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Reconstituting the Strategies of Sustainable Stormwater Management

Membangunkan Semula Strategi Kelestarian Pengurusan Air Banjir

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ABSTRACT

Sustainable stormwater management strategies such as stormwater wetland, swale, porous pavement and green roof are about the replication of hydrology cycles to reduce quantity and to improve the quality of stormwater through stormwater infrastructures. There are many strategies available, however, little discussion on the relationship of the strategies with the hydrology cycles made the implementation less successful in managing the problem caused by stormwater such as flash flood and water pollution. Hence, this research aims to review the strategies of sustainable stormwater management. Two objectives formulated are (i) to identify the strategies of sustainable stormwater management, and (ii) to identify the relationship of the identified strategies with hydrology cycles. Online journal, forum discussion and e-mail interview were used as methods of data collection in this qualitative research. Five steps of descriptive comparative analysis were used to analyse the data. Consequently, the researcher had identified 18 strategies and listed the strategies in priority order. The 18 strategies are urban stream reclamation, tree canopy cover, change impervious to pervious cover, vegetated surface channel, rainwater harvesting, stream daylighting, infiltration basin, disconnection of impervious area, green roof, modification of soil, stormwater wetland and bioretention pond, barrier system, narrow street, rain garden and greenway. The identified strategies were listed in priority order based on relationship with seven hydrology cycles, which are interception, infiltration, surface runoff, depression storage, evapotranspiration, groundwater flow and interflow. The strategies were analysed with hydrology cycles to ensure the sustainability factors in listing the strategies to manage the stormwater.

Keywords: *Strategies; stormwater management; sustainability*

ABSTRAK

Strategi pengurusan mampan banjir seperti tanah lembap banjir, kawasan berpaya, turapan berliang dan bumbung hijau merupakan tiruan kitaran hidrologi untuk mengurangkan kuantiti dan meningkatkan kualiti air banjir melalui infrastruktur banjir. Terdapat banyak strategi yang ada, bagaimanapun, kurang perbincangan berkenaan hubungan strategi yang dilakukan dengan kitaran hidrologi membuat pelaksanaan yang kurang berjaya dalam menguruskan masalah yang disebabkan oleh air banjir seperti banjir kilat dan pencemaran air. Oleh itu, kajian ini bertujuan untuk mengkaji semula strategi pengurusan air ribut yang mampan. Dua matlamat yang dirumuskan adalah seperti (i) untuk mengenal pasti strategi pengurusan banjir yang mampan, dan (ii) untuk mengenal pasti hubungan antara strategi yang dikenal pasti dengan kitaran hidrologi. Jurnal atas talian, forum perbincangan dan temu bual melalui e-mel telah digunakan sebagai kaedah pengumpulan data dalam penyelidikan kualitatif ini. Lima langkah analisis perbandingan deskriptif telah digunakan untuk menganalisis data. Oleh yang demikian, pengkaji telah mengenal pasti 18 strategi dan menyenaraikan strategi mengikut keutamaan. 18 strategi tersebut adalah penambakan bandar sungai, kanopi pokok penutup, menukar kedap kepada penutup kedap, Saluran permukaan tumbuh-tumbuhan, penuaian air hujan, sungai siang, lembangan penyusupan, pemotongan kawasan telap air, bumbung hijau, pengubahsuaian tanah, tanah lembap air banjir dan kolam bio retention, halangan sistem, jalan sempit, taman hujan dan Greenway. Strategi yang dikenal pasti telah disenaraikan mengikut keutamaan berdasarkan hubungannya dengan tujuh kitaran hidrologi, dimana pemintasan, penyusupan, air larian permukaan, penyimpanan tekanan, penyejatpeluhan, aliran air bawah tanah dan aliran antara. Strategi ini dianalisis dengan kitaran hidrologi untuk memastikan faktor-faktor kemampanan dalam senarai strategi untuk menguruskan banjir.

Kata kunci: *Strategi; pengurusan air rebut; kelestarian*

INTRODUCTION

Stormwater happens due to the decrease of interception and infiltration rate of rainfall and the increase of speed and volume of surface runoff (Ahmad Sanusi Hussin 2005; Marsh 2005; Day & Dickinson 2008). Thus, stormwater can be defined as an excessive amount of surface runoff during precipitation. Stormwater is related to the changes in hydrology cycle in terms of change in interception, infiltration and surface runoff cycles. This hydrology cycles alteration happens due to urban development where the pervious cover of natural environment was change to impervious cover of concrete surface. Large pervious surface in the city such as buildings, roads, parking lots, solid pavements and storm sewers caused high volume of stormwater with high frequencies within a short period during heavy precipitation. As a result, the river in the city cannot contain the overflow of stormwater and causes flash flood issue in the city (Chia Chong Wing 2004; Ahmad Sanusi Hussin 2005; Marsh 2005; Day & Dickinson 2008).

The conventional mitigation of flash flood in city was done through river modification like broadening, deepening, straighten, structured and diversion the river to a massive network of concrete drainage throughout the entire city. This conventional stormwater management is known as structural conveyance approach (Chia Chong Wing 2004). Unfortunately, due to massive concrete drainage network, the stormwater issue was failed to be mitigated and causes other issues such as riverbanks erosion, decrease of water quality and degradation of river habitat (Marsh 2005). Besides, according to Department of Irrigation and Drainage (n.d.), conventional stormwater management has been identified as ineffective to mitigate the occurrence of flood, involves high cost of construction and maintenance and unfriendly to the user and the environment.

The alternative solution or strategy to concrete drainage is known as green infrastructure or sustainable stormwater management strategy. There are many examples of sustainable stormwater management strategies such as porous pavement, green roof, stormwater wetland and swales (Hager 2003; Marsh 2005; Australian and New Zealand Environment and Conservation Council 2010; Toronto and Region Conservation 2010). The strategies were listed under various sustainable stormwater management approaches such as Sustainable Urban Drainage Systems (SUDS), Low-Impact Development (LID) and Water Sensitive Urban Design (WSUD). The sustainable strategies aim to replicate the natural hydrology cycles based on source control mitigation concept. Source control mitigation is about how to integrate landscape elements with the sustainable strategies. The landscape elements are designed to increase the interception of rainfall through vegetation cover and increase the infiltration rate of rain water into the soil. The benefits of sustainable strategies are less cost of construction and maintenance, aesthetic enhancement of urban image, rehabilitation of the urban ecosystem, robustness in use of space and user friendly (Department of Irrigation and Drainage, n.d.).

Even though there are many strategies of sustainable stormwater management, there is no clear elaboration of its relation with hydrology cycles. Thus, the research questions raised are "What are the strategies of sustainable stormwater management?" and "What is the relation of the identified strategies with hydrology cycles?" Hence, the aim of the research is to review the strategies of sustainable stormwater management. To achieve the aim, two research objectives have been formulated which are (i) to identify the strategies of sustainable stormwater management, and (ii) to identify the relationship of the identified strategies with hydrology cycles.

LITERATURE REVIEW

Since the research focuses on stormwater, it is related to hydrology cycle because sustainable stormwater management is about how the strategies are designed to replicate the hydrology cycles function in managing stormwater. Therefore, it is vital to identify the hydrology cycles and biophysical elements involved. Marsh (2005) said that cycles of hydrology within a landscape are interrelated with biophysical elements such as topography, soils, and vegetation. Moreover, hydrology cycle is a continuous process of inflow and outflow in various phases and forms in the air, on land and in the sea (Ferguson 1998; Steiner 2008).

Based on literature from Ferguson (1998), Marsh (2005) and Steiner (2008), there are seven hydrology cycles, which are interception, infiltration, surface runoff, depression storage, evapotranspiration, groundwater flow and interflow (Figure 1).

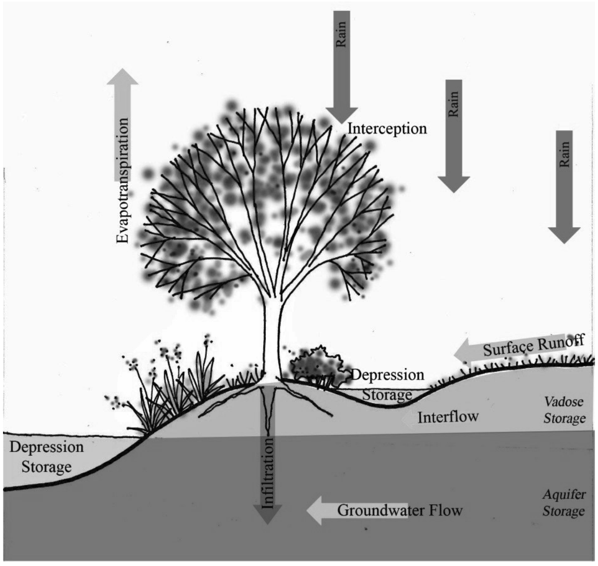

FIGURE 1. Hydrology Cycle
Source: Ferguson 1998; Marsh 2005; Steiner 2008

Meanwhile, there are four biophysical elements involved in the process of hydrology cycle, which are vegetation, soil, topography and slope and water bodies (Table 1).

In summary, the information gathered about hydrology cycle will be used as sustainability factors for the identified strategies in elaborating the relationship between the strategies with hydrology cycles.

TABLE 1. Hydrology Cycle and Its Interrelated Biophysical Elements

Hydrology Cycle	Biophysical Element Involved	Process
1. Interception	1. Vegetation (strata of trees, shrubs & groundcovers)	Interception & evapotranspiration.
2. Infiltration	1. Surface of landscape; 1.1. Soil (types, permeability & saturation) 1.2. Vegetation.	Infiltration & absorption through permeability of soil & by root systems of vegetation.
3. Surface runoff	1. Topography and slope. 2. Surface roughness; 2.1. Vegetation. 2.2. Soil type. 3. Water bodies (pond, lake, wetland & river)	Surface runoff flow into the lower area.
4. Depression storage	1. Topography (landscape depression) 2. Water bodies (pond, lake, wetland & river)	Collected within micro-topography & water bodies.
5. Evapotranspiration	1. Vegetation. 2. Water bodies (pond, lake, wetland & river)	Evapotranspiration; holding & retain the water & slowly evaporate to the air.
6. Groundwater flow	1. Soil (types, permeability & saturation)	Infiltration & absorption. Slowly discharge into streams through aquifer storage layer in the ground.
7. Interflow	1. Soil (types, permeability and saturation).	Infiltration and absorption. Slowly discharge into streams through vadose storage layer in the ground.

Source: Ferguson 1998; Marsh 2005; Steiner 2008

METHODOLOGY

Based on three elements of inquiry identified from Creswell (2003), qualitative approach was applied for this research. The first element of inquiry is constructivism as alternative knowledge claims which refers to the identified assumptions in research to seek for the complexity of views into few categories or ideas in understanding a process. Constructivism is appropriate to answer the research questions and objectives of research because researcher can classify the relationship between identified strategies with hydrology cycles. Secondly is grounded theory as strategy of inquiry. Grounded theory was selected because it can derive a general idea or theory (from the collected data) on how the biophysical elements of identified strategies replicate the hydrology cycle to manage stormwater sustainably (Charmaz 1994; Glaser & Strauss 1999; Merriam 2002;

Creswell 2003; Hunter & Kelly 2008). Lastly, methods used in this research were Google group forum discussion, e-mail interview and documents. Semi-structured forum discussion was used in Google group forum discussion (http://groups.google.com/group/rainwater-in-context). From the topic posted, 4 response were received with 8 attached links of documents were given by the respondents. Due to lack of respond, 20 posted topics related to strategies of sustainable stormwater management were reviewed. Furthermore, structured e-mail interview were sent to 578 of professionals and academicians in hydrology and stormwater management industry in Malaysia, United States of America, United Kingdom, Australia and Japan. Researcher received 8 responds with 13 attached documents. Besides, 35 topics (issue January 2007 until May 2012) from stormwater online journal (http://www.stormh2o.com) were reviewed.

Lastly, the collected data were analyzed based on five steps of analysis for qualitative approach by Creswell (2003). Firstly, the data were organized by transcribing interviews, forum discussions and documents. Secondly, obtain an overall understanding of the collected data. Thirdly, open coding was done by organizing the data into groups of information by comparing the similarities and differences of data. Fourth, elaboration of relationship between identified strategies with hydrology cycles was done. The elaboration was based on two questions which are (i) what are the biophysical element involved in the strategies? in addition (ii) how does the hydrology cycle work? Fifth, narrative passage approach was used to convey the findings by detailed elaboration of identified strategies with detailed discussion about interconnecting relationship of strategies with hydrology cycles. Finally, each strategy was listed according to list of priority. The list of priority was based on the highest relationship of identified strategies with hydrology cycles.

RESULT

There are 18 strategies have been identified after the analysis. First strategy is urban stream reclamation. Relation of urban stream reclamation with hydrology cycle comprises six cycles of interception, infiltration, surface runoff, depression storage, evapotranspiration and groundwater flow. Interception and evapotranspiration cycle happens through plant communities. Surface runoff and depression storage cycles happen through topography, slope and water bodies (stream). Lastly, infiltration and groundwater flow cycles happen through soil and plant roots. Meanwhile, interflow cycle cannot occur because reclamation of urban stream is within developed area. Based on argument by Stephens and Dumont (2011), in developed area, interflow has lost because of removal of vadose storage layer of soil through construction work such as insertion of pipe and digging of ditches.

Second strategy identified is tree canopy cover. Relation of tree canopy cover with hydrology cycle includes three cycles of interception, infiltration and evapotranspiration. Interception and evapotranspiration cycle happens through the foliage of tree. Meanwhile, infiltration happens through the roots of tree.

Third strategy is to change impervious cover to pervious cover. The goal of change impervious cover to pervious cover is to infiltrate rainwater and stormwater into the ground. Relation of change impervious cover to pervious cover with hydrology cycle involves two cycles of infiltration and groundwater flow. Infiltration and groundwater flow cycles happen through pervious cover medium and the porosity of soil. Meanwhile, even though interflow cycle happens in the soil, it cannot happen because the change of impervious cover to pervious cover strategy involves within developed or constructed soil where the vadose storage layer for interflow cycle has lost.

The fourth strategy is vegetated surface channel. There are three sequence sub-strategies in vegetated surface channel strategy which are (i) disconnection of pavement and roof drainage, (ii) directs runoff or stormwater into the vegetated surface channel, and (iii) the vegetated surface channel. The relation of vegetated surface channels with hydrology cycle consists of six cycles of interception, infiltration, surface runoff, depression storage, evapotranspiration and groundwater flow. Interception and evapotranspiration cycle happens through plant communities. Surface runoff and depression storage cycles happen through topography, slope and linear depression (channel). Lastly, infiltration and groundwater flow cycles happen through soil and plant roots.

The fifth strategy is rainwater harvesting. Rainwater harvesting relates to six hydrology cycles, which are interception, infiltration, surface runoff, depression storage, evapotranspiration and groundwater flow. The interception of rainwater harvesting refers to directing rainwater into a rain barrel to be stored. The infiltration, surface runoff, depression storage, evapotranspiration and groundwater flow refer to reuse of harvested rainwater for irrigation.

Sixth strategy is stream daylighting. Stream day lighting is an open drainage system to maintain natural hydrology cycle (Tunney 2001; Toronto and Region Conservation 2010). Stream daylighting strategy shows that it relates to six hydrology cycles, which are interception, infiltration, surface runoff, depression storage, and evapotranspiration and groundwater flow. Interception and evapotranspiration cycle happens through plant communities. Surface runoff and depression storage cycles happen through topography, slope and linear depression (stream or channel). Lastly, infiltration and groundwater flow cycles happen through the soil base of the stream and plant roots. Meanwhile, interflow cycle cannot occur because the stream daylighting strategy is a restored stream. This means that the vadose storage of previous stream had lost due to construction of the stream.

The seventh strategy is infiltration basin. Marsh (2005) indicated that detention and retention basins as a storage basin strategy to store rainwater and stormwater and allow it to discharge into the ground and evaporate over a period of time. In addition, the Toronto and Region Conservation (2010) listed the preservation or creation of micro-topography where infiltration basin is considered as micro-topography of depressed landform. The relation of the infiltration basin with hydrology cycle involves seven cycles, which are interception, infiltration, surface runoff, depression storage, evapotranspiration, interflow and groundwater flow. Interception and evapotranspiration cycle happens through plant communities. Surface runoff and depression storage cycles happen through topography, slope and landform depression. Lastly, infiltration, interflow and groundwater flow cycles happen through plant roots in the soil. All seven hydrology cycles are functioning if the basin is a natural basin. However, if the basin is constructed or fabricated, interflow cycle cannot occur because the vadose storage of the soil had lost because of construction of the basin.

The next strategy is disconnection of impervious area. Marsh (2005) stated that the disconnection of impervious surface from a drainage system is to reduce stormwater flow continuity. Meanwhile, Hager (2003) stated that the disconnection of impervious area is to redirect the runoff to vegetated area. The relation of disconnection of impervious area to hydrology cycle involves three cycles, which are infiltration, surface runoff and groundwater flow. The strategy focuses on surface runoff function through topography and slope. Lastly, infiltration and groundwater flow cycles happen through grassroots and porosity of soil when the runoff flowing along the impervious area.

The subsequent strategy is green roof. Relation of green roof with hydrology cycle is that it can function for three cycles, which are 1. interception through plant foliage, 2. evapotranspiration from plant foliage, and 3. absorption (limited infiltration) into the growing medium of soil. The researcher had classified infiltration cycle based on the consideration that infiltration of rainwater still happens even though the capacity is very low.

The following strategy is modification of soil. Modification of soil is crucial to repair the damaged and compacted soil during construction work for the improvement of subsurface hydrology cycles (infiltration and groundwater flow). The relation of hydrology cycle with modification of soil involves infiltration and groundwater cycle. The good aspect of this strategy is the improved capacity for runoff to infiltrate through soil pores and recharge the groundwater table and the improved of a healthy soil for root growth. Meanwhile, even though interflow cycle happens in the subsurface of the soil like infiltration and groundwater flow, this strategy cannot replace the lost vadose storage layer where interflow cycle is function.

The eleventh strategy is stormwater wetland and bioretention pond. Australian and New Zealand Environment and Conservation Council (2010) stated that the pond and wetland are used to remove nutrients, bacteria, fine, sediments and heavy metals. The stormwater wetland and bioretention pond strategy serves five hydrology cycles which are (i) interception; through plants in the wetland and pond, (ii) infiltration; through plant roots and soil base of the wetland and pond, (iii) depression storage; the concave depression of the wetland and pond, (iv) evapotranspiration; from the foliage of plants where the rainwater were intercepted, and (v) groundwater flow; through the underground soil after the water were infiltrated.

The twelfth strategy is barrier system. Marsh (2005) used the terminology of filter berm and infiltration trench to describe similar strategy, which is to contain and filter contaminants of stormwater. It was found out that the relation of barrier system strategy to hydrology cycle could be divided into two. First is the barrier system that directs the stormwater runoff into the natural depression infiltration site. The first category has seven hydrology cycles, which are interception, infiltration, surface runoff, depression storage, evapotranspiration, interflow and groundwater flow. The interception and evapotranspiration cycles happen through plants. The infiltration, interflow and groundwater flow cycles happen through the subsurface of soil with the help of plant roots. The surface runoff cycle is through the gradient slope or topography of grass surface that direct the stormwater runoff flowing into depression area. Lastly, the depression storage cycle happens within the depression of landform to retain and filter the collected stormwater. A second category of barrier system is that the depression landform of the barrier system is a fabricated or restored depression landform. In this category, the interflow cycle is not happening because of the absence of vadose storage layer in the soil.

The thirteenth strategy is narrow street. The first step of the narrow street strategy is to reduce impervious area of the street and its components like a lane of street, parking stall length and length of drive aisle. The second step is that the reduced impervious area will be integrated with rainwater strategies like swale, planter, vegetated buffer strip, rain garden, infiltration trench, dry well, permeable paving, channel, runnel, screen, inlet insert and pipe filter. Relation of narrow street strategy with hydrology cycle involves six cycles of interception, infiltration, surface runoff, depression storage, evapotranspiration and groundwater flow. Interception and evapotranspiration cycles occur through the plant of vegetated buffer strip, rain garden, screen, inlet insert and pipe filter. Next, infiltration and groundwater flow occur through the soil of swale, planter, vegetated buffer strip, rain garden, infiltration trench, dry well, permeable paving, channel and runnel. In addition, surface runoff cycle flows through the slope gradient of landform of swale, vegetated buffer strip, channel and runnel. Lastly, depression storage cycle occur through depression of landform of swale, planter, vegetated buffer strip, rain garden, infiltration trench and dry well.

The fourteenth strategy is rain garden. Rain garden strategy is related to six hydrology cycles, which are interception, infiltration, surface runoff, depression storage, evapotranspiration and groundwater flow. Interception and evapotranspiration cycles happen through foliage of plants. Infiltration and groundwater cycles happen through the soil medium of the rain garden. Surface runoff cycle happens along the edge slope of the rain garden. Lastly, depression storage cycle happens within the depressed landform of the rain garden area.

The fifteenth strategy is greenway. Greenway strategy is a combination of various strategies to form a series of interconnected green infrastructure strategies. Researcher classified greenway into two categories which it can be a conservation of the natural hydrology ecosystem like stream buffer and flood plain or a restored stream buffer and flood plain with others strategies. Researcher found out that the relation of greenway strategy to hydrology cycle could be divided into two. First is the greenway that uses conservation of the natural hydrology ecosystem like stream buffer and flood plain as the area to treat the stormwater runoff and control flood. The first category has seven hydrology cycles, which are interception, infiltration, surface runoff, depression storage, evapotranspiration, interflow and groundwater flow. The interception and evapotranspiration cycles happen through plants. The infiltration, interflow and groundwater flow cycles happen through the subsurface of soil with the help of plant roots. The surface runoff cycle is through the gradient slope or topography of fringe landscape of the greenway that direct the stormwater runoff flowing into the lowest depression area of the greenway. Lastly, the depression storage cycle happens within the lowest depression of landform to retain and filter the collected stormwater like a stream. A second category of greenway is the restored stream buffer and flood plain with others green infrastructure or rainwater management strategies. In this category, the interflow cycle is not happening because of the absence of vadose storage layer in the soil.

Lastly, the identified strategies were listed according to priority order. The priority order was based on the highest number of each strategy is related to the hydrology cycle. Table 2 shows the summary of strategies of sustainable stormwater management with the relationship to hydrology cycles.

TABLE 2. Relationship of hydrology cycles with the strategies of sustainable stormwater management

Strategies	Hydrology cycle	Interception	Infiltration	Surface runoff	Depression storage	Evapotranspiration	Interflow	Groundwater flow
1. Infiltration basins (use natural basin)								
2. Barrier system (with natural soil depression / channel)								
3. Greenways (with conservation of natural hydrologic landscape)								
4. Urban stream reclamation								
5. Vegetated surface channels								
6. Rainwater harvesting								
7. Stream Daylighting								
8. Infiltration basins (man-made basin)								
9. Barrier system (without natural soil depression or channel; man-made / restored)	Relation							
10. Narrow street								
11. Rain garden								
12. Greenways (without conservation of natural hydrologic landscape / restored)								
13. Stormwater wetland & bioretention pond								
14. Tree canopy cover								
15. Green roof								
16. Disconnection of impervious area								
17. Change impervious cover to pervious cover								
18. Modification of soil								

Legend:	
	Similar strategies with yellow colour code but with the present of natural / undisturbed biophysical elements
	Similar strategies with green colour code but without the present of natural / undisturbed biophysical elements (retrofit, restored, man-made)
	The strategies have a relation with the hydrology cycle
	The strategies do not have a relation with the hydrology cycle

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, there are 18 strategies have been identified where three similar strategies (refer to Table 2, number 1 is similar to number 8, number 2 is similar to number 9 and number 3 is similar to number 12) but has a different in terms the presence of natural or undisturbed natural water bodies ecosystem and without the presence of natural or disturbed natural water body's ecosystem. The strategies with the present of natural or undisturbed natural water bodies' ecosystem were coded with green color and the strategies without the presence of natural or disturbed natural water bodies' ecosystem were coded with yellow color. The list of differences found is vital in giving new insight in classification of sustainable strategies of stormwater management. The reason is that the strategies with presence of natural and undisturbed biophysical elements show the importance of conservation of natural biophysical elements in ensuring the hydrology cycle can function at optimum level. Whereas, similar strategies without the presence of natural biophysical elements (fabricated or restored) have lost certain hydrology cycles. Moreover, the 18 strategies were identified of their relationship with the hydrology cycles and its biophysical elements to ensure the strategies are comply with the aim of sustainable stormwater management, which is to replicate the hydrology cycle in managing stormwater. It is also to answer the research questions and to achieve the research objectives. Furthermore, the strategies were listed based on priority order in terms of their relationship with seven hydrology cycles (interception, infiltration, surface runoff, depression storage, evapotranspiration, groundwater flow and interflow). The benefit of priority list of order is to give a clear classification and information in decision making to the professionals.

In summary, three recommendations were identified. Firstly, identification and classification of strategies on the scientific information of local ecosystem and site condition needs to be carried out. The most important matter in the classification process is not the availability of scientific knowledge, but rather on how to relate and connect the availability of much scientific knowledge from different professional backgrounds into a consensus classification of the strategies. Secondly, it is crucial to raise the importance of sustainable stormwater management and to implement the strategies. In raising the importance, it is essential to illustrate the importance of sustainable stormwater management as a cycle phases where it involves the (i) awareness of sustainable stormwater management strategies among practitioners, (ii) need to implement the sustainable stormwater management strategies in every development, (iii) getting feedback from practitioners for future improvement as the practitioners are aware about any failure of the implemented strategies, and (iv) revision of the strategies over time by local authority to improve any deficiency. Lastly, to improve the strategies of sustainable stormwater management, researcher found out that the challenge is to outline the strategies in a compact built up urban area. Hence, a study on how to integrate the strategies with the impervious surface (buildings and roads) is needed. Current strategies such as green roof, green wall and porous pavement are a good start to manage the less availability of space.

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