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# MSMA 2nd Edition – Application of Green Infrastructures for Solving Sustainable Urban Stormwater Management Challenges

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## *Abstract*

*The introduction of Urban Stormwater Management Manual for Malaysia, or MSMA by the Department of Irrigation and Drainage (DID) Malaysia in 2000 changed the stormwater management landscape in the country. However, with the increasing need of meeting demands for green technologies and climate change, stormwater engineers are facing a stiffer challenge to produce effective and sustainable drainage system. This requires the need to inject new technologies or innovation into the design of drainage facilities. Emphasis has been stressed on the necessity of the use of MSMA in all drainage design and implementation in order to protect the environmental of the surrounding areas. This article takes a look into the 13-year old MSMA national pilot and show piece project, i.e. Bio-Ecological Drainage System (better known as BIOECODS) in the engineering campus of Universiti Sains Malaysia that has put forward the sustainable concept of urban drainage design. The BIOECODS is fully complied with the MSMA requirements which focus on the control of both the quantity and quality of urban runoff. The success of the BIOECODS implementation proved that with innovation, MSMA can be successfully implemented without compromising on the overall project cost, aesthetic, and function. In fact, the system adds in more value-added services for stormwater management, public amenity, and overall aesthetic.*

## Introduction

Urbanization results in the growth and spread of impervious areas and a diversification of urban land use practices with respect to the hydrologic and environmental terms. Rapid urban growth in Malaysia over the last 30 years has resulted in increased stormwater flow into receiving waters, increases in flood peaks, and degraded water quality. Traditionally, stormwater management in Malaysia has been focused primarily on managing flood impacts, which adopts the rapid disposal practice and conveyance-oriented approach. Stormwater systems so designed will collect runoff at some point, immediately and rapidly convey it to a discharge point, apparently to minimize damage or disruption that could result forms its passage to downstream areas. In the past, stormwater runoff has been generally regarded as a nuisance that must be disposed of as quickly and efficiently as possible. The consequence of removing the stormwater from the land surface so quickly is to increase volumes and peak rates of flow discharge and finally overloading conventional drainage system. This results in a greater runoff that generally requires expensive enhancement of drainage network to reduce severity and frequency of flooding in urban areas. This also results in a higher pollutant washoff from the urban areas leading to deteriorate water quality in the receiving water bodies (Zakaria et al., 2003).

However, such approach has failed to keep up with the country's rapid pace of urbanization and industrialization. As every development releases water rapidly, the natural receiving waters are unable to cater to such surge in flow and would subsequently overspill and induce floods. Frequent occurrences of flash flood in urban areas result in an average annual loss of RM 100 million in Malaysia. Government allocations to resolve flood issues under flood mitigation works such as construction of dam and reservoir, deepening and widening of rivers, are increasing from time to time. Department of Irrigation and Drainage Malaysia (DID) estimates that RM 10 billion is required to upgrade the conventional drainage system made up of concrete channels and channelized rivers to overcome the flash flood enigma. On the other hand, RM 828 mil is being spent on flood mitigation projects to conduct clearing clogged drains by local councils. Therefore, with the present conventional drainage system, new development means new and bigger concrete drains are required. Similarly the receiving river at the downstream end will require new flood defences that in most cases destroy the natural environment including flora and fauna.

## The Urban Stormwater Management in Malaysia

In response to the needs for paradigm shift the way stormwater is managed, the Malaysian government has launched the Urban Stormwater Management Manual for Malaysia, or known as MSMA (DID, 2000) incorporating the latest development in stormwater management that is known as control-at-source approach. From year 2001 onwards, all new development in Malaysia must comply with new guideline that requires the application of treatment devices or facilities to control stormwater from the aspect of quantity and quality runoff to achieve zero development impact contribution in stormwater management. This concept of treatments will be able to preserve the natural river flow carrying capacity.

In 2008, DID supplemented a series of checklist for submission of stormwater management in Malaysia (DID, 2008) in line with the One Stop Centre (OSC) for submission and approval of land development initiated by the Ministry of Housing and Local Government. This checklist provides further explanation and specific requirements of each nature of work (master plan, detailed design, etc) derived from the experience accumulated through MSMA implementation since 2000. The standard submission checklist is part of the strategy of DID being the relevant administrative agency for stormwater management in getting all parties involved such as planner, consultant, project owner/developer, contractor and the local authorities to improve their understanding and practices and achieve the required development control objectives.

When DID published the DID Manual in 2009, the manual encompass DID philosophy on water management covering issues of environment and its sustainability practices. The manual provides the principles, technologies and management techniques in flood management, emphasize the relevance and importance of control at source approach to urban stormwater management (DID, 2009).

In Year 2011, a new-look manual, i.e. the 2nd Edition of Urban Stormwater Management Manual for Malaysia has been anticipated and developed through contributions of professionals from the Government as well as private professionals and foreign experts. The second edition, which includes revision of design criteria and improved design calculation methods, had contribute greatly to the continual growth of sustainable urban drainage design in Malaysia. The Manual has been updated to serve as a source of information and to provide guidance and reference pertaining to the latest best practices for engineers and personnel (DID, 2011).

Recognising the important of MSMA has been served as invaluable references for both authority and private professionals and widely accepted term in Malaysia; Malaysian Standard on Urban Stormwater Management (MS 2526) has been anticipated and developed after ten (10) years time lapse. The Malaysian Standard is part of a series of Standards developed for stormwater management design practices in Malaysia. The series from Part 1 to 20 cover the majority of stormwater facilities, from quantity and quality design to erosion and sediment control. These Standards are derived mainly from the MSMA 2nd Edition, which already contains extensive explanatory material as well as detailed technical guides, including work examples. The Standards summarize the pertinent aspects of the manual which the user must comply with as minimum requirements in designing stormwater facilities, and set criteria to guide their design for subsequent project construction and maintenance.

## MSMA 2nd Edition: Concept and Design Requirements

The new MSMA 2nd Edition manual (20 Chapters) were prepared covering mainly administration, quantity control design, quality control design and conveyance design. They are accompanied by Annexure on planting and maintenance. The manual draws on various approaches of stormwater facilities now being widely applied worldwide to control the quantity and quality of runoff through detention/retention storage, which are the core elements of achieving one of the major stormwater quantity control criteria. Quality control facilities or

Best Management Practices (BMPs) such as bioretention, wetlands, water quality pond, etc. shall be planned, analysed and designed to protect the environmental values of the receiving water that receives discharges from the site. Stormwater conveyance systems (minor and major) shall be planned, analysed, and designed in order to provide acceptable levels of safety for the general public and protection for private and public property based on design storm average recurrence interval (ARIs). Design procedures for gate and pump, culverts and other hydraulic structures are also provided to guide users in solving stormwater disposal difficulties in difference design scenarios. The goal of the manual is to provide guidance to all regulators, planners and designers who are involved in stormwater management.

MSMA 2nd Edition identifies a new direction for stormwater management for urban areas in Malaysia (DID, 2011) to:

- Ensure the safety of the public;
- Control nuisance flooding and provide for the safe passage of less frequent or larger flood events;
- Stabilise the landform and control erosion;
- Minimise the environmental impact of runoff; and
- Enhance the urban landscape and ecology.

(a) Control at Source

Urbanisation of a catchment will always increase the quantity of stormwater runoff. The level of runoff quantity control required is dependent on the type of development proposed, new development or redevelopment. Flow control requirements are stipulated as the following (DID, 2011):

> Runoff quantity control requirements for any size of development or re-development project is "Post development peak flow of any ARI at the project outlet must be less than or equal to the pre-development peak flow of the corresponding ARI ($Q_{post} \leq Q_{pre}$)".

To maintain the post-development peak flow of runoff equal or less to the pre-development peak flow of runoff as idealised in 'zero peak flow contribution', "control-at-source" concept is the crucial solution to minimise the impact development on stormwater quantity. Stormwater quantity control facilities, either detention or retention facilities can reduce the peak and volume of runoff from a given catchment, which can reduce the frequency and extent of downstream flooding. Detention and retention facilities have been used to reduce the costs of large stormwater drainage systems by reducing the size required for such systems in downstream areas.

(b) Stormwater treatment train

The stormwater treatment train represents an ecological approach to stormwater management and has proven effective and versatile in its various applications. The stormwater treatment train was designed with sequential components that contribute to the treatment of stormwater, by minimise the amount of pollution entering the downstream waterways. The components of the stormwater treatment train system were designed to treat stormwater runoff for water quality benefits and to reduce stormwater runoff peaks and volumes. This alternative approach to stormwater management not only has the potential to reduce infrastructure costs, but it also reduces maintenance costs. As described above, native plants are adapted to the environment, and do not need extensive watering, chemical treatment, mowing, and replanting that non-native species demand. In addition, there is also a substantial benefit to downstream neighbours. By treating stormwater where it falls on the land, responsible landowners are reducing their contribution to downstream flooding and sedimentation.

The applicability of the design approaches are being tested initially with the national pilot and show piece project of MSMA at Engineering Campus, Universiti Sains Malaysia (USM) with the construction of BIOECODS completed at the end of the year 2002. BIOECODS (Zakaria et al., 2003; Ab Ghani et al., 2004; Ab Ghani et al., 2008; Zakaria et al., 2011) offers an exemplary model for urban stormwater management under tropical climates by implementing a source control and treatment train approach for stormwater management as suggested in the MSMA.

## Bio-Ecological Drainage System (BIOECODS)

The BIOECODS is developed by River Engineering and Urban Drainage Research Centre (REDAC), USM, which designed with the concept of control at source in mind. Consequently, BIOECODS is designed to combine infiltration, delayed flow, storage and purification as pre-treatment of stormwater before discharging to receiving water body. As a result, these provide time for natural processes of sedimentation, filtration and biodegradation to occur, which reduces the pollutant loads in stormwater runoff. In addition, BIOECODS blends easily into their surrounding, adding considerably to the local amenity and/or local biodiversity (Ab Ghani et al., 2004).

BIOECODS is made up of several important components that ultimately form an effective stormwater treatment train that control runoff quantity and preserve runoff quality, as follow:

(a) Grassed Swale

In order to reduce the drainage footprint of the BIOECODS, as well as to provide additional water treatment, a dual layer conveyance system is introduced. While the surface of the swale is generally not much larger than conventional drain, the total cross section area of the system provides much larger water storage and treatment function than a normal conventional drainage can offer. The surface layer resembles a grassed channel or a swale. Typical swale design, gentle side slope, low gradient and shallow depth applied to this layer. The underground layer, consist of a geosynthetic module enclosed in geotextile. It is connected to the surface layer via a layer of river sand or infiltration media.

As runoff builds up on the surface, it is first infiltrated into the underground module. This infiltration provides both quantity and quality treatments to the runoff. First, the infiltration delays flow. Then the infiltrated water is stored in subsurface module. Only after the pool of water generates enough energy will it flow downstream within the module. Along the subsurface module, water is loss to adjacent ground through exfiltration of water from the side or bottom of the module. On the surface, swale attenuates flow by providing larger surface friction than concrete channel. Finally, both the surface and subsurface flows will combine again by both discharging into the ponds and wetlands system (Zakaria et al., 2011).

Figure 1: Grassed Swale

(b) Bioretention

Bioretention are designed for water quality treatment, but has also recently been discovered to have contributed to flood control and urban ecology. Surface runoff is directed into shallow, landscaped depressions that are designed to incorporate many of the pollutant removal mechanisms that operate in forested ecosystems. However, there are still many technical loopholes to be patched up before bioretention facilities can be sustainably applied in our tropical climate.

As the bioretention facilities are developed in USA, and further applied in UK, Australia, and New Zealand, the technical design guidelines available are all specifically tailored to suit the conditions of respective countries/ region. As the behaviour of rainfall (in terms of volume and rate), climate, hydrology, soil type, and plant species are all different, blind application of overseas guideline could resulted in under design facilities that are expensive to maintain but yet not able to perform as expected. Since biorentention has been included as recommended BMPs in MSMA 2nd Edition, it is therefore important for in-depth research to gather sufficient local data to formulate a design guide for local application.

Bioretention pilot study sites (Figure 2) has been identify in USM Engineering Campus for construction, and the bioretention is designed based on the catchment hydrology of the site and the preliminary design guide (developed from laboratory findings). The objective of these test sites is gain more information on the design during laboratory test (hydraulic performance test, plant selection test , hydrology/ water cycle analysis and water quality assessment). It is expected through such systematic investigation from fundamentals to practical application, a set of 'best design guide' can be produce to facilitate nationwide application of bioretention facilities in Malaysia.

Figure 2: Bioretention Pilot Study Sites
(Under Construction)

(c) Dry Ponds

The excess stormwater is also stored on the dry ponds constructed with a storage function (Figure 3). The dry pond is essentially an onsite detention (OSD), which has been integrated with the ecological swale to temporarily store stormwater runoff. The module storage tank is placed beneath the detention basin where the stormwater is drained out by infiltration. The outflow path of the storage module is connected to the ecological swale at the lowest point, in order to drain the dry pond system in less than 24 hours. Dry ponds diffuse flow conveyed by swales and the reduced stormwater velocities enable more effective sedimentation, filtration and infiltration water treatments. The grassed surfaces of dry ponds are able to infiltrate a substantial portion of the annual surface runoff volume due to the increased soil permeability that is created by the deep and fibrous root systems of the landscape vegetation.

Figure 3: Constructed Dry Pond (after Storm Event)

(d) Constructed Wetlands

Constructed wetlands systems are shallow, extensively vegetated water bodies that use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from stormwater. Water levels rise during rainfall events and outlets are configured to slowly release flows, based on the hydraulic retention time and back to dry weather water levels. In addition to treating stormwater, constructed wetlands can also provide habitat, passive recreation, improved landscape amenity and temporary storage of treated water for reuse schemes.

i. Rehabilitation of USM Wetlands (Site 1)

The constructed wetlands at USM Engineering Campus (Figure 4), which is one of the components in the Bio-Ecological Drainage System (BIOECODS), is a surface flow type, consisting of an inlet zone, a macrophyte zone and open water zone. Flows are fed into the wetlands by an orifice arranged to achieve a uniform flow distribution across the width of the wetlands. The rehabilitation of the wetlands will be carried out based on the water quality volume (WQV) requirement, which include the new wetlands inlet and outlet configuration, obstruction designation, provide the hydraulic efficiency measure to defining the flow hydrodynamic characteristic of existing wetlands, and verify the wetlands plants pollutant removal performance.

ii. Newly Constructed Wetlands (Site 2)

As the allocation of surface area, length to width ratio and limiting water depths for adequate pollutant removal, ease of maintenance and improve safety are critical for an effective design of a constructed wetland in MSMA 2nd Edition, it is therefore a proposed newly constructed wetlands is suggested. The proposed wetlands is located at the southern part of USM Engineering Campus as illustrated in Figure 4. The wetlands will acquired some existing green field and also small part of swampy area (Figure 5). Examples of common species of wetlands plants will be planted for the water quality treatment performance. This wetlands plan to be a vegetated horizontal surface flow multi-cell wetland system, designed with different water levels in each of the cells that are separated by a weir. The water flows through these wetland cells and finally discharges into Ecological Pond at USM Engineering Campus.

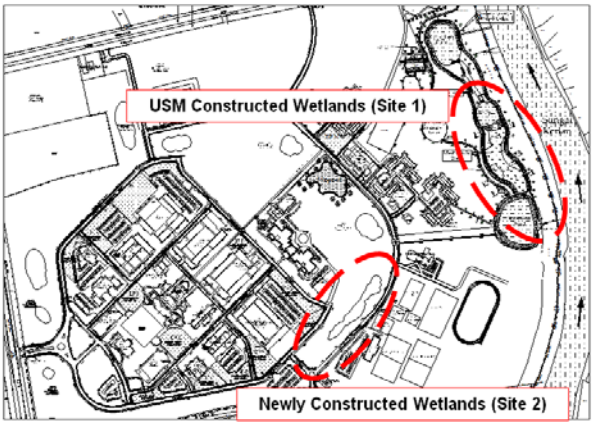


Figure 4: Existing Constructed Wetlands and Proposed Newly Constructed Wetlands Locations

Present study has been carried out by REDAC to determine the suitable wetlands plants and cell arrangement for optimum pollutant removal. Both wetlands at Site 1 and Site 2 are to measured and identify the pollutant and nutrient removal efficiency of native wetlands plants species. Common wetlands plants suggested at the macrophyte zone for both wetlands are Common Reed (Phragmites karka), Tube Sedge (Lepironia articulata), Common hanguana (Hanguana malayana), Cattail (Typha angustifolia), Greater Club Rush (Scirpus grossus), Bog bulrush (Scirpus mucronatus), Asiatic pipewort (Eriocaulon longifolium), Water chestnut (Eleocharis dulcis) and Common Spike Rush (Eleocharis variegata). The plant was selected based on their capabilities to reduce some suspended solids, chemical pollutant and biodegradable organic pollutant.

Figure 5: Newly Constructed Wetlands (One year after completion)

(d) Detention Ponds

Storage facilities (such as detention pond) are the core elements of achieving one of the major stormwater quantity control criteria which is the post-development peak discharge not more than the pre-development peak discharge. Detention ponds in USM Engineering Campus are the community facilities of the BIOECODS. They are primarily designed for attenuating runoff from developed areas through regulated outlet structures. The facility is typically designed to limit discharge to the pre-development stage, while storing water temporarily. The end product is expected to improve the aesthetic value for surrounding areas with the existence of the "Crystal Clear Blue Water Lake" at the most downstream end of the drainage system before discharging into rivers.

Figure 6: Constructed Detention Pond

(e) Wading River

Wading river (Figure 7) is designed to covey stormwater from the wetlands (Site 1) to recreational pond before discharging to Sungai Kerian. Meanders have been restored in wading river by using graded sediments and gravel. The wading river has two components, i.e. main channel and flood plains. The very large boulders are placed at several locations along the river bank to prevent bank erosion.

Figure 7 A Meandering Wading River Upstream of the Recreational Pond

(f) Recreational Pond

The end product is expected to improve the aesthetic value for surrounding areas with the existence of the "Crystal Clear Blue Water Lake" (Figure 8) at the most downstream end of the drainage system. The water level is maintained in the recreational pond by a 600 mm pipe culvert (Figure 9) discharging into Sungai Kerian.

Figure 8: Constructed Recreational Pond

Figure 9: Check valve used to provide flow in one direction only through a culvert

## Conclusion

The introduction of new Urban Stormwater Management Manual for Malaysia, or MSMA 2nd Edition, changed the stormwater management landscape in the country. With a good stormwater management practice in Malaysia, it is expected solving not only flash flood problems but also water quality degradation at urbanized catchments, to protect our rivers from any pollution and community need to be aware the importance of stormwater quality management. The Bio-ecological Drainage System or BIOECODS was introduced in 2001. Adopting the concepts of integration, control-at-source and treatment train, BIOECODS paved the way for a promising sustainable development in drainage design. The system is a living proof for feasibility and multi-benefits of MSMA implementation. BIOECODS also testified that the current stormwater management concept is ready to face the challenges and meet the demand for the nation, and most importantly, to secure a new source of water for the future generations.

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