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Inundation Map Development by Using HEC-RAS Hydraulic Simulation Modeling From Roseires to Khartoum Cities

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ABSTRACT

Inundation floodingmap aimedto find outearly warningsto avoidenvironmental damageandhumanin terms of theheight ofthe wave ofwater, speed time arrival, effects of inundation sideanddepth of the water/ distanceand reduce the impact of the flood wave after obtaining the process of collapse of the dam in the lower part of the river to the dam area. The study has been using a numerical model one-dimensional depends on the development of equations (Saint-Venant) so that parts of the river, any river channel main banks of the right and left treated as separate parts, that's the difference in the characteristics of the hydraulic and engineering, along the line of the flow will take into account in each section of the sections and flow in the river valley.

Throughapplied numerical model of the Nile River in the area between the Roseires dam and Khartoum is distance (630 km) south of Khartoum , to get a jest analysis of the impact of a wave of flooding in the river on the following parameters : the maximum discharge , the maximum of attributed, as underdevelopment of the discharge maximum , and the time defaults to the maximum level and the surface area on the banks of the river and its extension and different values of the coefficient of manning roughness to the banks of the river. Eight scenario have been prepared for the flood wave read to compare the effect amount of water flow in the channel resulting from the collapse of the dam was resulting of Roseires dam , eight scenario to represent the five and extract the resulting values of Inundation map to cities located on the downstream of the dam.Thefive scenarioswerecalculated by using (HEC-RAS 4.1.0), (HEC-GeoRAS)a GIS programs and the flood wave resulting from the collapse of the Roseires dam to compare the results showed that the scenario NO. 5 is the best scenario result from the collapse makes sense due to the form of the disposal of the flood wave resulting from the collapse of the Roseires dam and then get overtopping from Sennar dam to the inability of the reservoir and dam to stop the flood wave. The results also indicate that the time needed to reach the greatest discharge of the flood wave resulting from the collapse of the Roseires dam to the city of Khartoum is (4, 6, 7and 9) day on the cities (Roseires , Sennar , Wad Medani and Khartoum) respectively, of the cases . The maximum height of the flood wave reaching the city of Khartoum has given the scenario NO. 5 by height wave (3-50) meters respectively. As well as the delay in the arrival time of the maximum height of the flood wave to the city of Khartoum is one day for the five scenarios compared to the other.

The Inundation map development resulting from the collapse of the Roseires dam and get the flow overtopping the Sennar dam, arrival to Khartoum, was determined the surface area of the affected river and both banks of the depth of the wave and latency along the river has been selected four major cities along the river which Roseires,Sennar, Wad Medani and Khartoum.

KEYWORDS Roseires,Sennar, Wad Medani, Khartoum, Inundation,Blue Nile River,Eddiem.

1. Introduction

Inundation map is a surface profile is being done for the purpose of the extent of the impact of the flood wave after obtaining the process of collapse of the dam in the lower part of the river to the dam area. Inundationfloodingmap aimed-to find outearly warningsto avoidenvironmental damageand-humanin terms of theheight ofthe wave ofwater, speed time arrival, effects of inundation sides anddepth of the water/ distance.

Petra's and Sydler, (1984) demonstrated the sensitivity of peak flow, inundation levels, and flood arrival time to changes in breach width and breach formation time. For locations near a dam, both parameters can have a dramatic influence. For locations well downstream of a dam, timing of the flood wave peak can change significantly with changes in breach formation time, but peak discharge and inundation levels are insensitive to changes in breach parameter.

Sunitand Scott, (1998) studied the unsteady flow modeling is often used in dam breach analysis due to regulatory requirements or the need to obtain more detailed or results for inundation mapping than a simplified steady- state model can provide. However, use of unsteady models, such as the unsteady flow dam breach component within the U.S.Army Corps of Engineers Hydrologic Engineering Center–River Analysis System (HEC-RAS), can be time consuming and have extensive data requirements and has included the addition of unsteady one dimensional hydraulic modeling and dam breach modeling. Unsteady modeling of various aspects of the dam failure and downstream flood wave propagation with HEC-RAS can performed using differing techniques and assumption. They discussed some of the commonly used techniques and assumption and, through case studies on several dams in Texas and Kentucky compares the results obtained with each technique or assumption.

Cameron, and et. al., (2006) studied analysis of dam failure

models provides a scenario generating tool for identifying the resulting hazards. Floodplain managers and emergency management personnel may then utilize the resulting contingencies to protect against the loss of life and property damage. HEC-RAS can be used in concert with HEC-GeoRAS to develop Adam failure model. HEC-GeoRAS is used to extract geometric information from a digital terrain model and then imported in to HEC-RAS and results are mapped using the GIS. Inundation mapping of water surface profile results from dam failure models provides a preliminary assessment of the flood hazard and provides insight for emergency preparedness. The process for gathering and preparing data,creatingan unsteady–flow model in HEC-RAS,entry of dam breach parameters, performing Adam breach parameters, performing a dam failure analysis, and mapping of the flood progression is discussed.

Dam-break flood with high velocity, huge energy, and much higher peak discharge is extremely abnormal and dangerous for the human kind.**Jayawardena (2008)** have been collected around 200 notable dam and reservoir failures worldwide in the twentieth century, and caused catastrophic devastation in the valleys downstream both in terms of lives lost and widespread damage to infrastructure and property. An analysis on dam –break flood in the Mid-downstream of Han River,China,was performed.Among those big dams in Han River Basin,Danjiangkou Dam may cause disastrous effect if one or both of them break. After assuming failure parameters of these two dams, peak discharges and hydrographs at dam sites are calculated by empirical methods and with the help of HEC-RAS hydraulic model and ARC-GIS, main work is focused on how dam- break flood propagates along the river, what is the relationship between peak discharge and distance, and what are the effects in the downstream when one or both dams break.

Henry and et. al., (2010) studied a dam failure analysis was conducted for Seattle public Utilities to determine the flood inundation extents of a hypothetical failure of the Lake Younges Reservoir Outlet Dam in King Country,Washington. The 690-acre reservoir is unique as it is completely impounded by embankments and perimeter dikes without receiving natural inflows and probable maximum flood failure.

Eastern Nile Technical Regional Office (ENTRO, 2013) studiedthe dam safety risk assessment through various literatures and published project reports review, also the approaches to the demonstration of safety have been outlined, together with some of the strengths and weaknesses of each approach. The report has also assessed the current dam safety practice in the Eastern Nile countries in compare with the international practices, the study has focused on the Embankment dams in the Eastern Nile countries and has develop a baseline data and dam safety assessment toolkit by use of Excel applications, the toolkit contains information about the existing and proposed dams on the region, a case study has been undertaken to test the toolkit and explain the inundation map for the case steady.

An inventory of the existing available topographic data collection was performed in order to identify data gaps and the need for additional field surveys. The following data were collected and processed through field Survey Data for the Blue Nile River, 1992used in the configuration of the Flood Early Warning System (FEWS) developed for the River Nile were retrieved. A total of 87 field-surveyed cross-sections for the Blue Nile from Roseires Reservoir to Khartoum were available from this system. The cross-sectional data were available in distance-elevation format for each cross-section. As such, there was limited information with which to locate the specific cross sections geographically on a map for subsequent integration with other data sources for the development of a terrain model, for hydraulic modeling, and for inundation mapping. Bathymetric Survey for the 25 Km Blue Nile River Reach between Khartoum and Bagair, 2007 A recent bathymetric surveys was performed by the Dam Implementation Unit (Sudan) in association with Ministry of Irrigation and Water Resources (MOIWR Sudan). This survey covers a 25 km reach between Khartoum and Bagair and is a very dense bathymetric survey collected at an interval of 100 m. The available data are in distance-water depth format for each cross-section. The data were geo-referenced using the same approach outlined in the previous section. Almost no error or shift was encountered because of the large amount of cross sections and the short distance between cross-sections.A bathymetric surveys for Roseires Reservoir, 2007was performed by the Dam Implementation Unit in association with MOIWR for Roseires Reservoir. The survey covers a reach of about 110 km upstream of Roseires Reservoir with geo-referenced data. The data were pre-screened to check for the right datum projection (WGS-UTM84) and a number of referenced points were utilized to verify the accuracy of the data.

Field Survey performed by Riverside Technology (RTi, 2010) and UNESCO Chair in Water Resources (UNESCO-CWR) performed a field survey to supplement the available data and verify the accuracy of existing river cross-sections. The survey at each river cross-section was tied to a control point of known elevation. For the purpose of consistency, the Elevation Datum was chosen to be a MOIWR reference datum because all the previous cross-section surveys were based on MOIWR elevation data. There is a vertical shift of 3 meters between the survey datum and MOIWR datum.

This paper discusses the methods and assumptions used to build the HEC-RAS model to prepare inundation map by using (GIS) by linking HEC–GeoRAS and after the completion of the work of the mathematical model of the steady state by using the HEC-RAS. The paper presents dam break flood routing results, including the travel time (warningtime) of the flood wave to various key locations in the downstream valley and the representative channel/ valley cross-sections depicting flow depth and typical flow velocities. It finally presents the elements and information depicted on an inundation map, which is used by stakeholders and public agencies for the purpose of emergency alert and management.

2. Study area description

2.1 Blue Nile River

The Blue Nile sub system in this respect accounts for 76% of the total irrigated agriculture on the three Nile tributaries Atbara, White Nile and Blue Nile as shown in Fig. 1(Ministry Of Sudan's Irrigation, MOI). A major characteristic of the Blue Nile discharges is the remarkable seasonality of its flow, and more than 80% of the river discharge flows during the flood months, (June–October) Two Dams were built across the river (Sennar, 1925 and Roseires, 1966) to partially control the flows, which serve about (1.134 million hectare) of the Sudan irrigated area, as well as more than 40% of the total hydropower generation of the country (UNESCO Chair in Water Resources, 2011). There are seasonal rivers feed the Blue Nile, such as Rahad River Dinder and some of the big creeks like KhorAzcola and KhorBmada and Daca and Tamed (Dams Implementation Unit).

The Roseires dam, which spans the Blue Nile 630 km upstream of Khartoum, is a 1000 m long and 68 m high concrete dam with the crest at 482.2 m. The dam was completed in 1966 with an initial capacity of 3.024 km^3 at level 480 m level to be used for irrigation water supply as first priority, and hydropower generation comes secondly. The dam contains five deep sluices and a gated spillway, consisting of seven units, with a maximum discharge capacity at of 16500 m^3/s level 480 m. The hydro-electrical potential amounts to 212 MW. Fig. 2 shows the longitudinal profile along the Blue Nile.

The Sennar Dam is a dam on the Blue Nile near the town of Sennar, Sudan. It was built in 1925 by the British engineer, desert explorer and adventurer, Stephen "Roy" Sherlock, under the direction of Weetman Pearson. The dam is 3025 meters long, with a maximum height of 40 meters. It provides water for crop irrigation in the Al Jazirah region (Prowde, 1926). Once completed, the Dam was constructed on the Blue Nile

River at Sennar town some 300 kilometers south Khartoum the capital of Sudan. Construction works began in 1920 and completed on 1925/1926.Its main object is to provide irrigation water for the giant Jiziera agriculture scheme to help irrigates cotton and other crops .It provides irrigation water for about 60 percent of the country`s agricultural production. In addition it helps in providing the hydroelectric power. The dam extended over about 3.10m, i.e. over 3 km (3,025 meter) in length, and of a maximum height of 40- 45m(Dam Implementation Unit). Fig 3 and 4 show Surface areas-Level relationship for Roseiresand Sennar reservoir respectively.

2.2 Data Collection and analysis

Analysis of the system requires upper boundary condition that specifies the inflow to the system which is considered as lateral inflow hydrograph. So for this study Eddiem observed flow is used as upper boundary. The downstream boundary condition at Khartoum as the downstream end of the study area is set as normal depth. The effects of Rahad and Dindir were accounted for by lateral inflows at their respective confluences with the Blue Nile River. In addition nine internal boundary conditions were to be considered. These are observed stage and/or flow hydrographs at upstream and downstream of the two reservoirs, Roseires village and wad Alaies in the Roseires-Sennar reach, wad Medani, Kamlin and Soba in the Sennar-Khartoum reaches shown in Fig.5.The required available data for each of these stations were collected for the Ministry of water resources and electricity. The collected data were processed for use in the model calibration.

Reservoir characteristicswere collected from the dams' directorate of the Ministry of water resources and electricity andthe operation policy for each reservoir is also collected (Ministry Of Irrigation Sudan, 1968).

Field Survey, 2013during this study and for the sake of training three cross sections around Khartoum were done. These cross sections were used for checkup of validity of the existing ones. Materials used include: Global Positioning System (GPS) device used tolocate positions of each cross-section along river centerline. Theodolite, ADCP, and GPS instruments were used by the surveying working team.

3. TIN Creation and HEC-RAS Application

Tin is define the layer of earth which resulting from field surveying and take the deferent elevation to topographic of earth by using the surveying instrument ,after that is fixed by (GIS) program. A multi-step procedure was used to create a TIN from multiple sources of elevation data. The following steps were used:

1. Generate a TIN in ArcGIS using the survey data exclusively (no DEM data for the floodplain). The TIN generation is an automated GIS process that generates a preliminary TIN whose exclusive purpose is to incorporate the survey data into a surface for extraction into HEC-RAS.
2. Digitize the centerline and bank lines of the river from satellite imagery. This step adds additional information about river alignment and meandering that is not available in the reaches between surveyed cross sections.
3. Delineate cross sections in GeoRAS/ArcGIS that correspond to surveyed cross section locations, but that are confined within the bank lines drawn in step 2
4. Extract the cross sections, bank lines, and river centerline to RAS. This step provides HEC-RAS with all of the original cross section data in a geo-referenced form.
5. Interpolate additional cross sections at 100-meter spacing between surveyed cross sections, following the river centerline, and export the cross sections to GeoRAS/ ArcGIS. In many sections of the river, the surveyed cross section spacing was greater than 6 kilometers, so this step resulted in the addition of more than 60 interpolated cross sections between each surveyed cross section. In areas with surveyed cross sections that are spaced more closely than 100 meters (such as most of Khartoum), no interpolation is performed.
6. Delineate break lines in ArcGIS at the centerline and at previously defined bank lines with elevations defined by surveyed and interpolated cross sections.
7. Extract elevation point data for the floodplain from the 90-meter SRTM gridded DEM.
8. Generate a multi-source TIN surface by combining the break lines and cross section data points with elevation data from the 90 meter SRTM gridded DEM using ArcGIS 3D Analyst.

The resulting TIN can is used for extracting cross sections that extend into the floodplain, as well as for mapping flood hazard using results from a hydraulic model. The interpolation of the TIN points from the break lines between cross sections results in some generalization of the cross section into a triangular shape between cross sections in the final TIN. This aspect of the TIN does not impact the hydraulic model, which considers only the specific cross section shapes, and it does not impact the flood extent mapping because the effect is seen only within the low-flow channel. The effect is seen, however in the flood depth maps. The final TIN was used as the basis for extracting cross sections for the hydraulic model, and subsequently in mapping the flood hazard.

4. Result and Discussion

Figures6, 7, 8 and 9 were showed the amount of immersion surface and vertical to wave of flooding resulting from the collapse of the Roseires dam and wave from the over topping the Sennar dam on the areas that fall below the two dams, (Roseires dam, Sennar dam, Wad Medani and Khartoum) the values were confined from the 3.05m to 50.5m and the surface area explain in the figures from 6 to 9. The failure in Roseires dam cussed over topping in Sennar dam and

observed the existence of a passage of water over the Sennar dam The reason he size of inventories design to the Sennar and the structure of the dam (spillway) has been prepared on the basis of the natural state of water and not on the state of emergency caused by the failure of the Roseires dam which leads to increased speed , wave height and not the capacity of the spillway to allow amounts of water and the water continued to rise in spite of the functioning of spillway water or hydraulic gates leading to the passage of water over the body of dam.

Through the study, it was observed that the extent of side effect on the banks of the river right and left sharply lower and upper where either not to recommend the establishment of vital projects within this area or take in terms of design flood level expected.

Figure 6 shows the little affect output due to the collapse of the dam , which shows the area of the reservoir , dam and the downstream of the dam because the gradient very high after the dam directly and Fig. 7, notes the effect of the flood wave resulting from the collapse of Roseires dam to the reservoir area and Sennar dam, the area downstream the dam due to over topping , Figure 8 the effect of a wave in Wad Medani and affected by the right side more than the left because the topography of earth in that area and figure 9 shows the large affected of a wave in the Khartoum on the right and left of the river and was also explain the amount of surface area , which resulted from the collapse.Considered Khartoum city is more than areas affected by the collapse of Roseires dam, the values of elevation of water are (481.01, 428.37, 382.5) respectively and wave velocities8.97 m/s in the Khartoum.

5. Acknowledgements

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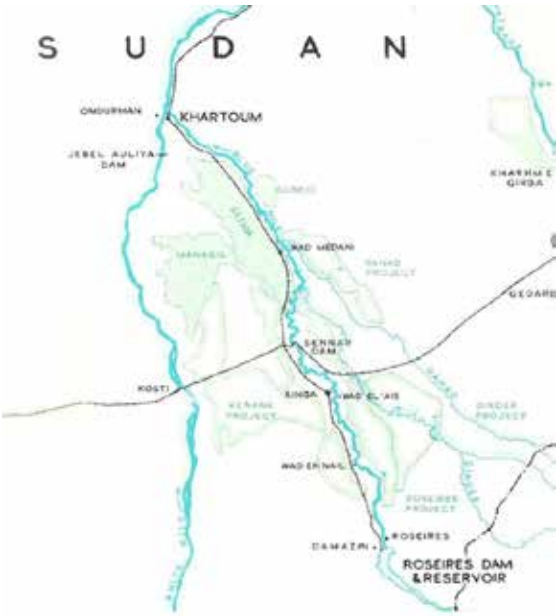


Fig. 1Blue Nile River system schematic in the study area.

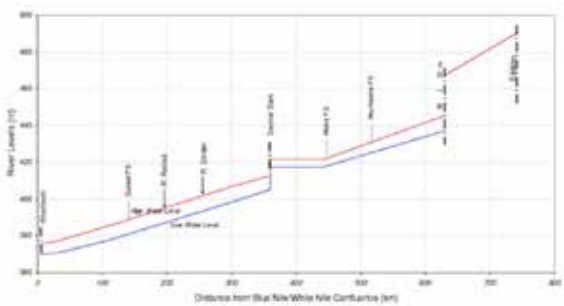


Fig. 2 Longitudinal profile of the Blue Nile River from Roseires dam to Khartoum.

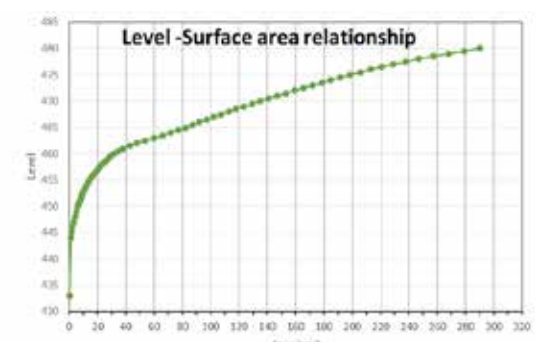


Fig. 3 Total amount surface area stored-level relationship forRoseiresreservoir.

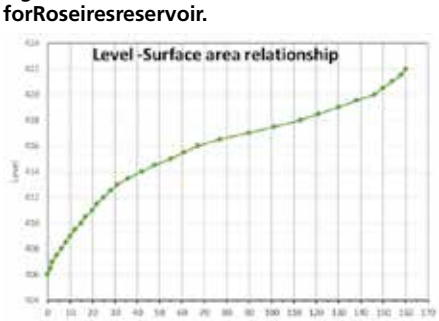


Fig. 4 Surface areas-Level relationship for Sennar reservoir.

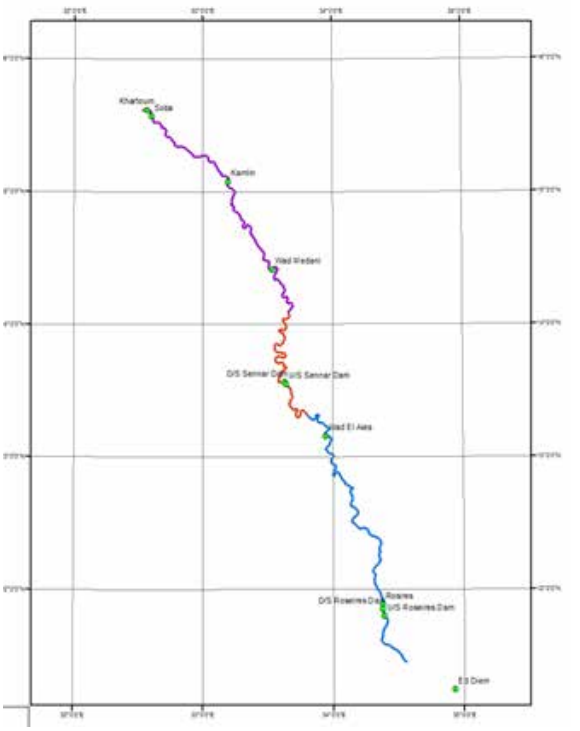


Fig.5 Location and type of each flow gauging station for modeling purpose.

Structures (Internal Boundaries
Lateral Inflow Hydrograph Points
Internal Observation Points
Normal Boundary Condition

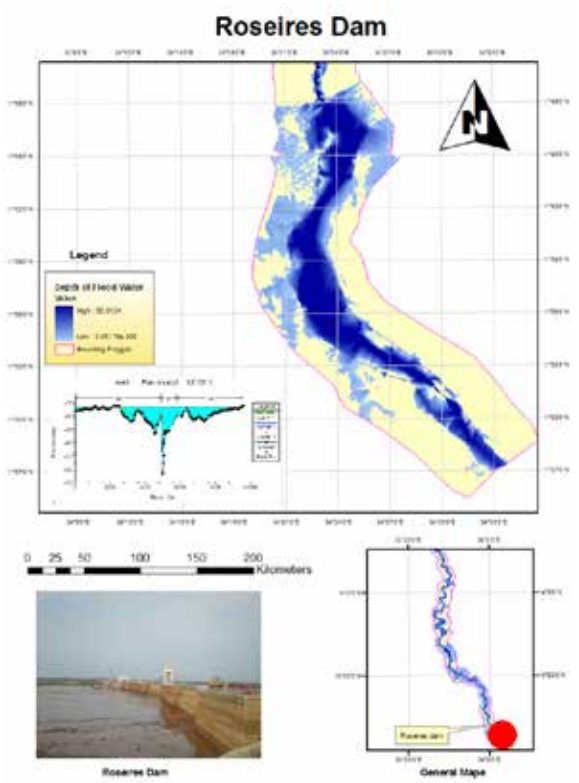


Fig.6Inundation Maps in Roseires dam.

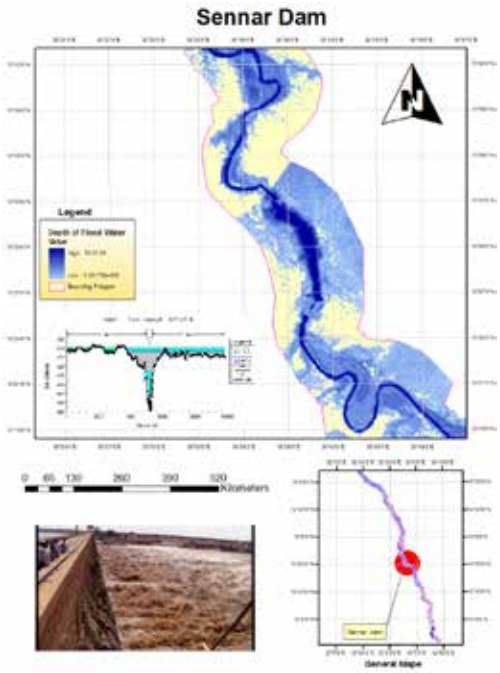


Fig. 7Inundation Maps in Sennar dam.

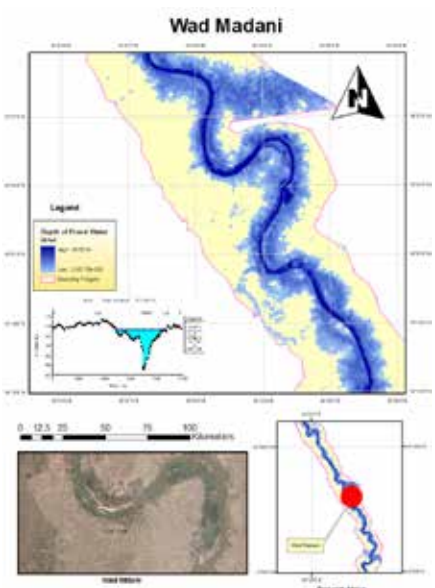


Fig. 8Inundation Maps in Wad Medani.

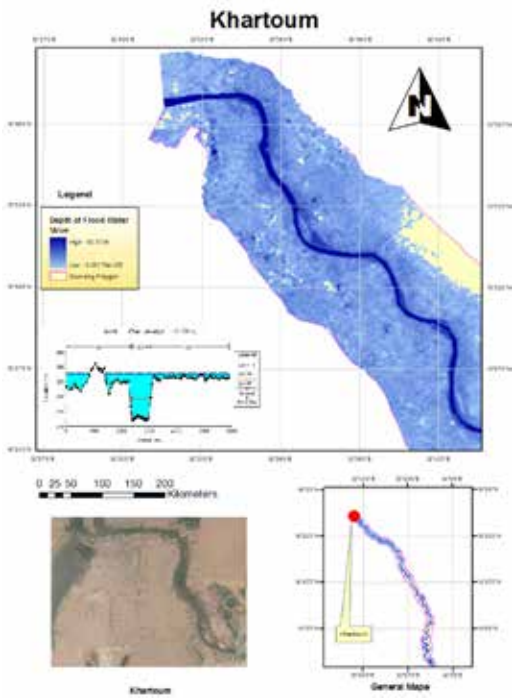


Fig.9Inundation Maps in Khartoum.

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