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ScienceDirect

Procedia Technology 24 (2016) 93 – 100

Procedia Technology

International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015)

Combined fluvial and pluvial flood inundation modelling for a project site

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Abstract

There are many sources of flooding viz. river flooding, coastal flooding, surface water flooding, drain and sewer flooding, groundwater flooding etc. This study envisages identification of various flooding sources, estimation of maximum floods and their routing through drainage system for a proposed industrial site. The digital elevation model (DEM) is developed from DGPS points, 0.5 m interval contour and spot levels and contours extracted from survey of India topographical maps for the surrounding area. The L-moments based rainfall frequency analysis has been performed to estimate 1 day maximum rainfall for various return periods. The synthetic unit hydrographs are derived from catchment characteristics and flood hydrographs for 10, 25, 50 and 100 year return periods are computed. The two major source of flooding are: flow in the drain and rainfall induced catchment flooding are modelled using MIKE FLOOD package. The bathymetry of the flood plain around the plant site at 5 m grid size is created from DEM in the 2-D modelling in MIKE-21. Local rainfall over the proposed industrial site is also modelled in the MIKE-21. The spills from drainage network due to upstream catchment flow and local rainfall are simulated in coupled MILE-11 and MIKE-21 i.e., MIKE FLOOD package. Various scenarios of flooding like flow in the drain and with and without rainfall of various return periods are simulated to develop corresponding flood inundation maps. Other parameters like flood extent, depth, level, duration and maximum flow velocity are also computed. The safe grade levels for the industrial site are proposed considering these parameters to safe guard the flood disaster.

Peer-review under responsibility of the organizing committee of ICETEST – 2015

Keywords: pluvial and fluvial flooding; flood frequency analysis; hydraulic modelling; flood hazard assessment

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Peer-review under responsibility of the organizing committee of ICETEST – 2015
doi:10.1016/j.protcy.2016.05.014

1. Introduction

Floods are one of the common and widespread of all natural disasters happening frequently over the globe. India is among the highly flood prone countries in the world due to various types of flooding like river flooding, coastal flooding, surface water flooding, drain and sewer flooding, cloudburst flooding etc. India receive high amount of rainfall in monsoon seasons, frequently causing pluvial floods in combination with embankment breach and riverine floods. In general, fluvial flood events considerably differ from pluvial (rainfall) flood events both in spatio-temporal scale including its magnitude. The fluvial events usually occur for duration of days, or even weeks with widespread damages in the floodplains of river system. On the other hand, pluvial flooding hardly ever happens for more than one day duration with influence on local regions. Whatever be the type of flooding, it causes huge losses in terms of tangible losses viz. damage to buildings with their contents; industrial facilities; rail and road network; other infrastructures; and intangibles losses due to business interruption causing huge economic losses, apart from loss of human lives. The impact of flood event can be limited to very local scale affecting a locality or society; to very large, affecting entire river basin with various districts and states. With time it has been realised that it is not possible to fully prevent flood disaster, however with adoption of suitable structural and non-structural measures and appropriate planning the losses due to flood can be minimized to certain extent. Flood inundation modelling plays a very important role for mitigating and reducing losses due to flood hazard by advance prediction of flood characteristics like its extent, depth, duration, velocity etc. These flood characteristics are used for development of flood hazard maps and also help in flood plan zoning [1]. Over the past decade significant advancement have been taken place in terms of development of 1-D and 2-D hydrodynamic models, satellite and remote sensing data products etc causing large improvement in the efforts towards flood inundation modelling and hazard assessment. Progress has also been made in the understanding of various processes controlling runoff and flood wave propagation, hydrologic and hydraulic simulation techniques with uncertainty handling, affordable high power computing facilities etc.

The most appropriate method for flood hazard assessment is a combination of hydrologic and geomorphologic approach [2][3][4][5]. The flood hazard maps are produced by simulation of detailed hydrological and hydraulic models with probabilistic rainfall and discharge analysis. These models are forced and parameterized by locally available, high resolution and preferably high quality spatio-temporal data. The hydrological-hydraulic mechanisms integrated with GIS approach for modelling of flood provides, systematic and consistent analyses of flooding together with their likelihood of occurrence in a given time period. The hydraulic packages solve 1D (river/drain) and 2D (overland) shallow water equations considering the topography of area. The combination of GIS and 1D hydrodynamic modelling may provide a cost efficient system for planning and management of flood.

Various researchers have applied coupled 1-D channel and 2-D overland flow models for simulating flow dynamics between rivers/ drains and floodplains for fluvial flood inundation modelling, [6][7][8][9]. In such aapproaches the flow in channel and overland are routed separately by solving 1-D and 2-D Saint-Venant's equations and linking them with structures like weirs or pumps. Modelling hydrodynamic channel flow in river or drain in conjunction with a full 2-D hydrodynamic model in order to describe the surface flow are very essential and described by many researchers [10][11][12]. In pluvial flooding studies, the 1-D channel flow models are developed to simulate interactions among various sub-catchments, and between the surface and sub surface flow [13][14]. The overland flow from channel system occurs when the runoff caused by pluvial events is higher than major channel capacity. In such scenario when the flow is no longer confined to predefined flow paths, the 1-D modelling approaches are believed to be inadequate to capture the process. Under such situation, 2-D overland flow models are required for better prediction of flood propagation. Therefore, a coupled 1-D channel and 2-D overland flood inundation models, which consider the interactions between channel and flood plain, are the best method to study details of overland flow propagations [15][16]. Recently, commercial software such as SOBEK, XP-SWMM 2D and MIKE FLOOD etc. provides various options for integrating 1-D channel and 2-D overland flow modelling functionalities in their packages.

Practically, pluvial flooding frequently occurs along with fluvial flooding, intensifying catastrophic consequences than that may be caused due to occurrence of a single type of flooding separately [17]. Hence, there is need to study them together in an integrated dynamic modelling platform to assess all potential drivers with their combined effects. In this paper, we have analysed the possible flood inundation for a proposed industrial site due to a combination of