POTENTIAL APPLICATION OF RAIN GARDEN TOWARDS SUSTAINABLE URBAN ECOSYSTEM AND ENVIRONMENT FOR STREETSCAPES

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ABSTRACT

Increased storm water runoff is a major concern in urban areas and it is mostly from the impervious surfaces. Therefore, the study of this research is on the potential application of rain garden in sustaining urban streetscapes as an innovative means for stormwater management to overcome the urban stormwater issues. The potential implementation of rain garden systems, types, and elements are further studied to discover the potential fitness in streetscapes particularly on street plantings. Native plants selection is one of a crucial part in enhancing the rain garden implementation. Then the most potential and ideal rain garden systems are recognized according to the level of issues and physical condition on the sites. The suggested implementation simply promotes vibrant living in urban area and harmonizes the relationship between green spaces and buildings spaces. Pedestrian walkway is one of the streetscapes elements identified that in need the rain garden system. Information was collected through the previous findings by some former researchers and it was supported by some local guidelines. A case study was conducted and the data collected were then compared to each other and with the existing condition of the sites that have been observed through field observation method. For median road and pedestrian walkways, open rain gardens would be the most suitable way to be applied where it holds a layer of pervious soil, which combines water restoration with plant life. It is recommended that the best materials that can be used for hard surface is interlocking bricks that can infiltrate the water effectively, and helped by the existence of vegetated land.

Keywords: *Rain garden, rain garden potential, streetscapes, stormwater runoff, storm water management*

INTRODUCTION

The rapid urbanization process is decreasing the portion of green areas that are advantageous to certain environmental changes in the future and it leads to the increment of cleared land to allocate such physical development such as road networks, housing area, paved surfaces and other manmade structures. In a way, this has given an undesirable effect to the environment and later could affect the society. Stormwater runoff is a phenomenon where whenever rain falls, it is not absorbed into the ground and flows over the land surface and become the stormwater runoff. Paved surfaces are impervious and the increment of them will increase the amount of stormwater runoff which causes flash flood to be happened (Strassberg and Lancaster, 2011). This research focuses on the application of rain garden as a stormwater management in sustaining urban environment particularly in streetscape areas. The

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elements of streetscapes involved in this research are the street plantings and ground surface materials used mainly for pedestrian walkways in mitigating the amount of storm water runoff. This research was conducted through document analysis and field observation method. Sites chosen for field observation are at the KLCC Park and Kuala Lumpur golden triangle (Figure 1) streetscapes which are; Jalan Bukit Bintang, Jalan Raja Chulan, Jalan Sultan Ismail, and Jalan Gading. The streets are chosen due to the rapid development within the area which simultaneously influencing the increment of paved surfaces.

The streets observation is focusing more on Persiaran Petronas for KLCC area (Figure 2), Jalan Bukit Bintang and Jalan Raja Chulan (Figur 3) for the Kuala Lumpur Golden Triangle. Therefore this research is to investigate on the streets that have the existing rain garden, the streets that do not have rain garden but have the potential to be improved, and the streets that do not have rain garden and potential.

Figure 1: Golden Triangle areas

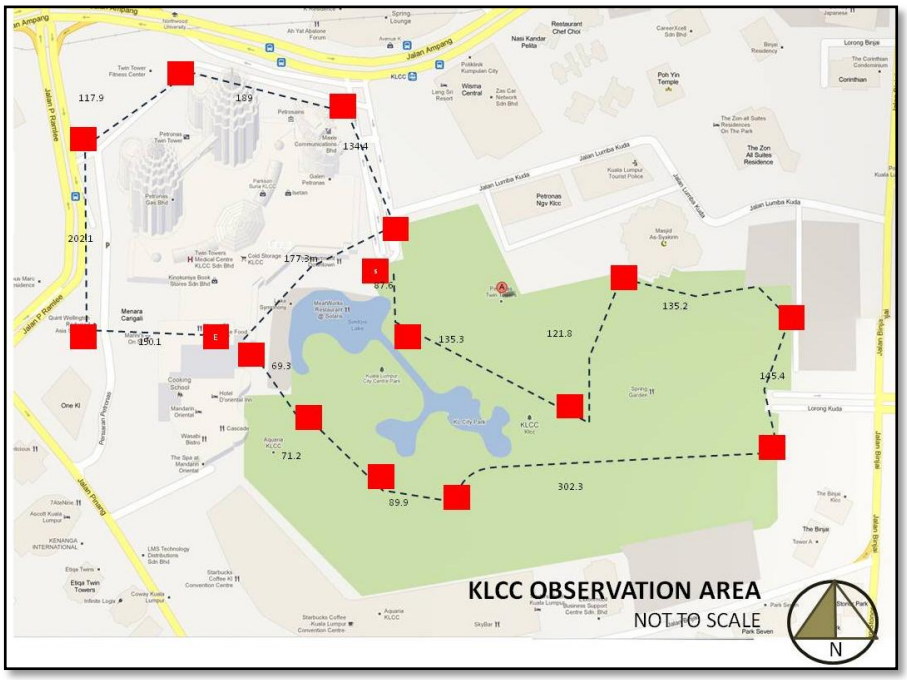


Figure 2: Persiaran Petronas to KLCC perimeter.

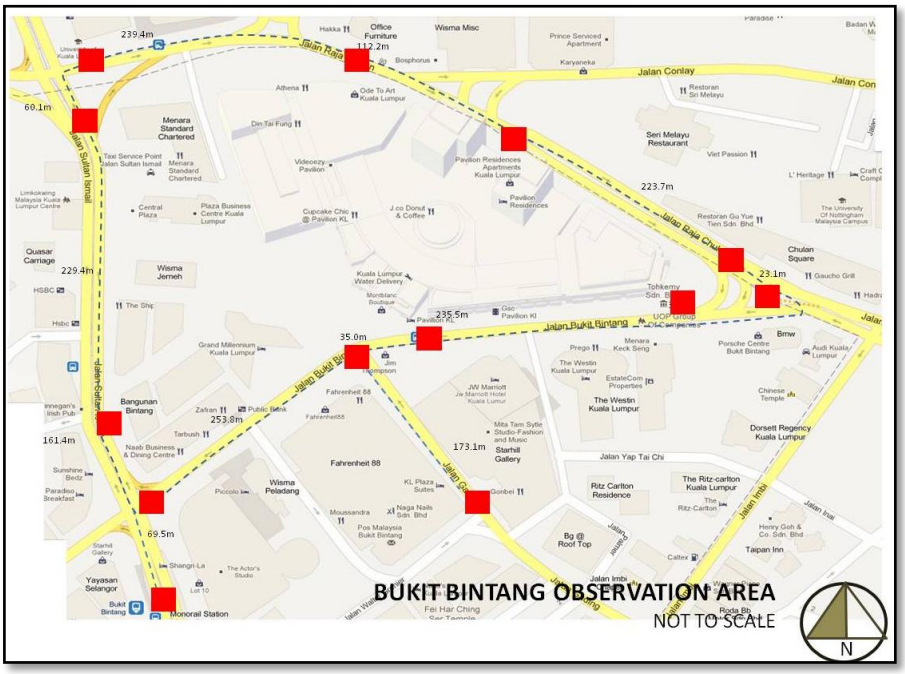


Figure 3: Bukit Bintang areas

All streets observed are mainly function as connection from a place to another for vehicular traffic and for pedestrian at the sidewalks. The aim of this research it to study the effect of streetscape designs of urban area in mitigating stormwater runoff. To achieve the aim, there are several objectives have been derived which are to study the street plantings and surface materials of the streetscapes, to study the relation of the street plantings and ground surface materials in mitigating the amount of stormwater runoff, and to compare the findings on the parameter observed based on the different site category and classification. This research is examined from two perspectives which are the ground surface materials analysis and comparison as well as the rain garden potential application in street planting. The harmonious proportion of material and ecological approach utilization are crucial in ensuring the sustainability of the urban streetscapes area.

THE ENVIRONMENTAL MATTERS RELATED TO THE URBAN AREA

Sani (1987:115) mentioned that Kuala Lumpur has been remarkably noticed of its environmental deterioration following the rapid urban growth and the industrial expansion. In a developed city, people are tend to build more buildings and use paved surfaces for the ground and deteriorate more existing green areas. This has led to the several

environmental matters such as excess stormwater runoff that cause flood to occur in urban area. The hydrological system of an urban area is greatly disturbed in relation to the land imperviousness. The degree of land imperviousness in urban area indicates the quantity of water surface run off. " The flow rates of water from development sites with high proportions of sealed surface can be two to three time that from predominantly vegetated surface" (City of Chicago, 2003-online). The consequence of the water surface runoff than lead to increased incidence of flood events in which not occur naturally but according to human acts towards natural environment (Göbel et al). Basically, when every time it rains, the excess water cannot be absorbed into the ground, then the stormwater will occur and flow directly to the nearest receiving water. Impervious surfaces such as asphalt, concrete, rigid brick paving which laid over a mortar bed and synthetic materials in urban areas have lower ability in infiltrating water than grass and gravel surfaces. Dunnett and Clayden (2007) identified that where there is an impervious surface, there is reduction in the amount of infiltration and increase in the amount of stormwater runoff. According to Barnes et al., (2002:4), there are five broad interrelated impacts which are water quantity changes, water quality changes, local energy balances and microclimates changes, degradation of habitat, its loss and fragmentation, and changes to stream and landscape aesthetics. These impacts could be mainly caused by an ultimate factor which is flooding that is caused by the excess stormwater runoff thus giving further bad impacts to the society. Excess stormwater runoff gives bad impacts to the environment that always lead to the flooding problem which lead to further destruction and obstacles to everybody involved with it. The decline of flood mitigation in urban area protects the property value up to 60%, saving about 27% of million budget infrastructures replacement or upgrade and cover up to 55.8 % cost of improving land condition for any development (Haughland, 2004).

Roles of Rain Garden as a Stormwater Management in Urban Area

Hunt et al. (2006:600) stated that *"a rain garden or also termed porous landscaping detention basin (PLDB) is designed to provide an infiltrating bed that is blended with landscaping bushes and vegetations."* Rain gardens are simply described as bioretention system to lessen the use of impervious surface areas and hold the ability to absorb water into the ground in degrading stormwater runoff. Researchers found a number of potentials of rain garden in the aspect of environment, social and economy which are mitigating stormwater runoff, runoff water treatment, enhancing the pedestrian environment, improve urban ecosystem structure, and promoting sustainability practice in design, construction and maintenance (Aravena and Dussaillant, 2009). Dunnett and Clayden (2007) added that rain garden is designed to take as much as possible of

the excess rain water runoff from its surroundings. Rain garden acts like sponge where rainfall can be captured and absorbed from the buildings and sealed surfaces and stored and released within the landscape.

Rain garden is one of the solutions in stormwater management. It can be implemented in various ways such as rooftop garden, vertical garden, wetland and others as long as it is implementing the practice of rain water infiltration. Rain garden can be in a form of natural wetland or can be technically constructed on the ground. For instance, some of the stormwater management used are extended detention pond, wet pond, infiltration trench and vegetative buffer strip. These stormwater managements basically consists of the combination of pervious pavement and vegetative elements to maximize the infiltration rate into the ground and minimizing the amount of the stormwater runoff before it is discharged to the receiving water.

For pocket spaces in urban areas, rain garden holds a layer of pervious soil, which combines water restoration with plant life (Ferguson, 2012). It will receive excess stormwater runoff, infiltrate it, treat it, and transpire it through the leaves of living plants. Street planting selection should be among the native plants because of its tolerance with the environmental conditions and enhancing the scenic beauty to the street spaces (Native Landscaping Conference, 2004). Montgomery (2004) in his research discover that native plants function optimally in the basic hydrological process (infiltration, evapotranspiration, interception, run off and conservation) that affected urbanization if exceeded interruption occurs. The native plants have been found initiating the recovery up to 82 % of the storm water excess in urban area. The capability water absorption and infiltration of native plants are better due to it complex rhizosphere or root system strength characteristic (Negri, 2004). Therefore, choosing the right planting and ground surface materials would be very helpful in infiltrating rainfall and the street planting could be able in enhancing soil perviousness to increase the rate of the water infiltration into the ground.

Modification of Streetscape Design through Characteristics of Surface Materials and Street Planting in Influencing the Amount of Stormwater Runoff

There are diverse types of streetscape design and it may consist of several elements such as street paving, sidewalks, curbs, street lighting, seating, street planting and others. Street paving plays a very important role in mitigating stormwater runoff. Common materials used for pavement are asphalt and concrete and they are widely used for vehicular

traffic and pedestrian walkways or sidewalks. Sidewalks could be comprised as a pedestrian zone which located nearest to the facade of building access and window shopping as well as an amenity zone nearest the curb for trees, plantings, street furnishing and cafe seating when there is sufficient width (Streetscape Elements - online). Normal asphalt and concrete widely used are in impervious condition due to its inexpensive costs for its installation and maintenance. This is also because it is easy to be installed and does not require a lot of manpower to install and maintain it. The perviousness of the surface materials is based on the materials component itself. Normally, other than asphalt and concrete, brick also has the minimum ability to absorb water into the ground. Impervious surfaces prevent water to infiltrate into the ground and will cause in the increment of excess stormwater runoff, while pervious surface will absorb water mainly from precipitation into the ground and help to reduce the quantity of stormwater runoff. Pervious surfaces also help to create sustainable urban ecosystem where it could help in reducing air temperature by evapotranspiration and help the street planting to grow healthily with the sufficient air voids provided by the soil.

Street planting can be placed anywhere on pedestrian walkways or vehicular traffic and also may function as a separation between both pedestrians and vehicles. In terms of design, plant materials should not interfere with circulation or users comfort. Street plantings can be trees, shrubs and groundcovers. Stormwater planter could be an element of street planting that able to retain and infiltrate water rather than put the plant on the bare land that could cause other problem such as soil erosion. For instance, as in Portland, they are "*planning to build 2,200 green infrastructure installations around the city and has a runoff retention standard that applies to building projects with even small amounts of impervious surfaces"* (To tackle runoff, cities turn to green initiatives - online).

Kuala Lumpur's Streetscapes

Streetscapes in Kuala Lumpur mostly composed by the infusion of old and modern structures with small to medium sized paved pedestrian walkways, where numbers of citizen appreciate the streetscapes as their business spaces. Since Kuala Lumpur was aggressively developed as business centre for Klang Valley, variety of streetscapes structure were introduced. Among them are sheltered pedestrian walkway and elevated pedestrian walkway function as the infrastructure to increase linkages from one point to another; connecting the public transportation system such as bus and light train to public areas, schools, and commercial buildings (Department of City Transportation-DBKL). Ironically, the increase of streetscapes

development in Kuala Lumpur is not according towards the mission of sustainability. The implication evaluation of streetscapes design toward drainage system in the future, the implementation of impervious materials and the efficient plant selection in streetscapes design are always being neglected by the developer in charged. These consequently contribute to the inefficiency of stormwater management in urban area of Kuala Lumpur.

Efficient drainage system must be at the top priority consideration for any streetscapes development due to the high imperviousness surface in urbanised area will directly drain the stormwater to the drainage lines. At certain point, drainage system sometimes incapable in holding high capacity of stormwater flow especially during the long duration of heavy rain. The installation of pervious materials simultaneously helps the water absorption process into the soils and reduces the stormwater amount transferred to drainage system. The water absorption process can be catalyzed up to the maximum level by implementing certain native plant species. Native plants species have the capability to absorb more stormwater because of its high resilient with the surrounding condition rather than indigenous species.

Rain Garden in Malaysia

The concept of rain garden is actually have been applied in this country but the term rain garden is still alien to be heard by the public. Therefore, the awareness of the rain garden existence and application is overlooked by the community as well as the authority. For instance, there is a pocket park of Japanese Garden (Figure 4) in the middle of the hectic road and that area is actually functions as an intersection or divider of the roads. Fortunately, it is functioning very well and the sense of calmness and feeling secure could be felt for whoever goes through or pass by that area.

Figure 4: Japanese Garden in front Standard Chartered Building at Jalan Sultan Abdul Samad- Jalan Raja Chulan Intersection

Rain garden terminology still a new exposure to Malaysia. The practice limited within new developed urban area and green-technology structure such as Iskandar Malaysia project in Johor and Putrajaya. However, some of core concept of rain garden is abundantly practiced all around Malaysia.

METHODOLOGY

Document Analysis

To study the ways or solutions to mitigate the quantity of stormwater runoff, the elements of rain garden are further studied to achieve the most appropriate way to apply it on the potential site. Rain garden may consist of natural elements such as plantings and technically constructed (engineered) such as trench or a combination of both. Therefore, data about street planting selection and ground surface materials are further studied and analyze. The data was obtained from the previous researchers that have been research about the rain garden elements that consist of its system, street planting selection and ground surface materials. Some of the findings from those previous researchers were then be guidelines in finding the right selection for the issues which are:

- Data about the rain garden system - to obtain the elements used in rain garden and their functions in urban areas
- Data about planting selection from Department of Irrigation and Drainage for Malaysia - to obtain the right planting selection to be used in urban areas.
- Data from the previous researchers about the ground surface materials - to obtain the component of each materials, rate of water infiltration of different surface materials thus to select the right materials.

These data were then analyzed to get the right suggestion to be applied in rain garden in urban areas to mitigate stormwater runoff.

Field Observation

Figure 5: Bukit Bintang route

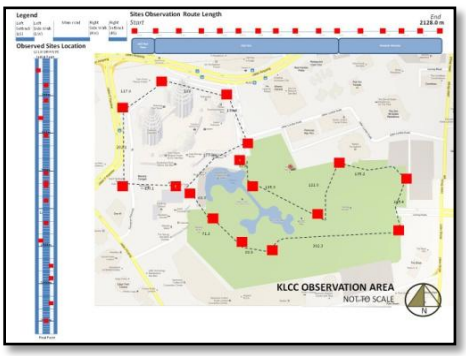


Figure 6: KLCC route

A field observation was conducted at the Kuala Lumpur Golden Triangle areas; Jalan Bukit Bintang, Jalan Raja Chulan, Jalan Sultan Ismail, Persiaran Petronas, Jalan Gading, Jalan Ampang and Jalan P. Ramlee. for this research, the focused areas are sidewalks including pedestrian and the median of vehicular traffic. For Bukit Bintang area, total distance that has been covered is 1.95km (Figure 5) and for KLCC area is 2.23km (Figure 6). The technique used was by walking along the street and images were captured to record areas that cover the existing basic system or practice of rain garden and areas that have potentials to install rain garden. Some areas were not assessed due to the tendency of observed sites along the streetscapes (either left or right of street) varies from one checkpoint to another due to the planting location, main road types, and current land uses or status such as construction site. The potential areas were identified to be improved mitigating stormwater runoff efficiently.

The streetscape covered and found along the journey of the field observation are including formal garden, park, plaza, pocket park, building setback, median road, sidewalk, and pedestrian walkways.

ANALYSIS AND RESULTS

Inventory and analysis of the field observation

Observation Site	Classification					
	Ground surface material		**Pedestrian walkway**		**Street Planting**	
	Pervious	**Impervious**	**With**	**Without**	**With**	**Without**
Bukit Bintang						
i.Jalan Sultan Ismail	✓	✓	✓		✓	
ii.Jalan Bukit Bintang		✓	✓		✓	
iii.Jalan Gading		✓	✓		✓	
iv.Jalan Raja Chulan	✓	✓	✓		✓	
KLCC						

i.JalanP. Ramlee-KLCC		✓	✓		✓	
ii.Jalan Ampang-KLCC		✓	✓		✓	
iii.KLCC Park	✓	✓	✓		✓	

Table 1: Classification of the observation areas

Table 1 shows the classification of the streets in terms of ground surface materials; pervious or impervious, the streets with or without pedestrian walkway, and the streets with or without street plantings. For ground surface materials, it is focused on the sidewalks and the majority of the materials used are impervious and only some of the route used combination of pervious and impervious materials. Based on the table also, most of the street that have been covered included the spaces for pedestrian as well as street plantings. This is shown that there are areas provided for pedestrian and street plantings but it is in the matter of how it has been applied on those particular areas. The analysis of the table as follow:

- For the materials used, the matters concerned are how pervious or impervious are the surface in absorbing water during rain.
- Pedestrian walkways were identified the width of areas whether it is sufficient or not so that it could be further identified whether it has potential or not to install rain garden on those particular spaces.
- Lastly, for the streets with or without street planting, it could be identified as the existing rain garden and could be further improved in terms of the better plant selection for improvement of the area.

Observation route for Bukit Bintang are shown in figure (Table 2) and KLCC in (Table 3). There are 14 checkpoints sites for Bukit Bintang and 16 checkpoints sites for KLCC selected based on streets taken to cover sites study perimeter.

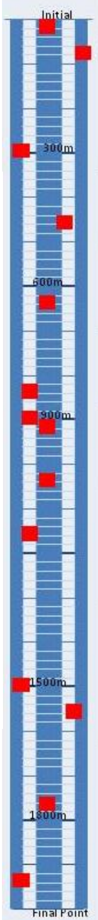
Observed Sites Location	Detail Site Location	Distance	Type of Site Observed	Grass swale	Sand or Organic Filtration	Rain Harvesting	Infiltration Trench	Pervious Paving		Storm drain Inlet/Outlet	Curb Inlet	Storm Water Planter
								Pervious	Impervious			
	*Jalan Sultan Ismail*	-	Median Road	/	/	X	X	X	X	/	X	X
	Jalan Bukit Bintang	69.5m	Sidewalk, Pedestrian Walkway	/	/	X	/	X	/	/	/	/
		253.8m	Sidewalk, Pedestrian Walkway	X	X	X	/	X	/	/	/	/
	Jalan Gading	173.1m	Building Setback, Sidewalk	X	X	X	X	X	/	/	/	X
	Jalan Bukit Bintang to Pavilion KL	35m	Pedestrian Walkway	X	X	X	X	X	/	/	/	/
	Pavilion Walkway beside Jalan Bukit Bintang	235.5m	Pedestrian Walkway	X	X	X	/	X	/	/	/	/
	Junction Jalan Raja Chulan-Jalan Bukit Bintang	37.4m	Sidewalk, Pocket Park	/	/	X	/	X	/	/	/	/
		23.1m	Median Road									
	Jalan Raja Chulan	223.7m	Sidewalk	X	X	X	/	X	X	X	X	/
		112.2m	Pocket Park	X	X	X	/	X	/	X	/	/
		239.4m	Sidewalk	/	/	/	/	/	/	/	/	/
		60.1m	Sidewalk	/	/	X	X	X	/	X	/	/
	Jalan Sultan Ismail	229.4m	Sidewalk	/	/	X	/	/	/	X	/	/
		161.4m	Sidewalk	/	/	X	X	X	X	X	X	X

Table 2: Bukit Bintang Observation Result

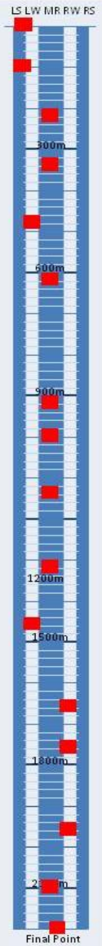
Observed Sites Location	Detail Site Location	Distance	Type of Site Observed	Grass swale	Sand or Organic Filtration	Rain Harvesting	Infiltration Trench	Pervious Paving		Storm drain Inlet/Outlet	Curb Inlet	Storm Water Planter
								Pervious	Impervious			
	KLCC Park Plaza	87.6m	Pedestrian walkway	X	X	X	/	/	/	/	X	/
	KLCC Park	135.3m	Pocket Park	X	/	X	/	/	X	/	X	/
		121.8m	Pedestrian Walkway	X	X	X	/	/	X	/	X	/
		135.2m	Pedestrian Walkway	X	X	X	/	/	X	/	X	X
		145.4m	Pedestrian Walkway	X	X	X	/	/	X	/	X	X
		302.3m	Pedestrian Walkway	X	X	X	/	/	X	/	X	/
		89.9m	Pedestrian Walkway	X	X	X	/	/	X	/	X	/
		71.2m	Pedestrian Walkway	X	X	X	/	/	X	/	X	/
		69.3m	Pedestrian Walkway	X	X	X	/	/	/	/	X	/
		177.3m	KLCC Park Plaza	X	X	X	/	X	/	/	X	/
	Persiaran Petronas	134.4m	Sidewalk	X	X	X	X	X	/	/	/	X
		189.0m	Sidewalk	X	X	X	/	X	/	/	/	X
		117.9m	Sidewalk, Median Road	/	/	X	/	X	/	/	/	X
		117.9m	Sidewalk, Median Road	/	/	X	/	X	/	/	/	/
		202.1m	Sidewalk	/	/	X	/	X	/	/	/	/
		150.1m	Sidewalk	X	/	X	/	X	/	/	/	/

Table 3: KLCC Observation Result

Figure 7: Existing streetscape condition in Bukit Bintang

In Bukit Bintang streetscapes, potential sites are observed according to the number of rain garden practices applied. The results shown in Table 2 that the minimal rain garden practices of observed sites is at least two, where the application tend to be located at dense human activities area with maximum paved surfaces; KL Pavilion Plaza and Walkway. The maximum result recorded at least six rain garden practices applied at the checkpoints where planting spaces are profusely available. The relevant of rain garden practices of observed sites are then identified according to the frequency of the practices applied. Rain water harvesting was observed hard to be found and

practiced. Whereas, storm water inlet/ outlet, trench infiltration, curb inlet and storm water planter were abundantly found in the site study particularly in high impervious covered surface area. Plants selection was observed are groundcover, shrubs, palms and trees. It was figured out that most of the plants were selected based on the purpose; greenery the city landscape rather than functioning the urban ecosystem living and controlling the stormwater flow.

Figure 8: Existing streetscape condition in KLCC areas

In KLCC streetscapes, Table 3 shown the minimal rain garden practice is at least three, where the applications tend to be located at dense human activities area with maximum paved surfaces; KLCC building setback, walkway and plaza. The maximum result recorded at least six rain garden practices applied at the checkpoints where all the checkpoints are located at KLCC Park. Rain water harvesting was observed hard to be found and practiced at ground level in contrast to KLCC Petronas Twin Tower that has water recycle technology. Contra from the Bukit Bintang area, the practice of storm water inlet/ outlet, trench infiltration, curb inlet, grass swale and storm water planter were found in high impervious covered surface area and KLCC Park. Although KLCC Park has high vegetation collection and green space, the grass swale practice were found not applied due to the area were mounded. In contrast to checkpoint at Persiaran Petronas, grass swale was practice in the KLCC front plaza and median road. There are lacks of research proving that the plants selected are able to tolerate and cooperate with stormwater management process. In KLCC, it was observed that

abundance of plants selection as the site was designed integrally including the landscape consideration. It was found that the plants selections in KLCC Park do have some influence in controlling stormwater flow. This is due to data finding that most of the checkpoints with the maximum potential show that site with open planting function better in stormwater absorption into the soil.

Generally, both observed sites study showing that the rain garden has various potential applications in urban environment. The results obtained from the two sites indicating almost similar result pattern in determining the most potential rain garden practices in a particular site. The results from both sites showing similar practices are applied in areas with similar characteristics which basically can be grouped into two; area with vegetation spaces and area almost paved. The data revealed that most sites with open planting spaces has the capability in integrating combined various practices to function efficiently rather than applying minimum practices. On the other hand, the data shown that most paved sites prone toward engineered approach if vegetation spaces are limited and the density of human activities are high. Areas with the absent of rain garden practices as mentioned reasons seem to have potential more in engineered aspects due to the capability of the sites to infuse with planting material are low or almost none. The engineered rain garden

Categorization of Ground Surface Elements on Sidewalks

Site / Material	**Jalan Bukit Bintang**	**Jalan Sultan Ismail**	**Jalan Gading**	**Jalan Raja Chulan**
Bukit Bintang				
Asphalt				
Concrete	✓			✓
Brick	✓			✓
Stone	✓	✓		

Wood				
Earth materials	✓	✓		
Synthetic				
Tiles	✓	✓	✓	✓
Kuala Lumpur City Centre (KLCC)				
Site / Material	**Persiaran Petronas**	**KLCC perimeter**	**KLCC Park**	
Asphalt				
Concrete			✓	
Brick			✓	
Stone				
Wood				
Earth materials		✓	✓	
Synthetic			✓	
Tiles	✓	✓	✓	

Table 4: Categorization of Ground Surface Elements found from the field observation of sidewalks of the sites

practices is suggested regarding it capability in increasing surface infiltration rate and drainage efficiency performance.

Based on Table 4, it shows that Jalan Bukit Bintang applied the various types of materials while Jalan Gading only applied one type of material which is tiles. For Kuala Lumpur City Centre (KLCC), the covered areas of the park for field observation are obviously seen using various types of materials as it is a park, while for Persiaran Petronas, it is just applied one type of ground surface material which is tiles.

Figure 9: Existing types of ground surface materials used in KLCC area.

From the same table, the material that has been widely used is tiles for both site areas of Bukit Bintang and KLCC areas. It can be seen that all of the roads involved in the observation have used tiles for the pedestrian walkways surfaces. This may be due to the use of tiles material have become a common practice in this country and influenced the authority to widely use it at this present time. Tiles is not too expensive in installing and do not require a costly maintenance, plus it is endured in extreme weather conditions. These reasons could be a factor in influencing the local authority to apply this material even though most of the condition is impervious to water.

It is also can be seen from the table that the areas covered for field observation for both Bukit Bintang and KLCC has the similarity of using the minimal material of earth materials. Earth materials include sand, gravel, soil, granular and turf and common of them used are sand, soil and turf. For Bukit Bintang area, the road that have applied earth materials on ground surface are Jalan Bukit Bintang and Jalan Sultan Ismail, while in KLCC area are at the KLCC perimeter itself and in the park. Earth materials are very cheap and easy to get from the supplier and it is as well may be cheap in installing it as the ground surface materials. However, it is costly in maintenance due to its characteristics and durability to the weather condition. For instance, soil will be muddy during wet period and become dusty during dry period.

Both Bukit Bintang and KLCC are well known as commercial and business districts which attract people to come and utilize the areas. Therefore, tiles material is used for ground surface because the authority

might need minimal maintenance to sustain the condition of the surface. Contrary to earth materials, even though it is cheap to install but it is hard and costly to be maintained in sustaining the condition. From the table, we could see that asphalt has not been used on both sites. This is because asphalt is commonly used for vehicular traffic and seldom used for pedestrian walkway, it is just not suitable for the sidewalks especially in business and commercial districts. Lastly, the table also shows that wood material has not been applied at any areas. This might be cause of the weather condition of this country that does not allow wood to be applied at outdoor environment. Furthermore, wood is costly in installing as well as maintaining it. However, those impervious materials used could be improved in its component to make it pervious to water thus, increase its ability in infiltrating water later help to mitigate stormwater runoff in urban area.

CONCLUSION

As a conclusion, it can be said that application of rain garden systems with pervious ground surface materials will be more efficient in mitigating stormwater runoff. When comparing these two factors to be applied in urban area, it shows that rain garden systems will consist of pervious materials in its component during the installation process. Rain garden would be in engineered system or natural system. The application will be depending on the sites characteristics where engineered systems will be applied on the areas that consist of the majority of impervious pavement, storm drain inlet outlet, curb inlet, stormwater planter and infiltration trench. While for natural system, as long as the place consists of vegetation, the rain garden system could be applied such as grass swale concept. Referring to this study, most of the ground surface materials are impervious but they can be improved in its aggregate component. The most effective materials found are pervious asphalt and pervious concrete. However, they are not really helping as a whole in terms of urban ecosystem where those materials will increase the air temperature surround it. Therefore, it can be concluded that each materials could be improved to make it pervious and can be used to increase the rate of water infiltration. Thus, whenever possible, vegetation and pervious ground surface materials should be incorporated in streetscape design as much as possible as to mitigate the quantity of stormwater runoff.

DESIGN RECOMMENDATIONS

Comprehensive of combined rain garden systems

From the research findings and literature reviewed, suggestion of appropriate combined rain garden practise for two different characters potential sites. Thus, Figure 10 shows the recommendation of combination of curb inlet, grass swale, infiltration trench, sand or organic infiltration and pervious paving; for the formation of complex rain garden system at the median road that already have rain garden elements. The

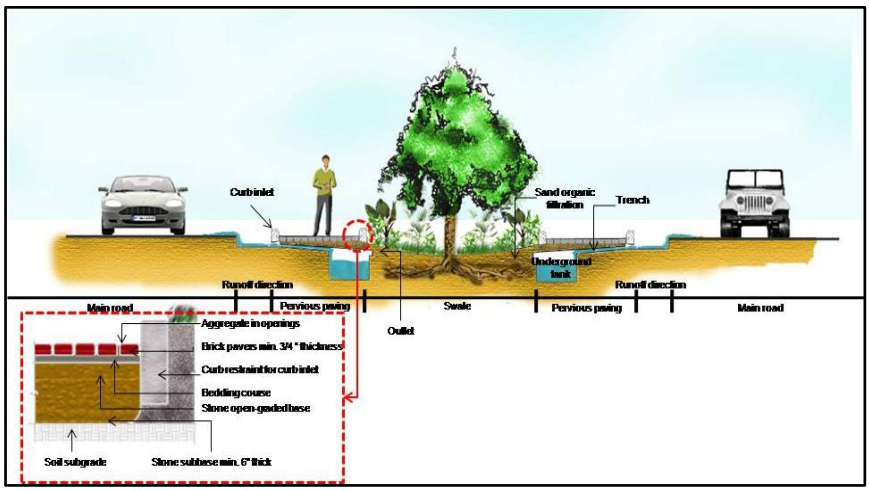


Figure 10: Recommendation of rain garden application of median road in Jalan Raja Chulan

underground tank is suggested into the rain garden practice system in the median road since that median road usually has disconnected drainage lines from the existing. The underground tank function as the temporary stormwater flow retention area before drain into the ground soil at the median road. These combination practices enhance the efficiency of stormwater runoff flow control and infiltration process before released into soils.

Figure 11 shows the recommendation of engineered rain garden practice. This recommendation is for streetscape that includes pedestrian sidewalks and the suggestion aims to mitigate the stormwater runoff effect by maximizing applicable rain garden practice in one comprehensive system for pedestrian walkways. The key concept is to imply pervious material that can allow stormwater to diffuse into infiltration channel and drain out to the nearest stormwater planter and absorb into the soil. Other option also can be done which is to imply pervious material connected to

infiltration channel and urban drainage system. The recommendation is focusing on the combination of curb inlet and outlet, trench, sand infiltration and stormwater planter box. This recommendation suits the area fully covered with impervious materials installation, building setback or sites with limited green spaces which have high rate of water runoff.

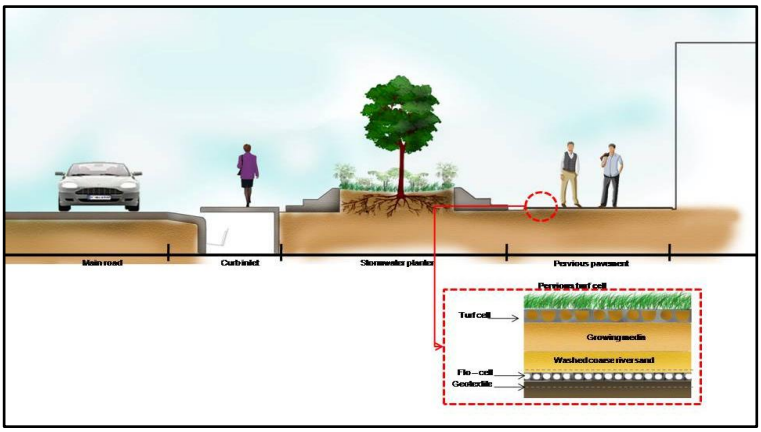


Figure 11: Recommendation of rain garden application of pedestrian walkway in Jalan Bukit Bintang

Suggested Plant Selection	**Suggested Ground Surface Materials**
 *Clerodendron peniculata* Pagoda tree  *Alocasia sp* Keladi	 • Pervious interlocking brick • Lay the bricks mortarless in sand. • Doing regular maintenance to avoiding sub base and joint

 *Canna generalis* Bunga Tasbih	 • Pervious turf cell • Allows water to infiltrate through it
 *Clerodendrum bucharanii* Java Glory Borneo	 • Pervious stone • Mix with bulky stone to create larger voids to absorb water.

Table 5: Recommended plant selection and ground surface materials

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