Decision Support System (DSS) for MSMA Integrated Stormwater Management Ecohydrology for Sustainable Green Infrastructure

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Abstract. Rapid urbanization has known to have several adverse impacts towards hydrological cycle due to increasing impervious surface and degradation of water quality in stormwater runoff. In the past, urban waterways have been confined to narrow river corridors with the channels canalised and concrete and other synthetic materials forming the bed and banks of the river. Apart from that, stormwater pollutants such as litter, debris and sediments in drainage system are common problems that can lead to flooding and the degradation of water quality. To solve this problem, implementing stormwater Best Management Practices (BMPs) proves very promising due to its near natural characteristics and multiple effects on the drainage of stormwater runoff in urban areas. This judgment of using BMPs depends on not only relevant theoretical considerations, but also a large amount of practical experience and the availability of relevant data, as well. To fulfil this task, the so-called Decision Support System (DSS) in MSMA Design Aid and Database system are able to assist engineers and developers in management and improvement of water quantity and quality entering urban rivers from urban regions. This system is also helpful when an expert level judgment procure some repetitive and large amount of cases, like in the planning of stormwater BMPs systems for an entire city catchment. One of the advantages of an expert system is that it provides automation of expert-level judgement using availability of checking tools system.

1. Introduction

Malaysia faces serious challenges in urban water management. In terms of stormwater management, even with the introduction of Urban Stormwater Management Manual (MSMA) in 2001 [1], many new technologies have yet to be studied in depth especially the interrelation between water quantity and quality. Rapid urbanization has known to have several adverse impacts towards hydrological cycle due to increasing impervious surface and degradation of water quality in stormwater runoff. Solids in stormwater runoffs adversely influence waterways located in or near urban area. [2] Stormwater pollutants such as litter, debris and sediments in drainage system are common problems, which can lead to flooding and the degradation of water quality.

In Malaysia, MSMA has introduced various storm water Best Management Practices (BMPs) as treatment control. BMPs proposed to be install at the downstream end of drains or engineered

waterways [3]. The installation of storm water BMPs at downstream end of drains or engineered waterways has become common practice since the introduction of the new MSMA [3,4]. This structural measure of urban stormwater is based on the concepts of "control at source" with the objective to control stormwater quantity and quality [4].

To fulfill this task, the so-called an integrated checking aid tools called Design Aid and Database System, is proposed and introduced. One of the advantages of a Design Aid is that it provides automation of expert-level judgment. This is extremely helpful when an expert-level judgment is needed repeatedly for a large amount of cases, like in the planning of stormwater BMPs for an entire city catchment.

Thus, MSMA Design Aid and Database System is capable to optimize the performance of storm water BMPs as it is strongly dependent on specific site criteria including type of land use, hydrological data and maintenance frequency with the objective to assist engineers and local authorities to select the most appropriate strategy for storm water BMPs trapping stormwater pollutants in urban area during construction and post-construction. This software can provide the detail design of each selected stormwater BMPs based on MSMA 2nd Edition. It is also aim to expand the sources for managing stormwater pollutants in order to rehabilitate the river system and prepare a budget allocation of using storm water BMPs in terms of installation cost and maintenance cost annually including the Life Cycle Cost analysis. MSMA Design Aid and Database System module framework covers six main components; Database, Hydrological component, Design Quantity Control, Design Quality Control, Conveyance component and Checking Tools component. Overall, this project describes a self-developed design aid tool and database, as well as a case study for the selection of stormwater BMPs measures for the selected area in Kuala Lumpur.

2. Materials and Methods

2.1 Module Framework MSMA Design Aid and Database System

MSMA Design Aid and Database System module framework covers six main components; Database, Hydrological component, Design Quantity Control, Design Quality Control, Conveyance component and Checking Tools component. Figure 1 shows MSMA Design Aid and Database Modules.

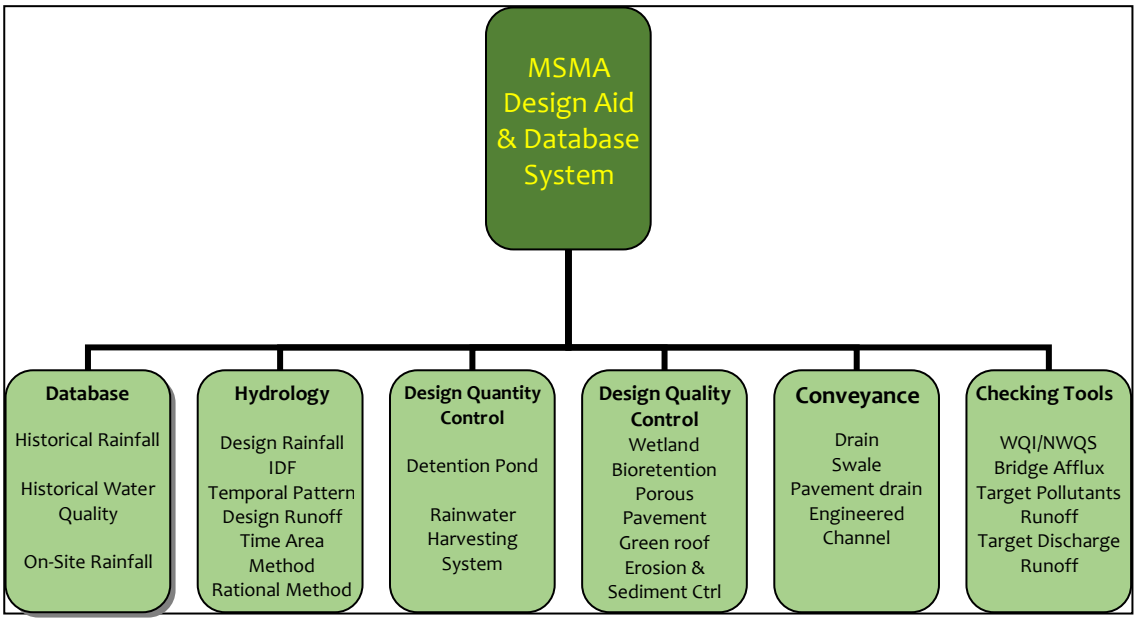

Figure 1: MSMA Design Aid and Database Modules

Figure 1 shows every component of MSMA Design Aid and Database Modules which consists of minimum two sub-components. Database component is divided into Historical Rainfall data (HTC and UNITEN Rainfall station), Historical Water Quality Data (HTC and UNITEN Rainfall station) and On-site Rainfall data Collection (HTC). Basic aims in Hydrological Module are to calculate the Design Rainfall and Design Runoff. Methods available in this module are Design Rainfall, IDF Curves, Temporal Pattern and Design Runoff using Time Area Method and Rational Method. In design Quantity control design menu, it consists of Detention Pond design calculation and Rainwater Harvesting System design calculation. In Design Quality Control module, it consists of several BMPs design preference; Wetland, Bioretention, Porous pavement, Green Roof, Infiltration facilities and Erosion and Sediment Control. For Conveyance Module, MSMA software provides design calculation for all types of drain available in MSMA Guidelines including pavement drain and swales. There are many options available in Checking Tools Module including target pollutants runoff, target discharge runoff, Water Quality Index (WQI) Calculation and Bridge Afflux.

2.2 MSMA Design Aid and Database System Database Work Flowchart

Database work flowchart consisting of three main phases as shown in Figure 2. The first phase is a data input MSMA Design Aid and Database System e.g rainfall data and water quality data. The second phase namely Model of is consisting of Data Entry Procedure, Data Record, Data search and Database management, Data analysis and search result and analysis. This model will integrate with User Input and External Model. The Third phase is aimed to depict the outputs in the form of report, tables, drawing, statistical report.

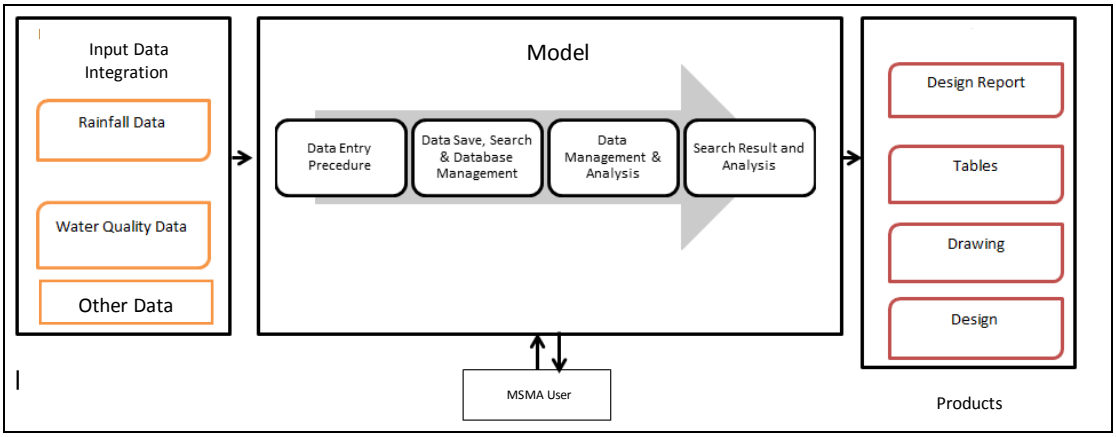

Figure 2: MSMA Design Aid and Database System Work Flowchart.

3. Results and Discussion

The users can select any one of the 135 stations in West Malaysia as in MSMA 2nd Edition, and the software will compute the design storm, plot the IDF curves and generate a comprehensive report automatically.

The users can compute the peak discharge for any location in Malaysia using the Rational Method, the user select the nearest stations enter the catchment area and select the runoff coefficient and the software will compute the design discharge and generate a report automatically. The same applies to the Time-Area Method where user can select the nearest station and the software will automatically generate the design storm data, and use them in the convolution procedure to compute the discharge. The users can calculate the pollutant loading for various landuse e.g. residential, commercial, industrial, roads and highways land use areas, which consists of up to 17 pollutant parameters.

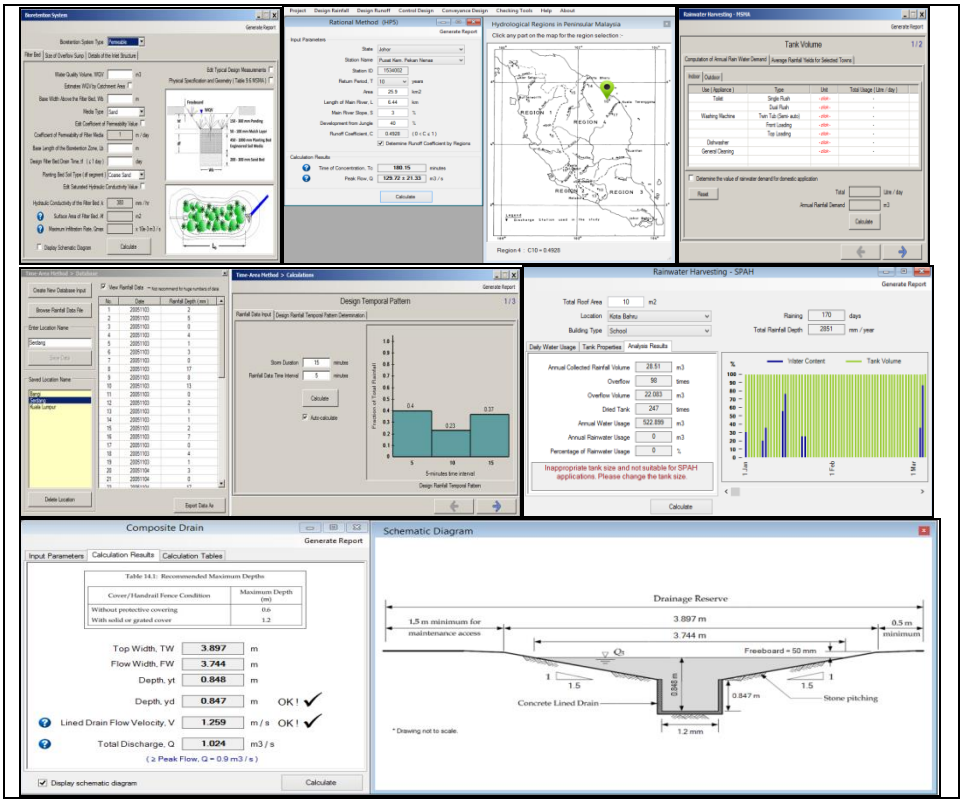

Figure 4: Snapshots of MSMA Design Aid and Database System User Interface

This software complies with editable function of the Event Mean Concentrations (EMC) values for each pollutant parameter and also supports more than 50 sub-catchments in one calculation process and generate automatically. The users can estimate the water quality volume before any assessment can be made of pollutant loads depending on landuse type. In this software, it consists of two calculation methods due to land use area either by percentage or by hectare based on 40 mm rainfall depth over the equivalent impervious contributing catchment area for water quality treatment. The detail design for each components in MSMA 2nd Edition can be done automatically in the software namely Quantity Design Control (e.g. detention pond, rainwater harvesting), Quality Design Control (e.g. wetland, water quality pond, bio retention, green roof, infiltration facilities, porous pavement) and Conveyance Design (e.g. open drain, pipe drains, composite drain, engineered channel, swale, curb opening inlet and road gutter). For detention pond design, the software allows the users to choose one out of three methods of computing the inflow hydrograph for reservoir routing i.e., Rational Method, Time-Area Method and user defined hydrograph.

The software computes the design storm for the hydrograph computation and single detention pond automatically. For Rainwater Harvesting (RWH) design, the software allows the users to choose one of two methods of designing RWH i.e. MSMA 2nd Edition method (Chapter 6) or SPAH method (JKR). The rainwater harvesting is a technique of collecting rainfall as a supplementary source of water supply for household, commercial, landscape and recommended to install for new development. The software can design the culvert based on the design discharge from one of three methods of computing peak discharge as follows: Rational Method, Time-Area Method and user defined discharge. The software provides checking tools for the users including Bridge Afflux Estimator, WQI Calculator and Statistical Analysis as an option for the users to evaluate the performance and reliability of the design.

MSMA Design Aid and Database System is interactive process software, which involves a number of different stakeholders such as water resource engineers, urban planners, economists, landowners and the public from, planning to designing stages. Therefore, this increases the pressure of making appropriate decisions when there are contrasting opinions from different stakeholders. MSMA Design Aid and Database System is suggested to upscale into Model driven Decision Support Systems (DSS) as in environmental/stormwater modelling are becoming more popular presently rather than the stand along modelling tools, which provide only a direct outcome. The major reason for that is DSS is a platform that combines both comprehensive modelling along with other important aspects such as social, technical and economic considerations that are becoming equally important in catchment modelling. However, along with the advancement of model driven DSS, some areas need be addressed in regards to increasing their accuracy and effectiveness. MSMA Design Aid and Database System can be further enhance by using the remote sensing and GIS technologies for large scale distributed catchment modelling and urban planning activities for processing, analyzing and visualizing digital spatial data. This also requires development of GIS and remote sensing mapping databases, developing links between models and the spatial software and enabling of the import and export of data sets between two platforms which itself needs to be further researched in the future.

MSMA Design Aid and Database System can be further improved by using Web based simulation as it provides a more integrated approach in modelling due to the ability to access a wider range of spatially distributed data sets. Future research studies need to conduct for selection of the best optimization algorithms for particular MSMA Design Aid and Database System selection processes. These optimization algorithms should also consider model runtimes and data handling capacities [7]. It is important for sustainability of MSMA Design Aid and Database System for the developer to consider the initial purchase price, upgrades and costs for on-going training and maintenance of the program are important criteria in model selection. Computers are routinely upgraded which directly affects programs due to different system requirements. Some programs may have a lower initial price but higher maintenance costs [8]. During urban stormwater modelling of a project, things can go wrong or data errors occur [9]. A hands-on software development is therefore an important part of the complete MSMA Design Aid and Database System software package.

4. Conclusion

The MSMA Design Aid and Database System have potential to be very useful software. The upgraded software development in the future will make MSMA Design Aid and Database System become portal based type decision support system. Further development in future will make MSMA Design Aid and Database System has the capability to integrate with GIS system and adopted by government agencies and engineering consultants in Malaysia.

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References

[1] Basri, N. (1999). An expert system for the design of composting facilities in developing countries. PhD Thesis, Department of Civil Engineering, University of Leeds
[2] Cohn, A. G., & Thomas, J. (1987). Artificial intelligence and its applications: John Wiley & Sons, Inc. USA
[3] DID. (2000). Urban Stormwater Management Manual, Volume 13, Chapter 34, Malaysia

[4] DID. (2011). Urban stormwater management manual for Malaysia: Department of Irrigation and Drainage Malaysia
[5] Gasching, J., Reboh, R., and Reiter J. (1981). Development of knowledge-based system for water resources problems: SRI international, Menlo Park, California
[6] Roesner, L.A., Amy Pruden And Elizabeth M.Kidner (2007). Improved Protocol For Classification And Analysis Of Stormwater Borne Solid, Water Environment Research Foundation, Colorado State University
[7] Saunders, M., Sullivan, T., Nash, B., Tonnessen, K., & Miller, B. (2005). A knowledge-based approach for classifying lake water chemistry. Knowledge-Based Systems, 18(1), 47-54
[8] Mohd. Sidek, L., Zakaria, N.A, Ab Ghani, A., Desa, M.N. & Othman, N. (2006). An Assessment Of Stormwater Management Practices In Malaysia, Jurutera IEM, p. 8-19
[9] Allison, R., Chiew, F and Mcmahon, T (1997). Stormwater Stormwater Pollutants Industry Report 97/11, Cooperative Research Centre For Catchment Hydrology, Monash University, Victoria