SOFTWARE DEVELOPMENT FOR REGIONAL DETENTION POND DESIGN USING VISUAL BASIC 6.0 – A CASE STUDY ON SUNGAI AIR SALAK CATCHMENT –

by

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ABSTRACT

Nowadays, detention ponds are widely used in controlling flood due to its capacity in storing the additional surface runoff generated from development. The procedures for the estimation and routing of design hydrographs are presented in the Urban Stormwater Management Manual for Malaysia (MSMA). However, the complexity of the calculations and the number of hydrographs that need to be estimated and routed through the basin makes manual calculation methods very wearisome and time consuming. Thus, this study was carried out to develop a computerised modelling using *Visual Basic 6.0* to ease and speed up the design process. In order to develop a computerised modelling of a detention pond, the catchment's area of the Sungai Air Salak was analysed. The study focused on the use of a regional detention pond which can provide satisfactory storage on catchments of more than 80 hectares. In regional detention pond design, Time-Area Method was used to obtain the inflow hydrograph for pre-development and post-development whereas Storage Indication Method was applied to design the pond size as well as the outlet structures. From the study and design that were carried out, a simple and user friendly computer modelling was developed. This system is easy to use and is able to provide an effective detention pond design without having to go through MSMA and design it manually.

ABSTRAK

Pada masa kini, kolam tahanan digunakan dengan meluas untuk membantu dalam mengawal masalah banjir kerana sumbangan kapasitinya untuk menyimpan air larian permukaan tambahan yang disebabkan oleh pembangunan. Tatacara untuk membuat anggaran dan penghalaan hidrograf rekabentuk telah disediakan dalam Manual Saliran Mesra Alam Malaysia (MSMA). Walaubagaimanapun, kompleksiti pengiraan dan bilangan hidrograf yang perlu dianggarkan dan dihalakan melalui basin membuatkan pengiraan secara manual adalah sukar dan memakan masa yang lama. Oleh yang demikian, kajian dijalankan untuk membangunkan suatu permodelan berkomputer menggunakan *Visual Basic 6.0* untuk memudah dan mempercepatkan proses rekabentuk. Bagi tujuan membangunkan suatu permodelan berkomputer, kolam tahanan di kawasan tadahan Sungai Air Salak dianalisis dan direkabentuk. Kajian ini memberi tumpuan kepada kolam tahanan jenis serantau di mana ia mampu memberikan kapasiti penyimpanan yang memuaskan bagi kawasan tadahan yang lebih daripada 80 hektar. Dalam rekabentuk kolam tahanan jenis serantau, kaedah Luas - Masa digunakan untuk mendapatkan hidrograf aliran masuk bagi pra-pembangunan dan pasca-pembangunan. Manakala kaedah indikasi storan diaplikasikan untuk mendapatkan saiz kolam serta struktur alur keluar. Melalui kajian dan proses rekabentuk yang dijalankan, suatu permodelan berkomputer yang mudah digunakan serta mesra pengguna telah dihasilkan. Tambahan pula, ianya mampu menghasilkan suatu rekabentuk kolam tahanan yang efektif tanpa perlu merujuk kepada MSMA serta merekabentuk secara manual.

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INTRODUCTION

1.1 Preface

Development on the land changes how water naturally travels through the watershed. As development occurs, the increase of impervious surface areas increase surface runoff volumes and decrease the volume of infiltration. The result of increased runoff and reduced groundwater are two-fold. Firstly, the large amount of extra runoff causes nearby streams to have much higher flows than natural, and the flow rate increases and drops off more rapidly after a storm. Secondly, due to the reduced infiltration volumes, there is less water available to be released slowly into the stream over time, resulting in lower water levels in streams between rainfall events. In effect, much of the water that under natural conditions, infiltrate into the ground and slowly make its way into nearby creeks now enters the stream all at once.

These changes from natural landscapes can have a number of effects on stream flow, including:

- More frequent flooding and erosion.
- Faster rising and falling flood levels.
- Increased flows in streams that are often dry.
- Reduced groundwater flow due to decreasing rainfall infiltration.
- Degradation of rivers, lakes, and coastal waters

(http://www.deh.gov.au/coasts/publications/stormwater/65)

In an effort to overcome the problem of flooding in the urban areas, various programmes have been carried out including river rehabilitation and the construction of main drains, drainage structures and pump houses. Studies have also been carried out to upgrade and improve the existing urban drainage systems.

As a result of the adverse consequences of urbanization, stormwater has become an important part of the general field of water resource engineering and environment. Today it has become clear that it is an important subject that must be addressed to solve problems of integration in water management. Stormwater is the integrating factor that connects water sources to receiving water. Stormwater management can help to achieve numerous objectives of urban development, including flood control, water quality enhancement and generally better living conditions in urban areas.

In view of rapid urbanisation in the region, Department of Irrigation and Drainage (DID) Malaysia has introduced the Urban Stormwater Management Manual for Malaysia (MSMA) in January 2001. The manual was prepared by DID to replace the earlier urban drainage manual, '*Planning and Design Procedures No. 1: Urban Drainage Design Standards and Procedures for Peninsular Malaysia' (1975)*. It is more comprehensive, considering the present problems faced by the nation such as flash floods, river pollution, soil erosion, development in the highlands and lowlands. The strategy is back-to-nature. This approach utilizes:

- detention/retention to temporary store some of the water
- infiltration to reduce the runoff
- Purification to improve the water quality reaching the river system.

With this new approach, the impact of new developments on the quality and quantity of the runoff can be minimised. The usage of the manual in development project can also reduce the project cost.

Since then, MSMA has been used by all regulators, planners and designers who are involved in stormwater management. It identifies a new direction for stormwater management in urban areas in Malaysia. This manual covers all aspects and requirements of stormwater management for urban area throughout Malaysia. (http://agrolink.moa.my/did/papers/laporanjps99_2.html)

1.2 Study Objective

The title of the proposed research is Regional Detention Pond Design for a Case Study on Sungai Air Salak Catchment's area. Computerised modelling is included in this project. This design is done according to the design procedure which is fulfilling the requirement stated in MSMA.

The main objectives of this study are as follow:

i. To study the flood problem in Sungai Air Salak area and to mitigate it with detention pond method.

ii. To proposed an effective and economic detention pond design procedure manually according to MSMA to prevent and mitigate flood disasters that occur in Malaysia

iii. To create a computerised modelling of regional detention pond design by using *Visual Basic 6.0* to make ease and speed up the design process.

The outcome from the study is an effective and economic detention pond and a computerised modelling of detention pond design in a Visual Basic form.

1.3 Scope of Study

This project includes study on detention pond design procedure which is fulfilling the requirement stated in MSMA to mitigate the flooding problems that occur in Sungai Air Salak area and also in the region. The study also includes:

- Carry out hydrological and hydraulic analyses
- Formulate concepts and criteria relating to the design of detention pond
- Carry out detailed design of the detention pond
- Developed a computerised modelling for a complete detention pond design

1.4 Background of Study Area

The study site was Sungai Air Salak which is located in Melaka Tengah District, Melaka. The length of Sungai Air Salak is 4.20 km and the project covers a catchment's area of 35.71 km^2. The project area is divided into three sub-catchment areas as shown in Figure 1.1. A detention pond is designed for the sub-catchment named S3 (MK 5350) which covers a catchment's area of 623.38 ha.

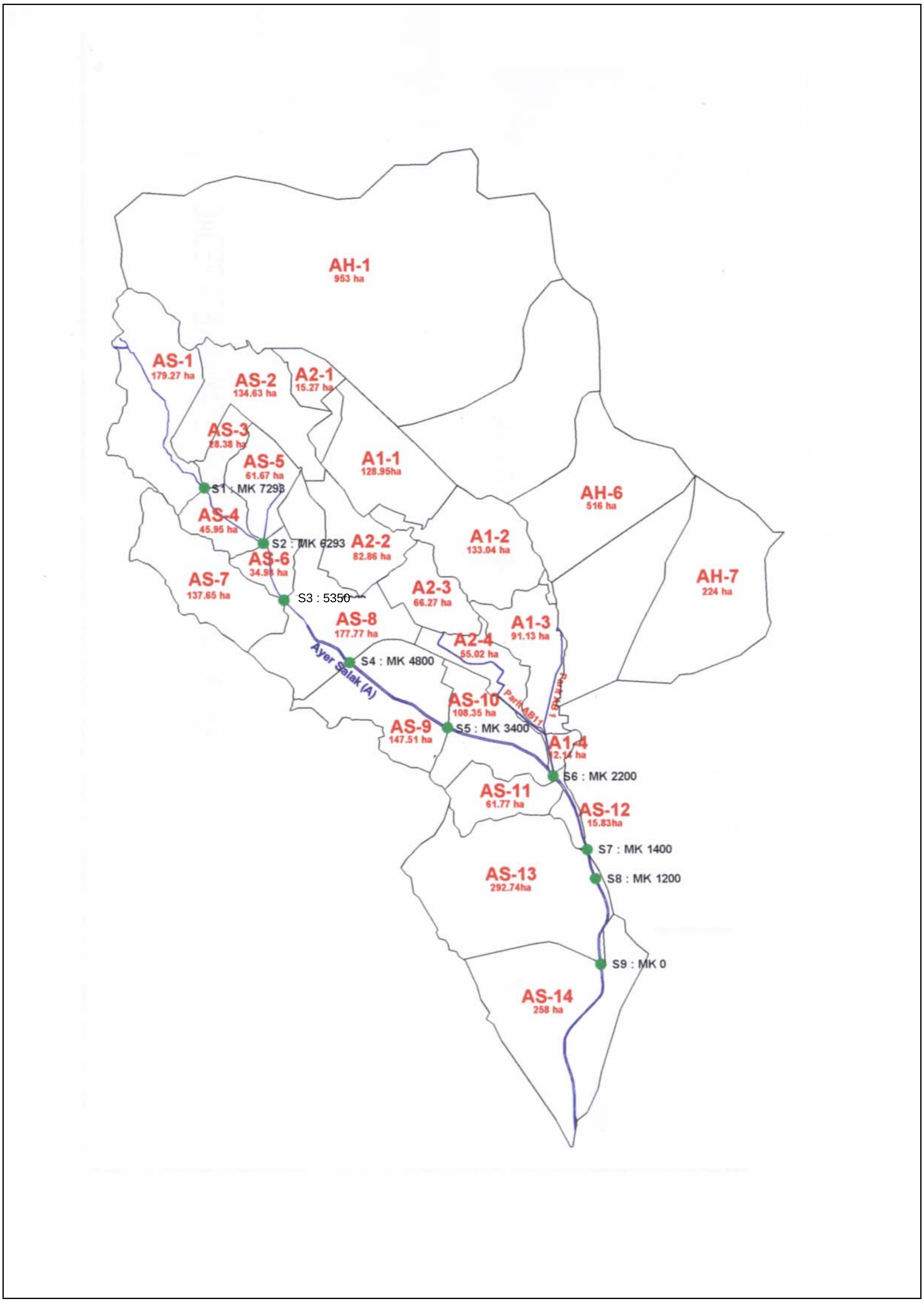

Figure 1.1: Sub-Catchment Areas Delineation

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The term “stormwater management” refers to the cooperative efforts of public agencies and the private sector to mitigate, abate, or reverse the adverse results, both in water quantity and water quality, associated with the altered runoff phenomena that typically accompanies urbanization. Stormwater management encompasses several controls measures, which may be either structural or non-structural (including policy and procedural measures) in nature.

There are various stormwater management strategies, which may be used to mitigate the effects of stormwater runoff problems. They vary from very simple to very complex techniques depending on specific site conditions and regulatory requirements, which must be satisfied. It involves the development and implementation of a combination of structural and non-structural measures to reconcile the conveyance and storage function of stormwater systems within the space and related needs of an expanding population. It also involves the development and implementation of a range of measures or Best Management Practices (BPMs) to improve the quality of stormwater runoff prior to its discharge to receiving waters. (Department of Irrigation and Drainage (DID), Sarawak)

Stormwater runoff is collected and disposed of through an integrated system of facilities. Storm drain systems collect the runoff water initially, and it is then handle by the following facilities:

- pumping stations
- detention systems
- retention systems
- sedimentation basins
- hazard spill tanks
- bio-filtration systems
- outfall appurtenances
- outfall channels
- man made wetlands

The primary options for handling or mitigating increased runoff are detention, retention, outfall appurtenances, and outfall channels. (Texas Department of Transportation (TxDOT), Hydraulic Design Manual , March 2004)

2.2 Stormwater Quantity Control Facilities

Stormwater quantity control facilities can be classified by function as either detention or retention facilities. The term control facilities are used in this manual to describe any combination or arrangement of detention and retention facilities in stormwater management systems. A classification is defined herein which will has been used throughout The Urban Stormwater Management Manual for Malaysia (MSMA) and it is based on the location of the facility.

The detention facilities are facilities that collect water from developed areas and release it at a slower rate than when it entered the collection system. The excess of inflow over outflow is temporarily stored in a pond or a vault and it is typically released over a period of a few hours or a few days. The detention concept is the most often concept that was employed in urban stormwater drainage systems. In this concept, the peak outflow rate for a specific range of flood frequencies is limited to that which existed from the same catchment before development. The primary function of the detention facilities are to reduce the peak discharge by the temporary storage and gradual release of stormwater runoff by way of an outlet control structure or other release mechanisms. Detention facilities also can reduce the volume of runoff from a given catchment, which can reduce the frequency and extent of downstream flooding.

Retention facilities commonly involve the process of collecting and holding surface and stormwater runoff with no surface outflow. However, peak flow reduction can also be achieved if the storage volume is large enough to capture the peak flow before the storage is filled, i.e. the time to fill the basin is longer than the time to peak of the inflow hydrograph.

Detention and retention storages may be classified base on the basis of their location and size as follows:

- *on-site storage* : small storages constructed on individual residential, commercial, and industrial lots
- *community storage* : larger storage facilities constructed in public open space areas, or in conjunction with public recreation and sporting facilities
- *regional storage* : large scale community storage facilities constructed at the lower end of catchments prior to discharge to receiving waters, often provided as flood storage within urban lakes and reservoirs

Detention and retention facilities can also be categorised as:

- *On-line storage*: A facility that intercepts flow directly within a conveyance system. On-line storage occasionally is provided as an on-site facility, though it is more often a community or regional facility
- *Off-line storage*: The diversion of flow from a conveyance system into a separate storage facility. A typical example is a side channel spillway that diverts flows from the conveyance system into an adjacent storage facility
- *Conveyance storage*: *Conveyance storage* may also function as *detention storage*. This is an often-neglected form of storage, because it is dynamic and requires channel storage routing analysis to identify. Slower-flowing conveyance caused by flatter slopes or rougher channels can markedly retard the build up of flood peaks and alter the time response of the tributaries in a catchment.

In addition to the traditional *conveyance-oriented approach*, a potentially effective and preferable approach to stormwater control is the *storage-oriented approach*. The function of this approach is to provide for the temporary storage of stormwater runoff at or near its point of origin with subsequent slow release to the downstream stormwater system or receiving water (detention), or infiltration into the surrounding soil (retention). This approach can minimise flood damage and disruption both within and downstream of the collection area. Runoff may also be stored for re-use as a second-class water supply for irrigation and domestic purposes.

Detention facilities are designed principally to reduce peak flow rates from large infrequent storm events. On-site storage is normally provided to reduce flooding in the surrounding local area whilst larger community and regional facilities are provided to increase public safety and to minimise property damage, channel erosion, and the disturbance of aquatic habitat in the downstream catchments and receiving waters.

Detention techniques include the temporary storage of runoff in the following facilities:

- small on-site tanks and above-ground storage areas
- dry detention basins
- ponds and wetlands
- flood reservoirs
- urban lakes

Retention facilities are designed primarily to reduce the volume of stormwater runoff from small frequent storm events by storing collected runoff and allowing it to infiltrate in to the surrounding soil. Retention is a suitable technique for infiltrating pre-treated runoff into areas with relatively high permeability soils. Pre-treatment by filtering to remove coarse sediment and debris is necessary to minimise blockage of the infiltration media. Regular maintenance is also essential for their effective operation.

Retention techniques include the following:

- on-site infiltration trenches, pits, wells, and ‘soakaways’ (for infiltration of roof runoff) either on an individual or multiple lot basis
- directing roof runoff to ponding areas within lots for infiltration
- grassed swales
- perforated stormwater pipes
- porous pavements
- community infiltration trenches and basins
- aquifer recharge wells

On-site detention or retention is provided to reduce the peak discharge in small storms, up to 10 year ARI. Community detention or retention should be provided to reduce peak discharges in storms up to 100 year ARI. Detention storages can be designed to include a permanent wet pond for water quality control.

On-site facilities are primarily minor drainage structures provided on an individual housing, industrial and infrastructure sites. They are usually built and maintained by private parties/developers. For quantity design, they are based on peak inflow estimates using the Rational Method with design storms between 2 year and 10 year ARI.

Community facilities are major drainage structures provided to cater for larger areas, which can combine different land use areas. They are usually built and maintained by the regulatory authority. For quantity design, they are based on peak inflow estimates using preferably Hydrograph Method with larger design storms, up to 100 year ARI in some instances, depending on the downstream protection requirement.

The methodology presented encourages efficient engineering design while promoting environmental protection by ensuring a maximum level of long-term pollution control. (Fabian Papa, Barry J. Adams, and Yiping Guo, 1999)

Since MSMA is endorsed by DID and is used as a reference and guideline for design procedure for any control structure and now has become a legislation and a requirement for such a design, it is the right time to master all the design procedures and requirements for stormwater management. There are many design procedures presented in this manual such as:

- retention pond
- detention pond
- drainage system
- wetlands
- closed conduit and open channel

However, in this project, the research is focused on the design procedures for detention ponds.

2.3 Detention Pond

Detention ponds are speed bumps to slow down stormwater. These ponds are popular in subdivisions and areas with multi-family dwellings. Some businesses use these ponds to control runoff from roofs and parking lots. Creating a wet detention pond needs advance planning. It can take a year to seal a pond that might be used to detain runoff at a construction site.

These ponds come in various shapes and sizes. Some take advantage of the natural land contour depressions. Ponds designed for removing pollutants, though, need to have enough storage capacity to hold all the runoff from a 1.5-inch storm. Stormwater ponds are most effective in removing pollutants when they have permanent pools of water with depth of three to eight feet. (Wisconsin Natural Resources Magazine)

Pond surface area is another consideration. The higher surface area a pond has for each acre of land it drains, the higher the percentage of pollutants it will remove. Another factor is the distance between the inlet and outlet. Overall, the pond should have a length to width ratio of at least 3:1. This design maximizes the detention time and allows for more sediment to settle be down.

Department of Natural Resources (DNR) monitoring found that stormwater ponds could remove 90 percent of suspended solids, 65 percent of phosphorus, 70 percent of lead and 65 percent of zinc found in runoff.

A DNR grant to the City of Delafield in 2002 studied the feasibility of the dredging of Nagawicka Lake and Bark River and building two stormwater retention ponds to control sediment runoff. Sediment on the lake and river bed from stormwater runoff makes navigation difficult for anglers, swimmers and boaters. Retention ponds would filter runoff before it reaches the lake and river or seeps into wells.

Landscaping is another consideration so the basin can provide habitat for frogs, birds and insects. All stormwater ponds should have gentle side slopes and a safety shelf (a 10-foot-wide ledge about one foot underwater on all sides of the pond). Plantings around the edges discourage swimming and wading.

An outlet should be located in the embankment and the pond should have an emergency overflow if large storms exceed the outlet capacity. Pipe openings should be covered with trash racks to keep people and debris out.

When planning for a detention pond, it is not sufficient to address only the hydrology and hydraulics. According to American Society of Civil Engineers (ASCE) (1985), successful detention facilities also have strong recreational or other community uses. The detention aspect is often considered secondary by the residents in the area. For these reasons, planning for detention also needs to consider the social, environmental, and recreational needs of each community. When open ponds are planned, an attempt should be made to combine the detention use with other community uses.

Open ponds are probably the most common type of detention used in stormwater management. They have the advantage of been dedicated totally to the task of stormwater management, which is not the case for rooftops or parking lots. They are also visible. This attracts attention for maintenance. Although there are examples of using open detention for control of combined sewer overflows, public health and aesthetic considerations generally limit the use of open detention ponds to the control of separate stormwater runoff (*Peter Stahre and Ben Urbonas, 1990).*

2.3.1 Description of Detention Pond Types

This information is obtain from Camp Dresser & McKee's "Regional Stormwater Management/Reservoir Protection Study Final Report," March 1992.

- **Wet Detention Ponds.** Wet detention ponds consist of a permanent storage pool and an overlying zone of temporary storage to accommodate increases in the depth of water resulting from runoff. An advantage of wet detention ponds is the pollutant removal capacity. Nutrients are removed from the water by algae and rooted aquatic plants. Heavy metals are removed from the water during sedimentation and adsorption onto bottom sediments. Aerobic conditions at the bottom of the permanent pool will maximize the uptake of phosphorus and heavy metals by bottom sediment and minimize pollutant releases from the sediments into the water column. Since ponds that exhibit thermal stratification are likely to exhibit anaerobic bottom waters during the summer months, relatively shallow permanent pools that maximize vertical mixing are preferable to relatively deep ponds. Other advantages of wet detention ponds should also be considered in Best Management Practice (BMP) selection. Wet detention ponds are usually more attractive than dry ponds, particularly if there is extensive wetland vegetation around the perimeter of the permanent pool. Wet detention ponds also offer the advantage of accumulating sediment and debris within the permanent pool. Since these accumulations are out-of-sight and well below the pond outlet, wet detention ponds tend to require less frequent cleanouts to maintain an attractive appearance and prevent clogging.

- **Extended Dry Detention Ponds.** An extended dry detention pond is an impoundment formed by constructing a dam or embankment or by a combination of excavation and an embankment with an outlet structure to detain surface runoff for periods of generally around 24 to 30 hours. Pollutant removal is achieved primarily by sedimentation. Extended dry detention ponds provide peak shaving control by regulating the outflow peak discharge and storing flood volumes within the detention pond. An emergency spillway is designed to pass extreme events to protect the dam from damage due to overtopping. The drainage area of an on-site extended detention pond is generally from five to 50 acres. Regional extended detention ponds can control up to 100 to 300 acres. The applicability of a site for an extended detention pond generally depends on site size and topography, value of land, accessibility, and environmental benefits. Since infiltration is acceptable but not necessary, soil characteristics are also important. Extended detention ponds can provide water quality and erosion/flooding control benefits. The water quality goals for a watershed must be considered in planning for extended dry detention ponds. The goal may be to limit or reduce the pollutant loading from runoff to the receiving streams. Another goal may be to reduce by a given amount the load into an environmentally sensitive area or downstream lakes. Since sedimentation is the primary pollutant removal mechanism, the pollutant removal efficiency of an extended dry detention pond depends primarily on the size, shape, and outfall characteristics of the pond. Erosion and flooding control goals and/or policy must also be considered for multipurpose ponds. Outlet structures can be designed to control future development peak discharges so that the release can meet any required performance standards. The planning of extended detention ponds must be performed in coordination with a watershed wide stormwater management study since the desired goals of ponds may vary from location to location within the watershed. For example, peak shaving may not be necessary in the downstream portion of a watershed, but pollutant control might be desired. The location, size and outlet structure design for detention ponds should be developed not only to provide the desired control at the detention pond site, but also to provide the maximum benefits throughout a watershed.

2.3.2 Types of Detention Pond Outlet Structures

Detention pond is designed to consist of two stages, primary and secondary outlet. Primary outlets are such as orifices, weirs, box culverts, trash racks and mechanical devices. Box culverts are often use as outlet structures for detention facilities. (MSMA) While the most common type of secondary outlet used is a broad-crested overflow weir cut through original ground next to the embankment.

Figure 2.1 shows typical dry detention basin components. The primary outlet shall be designed to reduce post-development peak flows to match pre-development peak flows for both minor and major system design storm ARI. The secondary outlets for all detention basins shall be designed to safely convey a minimum design storm of 100 Years ARI through the pond.

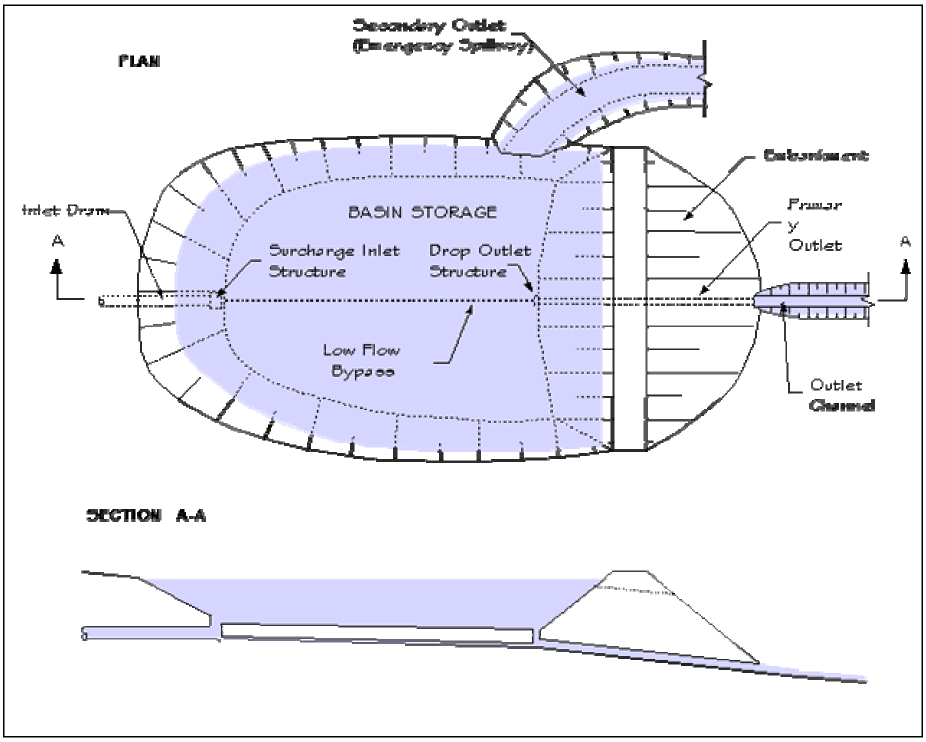

Figure 2.1: Typical Dry Detention Basin Components

2.3.3 Detention Design Concepts

The sizing of a detention facility required an inflow hydrograph, a stage-storage curve and a stage-discharge curve. Inflow hydrographs for a range of design storm durations must be routed through the basin to determine the maximum storage volume and water level in the basin corresponding to the maximum allowable outflow rate.

The design storm duration that will produce the maximum storage volume in a basin will vary depending on catchment, rainfall and basin outflow characteristic. It is typically somewhere between one and three times the peak flow time of concentration for the basin catchment. The design storm duration that produces the maximum storage volume is called the critical duration.

The inflow hydrograph shall be determined using time-area method or other hydrograph methods. There are various stages and methods employ to obtain the runoff hydrograph. The methods are such as hydrologic routing, Level-Pool routing and Rational Method (Daena). According to Christopher, Level-Pool Routing is the simplest hydrological routing method. Level pool routing is generally used to route floods through reservoirs and detention basins

2.3.4 Detention Design Criteria

- The maximum pond depth within the basin should not exceed 3.0 m under normal operating conditions for the maximum design flow for which the primary outlets have been designed.

- Minimum recommended embankment top width are provided in Table 2.1

Table 2.1: Minimum Recommended Top Width for Earthen Embankment (MSMA, 2000)

Height of Embankment (m)	Top Width (m)
Under 3.0	2.4
3 to 4.5	3.0
4.5 to 6	3.6
6 to 7.5	4.2

- The side slopes of grassed earthen embankment and basin storage area should not be steeper than 4(H):1(V). This is for ease of maintenance. However to increase public safety and facilitate ease of mowing, side slopes of 6(H):1(V) or flatter are recommended.

- The elevation of the top of the settled embankment shall be a minimum of 0.3 m above the water surface in the detention basin when the emergency spillway is operating at maximum design flow.

2.4 Technology Development in Detention Pond Design

Graphical relationships software is developed to facilitate the planning and design process of detention pond. Nowadays there are various softwares were developed to make ease the detention pond design process. But it is a complicated model. Therefore not many people will use it.

It is needed to develop a computer model that is simple enough for general ease of use. Simplification is the key for ease of use of these sophisticated models. Models should be used as a scientific basis, support for policies and to provide designer with a design that meets the specifications where feasible.

CHAPTER 3

METHODOLOGY

3.1 Introduction

There are various of methods that can be used in designing a detention pond. These methods are dependant on the size of the catchments' area. For complex systems such as larger detention ponds, the design should be carried out as a series of analysis. A trial outlet structure is preset and then modified as different storms conditions are modeled.

In this study, the design procedure of detention pond using Hydrograph Method will be discussed in detail. This method is suitable for catchment areas of more than 80 hectares. The summary of the methodology is shown in Figure 3.1.

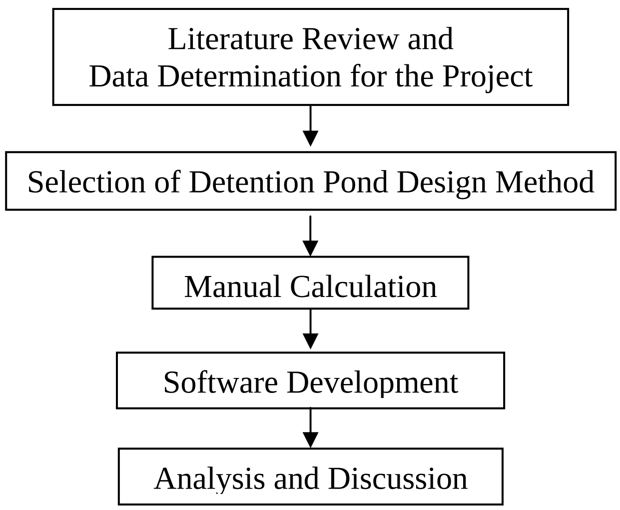

Figure 3.1: Flow Chart of Methodology

3.2 Data Determination of the Project

Firstly, a literature review is carried out to review the design criteria, concepts and procedures. The design concepts and procedures for detention ponds can be obtained from the Urban Stormwater Management Manual for Malaysia (MSMA) in volume 4, 5 and 7 in addition to other stormwater management reference books. But since stormwater management projects should comply with the requirements stated in MSMA, therefore the design criteria for the regional detention pond in this study is referred to MSMA. Design criteria and procedures can also be obtained from the "Example of Design Calculation Using MSMA for Proposed Housing Development of Tuanku Heights".

All raw data such as existing sub-catchment characteristic and projected sub-catchment characteristic are obtained from the report of "Cadangan Menaiktaraf Sungai Air Salak".

3.3 Selection of Detention Pond Design Method

After the design criteria and procedures are reviewed, the type of detention pond is selected according to the project's site condition. Since the project area is larger than 80 hectares, the Regional Detention Pond is selected for design. The design and analysis involve hydrological calculations to determine the flow rate and hydraulic calculations are employed to route flows through the storage.

The Time-Area method is used to derive the direct runoff hydrograph generated from the catchment for both the pre-development and post-development condition and Level Pool Routing is used to route the post-development inflow hydrographs.

3.4 Manual Calculation

After selection of the detention pond design method is made, the design is carried out manually by following the detention pond procedures shown in Figures 3.2 and 3.3. This manual calculation is carried out using Excel spreadsheets. All the necessary formulae are keyed in into the Excel spreadsheets. The detention pond sizing procedure for basin and primary outlets is shown in Figure 3.2, while the detention pond sizing procedure for secondary outlet is shown in Figure 3.3.