Modeling Floodplain Inundation by Integration of Hydrological With Hydraulic Model, Case Study: Muda River, Kedah

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ABSTRACT
River flood is recurrent natural phenomena in tropics and sub tropical climate. Among all kinds of natural hazards of the world flood is probably most wide spread, frequent and destructive. In recent years, remote sensing and GIS has become the key tool for flood modeling. This paper will discuss the modeling of floodplain by integrated hydrological with hydraulic model. The hydrologic model will determine the runoff that occurs following a particular rainfall event. The primary output from the hydrologic model is hydrographs at varying locations along the waterways to describe the quantity, rate and timing of stream flow that results from rainfall events. These hydrographs then become a key input into the hydraulic model. The hydraulic model simulates the movement of flood waters through waterway reaches and calculates flood levels and flow patterns. Furthermore, 2D simulation will apply to simulate and analysis of river flows with complex topography and to predicting river bed and bank erosion. The model should be capable of simulating transition between subcritical and supercritical flow in or near hydraulic structures, flow near channel confluence, and sudden river morphological changes such as channel expansion and contraction.

Keywords: floodplain; hydrological with hydraulic model; Radar; erosion.

1 Introduction

Flooding is ranked the most destructive disaster in the world, caused extensive damages in the world over the past years resulting in human losses and extensive economic damages. (Environment Agency, 2001) Floods are regular natural disasters in Malaysia which happen nearly every year, most floods that occur are a natural result of cyclical monsoons during the local tropical wet season that are characterized by heavy and regular rainfall from roughly October to March. (Ho, 2002). Malaysia covers an area of 330,000 km² comprises two regions, namely Peninsular Malaysia and the States of Sarawak and Sabah, The average annual rainfall is estimated at 2420 mm for Peninsular Malaysia, 2630 mm for Sabah and 3830 mm for Sarawak. The total annual surface water resources are estimated at 566 billion m³ with 147, 113 and 306 billion m³ for Peninsular Malaysia, Sabah and Sarawak respectively. The topography of Peninsular Malaysia is characterized by central mountains which slope steeply to the relatively flatter undulating coastal plains on the eastern and western sides with ground elevations of up to 2000 m above mean sea level. Similar terrain exists in Sabah and Sarawak. More than 150 rivers existed in the country; the rivers path is short with steep gradients in the upper stretches and flat with meandering stretches in the lower reaches. It has been estimated that some 29,000 km² or 9% of the total land area are flood prone, affecting more than 15% of the total population. (Keizrul, 2003) The objectives of the present study include the following: (1) to develop a hydrological model for the rivers of the Muda Basin (Figure 1) that is capable of accurately simulating spatially distributed flow patterns within ephemeral rivers that are characterized by exceptionally complex channel systems, highly variable flow regimes. (2) develop a computer model of the Muda River System within the study area to define the nature and extent of the flood hazard;(3) model the effects of existing developments and existing flood mitigation measures to determine their impact on flooding.

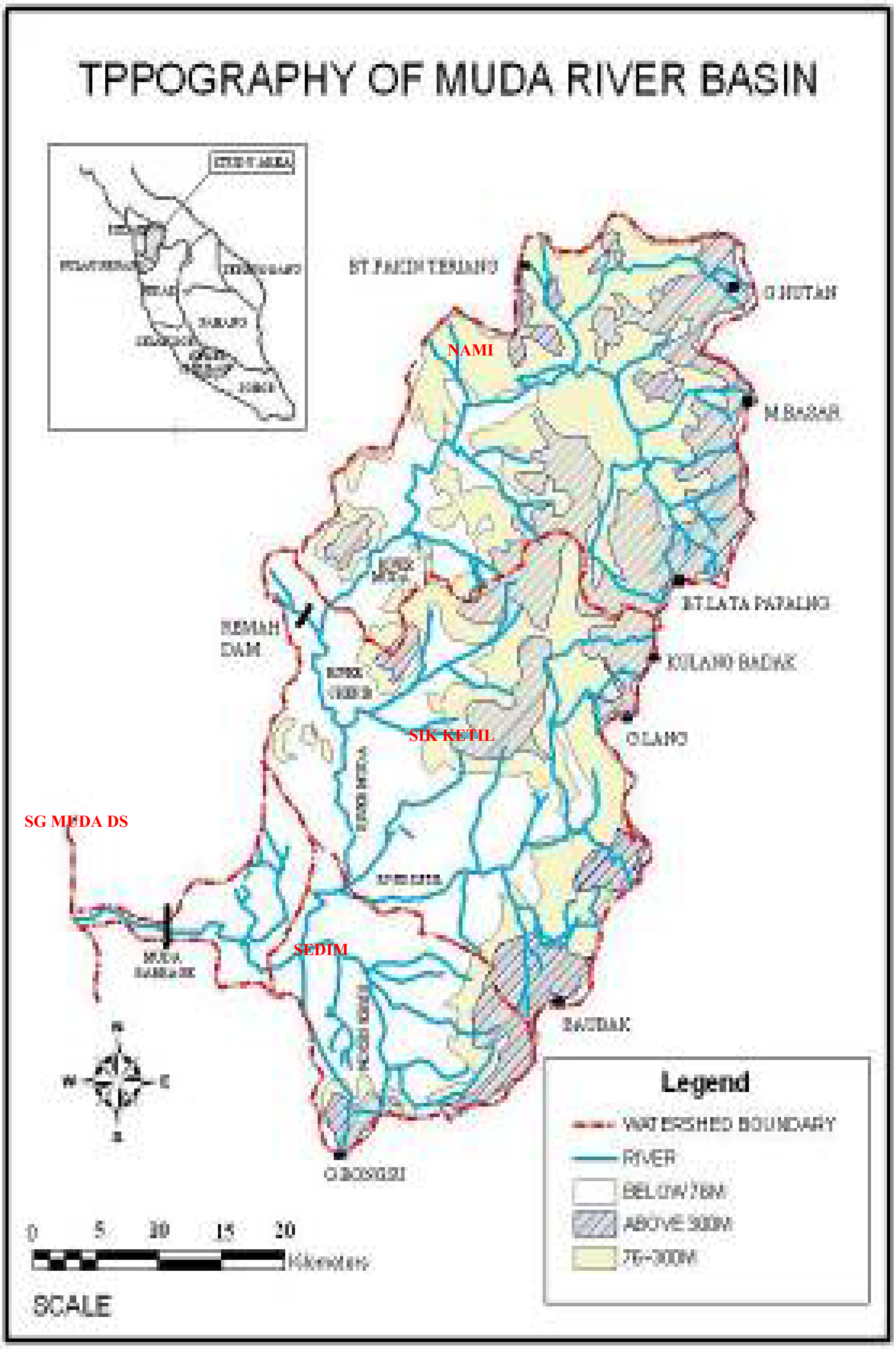

Figure 1 topography and Subcatchment Area of Muda River basin

2 Site Description

Muda River with a catchment area of 4,210 km^2 originates in the north mountainous area of Kedah State and flows down toward the south. It changes its course towards the west coast after passing the confluence of the main stream and its tributary, Ketil River. The total length of the main stream is about 180 km. There are three major tributaries of the Sg. Muda river system; namely, Sg. Ketil with a catchment area of 868 km^2, Sg. Sedim with 626 km^2 and Sg. Chepir with 335 km^2. Sg. Ketil is the largest tributary including its secondary tributary, Sg. Kupang that has a catchment area of 147 km^2.

The riverbed subsidence seriously affects river structures such as bridges and water intake facilities. Foundation piles of the bridge at Ldg. Victoria are exposed by 2 to 3 m above the eroded riverbed (Figure 2) (Julien et al., 2007). Moreover, the lowering of water level also causes difficulty in abstracting water from the river at the existing intake points. The study area has two typical monsoons; namely, the northeast monsoon and southwest monsoon. The northeast monsoon usually occurs from November to February. The annual rainfall depth in the Study Area is about 2,000 to 3,000 mm. The heavy annual rainfall is observed around the central mountain of Gunong Jerai and the southern mountainous areas declining northward and to the river mouth (JICA, 1995) (see figure 1)

Figure 2 Bridge Crossing Ketil River (1km Upstream of Muda River)

3 Method

The evaluation procedure consists of the following steps:

3.1 DEM

Digital elevation models will prepare using Radarsat synthetic aperture radar (SAR) fine mode 10m. The DEM will generate from Radarsat stereo-pair using Erdas imaging. DEM accuracy will assess through comparisons of DEM-derived to field surveyed value for elevations. the DEM is WGS84 projection and the elevation area is mean sea level MSL The quality of a DEM is a measure of how accurate elevation is at each pixel (absolute accuracy) and how accurately is the morphology presented (relative accuracy).one of the requirement for flood model is DTM, digital terrain model is a filtered version of DEM, the DTM provides a bare-earth model, devoid of landscape features.these model then become a key input into the flood model (Musa, 2004) (See Figure 3)

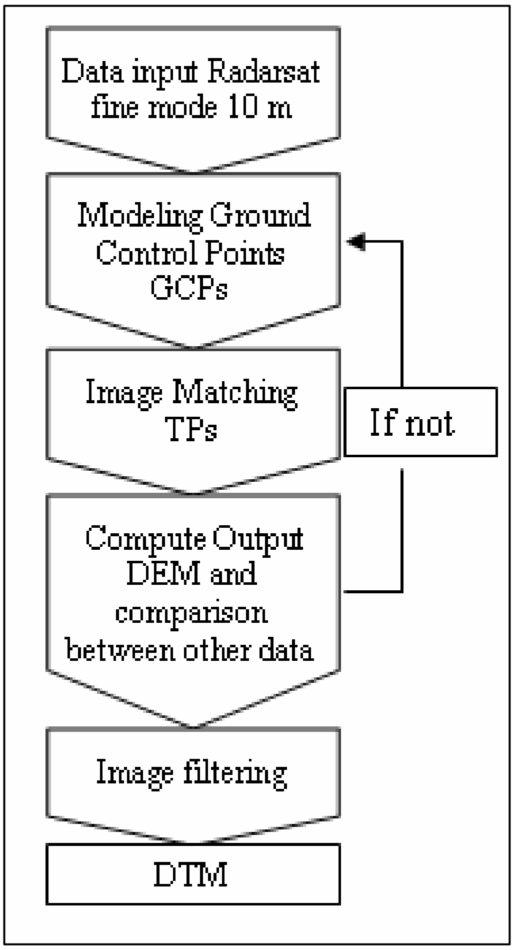

Figure 3 Stereo Processing Flow Diagrams, Moderated from Musa (2004)

3.2 Flood Model

The flood model comprises a hydrological model and a hydraulic model. The hydrologic model determines the runoff that occurs following a particular rainfall event. The primary output from the hydrologic model is hydrographs at varying locations along the waterways to describe the quantity, rate and timing of stream flow that results from rainfall events. These hydrographs then become a key input into the hydraulic model. The hydraulic model simulates the movement of flood waters through waterway reaches, storage elements, and hydraulic structures. The hydraulic model calculates flood levels and flow patterns and also models the complex effects of backwater, overtopping of embankments, waterway confluences, bridge constrictions and other hydraulic structure behavior. (Earthsci, 1996) For both hydraulic and hydrologic modeling for the Muda catchment, 1 D hydrodynamic ISIS Flow simulation combined in Infoworks RS will be implementing to create the model. The software includes modeling of floodplains, embankments, hydraulic structures, and Rainfall-runoff simulation. All hydrological data and previous reports such as the Annual Flood Reports used in this study were provided by the Department of Irrigation and Drainage. Figure 4 describe the general approach in this model. (DID, 2000).

3.3 Roughness Zones

Roughness zones describe areas of similar roughness. Roughness Zones are not physical areas. They are simply a description of the characteristics of a particular terrain type from which a roughness value for that terrain type is calculated. In order to define areas on the ground with this terrain type, it should be create Roughness Polygons on the GeoPlan View (or import polygons from a GIS) and then set the Roughness Zone ID field for the polygon to refer to the appropriate zone. Roughness value for Floodplain zones can be calculate from three roughness components (i) vegetation (Figure 5) (ii) a substrate component (bed material, bank material or ground material) (iii) and an irregularity component. Floodplain vegetation (Figure 6) components are sub-divided into the following sub-categories: (1) Coniferous Tress (2) Crops (3) Grass (4) Hedges (5) Trees. Data can be edited manually or loaded from a Roughness Database. (HR Wallingford, 1992).

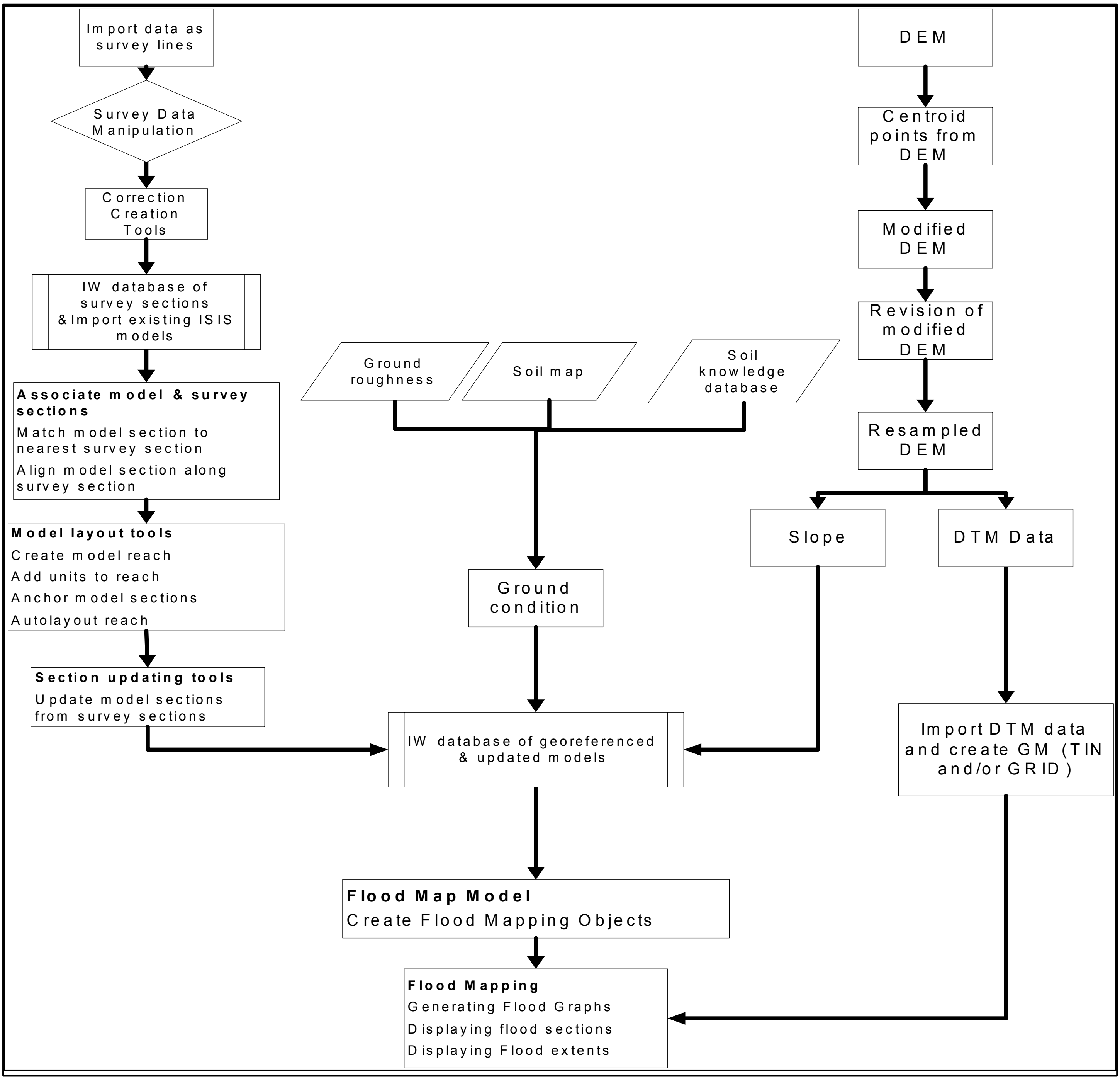

Figure 4 Scheme of Methodological Approach for the Work Modeling in GIS

Figure 5 Vegetation along the river

Figure 6 Floodplain Cover Type (Paddy Field)

3.4 River Bed and Bank Erosion

In rivers, turbulence is the most dominant factor in cohesive sediment transport processes. CCHE2D is a state of the art two-dimensional depth-integrated free surface hydrodynamic model. The model is targeted for applications in the areas related to predicting river bed and bank erosion for both uniform and non-uniform sediment, The model should be capable of simulating transition between subcritical and supecritical flow in or near hydraulic structures, flow near channel confluence, sudden river morphological changes such as channel expansion and contraction, and river mixing processes for water quality and pollutant transport. In addition, a state of the art sediment transport model, both for uniform and non-uniform sediment, needs to be developed for predicting river bed and bank erosion and sediment transport with armoring effects (Yafei, 2001). The main objectives of 2D simulation:-

- Simulate non-equilibrium transport of non-uniform sediment mixtures.
- Simulated Channel bed erosion and deposition.
- Hydraulic sorting and armoring of bed material.
- At an inlet, provide either steady or unsteady sediment boundary conditions.
- Simulate bedload, suspended load only, and total load.

4 Conclusion

The operational coupling of 1D and 2D techniques with a 'hydrologically oriented' Geographical Information System is done with particular emphasis on the suitability of distributed hydrological modeling for the implementation of reliable flood simulations. In this study the steps for the development of flood simulation for the Muda basin were proposed. An integrated Infowork RS hydrodynamic model and GIS are used for runoff and water level simulation and hydrological data process to generated flood inundation maps.

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