Management of Storm Water Quality in Urban Areas

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Abstract— The main aim of this paper is to highlight the importance of the management of storm water quality in enhancing their activities to improve regional water quality. The procedure on developing storm water management strategies consists of reviewing existing water quality data, identifying water quality issues and developing a decision making tool for the officers, managers and decision makers. It was found that land use activities are the main factor affecting the water quality. Therefore, activities, sources and pollutants related to different land use types including residential, industrial, agricultural and commercial are given high importance during the study. Different management groups and authorities were analyzed in order to understand the associated management framework and issues. The issues identified were used in preparing the decision making tool. Variables associated with the defined "value versus threat" decision making tool are obtained from the intensive literature review. The main recommendations provided for improvement of water quality, include non-structural, structural and management controls.

Index Terms— Storm water, water quality management, pollutants, land use.

I. INTRODUCTION

Storm water quality improvement is one of the highly important tasks which significantly affect the environment and the community. Development of innovative storm water quality management strategies and pollution control techniques will be required to control storm water pollution effectively [1]. Storm water runoff picks up natural and human-made contaminants that accumulated on surfaces during the dry days and transports them to the receiving waters bodies such as rivers, lakes and ocean. An approach that could identify the storm water quality would be a first step in solving this problem. Several studies have shown that the contribution of storm water pollutants must be considered in order to correctly implement an environmental preservation method for a receiving water body [2]. A common objective of most urban water quality studies has been to strive to relate land use to pollutant loadings [3] - [6].

As storm water typically flows into rivers and ocean or infiltrates back into the groundwater system which is used for drinking, storm water quality is an issue in most of the area. Literature show that storm water may contain different substances including heavy metals, nutrients, petroleum hydrocarbons, suspended solids and microbiological organisms, all depending on the land use of that area. The problem of storm water pollution is becoming worse because of population growth, which results in increased impermeable surfaces. With these increases the quality of storm water is becoming more of an issue around the world as general water quality awareness increases [7-8].

Storm water quality improvement strategy plans are documents that detail policies, strategies and regulations for storm water quality improvement in a defined area [9]. These plans provide a ways of prioritizing recommendation and resources to improve storm water quality in local authorities [10]. Several research have been highlighted in the literatures in drafting storm water quality improvement strategies, which are used by local authorities, managers and decision makers as technical guidelines. Storm water quality improvement strategies consist of discussion of existing storm water management system and the activities involved as well as the values, threats and issues. In order to prepare management strategies, it is important to analyze the land use types, existing storm water management systems and current issues related to storm water quality.

II. METHODOLOGY AND MATERIALS

Research approach is categorized in to four phases to ensure proper attention is given to appropriate issues. First phase is the preliminaries which includes understanding of storm water quality and their impacts on social, economic and environment. Data collection is the second phase in which existing storm water quality data, water quality improvement management procedures, strategy plans and other documents are collected from various sources. Figure 1 shows the summary of collected information. Semi structured interviews were also carried out with several water users and management authorities. Third phase is analyzing the collected data. This phase includes reviewing existing storm water quality strategy plans and other management procedures from local authorities, and other management bodies, reviewing management structures of local city councils and identifying issues associated with managers in terms of storm water. The last phase is results and discussion and providing recommendations for local authorities and storm water managers and users in a form of strategic plans and guidelines.

III. DATA COLLECTION AND DATA ANALYSIS

Fig 1 summarizes the storm water quality issues associated with urban areas. The areas have been divided into categories based on their land use activities.

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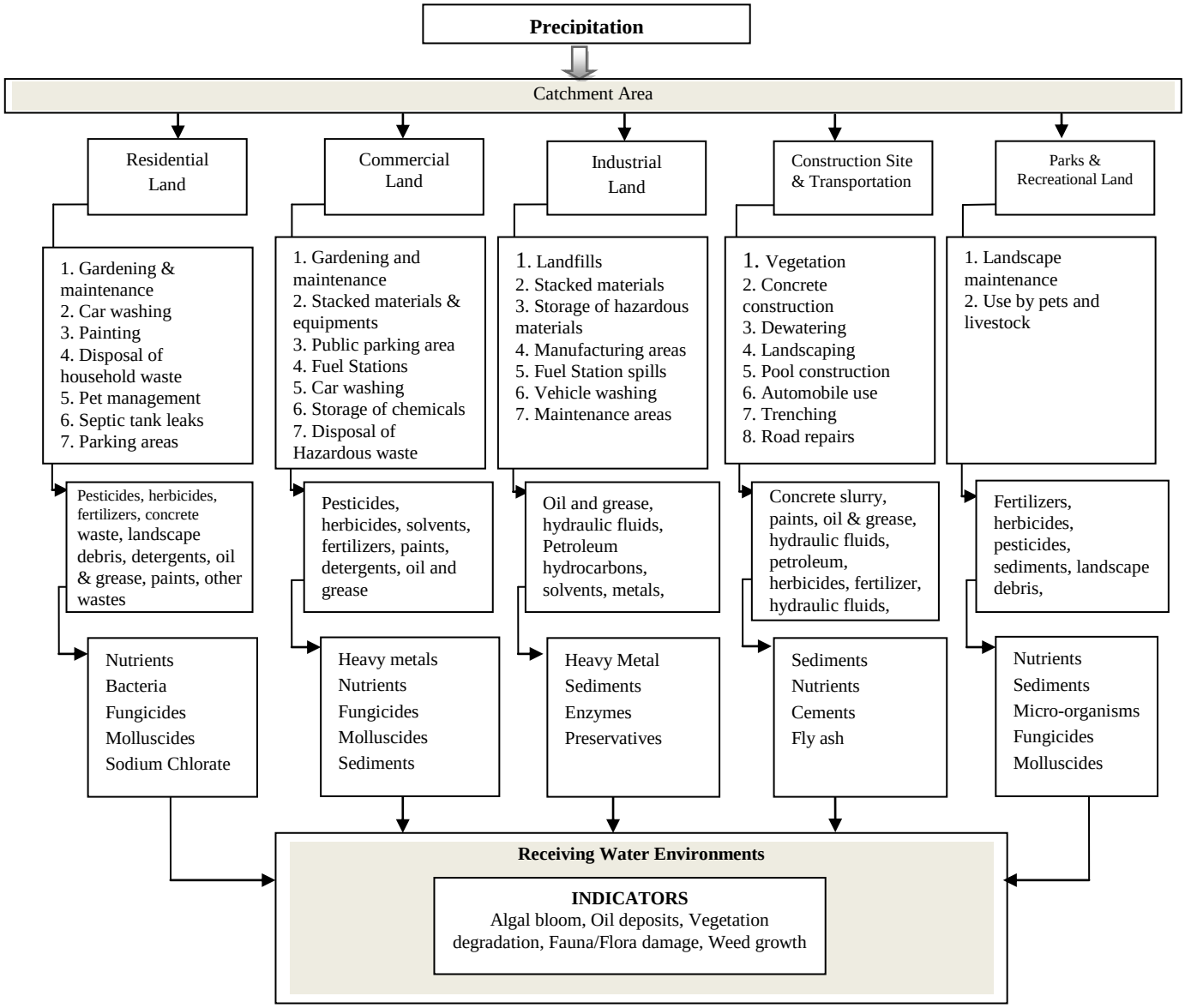

Fig 1 Storm water quality issues in urban areas

Table 1: Value vs. Threat decision making tool

	Threats							
Values	Residential land use runoff	Industrial land use runoff	Commercial land use runoff	Major road runoff	Public Open space runoff	Residential development runoff	Contaminated Sites	Sewer leakage
Environmental								
Amenity								
Economic								
Social/Cultural								
Impact Level								

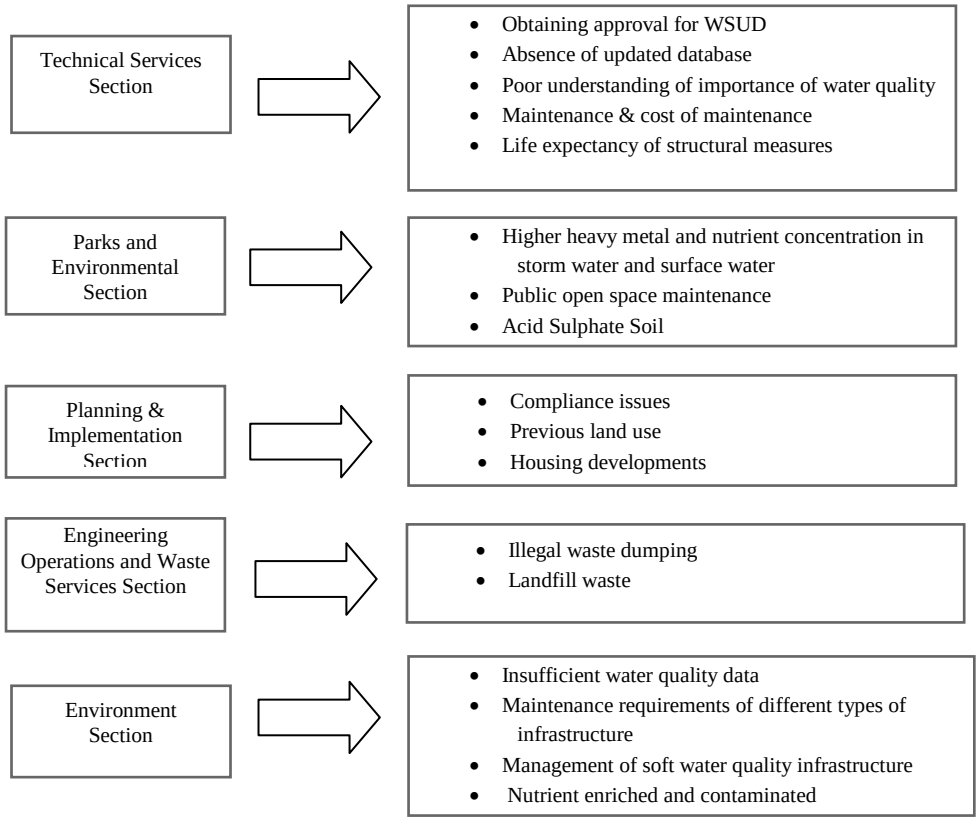

Fig 2 Different issues in water quality management structures and authorities

Main land use types are residential lands, commercial lands, industrial lands, construction sites and transportations, parks and recreational lands. Each land use type has different impacts and issues regarding storm water quality.

Semi-structured interviews were carried out with storm water users and management authorities to understand their responses and actions on storm water quality. Fig 2 shows that different issues in different water quality management structures and authority in terms of their actions and working procedures. These issues are identified common to most local authorities and local management bodies related to storm water quality management.

A. Values versus Threat Tool

As the main purpose of the Storm water Quality Improvement Strategy is to protect and enhance the values of receiving environment, a "Values versus Threat" tool was developed to assess the impacts of storm water quality on the environment. Values should reflect the uses of receiving environment to the community. The values can include environmental, various types of amenity, places of heritages significance and economic issues related to the receiving environments. Storm water threats include pollutants from land use activities. Table 1 provides the threats and values that can be used as guidance for the preparations of storm water management strategies.

Storm water managers can determine the impact levels related to threats on each values according to the existing storm water guidelines and by visual inspection of sites. These impact levels can be defined for each threat. The impact level for a site can be determined by adding the threats values. Table 2 provides a classification of impact levels. However, these impact levels should be defined appropriately by the councils according to their storm water quality issues and according to the recommendations by this study and future studies. During site inspections, compliance officers can assess the impact on a particular site by marking number one in the cells related to the inspection site. Summation of numbers will provide an impact level for each site. The necessary actions and related fund allocations can be obtained according to the impact levels for the particular site (Table 2).

Table 2: Classification of Impact Levels

Impact level	Description
0	Insignificant impact - No action required
1	Minor impact - Action required
2	Moderate impact - Action required
3	High impact - Action required
4	Extreme impact - Action required

IV. PROPOSED ACTIONS FOR SPECIFIED STORM WATER QUALITY ISSUES

Based on the outcome of the study, several actions and processes are proposed to manage the storm water quality issues and to improve the storm water quality.

They are classified in three groups as structural control, non-structural control and management controls.

A. Structural Controls

The following best management practices are essential in managing the storm water quality. These best management practices are effectively used by some local authorizes and managers, which contains some of retrofitting programs should assist in improving the effectiveness of these management practices.

Pollutant Traps (PT) –Source control is an effective way of treating the storm water. Pollutant traps can be employed in achieving source control for gross pollutants. The hotspots within the area should be identified for the construction of new pollutant traps.

Buffers – Buffers can be used to minimize polluted storm water runoff entering receiving environments such as rivers and streams. Also, buffer strips can be used around constructed wetlands and other storm water treatment infrastructure to reduce the frequency of maintenance due to sediments and litter.

Bioretention System – Bioretention systems include rain gardens and retention basins. Main purpose of constructing rain gardens is to uptake the excessive nutrients in storm water runoff which will then be used for growth of vegetation.

Vegetated Swales – Swales can be constructed either sides of roads as road reserves to minimize runoff from major roads. Vegetated swales are effective in sites where the longitudinal slopes are steeper.

Porous Pavements – Porous pavements are similar to vegetated swales. Authorities can implement these porous pavements in low traffic areas such as car parks and driveways.

Wetlands – Wetlands are very effective storm water quality control methods. However, the management and maintenance of wetlands should properly carry out. Regular maintenance of wetland is required to avoid the growth of unnecessary aquatic plants.

B. Non-structural Controls

Lack of community awareness of the importance of storm water quality is an issue which can be solved by introducing education campaigns. The following education campaigns can be commenced by local authorities and managers.

Fertilizer wise concept – This concept aims to reduce the amount of fertilizer in storm water runoff. It is useful to reduce fertilizer application in residential gardening. It also suggests the growth of native plants and type of fertilizer to be used for each soil type. This will also prepare community to adjust to decreased water usage due to climate change.

Green gardening program - The residents can be educated about alternative landscaping techniques which reduce the use of fertilizer. Authorities and volunteer groups can initiate the program by providing free gardening classes and donating plants for residents in the houses closer to waterways and surface water bodies, as they would have a significant impact on storm water quality compared to other residents.

Business education campaign - The purpose of this kind of campaigns are to educate the industrial and commercial sectors. This is very useful as cities contain larger proportion of industrial and commercial lands. The campaign can be targeted to ensure the business organizations comply with the existing storm water management guidelines.

C. Management Controls

Management controls are mainly institutions measures in managing storm water quality in an area.

Maintenance and cost –Maintenance of roads, street sweeping, litter collection and maintenance of storm water network is essential in improving the storm water quality. The maintenance of vegetated swales, buffers and rain gardens include watering them during dry periods, gross pollutant removal, weed control and litter removal. The cost of maintenance can be reduced by using native plants in vegetated swales, buffer strips and rain gardens which require less attention and fertiliser. Reduction of maintenance can be achieved by using biodegradable erosion control matting in swales.

Managing information - The absence of proper data collection system and database is a significant issue in most of the storm water quality management schemes. When considering the storm water treatment measures, a master database consisting locations, capacities, design drawings, dimensions and other technical information about the structural storm water management as well as the other useful information for the managers should be compiled for the proper and effective use.

Water quality monitoring - Water quality monitoring in different locations incorporating all the land use type is important in understanding the water quality issues.

Adoption to future climate change - As climate change affects the water quality changes and deterioration of water quality, climate change is one of the key areas to be considered. Climate change assessments should be carried out to identify the impacts of climate change on storm water quality and necessary management and adaptation processes should be started. Not only quality aspects, quantitative changes of storm water should be taken into account. Assessments of the impacts of climate change on storm water are important on catchment level, sub catchment level and basin level. It will help for local authorities to upgrade their drainage structures to adopt rainfall variations due to future climate changes.

V. CONCLUSIONS

Storm water runoff quality is an important aspect of natural water cycle. The main factor affecting the storm water quality as identified during this study is land use types. The main issues identified from interviews conducted with authorities and management bodies, are lack of understanding of the community regarding the storm water quality, maintenance and cost of maintenance of existing storm water structure and lack of communication among different management sections.

The decision making tool will assist local authorities and water quality managers and officers to determine whether or not the inspection site needs storm water management actions to improve the storm water quality and to determine the impact level. The storm water improvement strategies suggested in this study includes non- structural, structural and management controls. It is identified through the literature review that non-structural and management controls contribute to larger improvements in storm water quality.

It is discovered from the study that the impacts on storm water quality are mainly due to intensive land use. Therefore, it is essential to manage the release of nutrients and heavy metal concentrations. Public education campaigns can be utilized to control the fertilizer usage as discussed.

The storm water drains need regular maintenance and attention in order to prevent the pollution in receiving water environments. The gross pollutants should be trapped prior to discharging into receiving water environments. It is also recommended to identify gross pollutant hotspots prior to the installations of pollutant traps. The community involvement in the identification process is very useful and cost effective.

The lack of maintenance of structural controls in local and regional authorities indicates the lack of understanding of the importance of storm water management within the community. Therefore, managers and decision makers should be educated regarding the impacts of poor quality of storm water runoff. Also, preparing a maintenance plans with detailed maintenance steps will assist in achieving the best possible outcome from above mentioned education programs.

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Dr. Ranjan Sarukkalige is a senior lecturer in Civil Engineering at Curtin University, Australia. He completed his Bachelor degree in the field of Civil Engineering from University of Peradeniya, Sri Lanka and M.Eng degree from the Asian Institute of Technology (AIT), Thailand. He also completed his PhD in Civil Engineering at Tohoku University in Japan. He has over 10 years research and teaching experience in Civil Engineering including lecturer at University of Ruhuna Sri Lanka, Post-doctoral fellow at Tohoku University Japan. His research interests are mainly in water resources engineering especially in hydrology, storm water management and climate change impacts. He has published more than 30 research publications including the book titled "Effects of global warming on coastal groundwater resources", which has attracted significant attention among the professional and the community.