DAM BREAK FLOOD INUNDATION MODELLING FOR KLANG GATE DAM

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Specially dedicated to my beloved husband Mohd Irsyam Noorfawana Bin Masri and my lovely daughters, Nurin and Nadia.

I love you.

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ABSTRACT

Dams play a very vital role in the economy of a country by providing essential benefits like irrigation, hydropower, flood control and mitigation, drinking water and recreation. However in the unlikely and rare event of their failure, these may cause catastrophic flooding in the downstream area which may result in huge loss and damage to human life and property. In Malaysia, we have not had the experience of any such dam failures. However as the dams in the country get older, we cannot avoid but to face the reality that we have to take notice of the conditions of these dams from the safety point of view. This project report presents flood inundation mapping due to dam break of Klang Gate Dam. The Klang Gate Dam were modelled using a HEC-RAS one-dimensional hydraulic model to capture the hydraulic response of the river and its floodplains in extreme flooding condition due to dam break. Klang Gate Dam has been chosen as the study area where the dam has been classified as a significant high hazard. The purpose of this study is to determine maximum inundation depth of the flood waves, peak discharge and flood wave arrival time at various locations of the downstream valley and to develop flood inundation map depending on the severity of the flood in event of the failure of the Klang Gate Dam by using HEC-RAS. A steady flow HEC-RAS Model is developed for a probable maximum flood (PMF) failure for overtopping mode and the breach parameter of possible worst case scenario were considered in the study. The result showed that the peak discharge due to overtopping failure is 21,272 m^3/s with possible maximum velocity of 12 m/s. The result indicated that impact of breach outflow to the downstream area is significant. The finding, could benefit authorities or dam owner in an emergency response plans to prevent catastrophic damage at downstream in case of a dam break occurs.

ABSTRAK

Empangan memainkan peranan yang amat penting dalam ekonomi sesebuah negara dengan menyediakan manfaat seperti pengairan, janakuasa tenaga elektrik, kawalan dan mitigasi banjir, air minuman dan rekreasi. Walau bagaimanapun, kegagalan empangan boleh menyebabkan banjir di kawasan hiliran yang memberi kesan yang ketara dari segi kehilangan nyawa dan kerosakan harta benda. Di Malaysia, kita tidak berpengalaman dengan kegagalan empangan. Walau bagaimanapun memandangkan empangan di negara ini semakin tua, kita tidak dapat mengelak untuk menghadapi kenyataan bahawa kita perlu memperhatikan keadaan empangan dari sudut keselamatan. Laporan projek ini membentangkan pemetaan banjir terhadap jangkaan berlakunya kegagalan empangan di Empangan Klang Gate. Kegagalan Empangan Klang Gate telah dimodelkan menggunakan pendekatan permodelan hidrodanamik HEC-RAS satu dimensi untuk mengetahui sistem hidraulik sungai dan dataran banjir dalam keadaan banjir yang melampau/ekstrem disebabkan kegagalan empangan. Empangan Klang Gate telah dipilih sebagai kawasan kajian di mana empangan telah diklasifikasikan sebagai empangan berisiko tinggi. Tujuan kajian ini adalah untuk menentukan kedalaman banjir maksimum, kadar limpahan aliran puncak dan masa ketibaan banjir di pelbagai lokasi hiliran dan membangunkan pemetaan banjir bergantung kepada keterukan banjir sekiranya berlaku kegagalan Empangan Klang Gate dengan menggunakan HEC-RAS. Satu Model HEC-RAS aliran mantap dibangunkan untuk kegagalan kemungkinan maksimum (PMF) untuk mod ‘overtopping’ dan parameter senario kes terburuk pelanggaran yang mungkin berlaku telah dipertimbangkan dalam kajian. Keputusan menunjukkan bahawa kadar limpahan aliran puncak kerana ‘overtopping’ ialah 21,272 m^3/s dengan halaju maksimum 12 m/s. Hasil dari kajian ini, dapat memberi manfaat kepada pihak berkuasa atau pemilik empangan untuk digunapakai dalam merancang tindakan kecemasan untuk mengelakkan kerosakan bencana di hiliran sekiranya kegagalan empangan berlaku.

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LIST OF SYMBOLS

DID	-	Drainage and Irrigation Department
GIS	-	Geographic Information System
DEM	-	Digital Elevation Model
LiDAR	-	Light Detection and Ranging
HEC-RAS	-	Hydrologic Engineering Center’s River Analysis System
PMF	-	Probable Maximum Flood
km^2	-	Kilometre Square
1D	-	1 Dimension
SMPDBK	-	Simplified Dam-Break
NWS	-	National Weather Service
FEQ	-	Full Equations
FLDWAV	-	Flood Wave
DWOPER	-	Dynamic Wave Operation Network Model
DAMBRK	-	Dam-Break Forecasting Model
UNET	-	Unsteady Flow Engine
ISIS	-	Full Hydrodynamic Simulator
FSR	-	Flood Studies Report
FEH	-	Flood Estimation Handbook
USSCS	-	US Soil Conservation Service
VAW	-	Laboratory of Hydraulics, Hydrology and Glaciology
ETH	-	Swiss Federal Institute of Technology
CCHE2DFLOOD		Computational Hydroscience and Engineering
DSS-WISE	-	Decision Support System for Water Infrastructural Security
HEC-GeoRAS		Hydrologic Engineering Center’s Geographic River Analysis System

JUPEM	-	Jabatan Ukur dan Pemetaan Malaysia
TIN	-	Triangular Irregular Networks
m^3/s	-	meter cubic per second
m/s	-	meter per second

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CHAPTER 1

INTRODUCTION

This chapter consist of introduction, research problem, research objectives, research scope and significant of research.

1.1 Introduction

Dams play a very vital role in the economy of a country by providing essential benefits like irrigation, hydropower, flood control and mitigation, drinking water, recreation etc. A dam can also be used to collect water or for storage of water which can be evenly distributed between locations. However in the unlikely and rare event of their failure, these may cause catastrophic flooding in the downstream area which may result in huge loss and damage to human life and property. Some notable historic dam failure include Ka Loko Dam in Hawaii, 2006 ; Koshi Barrage in Nepal, 2009; Delhi Dam in United States, 2010 and Nieodo Dam in Poland, 2010 (Wikipedia, 2013a). In 1975 the failure of the Banqiao Reservoir Dam and other dams in Henan Province, China caused more casualties than any other dam failure in history. The disaster killed an estimated 171,000 people and 11 million people lost their homes (Wikipedia, 2013a). This loss and damage to life and property would vary with extent of inundation area, size of population at risk, and the amount of warning time available (S. Masood Husain, 1999).

1.2 Background of the Problem

In Malaysia, we have not had the experience of any such dam failures. However as the dams in the country get older, we cannot avoid but to face the reality that we have to take notice of the conditions of these dams from the safety point of view. We should not wait until failure occurs which may endanger public safety.

A distinguishing feature of dam breach floods is the great magnitude of the peak discharge in comparison to any precipitation runoff-generated floods, and its consequences are often catastrophic if human developments exist downstream of the dam. The prediction of the dam break flood is very important for the purposes of planning and decision making concerning to dam safety, controlling downstream developments, contingency evacuation planning and real time flood forecasting. For assessing the flood damage due to dam breach it is necessary to predict not only the possibility and mode of a dam failure, but also the flood hydrograph of discharge from the dam breach and the propagation of the flood waves. The studies are to map or delineate areas of potential flood inundation resulting from a dam breach, flood depth, flow velocity and travel time of the flood waves etc. Knowledge of the flood wave and flood-inundation area caused by a dam breach can potentially mitigate loss of life and property damage.

1.3 Statement of the Problem

A flood produced by a dam breach is very different from a flood produced by a rainfall event. In a dam-breach scenario, the subsequent flood wave develops over a relatively short time and flows rapidly through the downstream area as opposed to a rainfall event that would propagate more slowly through the downstream area.

When a dam fails or is deliberately demolished, large quantities of water are suddenly released, creating major flood waves capable of causing disastrous damage to downstream valley. Major flood waves may seriously damage or destroy power plants, industrial plants, roads and bridges and may cause loss of life, adverse ecological and environment impact.

Dam can fail either gradually or suddenly. The type of failure depends upon the cause of failure and the type of dam. The failure can be because of the prolonged periods of rainfall and flooding, inadequate spillway capacity, resulting in excess overtopping of the embankment, internal erosion caused by embankment or foundation leakage or piping, failure of upstream dams in the same drainage basin and improper maintenance, including failure to remove trees, repair internal seepage problems, or maintain gates, valves, and other operational components.

When the dam fails instantaneously, one assumes removal of the entire structure or a large portion thereof. The sudden release of water generates a flood wave that propagates over the initial stream flow and its front has the form of the bore. A negative wave is created upstream of the dam and it propagates up along the reservoir. The ruptured dam section becomes the pivotal point for the mass of water to be released. The topography of the reservoir controls the movement of the negative wave. (Muradee, 2009)

According to Emily Sirib (2005), there are about 75 dams in Malaysia and most of the dams located next to the residential area. Dams that located near to the residential posed high hazard to the downstream population. As results of the situation, Dam-breach analysis and flood-inundation maps are vital for providing data to make a better plan for and respond quickly and effectively to flooding. Advanced knowledge of what areas may flood, what infrastructures may be impacted, how long flooding may persist is necessary if units are to be able to respond to such treats in timely manners.

Regarding to the significant of dam break study, a cooperative study has to be done to simulate dam-break scenarios at Klang Gate Dam and to map the potentially resulting flood-inundation areas.

1.4 Research Objectives

Followings are the objectives proposed for this study:-

(1) To determine maximum inundation depth of the flood waves, peak discharge and flood wave arrival time at various locations of the downstream valley when the dam failure.

(2) To develop flood inundation map depending on the severity of the flood in event of the failure of the Klang Gate Dam by using HEC-RAS.

(3) To predict river flood risk map in Sungai Klang river basin.

1.5 Scope of the Study

A dam break flood modelling development of accurate flood-inundation maps requires high-resolution topographic data of known accuracy. More accurate topographic data lead to more accurate flood-inundation maps (Horritt and Bates, 2001). Field surveying produces the most accurate elevation data but can be time consuming and expensive. Light detection and ranging (LiDAR) is an airborne laser-profiling system that produces location and elevation data to define the surface of the Earth and the heights of aboveground features. LiDAR can produce a digital elevation model (DEM) with 1-foot (ft) contours that can be imported to a geographic information system (GIS) in a relatively short amount of time.

Dam-breach flood-inundation maps indicate areas that would be flooded as a result of a dam failure. The inundated areas depicted on flood-inundation maps are approximate, and accuracy of such maps is a function of the accuracy of the topographic data, the hydraulic models on which the maps are based, the assumptions made about the dam failure mode, and the initial flood wave. For this report, LiDAR data with a vertical accuracy of about 3.3 inches (in) were used to develop a 1-ft contour elevation map for the study area of Klang Gate Dam. The

Hydrologic Engineering Center's River Analysis System (HEC-RAS) modelling software developed by the U.S. Army Corps of Engineers, a standard for dam-breach flood-inundation models, was used to perform steady-flow simulations to model the dynamic nature of the flood wave produced by a dam-breach scenario (Hydrologic Engineering Center, 2010a).

The scope of this study is within this related area:-

- Data collection and analysis
- Dam breaks analysis with HEC-RAC modelling.

A dam break flood modelling will be conducted to determine the flood inundation extents of a failure of the Klang Gate Dam. A steady flow HEC-RAS Model is developed for a probable maximum flood (PMF) failure.

1.6 Significance of the Study

The significant of the study is to develop the river hydraulics model, simulate a dam failure and map the resulting flood wave. The proper modelling of the hazards associated with dam break will assist in land use planning and developing emergency response plan to help mitigate catastrophic loss to human life and property that might be inflicted by floods.

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