual Strategy would be augmented, however, by implementing a variety of source, conveyance, and end-of-pipe measures within existing rural areas.

Quoted from the Executive Summary document of Stormwater Master Plan - Class EA Final Report (City-Wide) (ABL 2007). Available at: http://www.hamilton.ca/CityDepartments/PublicWorks/Environment_Sustainable_Infrastructure/StrategicPlanning/StrategicEnvironmentalPlanningProjects/GRIDS/Stormwater+Management+Master+Plan.htm

Reference: Aquafor Beech Limited (ABL), 2007, City of Hamilton Stormwater Master Plan – Class environmental assessment report, prepared for city of Hamilton, Public Works Department.77 James Street N., Suite 320, Hamilton, Ontario.

Hamilton: Alternative Strategies

Applicable Land Uses and Flow Changes / Removal Rates	ALTERNATIVE STORMWATER MANAGEMENT STRATEGIES				
	Do Nothing Management Strategy	Business as Usual Management Strategy	Comprehensive Urbanization Approach Management Strategy	Business as Usual with Urban Retrofits Management Strategy	Business as Usual with Rural Retrofits Management Strategy
Applicable Land Uses where Strategies would be Applied	No Areas	Proposed Development Areas and Redevelopment Areas	Proposed Development Areas and Redevelopment Areas	Existing Urban Areas plus Development / Redevelopment Areas	Existing Rural Areas plus Development / Redevelopment Areas
Representative Flow Changes	Substantial Increase in Runoff	Moderate Increase in Runoff with Decreased Baseflow	Moderate Reduction in Runoff in Urbanizing Areas	Moderate Reduction in Runoff in Urban Areas	Current Condition
Representative Pollutant Removal Rates	Current Condition	Moderate Increase in Pollutant Removal Rates	Substantial Increase in Pollutant Removal Rates	Substantial Increase in Pollutant Removal Rates	Moderate Increase in Pollutant Removal Rates

[1] Flow changes and pollutant removal rates are based on changes as compared to existing conditions.

Hamilton: Strategy Selection

Selection of an alternative watershed management strategy for each of the 15 watersheds was partially based on specific criteria and potential impact of the strategy (see chart below). Certain measures for one watershed would not necessarily apply to the others. The intent of the evaluation was to provide a framework for future development (including intensification) and implementation of a new approach for the municipality and agencies to undertake works in a collaborative manner in existing urban and rural areas.

Criteria		Impact Indicator
Natural Environment	Potential Aquatic Habitat Benefit	• Potential to improve aquatic habitats or systems • Scoring based on fish type and size of stream
	Potential Water Quality Benefit	• Scoring based on existing conditions in stream and ability to provide improvement
	Potential Erosion Control Benefit	• Scoring based on existing condition of stream and ability to reduce erosion potential
	Potential Terrestrial Habitat Benefit	• Potential to improve terrestrial habitats or systems within valleylands • Scoring based on significance of existing vegetation features
Social Environment	Aesthetics/Recreation	• Potential for proposed works to be an asset to community • Scoring based on ability of proposed measure to be integrated into community
	Compatibility with Adjacent Land Uses	• Potential impacts associated with construction or maintenance of proposed works
	Public Health and Society	• Scoring based on potential of proposed works to reduce/increase public health and safety
Financial	Construction costs	• The cost of constructing the proposed works
	Operation and Maintenance Costs	• Operation and Maintenance costs associated with the proposed works

Hamilton: Process Outcome

Ultimately, the city selected a best management scenario for each watershed based on existing and proposed land uses, existing environmental conditions and issues within the watershed, remedial action plan requirements, and the ability of each alternative strategy to meet the study objectives. Their proposed measures for stormwater management included:

Source control measures:

Source control measures are physical measures that are located at the beginning of a drainage system, generally on private property, including residential, commercial, industrial and institutional properties, i.e. Rain Barrel, Roof Garden, etc. @ cost $35,000,000 for the city.

Conveyance control measures:

Conveyance control measures are physical measures that are located within the road right-of-way where flows are concentrated and are being conveyed along the right-of-way, i.e. swales, ditches, culverts, etc. @ cost of $32,000,000.

Hamilton: Process Outcome

End-of-pipe measures:

End-of-pipe measures include best management practices that are installed at the end of the storm sewer system prior to discharge to the stream or river, i.e. stormwater ponds, wetlands, infiltration basins, etc. @ $19,140,000.

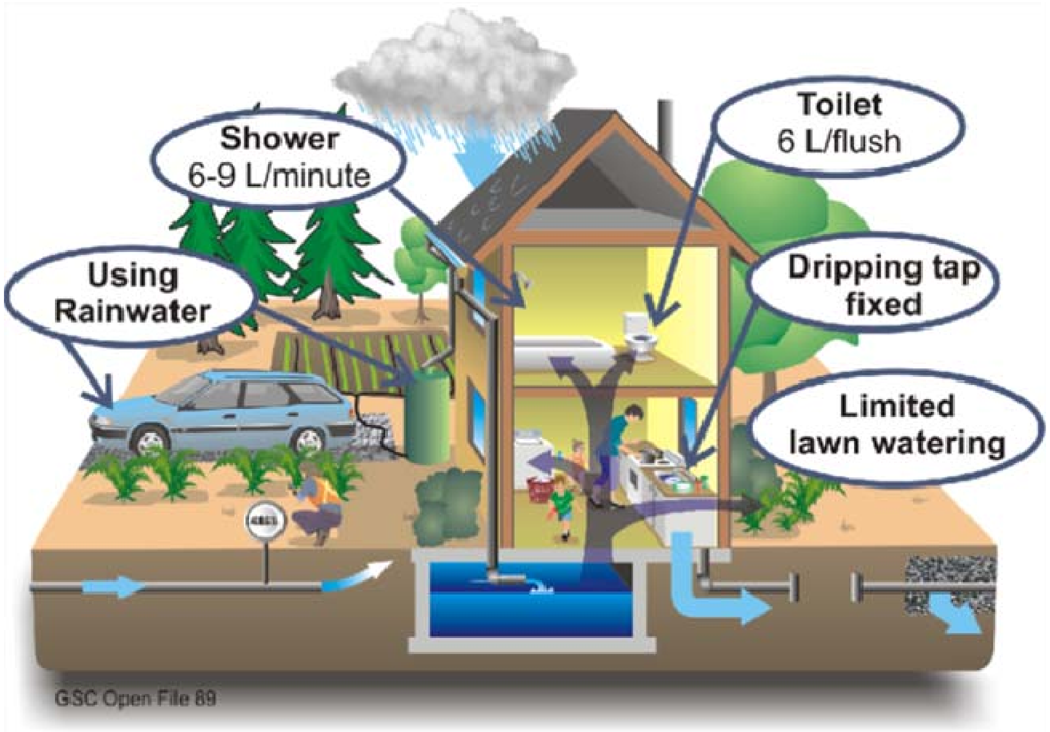
Stream restoration measures:

Stream restoration measures are undertaken in order to restore degraded streams as a result of hydrologic, water quality or erosive impacts associated with urbanization. The total cost to restore the streams is $21,557,000.

Hamilton: Implementation Plan

The next step was to design an implementation plan which included: implementation considerations for each type of measure that was recommended, policy review and implications, administration, direction for future studies, funding considerations and alternatives and staffing requirements.

More specifically it includes changing the mindset of consultants, city staff, developers, and agencies with respect to the current approach and focus for undertaking stormwater management in the City of Hamilton; consideration of the impact of existing urban and rural areas on the environmental resources and the initiation of pilot projects (e.g. green roofs, roof downspout disconnection, filtration systems, alternative municipal infrastructure systems, rural best management practice programs); and revisiting/modifying existing municipal and agency policies and standards to accommodate change.

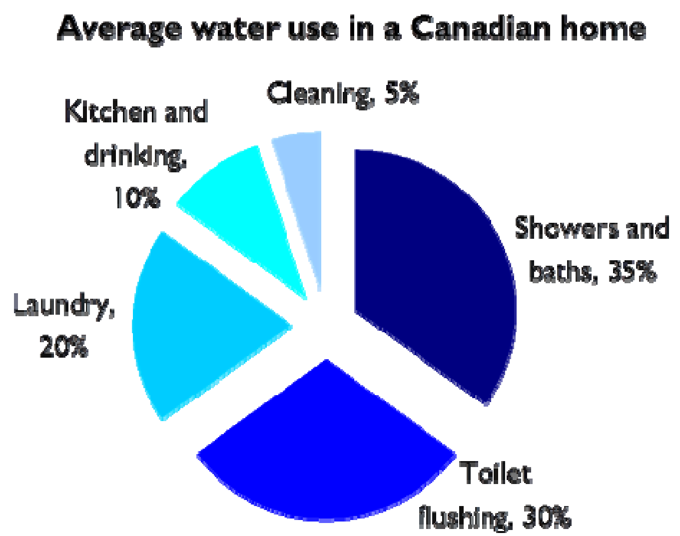


Water Quantity (Usage) and Quality Management

Water Usage

In 2001, Canadians, on average, used 335 liters of water per person per day. Compare that to 150 l/day in the EU, and 105 l/day in Eastern Europe. Clearly Europeans manage their water usage differently, and with conservation in mind.

As we saw earlier, the amount of water on our planet does not change, but the population is constantly increasing. This chapter will take a look at some of the ways water conservation can occur at a number of levels.



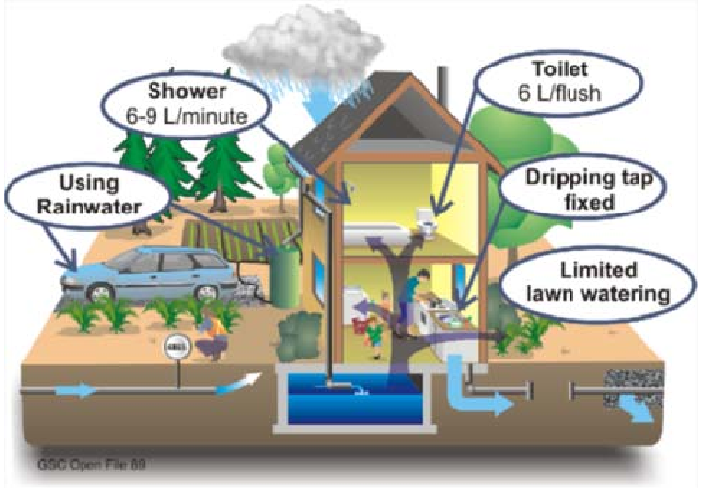
Source: Environment Canada

Water Quantity Management: Residential

There are many low-cost approaches to conserve water in a home.

Repairs: Leaking faucets, toilet bowls and pipes waste a lot of water. Insulate hot water pipes—hot water comes faster and water isn't wasted waiting for it to heat up.

Low-flow devices and equipment: Water-saving devices on toilets, dual flow and high-efficiency toilets, low-flow showerheads and faucets can reduce water use by as much as 35%, thereby saving you money in energy, water and wastewater charges. Horizontal axis washing machines save up to 40 percent of the water used by a conventional model.



Better water usage habits: Wash only full laundry loads. A running hose to wash a car can waste about 400 liters of water; using a bucket, sponge and a trigger nozzle on the hose can save you 300 of those liters. Water lawns in the early morning or late in the evening; turn off the tap while brushing your teeth; shorten your shower by one minute.

Residential Quantity Management: Rainwater Harvesting

Rainwater harvesting is a practical (low-cost) tool to make use of rainwater and an efficient way of reducing water consumption. In most cases, a roof is used to collect the water then send it into a collection tank. The size of the tank is dependant on the amount and purpose of the water but also on the annual rainfall and the size of the roof.

The collected water can be used for small-scale irrigation (of vegetable gardens, etc.), clothes washing, bathing and, after treatment, also drinking and food preparation.

Residential Quantity Management: Rainwater and Grey Water Recycling

Captured rainwater can be redirected to toilets and landscape irrigation. Treatment of the water is required, and it is ideal to store only treated (filtered water). Methods of treatment include UV treatment, filtration, ozonation and chlorination. These treatment methods require specific equipment and knowledge and are not appropriate at all scales.

Water Quantity Management: Xeriscaping

Xeriscaping is designing a landscape with water requirements that closely match the amount of natural precipitation. The City of Kamloops, BC lists these seven principles of xeriscaping:

- Planning
- Soil Improvement – i.e. compost, peat moss or manure to help soils retain moisture and nutrients
- Appropriate Plant Selection – Use low water use plants that can withstand periods of dryness and high temperatures with minimal irrigation.
- Practical Turf Areas – Remove impractical turf areas.
- Efficient Irrigation – Apply the amount of water that is required by a plant, with minimal wastage.
- Mulches – Use mulches to reduce evaporation and to moderate soil temperature.
- Appropriate Maintenance – Do not overwater.

Water Quantity Management: Xeriscaping

The benefits of xeriscape are many. Foremost is reduced water consumption, which lowers the demand on water supplies, and which lowers costs. Mulching and efficient irrigation reduce landscape maintenance. Appropriate plant selection will reduce fertilizer and pesticide use.

Multiple small-scale conservation activities such as these can together have a huge impact on overall community usage as shown in the following example.

Source: City of Kamloops website

Water Quantity Management Plan: Boston, MA

In 1987, the City of Boston realized that with projected growth and current water use habits they would be drawing far more water from their local reservoirs than was sustainable. Historically, Boston relies on two local reservoirs serving 2.5 million water customers using approximately 300 million gallons per day (mgd). Projections revealed that by 2000 they would be drawing 450 mgd.

There were two solutions:

1. the traditional approach which was to acquire another source of water, or
2. find ways of reducing water usage.

Picture from:
http://en.wikipedia.org/wiki/Quabbin_Reservoir

Water Quantity Management Plan: Boston, MA

The Massachusetts Water Resources Authority (MWRA) performed studies and analyses of the following questions:

- Which clients were the largest water users?
- Where were the leaks in the system?
- Could the public be educated and would they be willing to reduce water consumption?
- Would industry also reduce water consumption?

Their findings:

- Water audits confirmed one-third of the water could not be accounted for.
- Some water was not property metered and some public users not metered at all.
- There were leaks found in the 6,000 miles of piping. Testing of this piping—not all of which was owned by the water authority—was done for free.

Source: Brzozowski, Carol. "The Secrets of Their Success." *Water Efficiency,The Journal for Water Resource Management*, January/February 2008. http://www.waterefficiency.net/WE/Articles/The_Secrets_of_Their_Success_556.aspx

Water Quantity Management Plan: Boston, MA

Along with hiring leak detection crews and repair work, the city increased the cost of water by 600%, encouraged the use of water-saving devices, instituted a program of education about water conservation and introduced water reuse options.

This program allowed the city to go from 340 mgd in the early 1980s to below 300 million by 1989, two years after the program started. By 2006, the city's demand had evened out at around 212 mgd as opposed to the 450 mgd projected by the MWRA.

Water Quality Management: Pollution Prevention

Water quality can also be managed at an individual home or residential scale by using the following guidelines:

- Minimize the waste you produce: reuse, reduce, recycle and compost.
- Cleaning products: Use non-toxic cleaning products. Look for an ECO type of logo on products and read labels. Properly dispose of cleaning products.
- Properly dispose of products that contain toxic chemicals, pesticides, paints, solvents, gasoline, and flammable liquids (i.e. do not dump in the sewer system). Further, properly dispose of pharmaceutical products and batteries.
- Prevent pollutant runoff from entering storm sewers (for example, clean the car at a “auto spa”).
- Minimize the amount of road salts in wintertime.
- Reduce urban runoff by replacing impervious/ paved surfaces like the driveway and backyard terrace with partially permeable material.
- Protect and maintain private wells. Maintain good hygiene around the well. This includes keeping adequate distance between the well and contaminating activities (such as cattle, pesticides, fertilizers, car workshop, sewer system, disposal pits), no ponding of water around the wells, and regular monitoring (water quality testing).

Water Quality Management: Pollution Prevention

Sources of pollution can be classified as follows:

- Point sources of pollution refer to localized pollution (i.e. contamination originating from one single point).
  - *Examples are: sources designed to store and dispose toxic substances: landfills, lagoons, open dumps; salt water intrusion; dumping of damaged containers with toxic substances in waters; accidental spills; spill from oil tanker; leakage from (underground) petroleum tank; leakage from sewer and septic systems; releases and spills from industries.*

- Non-point source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. For example, NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water.
  - *Examples are: excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas; oil, grease, and toxic chemicals from urban runoff and energy production; sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks; salt from irrigation practices and acid drainage from abandoned mines; bacteria and nutrients from livestock, pet wastes, and faulty septic systems; atmospheric deposition.*

Water Quality Management: Water Treatment

The following are treatment options for community drinking water systems:

Point-of-Use (POU) devices: treat water intended for direct consumption (e.g. pumped in units with separate faucet, typically installed under the kitchen sink).

Point-of-Entry (POE) systems: treat all water entering a single home, business or other facility.

POU and POE treatment devices rely on many of the same treatment technologies that have been used in central treatment plants. However, while central treatment plants treat all water distributed to consumers to the same level, POU and POE treatment devices are designed to treat only a portion of the flow. The cost savings achieved through selective treatment may enable some systems to provide more protection to their consumers than they might otherwise be able to afford. These devices may be an option for public water systems where central treatment is not affordable (EPA, 2006).

Water Quality Management: POU and POE

These are examples of POE and POU treatment technologies:

- Ion exchange (for POU):
  - Purification process of the aqueous phase that involves the exchange of ions between two electrolytes
- Reverse osmosis (for POU):
  - A separation process that uses pressure to separate the solute (contaminant) from the solvent
- Granular activated carbon (for POU and POE):
  - Porous adsorbent material; removed solutes by absorption onto the activated carbon
- Ultraviolet light (for POE):
  - Solute is exposed to ultraviolet light

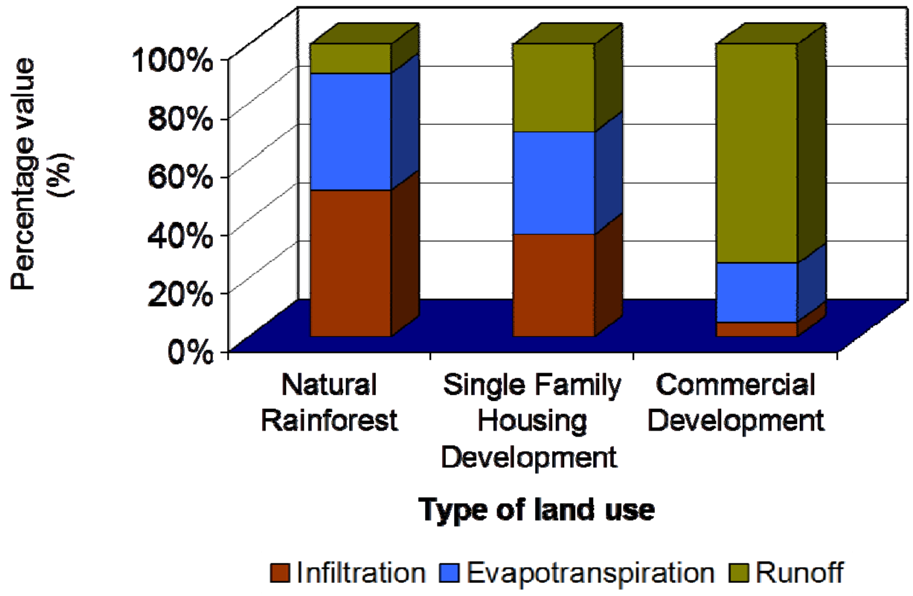
Community Development Strategies

The City of Boston example we saw shows how an established community can modify existing infrastructure and usage patterns. However, modification of established communities is limited by cost, and some best practices may not be possible. There are a number of new development strategies that include effective water quality and quality management as part of their central principles. These management practices all try to achieve appropriate water balance.

Water Quantity Management: Water Balance

Water balance includes three components: evapotranspiration, runoff, and infiltration. The proportion of each component in the water balance is a function of the degree of development.

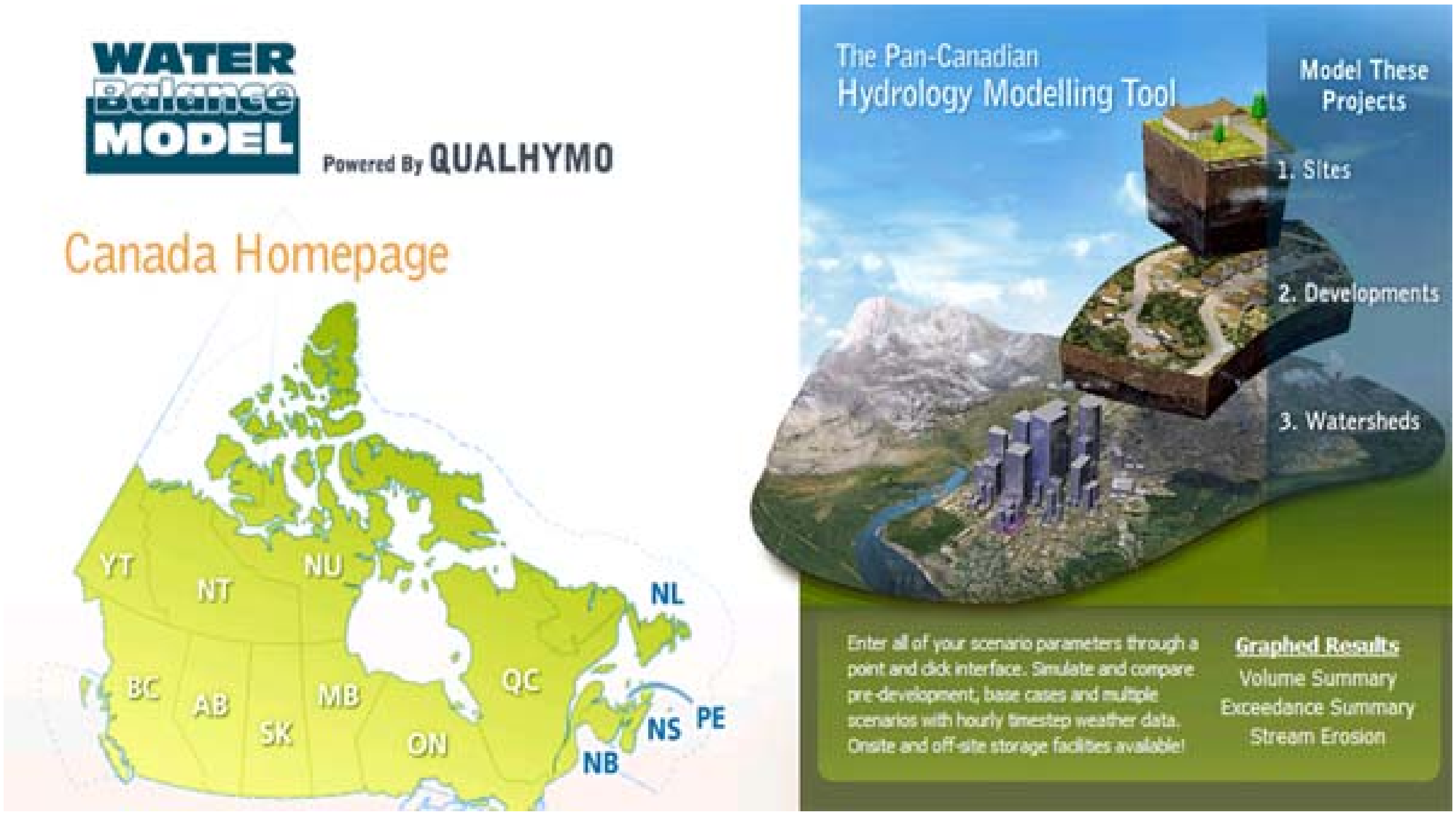
The chart at right demonstrates three development scenarios. The graph illustrates that runoff is highest for commercially developed areas. This is due to the increase in impermeable surfaces that accompanies traditional development.



Developed areas have extensive roof and paved areas which create more runoff than land uses with extensive areas of absorbent soils and forest cover.

Water Quantity Management: Balance Modeling Tool

Tools for developing water balance scenarios can be found in the public domain.



Source: http://www.waterbalance.ca/

Water Quantity Management: Capture Small Events

A good stormwater management plan ensures that rainfall from frequent small events (about 75% of rain events) be infiltrated into the ground or reused within the watershed.

When water is infiltrated where it falls, it ensures a replenished water table and limits the use of the stormwater system. Traditional development with a higher percentage of impervious surfaces can cause flooding, loss of aquatic habitat and increase in NPS water pollution in downstream receiving waters.

Capturing the small events reduces wear-and-tear in watercourses that degrades or eliminates fish habitat. Small events are manageable, and the water captured can be reused within the watershed.

Water Quantity and Quality Management: Low Impact Development (LID)

Low impact development (LID) is a stormwater management strategy that is integrated with engineered, small-scale hydrologic controls to more closely mimic pre-development hydrology, with the goal of preventing measurable harm to streams, lakes, wetlands and other natural aquatic systems from commercial, residential or industrial development sites. It is also able to address both water quantity and quality issues at a neighborhood scale.

This method of development emphasizes conservation and use of on-site natural features. It employs a variety of natural and built features that reduce the rate of runoff, filter out its pollutants, and facilitate the infiltration of water into the ground. By reducing water pollution and increasing groundwater recharge, LID helps to improve the quality of receiving surface waters and stabilize the flow rates of nearby streams.

LID Development Strategies

Some low impact development strategies include:

Green roofs, also known as living roofs, vegetated roofs, or eco roofs, are building roofs which are purposely covered with vegetation. Green roofs can be below, at, or above grade, but in all cases the plants are not planted in the ground, but rather, in the roof itself.

Living walls are also known as green, bio, vegetated, or eco walls and as vertical wetlands. At their simplest, they are vertical gardens and can include any type of vegetative covering of a standard wall, such as hanging gardens and climbing vines.

Rain gardens, also known as vegetated infiltration basins, biorentention gardens or facilities, and infiltration rain gardens, are landscape features designed to treat stormwater runoff from hard surface areas such as roofs, roads and parking lots. They consist of depressed garden spaces where runoff can pond and infiltrate into deep constructed soils and then into the native soils below.

Permeable pavement, also known as pervious or porous paving, is a type of hard surfacing that allows rainfall to percolate to an underlying reservoir base where rainfall is either infiltrated to underlying soils or removed by a subsurface drain.

LID Development Strategies

Swales, also known as infiltration swales, biofilters, grassed swales, or in-line biorentention, are vegetated open channels specifically designed to attenuate and treat stormwater runoff for a defined water volume. Like open ditches, they convey larger stormwater volumes from a source to a discharge point, but unlike ditches, they intentionally promote slowing, cleansing and infiltration along the way. A sloped base to facilitate this water movement distinguishes bioswales from rain gardens.

Erosion prevention and sediment control, also known as stormwater runoff control, is not one technology, but rather a suite of methods that can be used both to prevent soils from eroding from a piece of land, and to capture any that do erode. These individual techniques, or erosion best management practices (BMPs), are each applicable to different situations and must be chosen carefully for each project.

The swale in this photo replaces a storm sewer, and by slowing runoff, improved a nearby stream to the point where salmon have returned to spawn after a multi-year absence.

LID Advantages

Runoff volumes (green roofs):

Growing mediums, and any additional substrate or integrated water storage, can store significant volumes of rainwater, preventing runoff in small storm events, and delaying peak runoff for larger storms. Runoff is extended over several hours, reducing peak flows. The plants themselves can return some of this moisture to the atmosphere via evapotranspiration. Studies in Berlin show that green roofs absorb up to 75% of precipitation that falls on them. A study from Portland confirms similar results, with green roofs mitigating from 65% to 94% of runoff. As eco roofs reduce runoff volumes for most storm events, this can improve the performance of other on-site cleaning, infiltration, detention or storage facilities.

Runoff volumes (rain gardens):

Rain gardens can be sized to temporarily store runoff from smaller to medium sized storm events in the depression area itself, the constructed soils, and any constructed reservoir.

LID Advantages

Runoff volumes (permeable pavements):

Research has shown that pavers can significantly reduce runoff volumes, thereby reducing the erosive power of stormwater entering creeks and inter tidal areas. This helps to protect backwater refuges, brings less sediment to spawning areas, and prevents down-cutting of streams and loss of bank stability.

Runoff volumes (bioswales):

Even where soils have very poor hydraulic conductivity (around 1 mm/h), a 4 m swale/trench can reduce the volume of runoff from a typical local road to about 25% of total rainfall. In general, infiltration facilities along roads are more effective than on-lot infiltration facilities because there is typically less concentration of runoff (i.e. the ratio of impervious area to infiltration area tends to be lower).

LID Advantages

Pollutant removal (green roofs):

The temperature of water runoff leaving a green roof will be cooler than that coming off a standard roof surface, especially during warmer months of the year. Green roofs thus protect water of a fish habitat from heat pollution. In addition, C02 is absorbed, and some airborne and precipitation-borne pollutants are filtered out by the plants and growing medium.

Pollutant removal (rain gardens):

Studies have shown that vegetated soils remove more stormwater pollutants than non-vegetated soils through processes of absorption, filtration, sedimentation, infiltration, phytoremediation, volatilization, surface resistance and thermal attenuation. Bioretention systems have demonstrated excellent removal for heavy metals, with some research showing the most uptake occurs in the mulch layer. Estimates from research suggest that metal accumulation would not create any environmental concerns for at least 20 years in these systems.

LID Advantages

Pollutant removal (permeable pavements):

Long term research on permeable pavers shows their effective removal of pollutants such as total suspended solids, total phosphorous, total nitrogen, chemical oxygen demand, zinc, motor oil, and copper. In the void spaces, naturally occurring micro-organisms break down hydrocarbons, and metals adhere.

Pollutant removal (bioswales):

As stormwater runoff flows through bioswales, pollutants are removed through filtering by vegetation and soils. Above ground plant parts (stems, leaves, and stolons) retard flow and thereby encourage particulates and their associated pollutants to settle. The pollutants are then incorporated into the soil where they may be immobilized and/or decomposed. In particular, bacteria within healthy soils can help break down carbon-based pollutants like motor oil.

LID Advantages

Groundwater recharge (rain garden):

Because stormwater in rain gardens is detained for period of time, it has a chance to infiltrate, replenishing soils and replicating the natural hydrology.

Bioretention areas can be applied in almost any soils or topography, since runoff percolates through a man-made soil bed and the design can return excess flows to the stormwater system.

LID Advantages

Groundwater recharge (permeable pavements):

In areas with suitable soils, permeable pavements allow stormwater to enter the sub-soils, replicating the natural hydrological cycle by allowing for groundwater recharge and moderating the fluctuations of flows in watercourses.

Groundwater recharge (bioswales):

Grassed channels and dry swales provide some groundwater recharge if a high degree of infiltration is achieved by the practice. Wet swales typically do not contribute to groundwater recharge, as infiltration is lessened by the accumulation of organic debris on the bottom of the swale.

Heat pollution reduction (rain garden):

Some aquatic wildlife is sensitive to changes in water temperature. Bioretention is a good option for coldwater streams because water ponds in them for only a short time, decreasing the potential for warming. Rain gardens have been shown to decrease the temperature of runoff from certain land uses, such as parking lots.

LID Advantages

Heat pollution (permeable pavements):

Porous pavement can help lower high runoff water temperatures commonly associated with impervious surfaces. Stormwater pools on the surface of conventional pavement, where it is heated by the sun and the hot pavement surface. By rapidly infiltrating rainfall, porous pavement reduces the water's exposure to sun and heat. Cool stream water is essential for the health of many aquatic organisms, including trout and salmon.

LID Advantages

Stormwater retention (living wall):

Though there is little evidence that stormwater is a design consideration, living walls can be designed to slowly use up stormwater which lands on the roof or other hard surfaces of a building site. Plants in a soil-less design need a relatively constant supply of water. This could be provided with the aid of a cistern placed higher than the top of the growing medium. Some cleansing would be provided by the plants and soils, and by the bacteria which would eventually inhabit the growing medium and root surfaces. Indoor and outdoor living walls could both take advantage of stormwater for reuse.

Image of the living wall at the new Centre for Interactive Research on Sustainability at UBC. The vines will grow to shade much of the façade.

Cluster Development

Smart Growth, a community development program from the U.S. EPA, focuses on a balance between urban development and open spaces, emphasizing maintaining available areas as protected open space.

By planning for protection of open spaces within an urban development, water resources can also be protected, along with surrounding ecosystems and wildlife habitats.

Cluster Development: Abacoa, FL

Abacoa, Florida is a 2,055-acre, planned mixed-use community that preserves 393 acres of land for open space. Work began on the town in 1996 with one of the goals to provide compact community design and open space restoration.

Along with an intensive mix of land uses such as 5800 residential units, 1 million square feet of retail space and 1.9 million square feet of commercial space, this development preserves natural habitats and reduces pressure for development near the Everglades.

Source: EPA website

Cluster Development: Abacoa, FL

Within the open space is a 260-acre greenway that protects the natural environment of wetlands and pine woods, home to a diversity of wildlife, including birds, mammals, amphibians, and reptiles. Sixty acres of the greenway are set aside as an endangered gopher tortoise habitat.

In addition to providing wildlife habitat and recreational and educational opportunities for residents, the greenway serves as a unique stormwater management system for the entire community.

Source: EPA website

Cluster Development: Abacoa, FL

There are 10 principles within the EPA's Smart Growth guidelines:

1. Mix Land Uses
2. Compact Building Design
3. Range of Housing Choices
4. Walkable Neighborhoods
5. Distinctive and Attractive Places
6. Preserve Open Spaces and Farmland
7. Development in Existing Communities
8. Transportation Choices
9. Predictable and Fair Decision Making
10. Community and Stakeholder Participation

The Abacoa example illustrates principles one through six.

Source: EPA website

Green Space Protection: Natural Wetlands

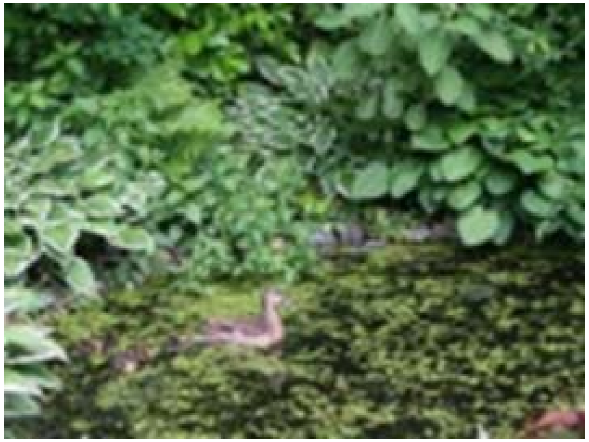
Wetlands are important elements of a watershed because they serve as the link between land and water resources. Wetlands protection programs are most effective when coordinated with other surface and groundwater protection programs and with other resource management programs, such as flood control, water supply, protection of fish and wildlife, recreation, control of stormwater, and non-point source pollution.

Hamilton Marsh, Vancouver Island, Canada

Green Space Protection: Wetlands Restoration

Wetland restoration is an essential tool in the campaign to protect, improve, and increase wetlands. Wetlands that have been filled and drained retain their characteristic soil and hydrology, allowing their natural functions to be reclaimed. Restoration is a complex process that requires planning, implementation, monitoring, and management. It involves renewing natural and historical wetlands that have been lost or degraded and reclaiming their functions and values as vital ecosystems. Wetland restoration efforts are discussed in the following slides.

Mitigation banks typically involve consolidating many small wetland mitigation projects into a larger, potentially more ecologically valuable site. Further, mitigation banks require the up-front compensation prior to affecting a wetland at another site. This ensures the success of the mitigation before unavoidable damage occurs at another site. With proper implementation and guidelines, mitigation banking has the potential to increase ecological benefits, save money for project applicants, and improve efficiencies in application and permitting processes.



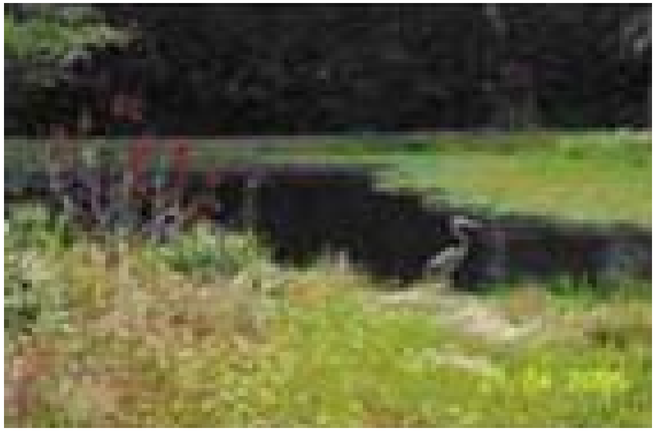
Quoted from: Washington State, Department of Ecology website: http://www.ecy.wa.gov/programs/sea/wetlands/mitigation/banking/index.html#regnow

Green Space Protection: Stormwater Detention Ponds

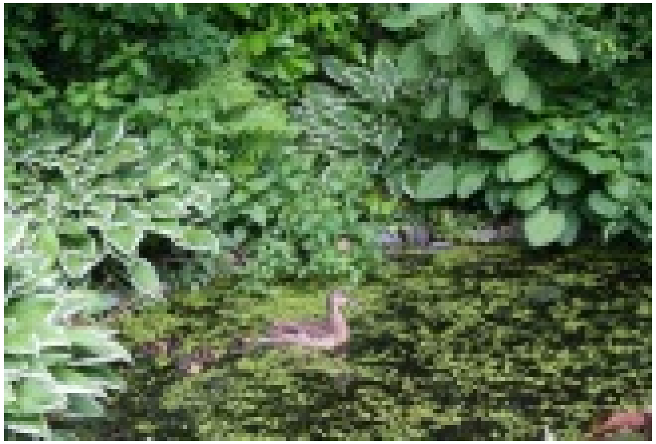
Stormwater detention ponds reduce downstream flooding and erosion by controlling the peak flow, the frequency of peak flow and the velocity of stormwater.

Detention ponds trap and settle much of the solid material carried by the stormwater as sediment, which improves water quality and helps reduce contaminant loads into rivers or lakes.

Aquatic vegetation planted in the ponds can serve as a biological filter to retain fine sediment and the contaminants bound to this sediment.



Stormwater retention pond



Green Space Protection: Constructed Wetlands

Although stormwater ponds are designed to protect downstream areas by containing material that could create undesirable conditions for aquatic life, the accumulation of contaminants within the ponds could pose a threat to local wildlife using these facilities as habitat, unless ponds are properly managed.

Because stormwater detention ponds are exposed water bodies, and may be located in or near natural green spaces, wildlife is likely to be attracted and use them as habitat.

Constructed wetlands at the Toronto Evergreen Brickworks project

Although wetlands can develop in stormwater ponds over time as a result of natural seeding and succession, it is possible to create wetlands. These elements, called constructed wetlands, are purpose-built to improve downstream water quality. Combined with ponds, they generally provide increased water storage time, allowing a greater number of the lighter particles, such as clays, to settle out of stormwater. Plants growing in the wetland further improve downstream water quality by assimilating phosphorus and nitrogen from the stormwater.

Green Space Protection: Wildlife Corridors

Wildlife corridors are designed/designated spaces for wildlife to freely move around or migrate to other places without human-induced disturbances. A network of corridors is able to ensure safety for wildlife and for human beings.

For instance, in the Rocky Mountains, valley bottoms are critical. Not only do they provide high quality wildlife habitat, but they also offer a way for wildlife to move through an otherwise inhospitable mountain environment. Valleys are also important to people. Most human activity in the Rockies, including roads, railways, buildings, trails and facilities, is confined to the valley bottoms. This competition for space poses a significant problem, especially for wide-ranging species such as wolves and grizzly bears.

Green Space Protection: Wildlife Corridors

The ideal corridor depends on the species using it. For example, wary species require wider, more secure corridors than species accustomed to human presence. In addition to width, other factors that influence corridor success are: ease of travel, terrain, vegetation cover, topography, snow depth, physical barriers, and human presence such as smells and noise. The length of a corridor, or the distance between quality habitat patches, must also be short and direct.

Individual corridors connect particular species with specific habitat patches. In order to meet all species' needs and connect wildlife to the larger region, a network of corridors must be protected.

★ Please remember the **exam password** HABITAT. You will be required to enter it in order to proceed with the on-line examination.

Green Space Protection: Sediment and Erosion Control

Erosion is a naturally occurring process, but is often aggravated by activities such as road building, new construction and deforestation. Erosion occurs when wind and rain dislodge topsoil from fields and hillsides. Eroded topsoil can also be carried into rivers, streams, and lakes. This excess sediment, sometimes containing fertilizers or toxic materials, threatens the health of aquatic organisms and water resources. Controlling erosion is essential for protecting waterways and maintaining the quality and productivity of the soil.

Erosion can be controlled by fairly simple and low-cost techniques. Lining of sloped terrain and proper vegetation ensures that soil is kept in place (i.e. eliminates erosion). Compost is an effective tool because it improves the infrastructure of the soil. On steep slopes, mounts of compost at the top or bottom can be used to slow the velocity of water and provide additional protection for receiving waters. Similarly, re-vegetation ensures strengthening of the soil, mitigating chances of soil erosion.

Green Space Protection: Riparian Zones

Riparian areas are the transitional zones between the land and the water of streams, lakes, rivers, and springs. These have been degraded in much of the world. Their loss affects the natural water balance, habitats and stream ecological and aquatic systems (i.e. its biodiversity).

Riparian ecosystems are vital to the health of all other aquatic ecosystems; they filter out pollutants from land runoff and prevent erosion, supply shelter and food for many aquatic animals, and provide shade, which helps to regulate the temperature of the stream.

Green Space Protection: Riparian Zones

There are a number of ways to prevent damage to riparian zones:

- Maintain a natural stream bank and prevent erosion.
- Prevent water depletion or impacting of natural stream flow and minimize diverting of water.
- Control and prevent pollution.
- Minimize loss of recreational use.
- Maintain a wide, native vegetative cover along streams, ditches and runoff channels to prevent erosion and filter nutrients and sediment.
- Discourage or prevent livestock from entering watercourse and provide livestock with an alternative water supply.
- Prevent bed load deposition.
- Manage stormwater flows.

Green Space Protection: Lyall Creek

Lyall Creek is located on Saturna Island, one of the Gulf Islands of British Columbia, Canada. This creek is home to trout and salmon; however, habitat alteration resulted in the loss of some fish populations. In September of 2005, in-stream restoration works for the Lyall Creek habitat restoration effort were completed.

Before

After

© T. Golumbia, Parks Canada / 2005

A new culvert was installed and root wads, logs and large boulders were anchored into the banks of the creek upstream of the culvert to create structures which function to increase the complexity of the water course and improve habitat for all aquatic and riparian species.

Stewardship & Community Involvement: Management & Monitoring

Public Stewardship

Effective water management requires not only municipal regulation, but also public stewardship and participation. This holistic approach is essential to ensure sustainable use of water resources.

Involving the public and encouraging them to care about preserving and protecting water resources is a challenge. Some options for educating the public and igniting interest are the following:

- Lectures and small participatory workshops at local community centers
- Yearly recurring events (like a fair or charity)
- Trails and city parks displaying educational information
- Changing the perceptions that being concerned about water is only for environmentalists
- Improved information flow through: Internet website, specific for a community, e-mail newsletters and updates

Community Involvement

Public participation usually begins with education. The most common method is using the internet through national or local environmental websites. However, a very powerful tool is educating future generations.

For instance, the EPA dedicates a section of its site to teaching material for school teachers, encouraging water science be included in school curriculums.

Awareness Building

Pilot projects and demonstration sites are also effective ways to show a community how a water-saving or source protection project is implemented. As an alternative, having the community participate in a pilot project creates a sense of ownership. Good examples of pilot projects are water-saving techniques for gardening (low-cost xeriscaping techniques); rainwater harvesting project; and simple erosion control measures.

When communities practice environmental stewardship, they magnify the results of individual efforts. Community service organizations, civic groups, religious congregations, school districts, and local governments can all instigate water-saving measures and educational events.

Management and Monitoring

Local stewardship groups:

- Local/regional involvement in water quality monitoring and cleanup activities
- Work with local stream keepers

Responsibility of local government:

- Enforcement of water quality standards and other water/stormwater related legislation, acts and (implementation) standards
- Development of a long-term water management plan

Universities and community colleges:

- Involvement in regional/local studies
- Organizing workshops, lectures, awareness campaigns

Mount Baker, Washington State, U.S.A.

Summary

Summary

Water, in all its forms, must be managed in order to ensure safe, healthy and sustainable communities.

Water management is the responsibility of many authorities as well as the community planner and building designer.

Community plans must integrate water, stormwater and wastewater management into their overall planning strategies and processes.

Buildings and projects must adopt water management practices to support these strategies.

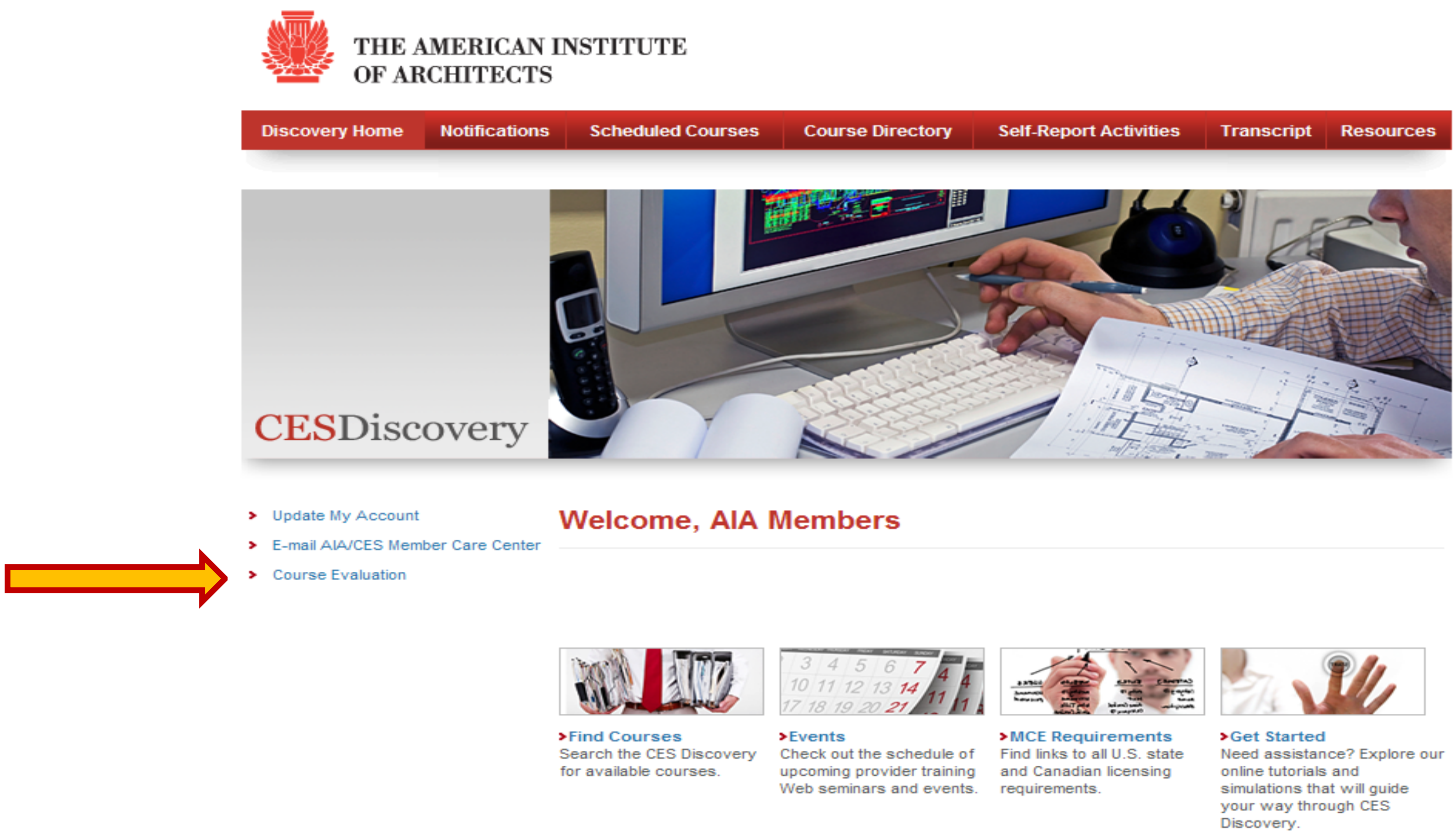
Water management can be a powerful and beautiful design element in the design of communities, neighborhoods, roadways and green spaces, sites and buildings.

Management practices must be continuously monitored to ensure proper water quality and quantity is sustained.

Community members should participate in this monitoring and stewardship activity.

Course Evaluations

In order to maintain high-quality learning experiences, please access the evaluation for this course by logging into [CES Discovery](#) and clicking on the Course Evaluation link on the left side of the page.



CMHC International Training Program

Introduction to Sustainable Community Planning	Essentials of Sustainable Community Planning	Master Class of Sustainable Community Planning
2-3 hour workshop	1 day workshop	Customized 3-5 day training course
Introduction to sustainable planning principles, best practices and issues.	Understanding of Integrated Design Process (IDP), step by step planning, charrettes and other community engagement techniques and case studies.	Essentials course, plus choice of topics such as water, waste, energy, etc. based on client needs. Enables participants to make sustainable planning decisions for themselves.

Training is delivered by a team of subject matter experts selected to suit client needs. Training can be a component of a larger event, a stand-alone workshop or class or a design charrette related to a specific project.
For details visit http://www.cmhc-schl.gc.ca/en/hoficlincl/cmhcin/inre/inre_005.cfm

Conclusion

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