5.0 MONITORING

A fundamental component of implementing stormwater management plans and operating facilities is a monitoring program to evaluate if the facilities are functioning as designed and how effective the plan was in meeting the environmental and public health and safety objectives they were designed to meet. Too often, stormwater management systems are not evaluated with regard to performance, nor the cumulative environmental effects, so little knowledge or experience is available about the benefits or which aspects of the project were successful versus which aspects failed.

Most agencies have adopted a new approach to project development and implementation that recognizes the importance of monitoring as a feedback mechanism that can improve the effectiveness of future projects. The approach is called “Adaptive Environmental Management” (AEM) and can be defined as follows:

> “Adaptive management is a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding, and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptife management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.”

AEM makes monitoring a key link in this knowledge building and learning process (Figure 5.1).

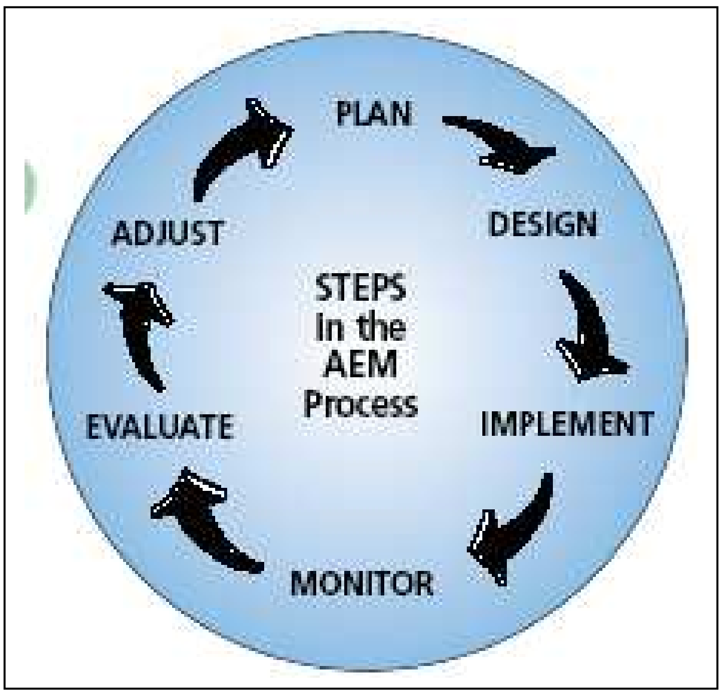

Figure 5.1
The adaptive environmental management cycle

As indicated in Chapter 1, the field of stormwater management has evolved rapidly in the past several decades and stormwater management practices (SWMPs) are now being designed to address a broad range of environmental and public health/safety objectives and targets. It is also widely recognized that the watershed response to changing land use occurs over an extended period of time, in the order of decades, therefore it may be yecrs before the effectiveness of stormwater management systems is truly understood. For example, early facilities were designed to reduce post-development peak flows to pre-development peaks, and this practice was implemented for many years, until monitoring studies showed that while this design addressed flooding objectives, it actually increased in-stream erosion (Aquafor Beech Ltd., 2006). Subsequently, facilities are now being designed to address both the peak and the volume of flows to ensure that erosion objectives are also addressed. This monitoring work also indicated that not only was there a need to look at a wider range of monitoring parameters but also a need to look at different spatial scales.

Monitoring can be generally separated into three types:

- *Compliance Monitoring:* Monitoring designed to evaluate whether a management measure or facility is functioning as designed to meet minimum acceptable requirements (*e.g.*, MOE Certificates of Approval for stormwater management facilities, municipal requirements prior to assumption of stormwater management facilities).

- *Performance Monitoring:* Monitoring designed to evaluate how well a management measure or facility performs in comparison with a range of performance indicators or targets to allow comparison with other facilities, technologies and/or development contexts.

- *Environmental Effects Monitoring:* Monitoring designed to assess the environmental health of a watershed, subwatershed, or individual community or feature (measured based on a range of environmental indicators). Such monitoring programs can be designed to evaluate the cumulative effects of the various management measures implemented to mitigate environmental impacts associated with changes affecting the watershed, subwatershed, community or feature.

5.1 Compliance Monitoring

Compliance monitoring typically focuses on assessing whether the facility is built as designed and whether it meets minimum acceptable regulatory requirements. Generally the emphasis is on measuring inlet versus outlet conditions; primarily outlet flow characteristics and selected water quality parameters. In addition, assessments of plant survival, condition of inlet/outlet structures and any maintenance issues are also undertaken. A typical timeframe for compliance monitoring for new facilities is within 2 to 5 years following construction, which is generally sufficient to expose the facility and the receiving waterbody to a broad range of environmental conditions and to allow conditions to stabilize post-construction. Typical monitoring components may include:

- flow;
- water quality;
- erosion and slope stability;
- vegetation cover/plant survival;
- condition of inlet/outlet structures; and,
- sediment accumulation or other maintenance issues.

Compliance monitoring typically is undertaken as part of the construction and commissioning of a facility (*e.g.*, as condition of Certificate of Approval or assumption of the facility by a municipality), or as part of a municipal stormwater infrastructure operations and maintenance program. Compliance monitoring for new facilities is the responsibility of the developer of the facility, and is undertaken to demonstrate that requirements for commissioning of the facility have been met. Once facilities on public property are assumed by municipalities, compliance monitoring becomes their responsibility and is undertaken as part of a municipal stormwater infrastructure operations and maintenance program. For facilities on private property, provisions need to be included in legal agreements between property owners/managers and the municipality to allow the municipality to undertake compliance monitoring from time to time in order to ensure that the facilities are being operated and maintained properly. Alternatively, the legal agreements could stipulate that property owners/managers must undertake compliance monitoring from time to time and submit the results to the municipality to demonstrate that the facility is being operated and maintained properly.

5.2 Performance Monitoring

Performance monitoring measures how well (or poorly) a management practice or stormwater management facility performs according to design objectives and targets. Performance monitoring programs are typically undertaken when little information is available regarding the effectiveness of a certain type of facility in a certain environmental context, or when a new technology is being implemented for the first time in a certain context or geographic region. Performance monitoring programs differ from compliance monitoring in that they typically require different parameters to be monitored and the rigor of the evaluation typically goes beyond whether or not the facility meets minimum regulatory requirements.

New or emerging technologies need to be assessed in terms of their performance in order to gain acceptance by review and approval agencies. Performance monitoring is also needed to develop a better understanding of how the design of conventional end-of-pipe facilities can be adapted when LID practices are implemented upstream as part of a treatment train approach. TRCA, CVC and other agencies have been monitoring and evaluating new and emerging technologies under two jointly funded programs, called the Sustainable Technologies Evaluation Program (STEP) and the Stormwater Assessment Monitoring and Performance Program (SWAMP).

Sustainable Technologies Evaluation Program (STEP)
STEP is a multi-agency program, led by TRCA. The program was developed to provide the data and analytical tools necessary to support broader implementation of sustainable technologies and practices within a Canadian context. Its main objectives are to:

- monitor and evaluate clean water and clean air technologies;
- develop strategies to overcome implementation barriers;
- develop tools, guidelines and policies; and
- promote broader use of effective technologies through research, education and advocacy.

The mandate and organizational structure for the water component builds upon experiences from the Stormwater Assessment Monitoring and Performance (SWAMP) program and feedback from various agency and industry representatives. The technologies evaluated under STEP are not limited to physical structures; they may also include preventative measures, implementation protocols, alternative urban site designs, or other practices which promote more sustainable lifestyles. To date, a number of different types of facilities have been constructed and evaluated under the STEP program. These include:

- Green roofs;
- Permeable pavement;
- Rainwater harvesting;
- Erosion and sediment control practices;
- Bioretention systems;
- Perforated pipe systems; and
- Infiltration chambers.

Stormwater Assessment Monitoring and Performance (SWAMP) Program
SWAMP was initiated in 1995 by the Government of Canada's Great Lakes Sustainability Fund, the Ontario Ministry of the Environment, TRCA and the Municipal Engineer's Association, along with host municipalities and other owner/operators. The major goals of the program were to evaluate the effectiveness of stormwater technologies and disseminate study results and recommendations within the stormwater management community. Between 1995 and 2002, ten stormwater management facilities were monitored and evaluated. These included:

- Wet ponds and constructed wetlands (4 studies)
- Underground storage tanks (1 study)
- Flow balancing systems (1 study)
- Oil and grit separators (2 studies)
- Infiltration/ exfiltration systems (2 studies)

Other products of the SWAMP program included an investigation of the storage and transport of chloride (a major constituent of road salt) in stormwater ponds, a discussion paper summarizing data analysis and statistical evaluation methodologies used in SWAMP studies, a stormwater pond sediment maintenance guide, and the proceedings of three major conferences.

5.3 Environmental Effects Monitoring

Both TRCA and CVC have established a network of regional environmental monitoring stations in the last decade. These integrated watershed monitoring programs (IWMPs) were designed to help determine progress in achieving a broad goal of ensuring environmentally healthy river systems for economically and socially healthy communities. The major objectives of the programs are:

- to protect and improve water quality and quantity in the watersheds; and
- to protect and improve the biological diversity and productivity of the watersheds.

The IWMPs use a diverse range of monitoring parameters that act as indicators of ecosystem health (Table 5.3.1). Integrating expertise from such disciplines as meteorology, hydrogeology, hydrology, terrestrial ecology, fluvial geomorphology, water quality, and aquatic ecology allows for many facets of the environment to be simultaneously analyzed and measured against benchmarks or environmental targets representing healthy conditions. Collectively, the two agencies have established over 300 monitoring locations throughout their jurisdictions representing both reference (un-impacted) and impacted conditions.

The intent of IWMPs is to detect environmental changes (both spatially and temporally) within the watershed over time. The parameters measured provide a benchmark against which historical conditions can be compared and future conditions can be assessed to identify trends in environmental health. They also allow comparison of current conditions with environmental targets established at a watershed scale. The following table illustrates some of the physical (including hydrologic), chemical and biological components of these monitoring programs.

This regional IWMP databases are invaluable in answering the following questions:

- Are watershed goals, objectives and targets being achieved?
- Are trends in indicators moving closer to, or further from achieving the goals, objectives or targets?

Table 5.3.1 Components of integrated watershed monitoring programs

Discipline Name	Area of Focus	Example Indicator
Meteorology	weather	precipitation, temperature
Hydrogeology	groundwater	baseflow and groundwater levels
Hydrology	stream flow regimes	temporal trends, time series flows
Terrestrial Natural Heritage	forests, meadows, wetlands, shorelines and their flora and fauna,	quantity of natural cover, vegetation communities
Fluvial Geomorphology	stream form and channel shaping processes	channel stability, RGA protocols
Water Quality	water chemistry, benthic invertebrate species, populations and communities	parameters of concern, community composition
Aquatic Biology	fish species, populations and communities	Index of Biotic Integrity, OSAP protocols

These regional databases can also provide some insight into cumulative effects of changes and impact mitigation measures implemented within a watershed over time.

Environmental effects monitoring at finer scales, such as the subwatershed, community or individual feature scales, requires special studies or more detailed programs to establish baseline conditions and allow change to be detected. Such monitoring programs are undertaken to evaluate the extent to which objectives and targets for subwatershed, community or individual features have been achieved through implementation of a management strategy. These types of environmental effects monitoring programs typically include assessments of “before” and “after” receiving water conditions, from physical, chemical and aquatic habitat perspectives. For example, CVC has been monitoring the cumulative effects of land use changes and management measures implemented within Fletchers Creek, which has undergone rapid urbanization within the last decade. Preliminary results indicate that the water quality, stream stability and aquatic habitats have deteriorated; indicating that the stormwater management measures implemented have not achieved the stated subwatershed objectives (CVC, 2007c).