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Urban Flood Control and Management - An Integrated Approach

Ranjan Sarukkalige and Joseph Sanjaya Ma

***Abstract*—**Flood management is one of the important fields in urban storm water management. Floods are influenced by the increase of huge storm event, or improper planning of the area. This study mainly provides the flood protection in four stages; planning, flood event, responses and evaluation. However it is most effective when flood protection is considered in planning/design and evaluation stages since both stages represent the land development of the area. Structural adjustments are often more reliable than non-structural adjustments in providing flood protection, however structural adjustments are constrained by numerous factors such as political constraints and cost. Therefore it is important to balance both adjustments with the situation. The technical decisions provided will have to be approved by the higher-ups who have the power to decide on the final solution. Costs however, are the biggest factor in determining the final decision. Therefore this study recommends flood protection system should have been integrated and enforces more in the early stages (planning and design) as part of the storm water management plan. Factors influencing the technical decisions provided should be reduced as low as possible to avoid a reduction in the expected performance of the proposed adjustments.

***Keywords*—**Urban Flood, flood protection, water management, storm water, cost,

I. Introduction

FLOODS are the costliest disaster in the whole world, especially in the last few decades where we experience the changes in weather pattern and the increasing number of major storms [1]. In Australia alone, there are many areas that experience huge storm that was never experienced before even though it is considered a dry winter. The existing drainage system in Australia is built on 1:5 to 1:10 ARI rainfall capacity; however this is inadequate for some of the recent major storm and possibly in the future, therefore there is a major concern in regards to the existing drainage system capability. Urban flood management is necessary to avoid unwanted flooding event which can be prevented if it was properly planned and maintained. With the ever-changing environment, weather and surfaces, urban flood management has become something to be recognized and considered highly in storm water management. Storm water management consists of two main categories: storm water quality and storm water quantity. Storm water quantity is the main category that we will be looking at for dealing with flooding. Storm water quantity has several sub-categories that are related to flooding such as runoffs and storages [2]. Hydrological cycle has several factors influencing the process such as: land-use, soil condition, and climate change [2]. Land-use is the governing factor in determining the hydrological processes since it defines the shape, sizes and surfaces of an area. Climate change has begun affecting the hydrological process and it causes the change in the rate of precipitation and evaporation which it ultimately causes a change in the frequency of storms around the world [3].

Urbanization is the main contributor of the increase in urban area's impervious surfaces. In urban area, storm water storage management and runoff control are important factors in managing storm water. The utilization of storm water storages is to ensure the maximum usage and temporary volume control of storm water at all times in urban area [4]. Runoff control in urban areas is equally important to the existence of storm water storage. The increase in direct runoff due to the increase in impervious surfaces contributes to the change in storm water management of certain areas. The use of geographical mapping or numerical modeling is often introduced to analyze the urban runoff [5].

Storm water management has taken billions of dollars to plan and implement in Australia. A cost-effective approach has been introduced in the last few decades to get the maximum results from a minimum price. Case studies are often introduced in order to produce a cost-effective approach on decisions regarding storm water. Cost-effectiveness is often accompanied with sustainability. Sustainable development is highly regarded in the last few decades due to the increase in awareness of green environment. Sustainability does not only mean environmentally friendly, but also to increase the life-cycle of certain product to ensure minimum changes and maintenance that will generate a lesser environmental value [6].

II. Materials And Methodology

The methodology used in this study consists of data gathering, producing a priority list using a scoring matrix system, and providing a flood management solution to the flooded area. Data gathering consists of collection of appropriate materials and information on flooded areas, consultation with the local residents, flood managers, decision makers and policy makers analysis of the gathered data, determining causes of flooding, presentation of materials

Dr. Ranjan Sarukkalige, Senior Lecturer, Department if Civil Engineering, Curtin University, GPO Box U1987, Perth, Western Australia phone: +61-8-9266-3530; fax: +61-8-9266-2681; e-mail: P.Sarukkalige@curtin.edu.au
Mr. Joseph Sanjaya Ma, Civil Engineer, Victoria Park city council, Victoria Park, WA6100. phone: +61-402902785; e-mail: josephsanjayama@hotmail.com

gathered for next stage.

The next step will be to produce a priority list that uses a matrix scoring system. Categories in the scoring matrix consist of types of flooding (magnitude), types of land-use, and the history of the area in regards to flooding. Each category will present each area with the appropriate score with the combined score of the three category determines the priority of each of the flooded areas. In cases of equivalent total scores, the determination of the priority will come from the higher score of each area. The first category is the magnitude of floods, and the second is types of land-use, and the third is history or occurrence of flood. For flood areas that still have the same priority, the options are to either tackle the areas simultaneously or get an opinion from the higher-ups.

The last step is determining the appropriate solution for a flooding. The determination of causes of flooding will help to choose the appropriate flood management and to provide flood protection in the future.

III. Results And Discussions

A. Flood Disaster Management Cycle

Flooding is considered a disaster no matter how big or small the scale is. In dealing with disaster, we have to take the appropriate steps and understand all the factors involving the disaster. The disaster management cycle as shown in Figure 1 is a basic disaster cycle developed for floods.

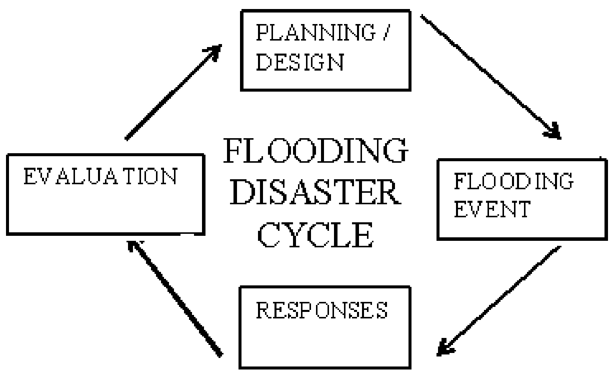

Fig. 1 Flood Disaster Management Cycle

An area always starts with a pre-development stage or planning and design stage where all criteria set by client is measured and check in compliance with the appropriate standards. In this stage the flood protection system is often not taken as in-depth as the other criteria, but the storm water management is usually introduced. Storm water management in planning stage includes the building standards such as the number of detention wells (soakwell), height of building relative to road level, and design of crossover; additionally storm water management also includes the requirement to follow the Water Sensitive Urban Design (WSUD) parameter. WSUD dictates the land-use has to be able to function while maintaining the environmental value and the use of storm water to its fullest. Although WSUD does not directly involve in flood protection, the requirement set by WSUD can be used as a foundation for a better flood protection. In some cases, the introduction of Best Management Practices (BMP) in the planning and design stages can happen. BMP is a structured method of getting, as the name implies, the best practices from the available management. Often BMP is introduced for a post-developed area; however it can also be applied to a new development as long as the BMP is applicable.

The next stage is the storm or flooding event itself, where depending on the system; flood warning and forecasting might be made available to the area. Flood warning is a system to allow people a certain amount of time to prepare for flooding either for the people to evacuate, build a last minute protection, or brace for the flood; and to allow the appropriate organizations in charge of flood protection some initiative time. Flood forecasting is a tool for predicting flood. It is usually done by a separate body of organizations that are in-charge of meteorology by predicting the change in weather, wind speed, humidity, cloud pattern and many more. Both flood forecasting and flood warnings are used to reduce the potential damage that will be done due to unpreparedness of people.

The appropriate step after the event will be the responses. Some of the common responses to flooding are damage controls, flood insurance and flood relief; in which all of them falls under flood mitigation. Flood mitigation is a well-planned and systematic approach or method that allows the people to take steps in dealing with the impacts of flooding. Some example of flood mitigations are helping out residents caught in a flood, supplying emergency provision and providing shelters to the victims of flooding, initiating flood modifications to reduce further damages, and preparing medical assistance in the flooded area. Flood reliefs are usually in the form of physical help from the higher authority whereas flood insurance is usually covering the costs side of the flood. In extreme flood cases, damage control is put into action to avoid a post-disaster accident such as health issues and structural/infrastructure safety. Flood insurance and flood relief however does not provide a solution towards flood protection or prevention. They are only the means of alleviating impacts or damages of floods. Flood mitigation that is intended as a flood modification instead is technically capable of providing flood protection and prevention albeit only to some degree. Flood modification allows the channeling or diversion of the current flood into some other places that is/are capable of storing the storm water, or to a permanent body of water that is still capable of holding enough storm water.

The last stage in the disaster management cycle is the evaluation stage. Evaluation period does not have a fix amount of time since the damage and extremity of flood are the factors in determining the amount of time needed. Often in evaluation period, the authorities are required to produce several solutions and proposals regarding the flood in both short-term and long-term effect. Some of the required data for producing such proposals are the extent or magnitude of the flood, intensity of the flood (flash flood or low flow rate over a long period of time), and the number of areas affected. The use of numerical modeling is highly recommended in this stage to provide a better solution in both long and short term. With that saying, it is safe to say that flood protection generally is made, designed, and planned in this stage.

A. Urban Flood Management – Response and Evaluation Stage

There are numerous methods that can be used in response and evaluation stages. Some methods rely on just technical aspects, while others rely on political judgment or financial capability only. A combination of those aspects are generally preferable in an ideal case, however since every local or higher authority have different approach in tackling flood problem then it is best to define a certain guidelines or a set of requirement that can used in those stages.

Starting from the earliest evaluation stages or immediately after responses has been given, we can try to prioritize the most severe of significant flooded area to be evaluated and implement the solutions as soon as practical. One of the methods that can be used to prioritize flooded areas is the use of a Priority Scoring Matrix.

1) Priority Scoring Matrix

A Priority Scoring Matrix is a scoring matrix or table which is basically a system that allows several cases to be analyzed simultaneously and categorically in order to determine the lowest and highest scores out of each other. The categories chosen were set as such to place it as a guideline for everyone to use and perhaps a modification by each authority might be needed to suit the organization's profile. The magnitude of flood as shown in Table 1 is the scale of flooding in terms of the size of the flooded area. The highest score is given to a larger and more significant area which is a suburb flood.

The second highest score or a score of 6 is given if a catchment or a floodplain is flooded. The lowest score or a score of 1 is given if a flood happens up to the point of a drainage system is flooded. In this category, the score is given based on the governing magnitude of flood that exist in an area. In other words if a residential property is flooded including the house, the higher score is given (4). Therefore if the house is also flooded, index has a higher score than just a property flood.

The second category is the types of land-use of the area. This category is simply awarding scores based on the types of land-use the flooded area currently sitting on. In this category the highest scores is given to commercial and multiple dwellings in a residential area; and the lowest score is given towards a park or a recreational area. This category emphasizes on the level of importance of the existing types of land-use, but this is subject to a modification by the appropriate authority to suit their organizational profile.

The last category is the history of the area in regards to flooding. This category is included to show the importance of the history of flooding in an area. Often, an area that has history of flooding is due to the geographical location or the nature of the drainage system of that area; therefore it is important for areas with history of flooding to have a higher priority than areas that has no history of flooding.

2) Flood Management Solution

After separating the flood cases based on their priority, we can move on to the analysis of each of the flood cases and find out the reason why the flood occur in that area. Generally, flooding occurs due to several causes. Therefore it is crucial for the authority to list out the causes of flooding for each area. From the list of causes of flooding, there are a number of ways on tackling the flood and provide a flood protection system to that area. Table 2 shows a simple guideline of getting the appropriate flood management solution for some of the general causes of flood. This guideline can be used or modified to match the most up-to-date information regarding causes of flood and the flood management solution.

TABLE I
SCORING MATRIX TABLE

Magnitude of Flood (score)	**Types of Area Land-use (score)**	**Flood History of the Area (score)**
Property flood (3)	Commercial (4)	No history of Flood (1)
House/Building flood (4)	Residential - single dwelling (2)	has History of Flood with implemented solutions (2)
Road flood (3)	Residential - multiple dwelling (4)	has History of Flood without implemented solutions (3)
Drainage overflow (1)	Industrial (3)	
Catchment/floodplain flood (6)	Agricultural (2)	
Suburbs flood (10)	Parks/Recreational (1)	

TABLE II
GENERAL CAUSES OF URBAN FLOOD

Code	General Causes of Flood
1	blocked storm water entrance
2	inadequate entrances or interceptors
3	inadequate piping or shortcuts or bypasses
4	inadequate storm water output storages
5	blocked storm water exits or outputs
6	low floor level or finished level
7	inadequate detention basin or wells
8	storm water overflow into property
9	storm water overflow into roads
10	inadequate overland flowpath capacity

TABLE III
FLOOD MANAGEMENT SOLUTION AND THE ASSOCIATED CODE FOR THE CAUSES OF FLOOD

General Flood Management Solution	Code Associated with Causes of Flooding
Drainage System Improvements	(2,3,4,5,7,10)
Flood Warnings and Public Awareness	(6,7,8,9)
Flood Reliefs and Flood Insurances	(ALL)
Landscaping	(2,3,4,6,7,8,9,10)
Maintenance	(1,5)
Land Use / Building Requirement Enforcement	(6,7,8,9,10)

Flooding can be prevented in the future by providing structural and non-structural adjustments to a flooded area. More often than not, structural adjustments are required to get a flood protection in an area. Table 3 provides the flood management solutions in relation to the causes of floods which were listed in Table 2. It needs to be pointed out that the causes of flooding could be managed and recommended to have a flood management solution as shown in Table 3; however this does not close the opportunity for another flood management solutions to be applied to the flooded area.

Flood reliefs and flood insurances as shown in Table 3, can be applied to all causes of flooding. The reason behind it, was due to the nature of flood relief and flood insurances being the common responses given by the government or any organizations as a result of flooding no matter the causes. However, it is more appropriate for flood reliefs to be implemented for larger magnitude of flooding; whereas the flood insurances are given to either a large magnitude of flooding or smaller scale flood but in large number.

3) Flood Management Issues: Influencing Factors

Flood management is often influenced by factors affecting the decision made such as politics, costs, and national guidelines or standards. Those factors are common in any organizations especially local government authority. To better illustrate those factors, the figure below can be used to see the influence of the factors mentioned previously.

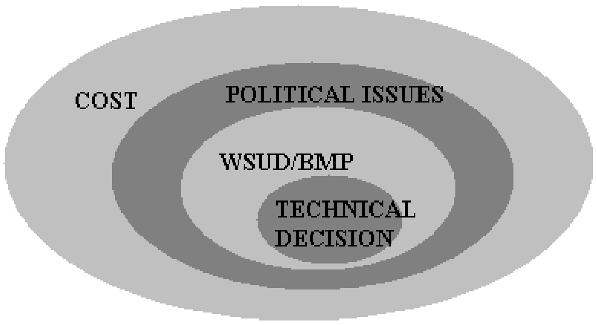

Fig. 2 Influencing Factors in Flood Management

As shown in Figure 2, the technical decisions provided as a result of analysis and investigations are often changed due to the some factors. The first factor influencing the decision is the requirements either set by the government or the organization itself. Water Sensitive Urban Design (WSUD) is one of the factors in determining the appropriate structural or physical adjustments made in relation to storm water. Some organizations will provide a Best Management Practices (BMP) as a guideline into getting the appropriate decisions for a flooded area. Above the requirements, political interferences are often encountered. Political interferences in this matter can be in the form of prioritizing certain areas by the order from the higher-ups, or interfering with the technical decisions provided by changing the decisions in order to suit the organization or individuals. Political issues are encountered especially in larger organization and government authority, even though it might not be often. Cost however, is the biggest factor when determining the appropriate action for a flooding. Structural adjustments are often constrained by the available funding; therefore there needs to be additional proposals generated in order to avoid costs issue. In local government, funding is limited to certain amount, and the worst part of it is the limited funding has to be separated into several categories such as road works, maintenance, government plans, and many more including storm water. Costs therefore are the main issue especially for structural adjustments.

IV. CASE STUDY FROM VICTORIA PARK, WESTERN AUSTRALIA

A case study was conducted on two flooded areas within the Town of Victoria Park, Western Australia. This case study is purely for educational purposes, therefore specific information will not be shown and instead it is masked as another name but with the same condition of property. One of the flooded areas is called property A, which was flooded due to excess storm water coming from across the road during a huge storm. It was found out that the storm water entrances and pits were not adequate to support more than 1:5 ARI storm, and property A has a history in flooding as well. One of the biggest issue near property A was the main storm water pipe leading from the entrances towards the sump was graded negative (i.e. flowing back towards entrance), which is opposite of what the expected performance is. Some technical decisions were made such as upgrading the existing sump along with fixing the gradient of the main pipes, or building a new sump across the street and install a new pipe leading towards the new sump. However, the final decision made was actually re-constructing the storm water entrances from gullies into a side-entry-pit due to cost constraint even though it does not increase the storm water capacity of property A to more than 1:5 ARI.

By studying property A and the process leading to the implementation of solutions, we can see that the final decision made was influenced heavily by cost even though the problem lies with the storm water capacity of the area, and requires structural adjustments that will increase the storm water capacity of the area. If another storm larger than 1:5 ARI do hit the area again, the chance of flooding will still be very high since the structural adjustment made were not adequate to support more than 1:5 ARI. It needs to be noted that by using the flood management solution as shown in Table 2 and 3, for any inadequacy of storm water capacity the appropriate solution is to implement drainage system improvement in however, it need to be able to increase the capacity higher than before such as 1:10 or 1:20 ARI.

V. Conclusions And Recommendations

Flood management is one of the important fields in urban storm water management; even though it is merely a small part of it. Identifying the characteristic of flood itself will be the first priority in a flooding event. Flooding occurs due to the increase of huge storm event, or improper planning of the area. It is therefore important to spread out the understanding of the sequence leading to and beyond a flooding event such as the disaster management cycle. One of the contributing factors that will lead to flooding are climate change (increase in larger storm events), urbanization leading to more impervious areas and larger direct runoff, and the lack of resources being provided to boost the storm water management sector.

Flood protection can be provided in four stages; planning, flood event, responses and evaluation. However it is most effective when flood protection is considered more in planning/design and evaluation stages since both stages represent the shaping of the area. Structural adjustments are often more reliable than non-structural adjustments in providing flood protection to the area, however structural adjustments are constrained by numerous factors such as political constraints and cost, more than the non-structural adjustments. Therefore it is important to balance both adjustments with the situation. Political interferences will be encountered from time to time in any organizations. The technical decisions provided will have to be approved by the higher-ups who have the power to decide on the final solution. Costs however, are the biggest factor in determining the final decision. Therefore this study recommends flood protection system should have been integrated and enforce more in the early stages (planning and design) as part of the storm water management plan or drainage system. The standard requirements such as Australian Standards, Building Code of Australia, and WSUD should have been followed and supervised until the implementation or construction is finished on site. Factors influencing the technical decisions provided should be reduced as low as possible to avoid a reduction in the expected performance of the proposed adjustments.

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Dr. Ranjan Sarukkalige is a senior lecturer in Civil Engineering at Curtin University. 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 completed his PhD in Civil Engineering at Tohoku University in Japan. He has over 10 years research and teaching experience in Civil Engineering including lecturing at University of Ruhuna, Sri Lanka and being a Post doctoral fellow at Tohoku University, Japan. His research interests are mainly in Water Resources Engineering especially in hydrology, stormwater 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 professionals and the community.

Joseph Sanjaya Ma is a Civil Engineer at the Victoria Park City Council, Western Australia. He completed her Bachelor degree in the field of Civil Engineering from Curtin University, Australia. His research interests are mainly in Hydrology, Flood evaluation, Water Resources Engineering and storm water management.