UNIVERSITI PUTRA MALAYSIA

FLOOD SIMULATION USING SHUTTLE RADAR TOPOGRAPHIC MISSION DIGITAL ELEVATION MODEL IN HADEJIA RIVER BASIN, NIGERIA

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By

ABUBAKAR SANI KAZAURE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATIONS

This Thesis is dedicated to my late Grandmother Hafsat for her support and encouragement from the beginning until the time we parted, may Allah grant her Jannatul Firdaus.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

FLOOD SIMULATION USING SHUTTLE RADAR TOPOGRAPHIC MISSION DIGITAL ELEVATION MODEL IN HADEJIA RIVER BASIN, NIGERIA

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July 2013

Chair: Associate Professor Abdul Halim Bin Ghazali, PhD

Faculty: Engineering

In order to reduce the effect of flood, many research works have been conducted in various regions while others are ongoing. In most cases unavailability of detailed cross section data affected the accuracy of flood studies in many developing nations and hindered application of advanced modelling tools.

In this study, Hadejia River cross sections were created using Shuttle Radar Topographic Mission Digital Elevation Model (SRTM DEM) and HEC-GeoRAS in Geographic Information System (GIS) environment. The 90m SRTM DEM used was produced by NASA, downloadable free from US Geological Survey, DIVA-GIS, CGIAR Consortium for Spatial Information and many similar databases for different parts of the world. The Triangulated Irregular Network (TIN) for the study area was created in GIS environment and used for creating the geometry data covering the stream centerline, banks and flowpath lines, reach lengths, cross sections and stations details.

Hydraulic modelling of the river was performed with HEC-RAS using HEC-GeoRAS

extracted river geometry data imported from GIS to compute the water level and flood extent. The 2001 discharge of 690 m^3/s was used in the modelling along with the Manning roughness coefficients of 0.065 for the channel and 0.15 for the floodplain with an expansion and contraction coefficients of 0.1 and 0.3 respectively. Upon successful run of the model, cross sections output plot, water surface profile plot, XYZ perspective and the flooded areas were determined.

The HEC-RAS results were further processed in GIS environment facilitated by HEC-GeoRAS to produce the flood inundation map of the study area. An overlay of the flood inundation map obtained from the study showed the flood water covers most of the villages affected in recent floods with the highest inundation observed at far down stream of the reach near Hadejia. To protect those areas affected by the flood, embankment levees were proposed at such locations.

The study shows that the cross sections obtained using the SRTM-DEM give the required geometry data for an analysis in HEC-RAS. Despite the fact that the cross sections obtained using the 90m SRTM-DEM can provide the required geometry data for use in HEC-RAS and creation of the inundation map of the area, the cross sections are not very accurate and it is recommended that more accurately measured cross section data need to be obtained for future flood studies in the basin.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

BANJIR SIMULASI MENGGUNAKAN SHUTTLE RADAR TOPOGRAPHIC MISSION DIGITAL ELEVATION MODEL DI LEMBANGAN SUNGAI HADEJIA, NIGERIA

Oleh

ABUBAKAR SANI KAZAURE

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Bagi mengurangkan kesan banjir, banyak kerja penyelidikan telah dilaksanakan di kawasan-kawasan terlibat dan sebahagiannya masih diteruskan. Dalam banyak kes, ketidakcukupan data keratan rentas yang lengkap merencatkan ketepatan kajian banjir di kebanyakan negara membangun dan sekaligus menghalang aplikasi perkakas pemodelan yang canggih.

Dalam kajian ini, keratan rentas Sungai Hadejia dibina dengan menggunakan *Shuttle Radar Topographic Mission Digital Elevation Data (90m SRTM DEM)* dan HEC-GeoRAS dalam persekitaran sistem maklumat geografi (GIS). 90m SRTM DEM yang dihasilkan oleh NASA itu boleh diperolehi dalam pelbagai resolusi secara muat turun percuma dari US Geological Survey, DIVA-GIS, CGIAR Consortium for Spatial Information dan dari pangakalan data yang serupa bagi semua tempat di dunia. Triangulated Irregular Network (TIN) bagi kawasan kajian dihasilkan dalam persekitaran GIS dan digunakan untuk menghasilkan data geometri merangkumi garis tengah sungai, tebing dan arah aliran, panjang sungai, keratan

rentas dan butiran stesen.

Pemodelan hidraulik sungai itu dilaksanakan dengan HEC-RAS menggunakan data geometri sungai yang diambil menggunakan HEC-GeoRAS diimpot dari GIS untuk menentukan aras sungai dan keluasan kawasan banjir. Data aliran tahun 2001 bernilai 690 m^3/s digunakan dalam pemodelan berserta dengan pekali Manning 0.065 bagi saluran sungai dan 0.15 untuk dataran banjir serta pekali pengembangan dan pengecutan masing-masing 0.1 dan 0.3. Hasil pelaksanaan model, plotan lakaran keratan rentas, lakaran profil permukaan air, perspektif XYZ dan kawasan banjir telah ditentukan. Hasil pemodelan HEC-RAS diproses selanjutnya dalam persekitaran GIS dimudahkan dengan HEC-GeoRAS untuk menghasilkan peta banjir bagi kawasan kajian. Gabungan peta banjir dan peta kawasan kajian menunjukkan banjir tersebut merangkumi perkampungan yang terjejas di dalam banjir yang berlaku kebelakangan ini, dengan kedalaman aliran banjir yang tertinggi berlaku di hilir sungai berhampiran dengan Hadejia. Untuk melindungi kawasan yang terjejas oleh banjir berkenaan, tetambak dicadangkan untuk dibina di kawasan tersebut.

Kajian ini menunjukkan bahawa keratan rentas yang didapati menggunakan SRTM-DEM dapat menghasilkan data geometri yang digunakan dalam analisis HEC-RAS. Walau pun keratan rentas yang diperolehi dengan menggunakan 90m SRTM DEM boleh memberikan data geometri bagi menggunakan HEC-RAS dan menghasilkan peta banjir, keratan rentas berkenaan tidak begitu tepat dan bagi tujuan kajian banjir di masa akan datang data keratan rentas yang diukur secara tepat perlu diperolehi.

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I certify that a Thesis Examination Committee has met on **8th July, 2013** to conduct the final examination of **Abubakar Sani Kazaure** on his thesis entitled "**FLOOD SIMULATION USING SHUTTLE RADAR TOPOGRAPHIC MISSION DIGITAL ELEVATION MODEL IN HADEJIA RIVER BASIN, NIGERIA**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the **Master of Science**.
Members of the Thesis Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of **Master of Science**. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

ABUBAKAR SANI KAZAURE

Date: 8 July 2013

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 General

Flood can be defined as a hydrological event characterized by high discharges and/or water levels, leading to inundation of land adjacent to streams, rivers, lakes and other water bodies (Mohammed et al., 2011). It is therefore an extremely high flow or level of rivers, lakes, ponds, reservoirs and any other water bodies in which water inundates the outside bank areas (Smith and Ward, 1998).

Most of the largest documented floods are caused by excessive rain, streams overflowing channels, unusual high tides or waves in coastal areas, snowmelt, rapid release of water stored behind dams or within glaciers and inadequate drainage in the affected areas (Smith and Ward, 1998; O'Connor and Costa, 2004).

Flood is one of the major natural hazards in terms of economic and human losses (Mosquera-Machado and Ahmad, 2007; Cook and Merwade, 2009). It was reported that losses due to flood exceeded 100,000 deaths and displaced 320 million others, while economic damages exceeded USD1,151 billion in 56 developing countries from 1990 to 2000 (Bradshaw et al., 2007; Zhang et al., 2008). In addition, excessive flood were reported in Malaysia in the late 2006 and early 2007, Cleveland in 2006, Bolivia in January 2007, Namibia in February 2007, and Australia in March 2007. High rainfall witnessed in 2010 resulted to flood in Nigeria, Niger Republic, China and Pakistan. In all these cases of flood, lost of lives and damage to properties have been reported (Aljazeera, 2010; Gambrell, 2010; Tan-Soo, 2010; Yusha'u, 2010; Yahaya et al., 2010).

There are repeated cases of flood in the Hadejia River Basin Nigeria since early

sixties. Major floods in the basin occurred in 1964, 1984, 1988, 1994 and 1998, 2001, 2004 and 2010 and in all these cases large areas were inundated and damage to properties were observed (Schultz, 1976; Idris, 2002; Wallingford, 2002; Gambrell, 2010).

Extensive flood estimation studies have been carried out due to the increasing interest in flood impacts over the last decades in different countries by various agencies and researchers (Dawod et al., 2011). Through studies of previous events, flood hazard can be mitigated, measures to control future occurrences can be proposed and duly implemented.

1.2 Background of the Study Area

The Hadejia-Jama'are River Basin (HJRB) lies between 10° to 12°N and 8° to 12°E situated at Northern part of Nigeria, it comprises of two main rivers; Hadejia River flowing at the Northern and Jama'are River at the Southern part of the system (Kazaure, 2002; Schultz, 1976; Wallingford, 2002; Yahaya et al., 2010) thus forming Hadejia River Basin in its northern part and Jama'are River Basin in the southern part of the system. The Hadejia River flows in the northern part of Nigeria within the states of Kano and Jigawa towards North-eastern states of Nigeria where it joined other rivers and flow into Lake Chad along the Nigerian-Chad border.

The River is managed by the Hadejia-Jama'are River Basin Development Authority (HJRDA); one of the eleven agencies responsible for water resources and development in Nigeria. Although the RBDA's boundaries are based on political state borders, water resources can be managed at catchment level based on defin-

ing the basins as geographic units (Uyigue et al., 2007; Wallingford, 2002). The study area is fully described in Section 3.2. The lower portion of the Hadejia Basin covering Wudil; just downstream of the confluence of Kano and Chalawa Rivers to Hadejia was selected for this study. Hence, records at Wudil station are used for the flood simulation.

1.3 Problem Statement

The major problem in the Hadejia River Basin was attributed to excessive rainfall that resulted to flood downstream in several years.

Despite the repeated cases of flood in the downstream areas, detailed flood study was hindered by non-availability of detailed hydrologic records and lack of surveyed geometry data. This prevented many researchers and agencies from detailed modelling of the river to provide lasting solutions. Previous studies in the area did not emphasize much on flood modelling using tools such as HEC-RAS due to insufficient data.

The quest for alternative methods in tackling the flood problem in the Hadejia River necessitated the need for this study. Hence an ability to process a free downloaded Shuttle Radar Topographic Mission Digital Elevation Data (SRTM DEM) of the study area using HEC-GEORAS in GIS environment to extract geometry data employed in this study and simulation in HEC-RAS will help in solving the flood in the basin through identifying the affected areas and preparation of flood map of the area for making polices and providing possible control measures by the managing authorities.

Currently there is no such flood control measure in the basin apart from the temporary protection using sand bags by the local communities. Hence, levee construction recommended in this study will help in preventing the affected communities from further flood damage.

1.4 Objectives of Study

The study is mainly aimed at modelling of flood on Hadejia River in Northern Nigeria due to the combined effect of rainfall and reservoir releases using the U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center's River Analysis System (HEC-RAS version 4.1).

The specific objectives of this study were:

1. To generate cross-sections of the Hadejia River from the Shuttle Radar Topographic Mission Digital Elevation Model data using HEC-GeoRAS in GIS environment.

2. To compute the water level and flood extent for the Hadejia River using HEC-RAS modelling software.

3. To determine the configuration of levees as a possible mitigation measure in the flooded area.

1.5 Scope and Limitations of the Study

The study covers 1D Hydraulic modeling of Hadejia river reach from Wudil to Hadejia, using US Army Corps of Engineers Hydraulic Engineering Centre River Analysis System (HEC-RAS) version 4.1 of 2010 model. The study was faced with lack of sufficient data problem that hindered previous studies in the Basin. The

lack of sufficient good quality measured river geometry data. This was generally identified as common problem among the developing Nations. Similarly for the Hadejia River Basin, detailed surveys to generate the river geometry data was not earlier performed by the governing agencies. The required personnel and equipments needed to generate such data for this study were either lacking, obsolete or are not in good working condition. Thus making it a difficult and expensive task.

Lack of surveyed cross sections necessitated an alternative approach to process a Digital Elevation Model of the study area using GIS interface and HEC-GeoRAS tools for extracting the river geometry data. Based on this, the river geometry data for the study was extracted from Triangulated Irregular Network (TIN) created from a Shuttle Radar Topographic Mission Digital Elevation Model (90m SRTM DEM). High resolution Digital Elevation Models such as LiDAR data are not readily available for the area. Hence, 90m SRTM-DEM data was used as an available source for the study.

Similarly, there is unavailability of continuous data such as hourly time series rainfall records for the entire basin. There is problem of insufficient records of flow data and water level for all the gauging stations along the Hadejia river tributaries. These have prevented a detailed hydrologic Modelling of the basin. Although gauging stations exist in the basin, reports of missing or improperly kept data were made and only few rainfall and flow records are used to be maintained at the gauging sites. Hence, the model was calibrated using the 2001 flow data at Wudil and Hadejia, minor tributaries were not considered. The available stage and flow records for Wudil and Hadejia stations from Hadejia-Jamaare River Basin Development Authority (HJRDA), Water Resources and Engineering Agency Kano (WRECA) and the river flow database developed for Integrated Water Resources

Management Water Resources and Sanitation Sector Reform Programme (IWRM WSSSRP) obtained from IUCN - KOMADUGU YOBE BASIN PROJECT were considered.

Although an embankment levee was proposed as a possible flood mitigation measure in the study area, its detailed analysis was not considered in the study due to lack of design requirements such as soil data, high resolution Digital Elevation Model and topographic details. This is hereby recommended for further studies.

1.6 Significance of the Study

This study will be of immense use in decision making by the local authorities saddled with responsibility of managing the Hadejia River Basin, Nigeria. Results from the study will aid the government agencies in providing flood control measures at identified locations to protect the communities bordering the river that have been affected for decades and the flood inundation map will serve as a guide in implementing other non structural flood mitigation measures such as warning system and preventing encroachment through land use management.

This study is also intended to fill the huge knowledge gap and to serve as a new approach to solving flood problem in the Hadejia river basin through application of advanced modelling techniques. Similarly, the methodology adopted in this study will be of immense use to solving similar problems in other regions since many rivers in the developing nations are faced with the problem of unavailability of sufficient geometry data.

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