Management of the flood Disaster and Assessment their damaged areas using Remote Sensing and GIS Techniques: A Case Study of Tigris River – Maysan Governorate, Iraq

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Management of the flood Disaster and Assessment their damaged areas using Remote Sensing and GIS Techniques: A Case Study of Tigris River – Maysan Governorate, Iraq

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Abstract. Flood is the most widespread hazard across the world. Its management is a source of concern for all decision makers. During Spring 2019, this phenomenon occurred in Iraq, especially in the Governorate of Maysan, where the amount of water flowing into Tigris River increased. This led to rise the river level as a result of heavy and close periods of rain, in Maysan Governorate, the drainage quantities of water have been increased from Kut Dam. Remote Sensing (RS) techniques and the Geographic Information System (GIS) environment are used for the purpose of assessing the damage areas that resulting from flood and torrent in Maysan Governorate, which based on Sentinel-2 multispectral imagery data, by extracting the NDVI and NDWI values. Also, for the purpose of managing and reducing the volume of torrent and potential flood in the future, SRTM satellite is utilized to great hydrologic model based on the Arc Hydro tool in GIS environment to suggest a flood escape location. A couple hydraulic model (One Dimension (1D) and Two Dimension (2D)) is performed using HEC-RAS software for Maysan Governorate at the site of the proposed escape to determine the size of flood in the flood shelter. Accordingly, a flood map is produced for Maysan Governorate using the outputs from the analysis process and depending on the GIS environment.

Keywords. GIS, Flood Hazard, DEM, NDVI, NDWI.

1. Introduction

In the last decade, the climate is changed in the all world for many resins such as the increasing of urbanization, factories and population with decreased in the vegetation cover and water bodies. This led to inequality for the amount of rain through the season. Republic of Iraq is located in western Asia above the Equator. Also, it has been subjected to climate changing in the last decade. Especially in Spring 2019, heavy rain was fall in Iraq with snow melting in the north region. This led to increase the flow and water level in Tigris River and flooding areas around the river. Floods are one of the most effective dangers that lead to loss of life and property, and thus the need for appropriate mechanisms to mitigation their severity [1]. Therefore, flood management and control must be performed by conception the hydraulic flow in floodplains [2]. Remote Sensing techniques and GIS environment are sophisticated for monitoring and damage assessment of flood disaster by using multispectral images [3], [4]. Also, GIS is considered a powerful tool that can support flood plain management in detecting flood prone areas [5]. Also, DEM image was used for developing methodology to delineate the flood hazard through make flood escape by using GIS and HEC-RAS hydraulic model [6]. Therefore, this study has two objectives. Firstly, the assessment of damages areas in Salah Al-Din Governorate is preformed using multispectral images in GIS environment. Then, the mitigation processing is preformed to determination proposed flood shelter using DEMs in Arc Hydro tool and make hydraulic modelling in HEC-RAS.

2. Materials and Methods

2.1. Study Area

This study covers all Maysan city by (46º, 47º) longitude, (33º, 31º) latitude as show in figure (1). Maysan Governorate has an area of (16072) Km². Tigris River also passes through this Governorate, and due to frequent rainfalls and streams flowing from nearby high areas that flow into Tigris River. However, this led to a huge increase in the amount of discharge from the Al-Kut barrage towards Maysan Governorate. To handle these risks, the concerned authorities try to open flood escape on the shoulder of the river in order to avoid damages to the agriculture lands, starting from Qathaa Ali Al-Gharbi district towards the Al-Amara city in the Maysan Governorate. But those concerned has faced two problems. The first: is choosing the appropriate location for the flood escape. The second is the amount of the inundation and the damages which is related to the size of the inundation and the damages are a result from the drainage of water into a cavernous basin [7].

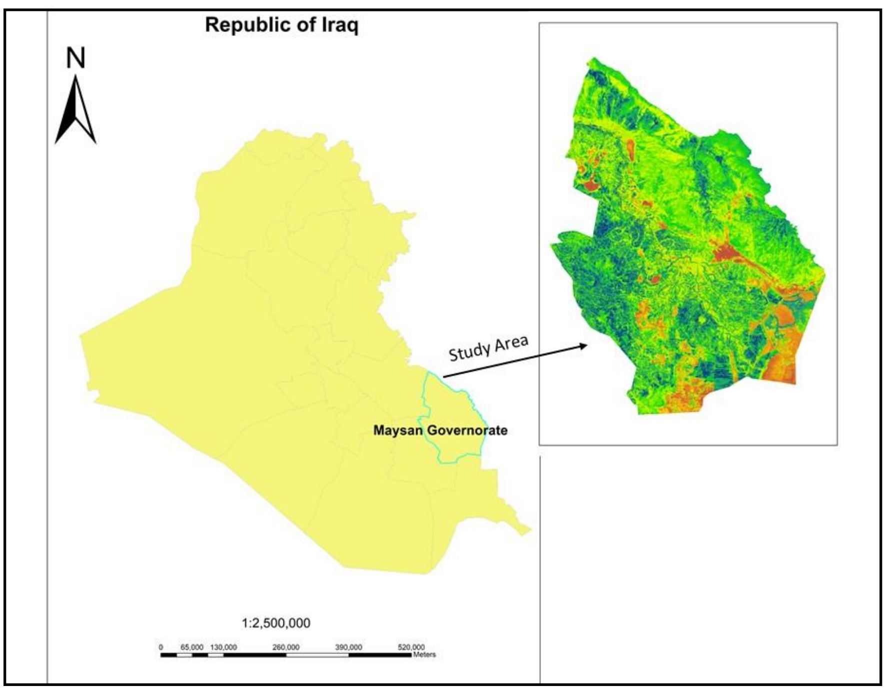

Figure 1. Location of the Study Area (General Authority of surveying)

2.2. Data Source

2.2.1. Sentinel-2 images

European Wide-Swath launched high-resolution multispectral imaging mission in 23/6/2015. Sentinel-2 mission is a land monitoring constellation of two satellites (Sentinel- 2a and Sentinel- 2b), which was designed to give a high revisit frequency of 5 days at the Equator, because of the specification of the twin satellites flying in the same orbit but phased at 180° [8], and it provides global optical imaging with 13 spectral band using MSI (Multispectral Imager) instrument (four band at 10m, six band at 20m, and three band at 60m spatial resolution) [9]. There are 5 rater images of Sentinel-2 that cover the entire area of Salah Al-Din Governorate, which is easily downloadable from https://earthexplorer.usgs.gov/. They are downloaded in the period before and after flood.

2.2.2. DEM Data

DEM is 3D representation of the of the Earth's surface that contains real height points appearing the topography of surface. The Land Processes Distributed Active Archive Center (LP DAAC) lately sent out additional tiles in the NASA SRTM Version 3.0 Global 1 arc second dataset (SRTMGL1), which is coverage Africa, Europe, North America, South America, Asia, and Australia in 1° X 1° tiles at 1 arc second (about 30 meters) resolution [10]. The SRTM data is easily downloadable from https://search.earthdata.nasa.gov/.

2.2.3 Cross-Section

The Cross-Section are considered one of the most important data and inputs in the HEC-RAS software, because they provide the values of the heights Z, especially for the main channels. Therefore, data from the General Authority of surveying was used to create a hydraulic model in the HEC-RAS software for the area of the flood escape. The data consist of 30 cross-sections for the area of the flood escape, and due to the large number of this data, it has not been included.

2.3. Methodology

Figure (2) gives a summary of the procedures performed to achieved the two objectives of this study.

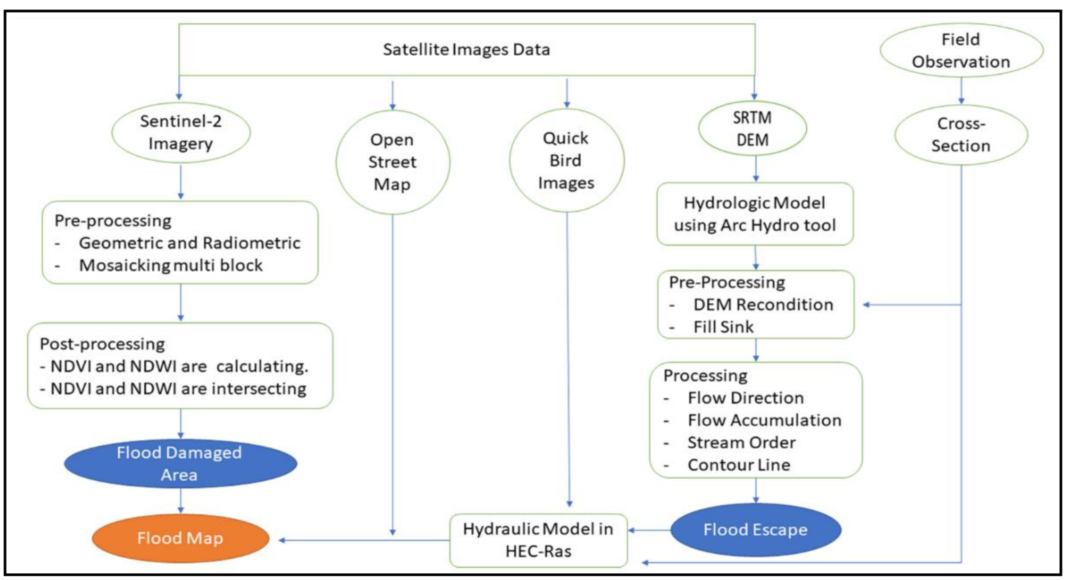

Figure 2. Flow chart of Methodology

2.3.1. Pre-Processing Methods

2.3.1.1. Sentinel-2

The Sentinel-2 Level-1C data has been used in this study. Therefore, this data does not need to be radiometrically and geometrically corrected, because it has produced with ortho-rectification and spatial registration on a global reference system (UTM/WGS84) projection, also it is providing the Top-Of-Atmospheric (TOA) reflectance [11]. However, the 5 raster images are mosaiced using rater calculator tool in GIS and resampled the Short-Wave Band from 20m to 10m using resample tool in GIS.

2.3.1.2. SRTM DEM

Terrain pre-processing is preformed using Arc Hydro tool, which includes DEM Recondition and Fill Sink. DEM Recondition is used Burning in Streams technique to adjusted Z value using equation [12]:

$$Z = E - (G/G+D))^{K} * H \ldots (1)$$

Where: Z = newly calculated grid cell elevation (m), E = old grid cell elevation (m), G = grid resolution (m), D = distance from a stream cell (m), k = decay coefficient and H = elevation decrement (m)

Fill Sink is utilized Topographic Depression technique to ensure that problematic DEM depression is corrected and removed from features as show below in figure (3) [13].

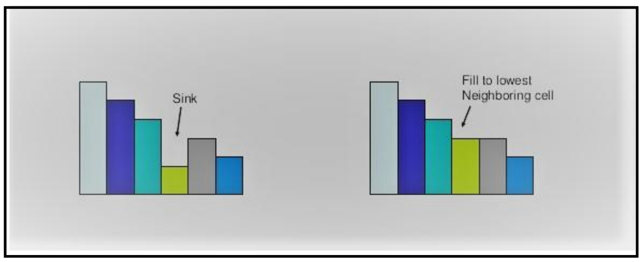

Figure 3. Fill Sink Process (www.google.com)

2.3.2. Processing Methods

Figure (2) shows the methodology of this study, which is divided into stages, the first includes assessing the extent of damage resulting from the flood and the second includes proposing a flood escape site to prevent future damage.

2.3.2.1. Vegetation Index

There are many of vegetation indices. But, Normalized Different Vegetation Index (NDVI) classification is considered the most common index, which is used to extracting the vegetation cover for Salah Al-Din Governorate before the flood by applying the equation 2 [14].

$$NDVI = (NIR-RED)/(NIR-RED) \ldots (2)$$

For Sentinel images, Band 4 and Band 8 are utilized to extract NDVI, which are represented the RED Band and Near Infrared Band respectively.

2.3.2.2 Water Index

For monitoring natural resources such as water bodies and also to enable a time and cost operative detecting of water resource with reliable data [15], Normalized Different Water Index (NDWI) is calculated using equation 4 after the flood, which is presented by McFeeters [16]. NDWI is utilized Green Band and NIR Band (Band 3 and Band 8 respectively) for Sentinel-2 images.

$$\text{NDWI} = (\text{Green} - \text{NIR}) / (\text{Green} + \text{NIR}) \ldots (3)$$

2.3.2.3. Drainage Model

For modelling drainage line, Arc Hydro tool is utilized to perform the Flow Direction, Flow Accumulation, Stream Order and Slope Map. The process of distributing and transporting of water across the ground have been employed flow route to calculated and extracted the hydrological attributes from DEM surface as show in figure (4). The direction of water from one grid cell may be distributed to any down slope (neighbor grid cells), has been determined by using developed flow routing algorithm (Deterministic 8 Neighbor (D8)) [17].

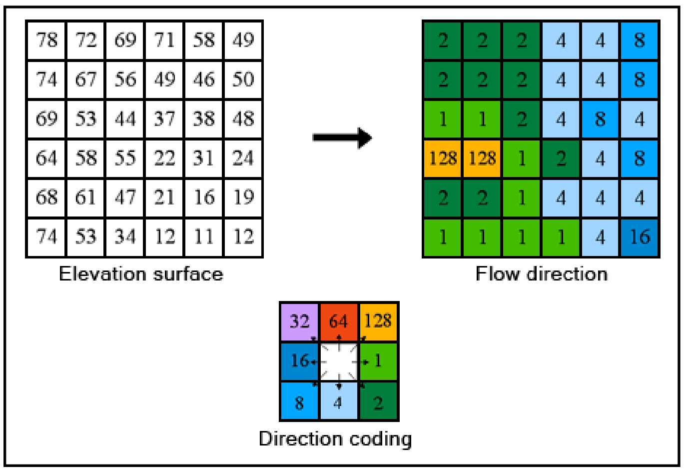

Figure 4. Deterministic 8 Neighbor (D8) (www.google.com)

2.3.2.4. Hydraulic Model

2.3.2.4.1. HEC-RAS

The hydraulic model (1D HEC-RAS) is intended to simulate a one-Dimensional unsteady flow of a complete network of natural canal. Therefore, physical laws are used to preserve mass and momentum that govern water flow in the current. The laws of maintaining momentum are expressed through Newton's second law mathematically in the form of partial differential equation (4) [18]:

$$\frac{\partial Q}{\partial t} + \frac{\partial QV}{\partial x} + gA\left(\frac{\partial z}{\partial x} + S_f\right) = 0 \qquad (4)$$

Where, Q: the total flow (m3 s −1) as a function of the distance, x, and time, t. V: the control volume (m3). g: the gravitational acceleration (m s−2). A: the total area (m2). $\partial z/\partial x$: the water surface slope. S_f: the friction slops.

2.3.2.4.2. The Couple of 1D-2D Hydraulic Model

The new version of HEC-RAS has offered the facility to make coupling in 1D and 2D model within the same unstable flow [19]. However, this helped work on large rivers to make 1D model and implement 2D modeling in areas requiring high hydraulic precision. To implement this combination, a lateral link is created, which is coupled 2D flow areas with the 1D cross-section of river, to preformed 1D-2D combination method in HEC-RAS environment [20].

3. Result and Discussion

3.1. Damaged Areas

Firstly, the NDVI index is extracted before the flood event to found the vegetation cover as show in figure (5a). Secondly, NDWI index is extracted to detection water bodies after the flood event in Maysan Governorate as show in figure (5b).

$$\text{Damaged area} = (\text{NDVI} == 1)\ \&\ (\text{NDWI} == 1) \qquad (5)$$

The damaged areas as show in figure (6) were calculated at (113,000 Dunam) in the Governorate of Maysan by applying band math as show above in equation (5), which intersects a value of 1 for NDVI and a value of 1 for NDWI using raster calculator tool in GIS.

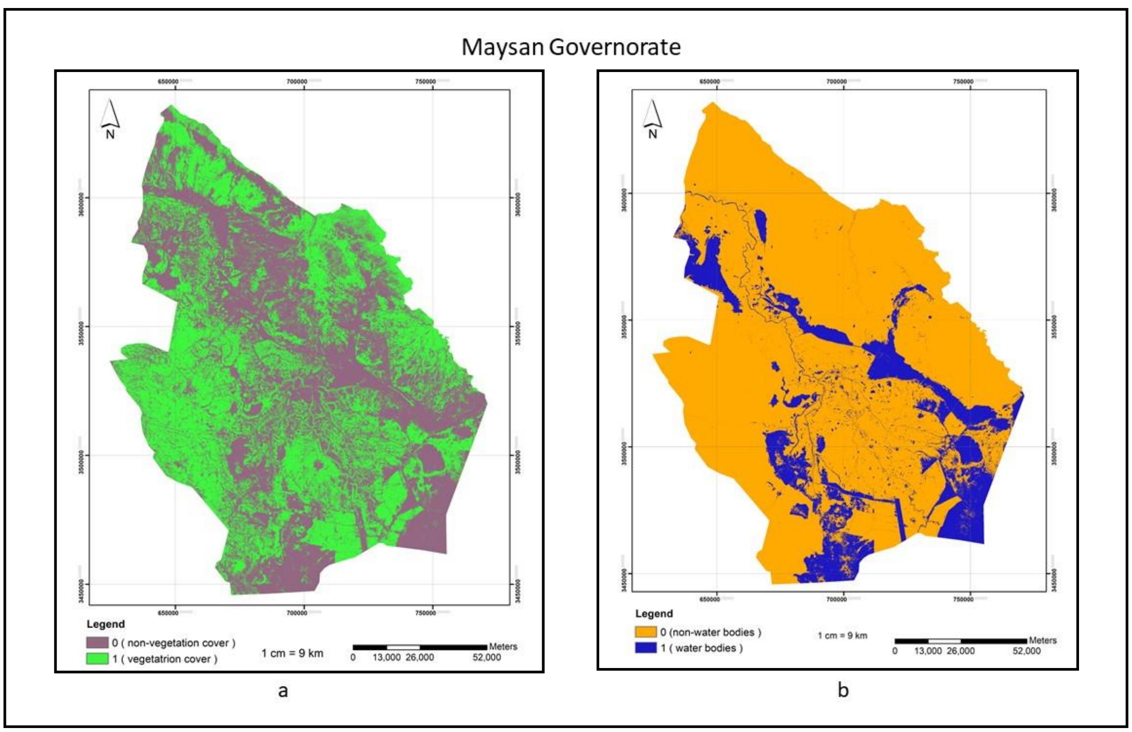

Figure 5. (a) NDVI index, **(b)** NDWI index

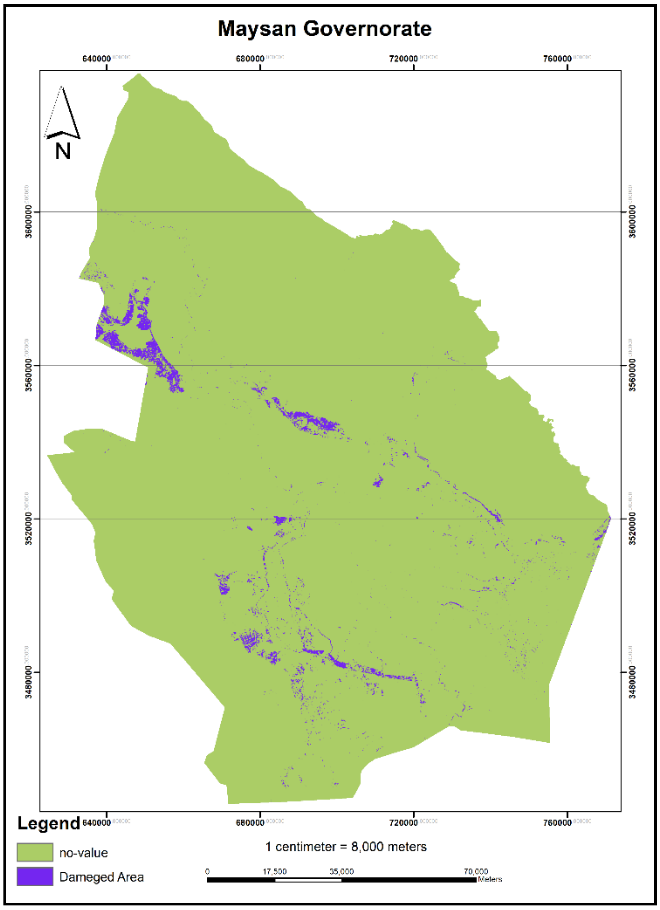

Figure 6. Damaged Area for Maysan Governorate

3.2. Mitigation processing

Because Tigris River was exposed to a flood in 1988, the concerned authorities made proposals studies for the sites were proposed in Maysan Governorate. The Tigris River flooded in Spring 2019; the concerned parties faced the problem of choosing the appropriate escape to accommodate the largest discharge with the least property losses. To mitigate future flood, firstly a flood escape location has been chosen from among several proposed locations during previous studies as result of 1988 flood. Therefore, the environment of GIS and RS techniques are utilized, which are used DEM for purpose of extracting flow channels and drainage point, as well as with the help of contour line, to suggest a suitable location for flood escape or to choose the best sites that have been proposed by the concerned authorities to drain the flood water as shown in figure (7).

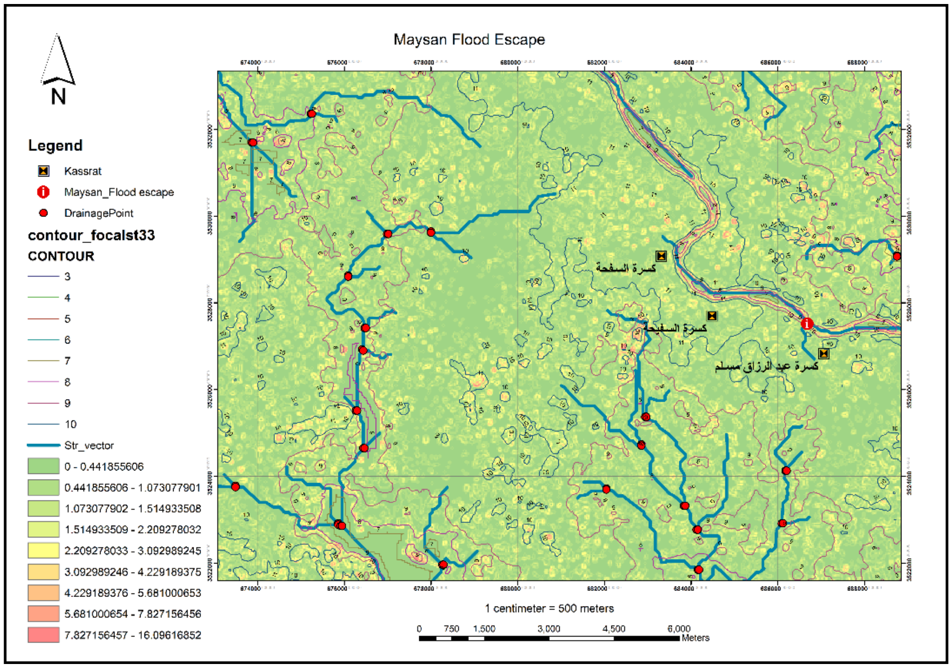

Figure 7. Maysan Flood Escape Map

Secondly, a couple 1D-2D model by HEC-RAS software is preformed to simulate flood model for Tigris River. The new version of HEC-RAS software has the ability to connect 1D model, which preformed using cross-section data [7] as shown in figure (8), for Tigris River using lateral structure (weir) as shown in figure (9), which represented the flood escape that has been suggested.

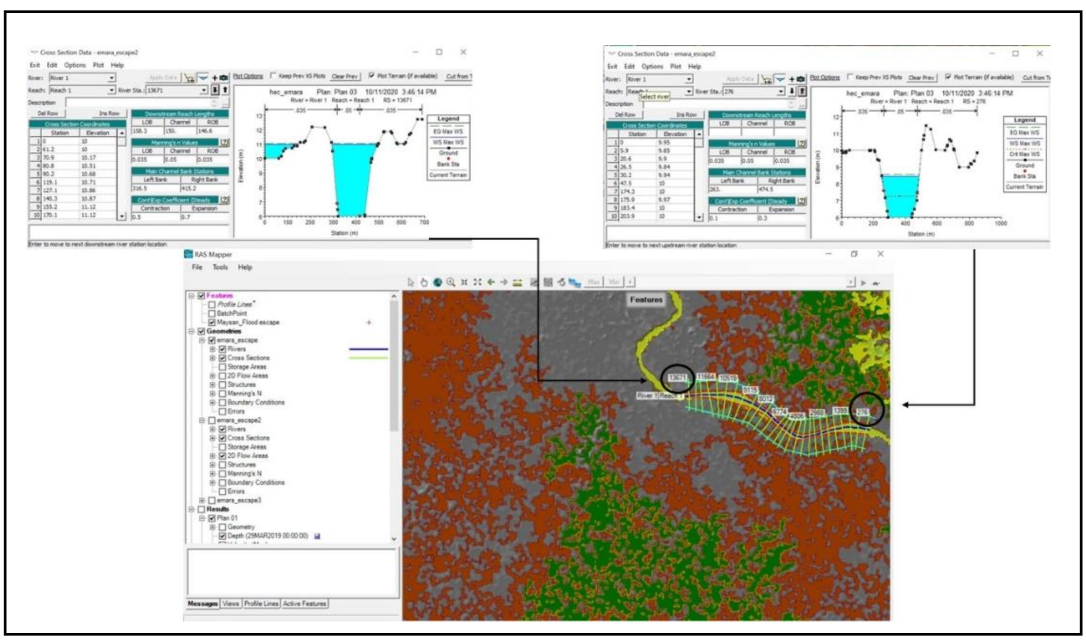

Figure 8. 1D Model to Extract Inundation Map for Maysan Governorate

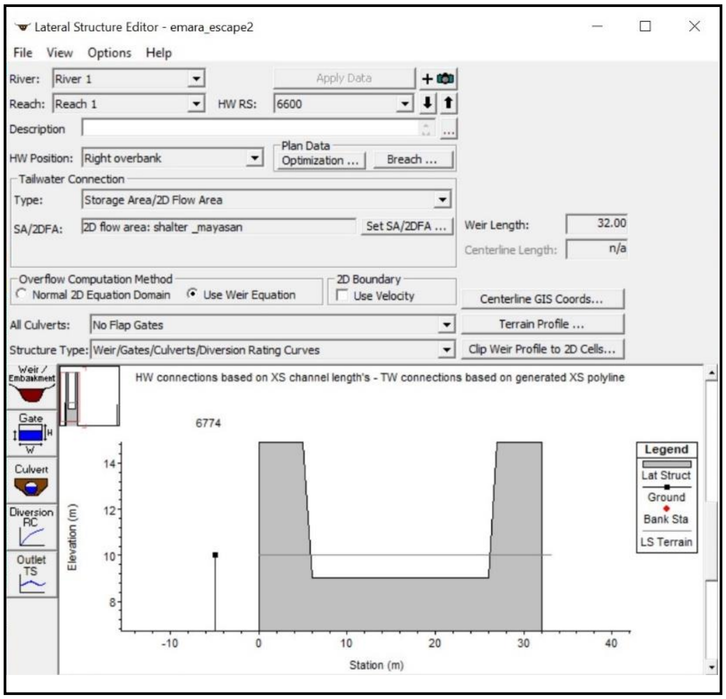

Figure 9. Lateral structure Design for Maysan Flood Escape

This lateral structure worked as an upstream for the flow area and linked the 1D model for Tigris Reach to 2D flow area. However, it is represented the flood shelter that inundated with excess water discharged through the flood escape as shown in figure (10).

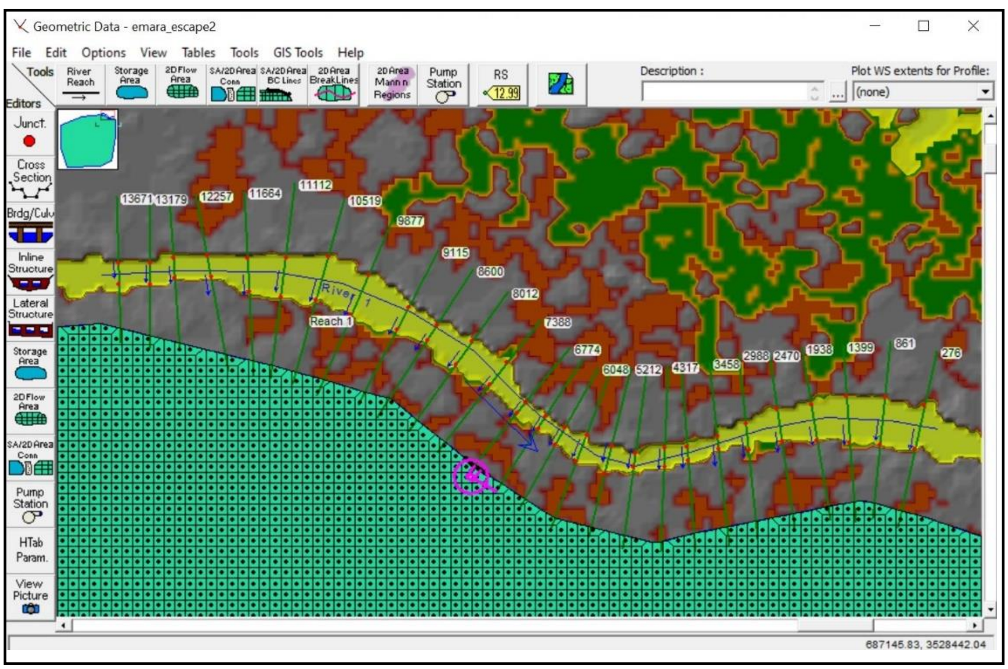

Figure 10. 2D Flow Area model linked with 1D model for Tigris River by Weir

Finally, the flood inundation map has been produced, after 1D-2D model connection is performed. This map shows the limits of the flood shelter, the depth of water in that area and the flood escape location as shown in figure (11).

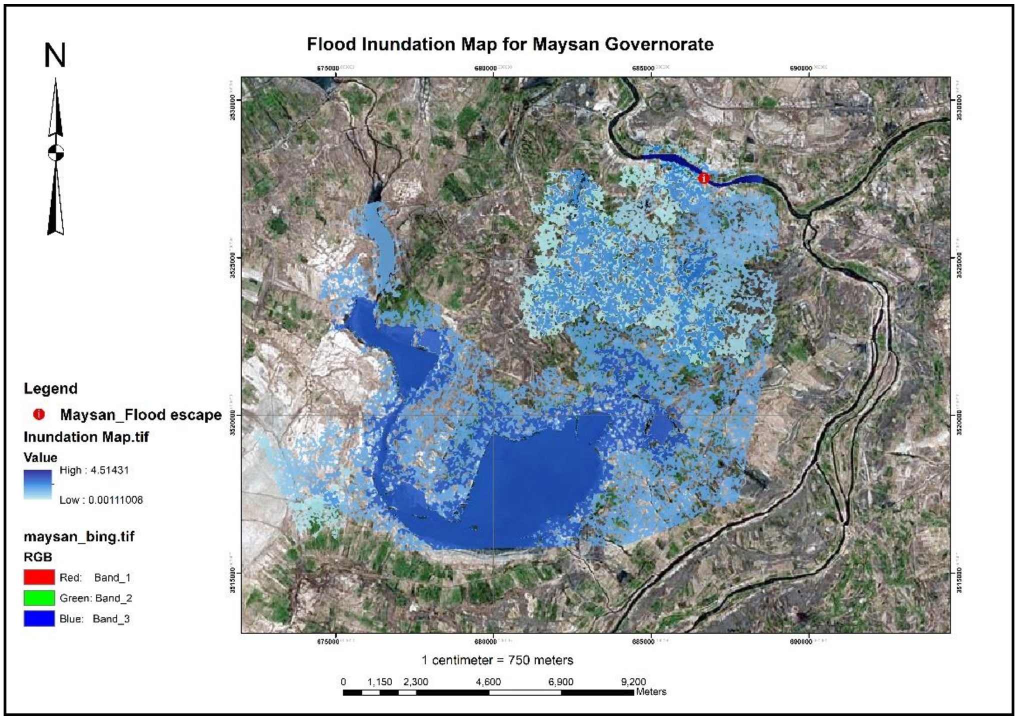

Figure 11. Inundation Map for Maysan Governorate

Also, the flood map for Maysan Governorate at flood escape site shows the boundary of inundation water as well as the features that will be inundated by the flood water discharged from the Tigris River as shown in figure (12).

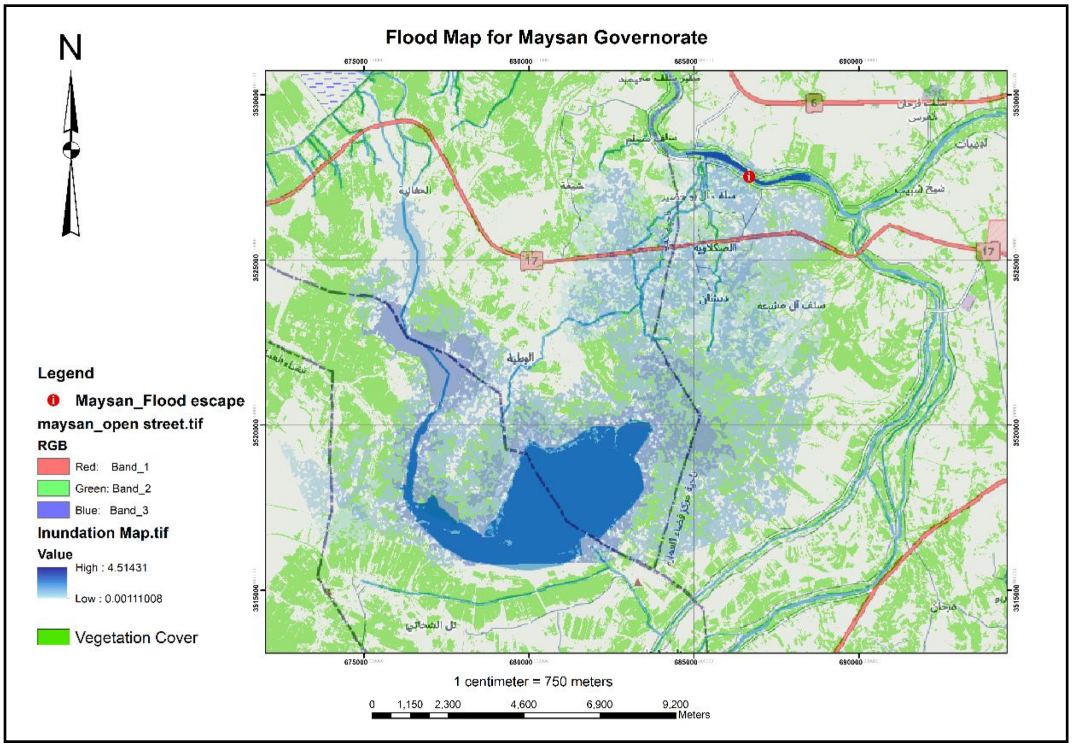

Figure 12. Flood Map for Maysan Governorate

4. Conclusion

In this study, Remote Sensing Techniques and Geographic Information System (GIS) were used for the purpose of managing the flood hazard that occurred in Iraq / Maysan Governorate at Spring 2019. This study has two objectives, the first is to assess and determine the amount and location of the damages caused by the flood using the multispectral images classification for Sentinel-2 satellite. The second is to find a way to mitigation and avoid flood hazard in the future. Therefore, flood escape makes on the Tigris River to drain the flood water in the flood shelter through the work of a hydrological analysis using DEM to extract the catchment area and suggesting a suitable location for the flood escape. Then, a couple hydraulic (1D-2D) model is preformed to discharging the excess water from the flood escape at Tigris River to flood shelter and extracting the flood inundation map using HEC-RAS model.

Reference

[1] Forkuo, E.K., 2011. Flood hazard mapping using Aster image data with GIS. *International journal Of Geomatics and Geosciences*, *1*(4), pp.932-950.

[2] Hashemyan, F., Khaleghi, M.R. and Kamyar, M., 2015. Combination of HEC-HMS and HEC-RAS models in GIS in order to Simulate Flood (Case study: Khoshke Rudan river in Fars province, Iran). *Research Journal of Recent Sciences.*

[3] Abbas, Z., Jaber, H.S. 2020. Accuracy assessment of supervised classification methods for extraction land use maps using remote sensing and GIS techniques. IOP Conference Series: Materials Science and Engineering.

[4] Merzah, Z.F., Jaber, H.S. 2020. Assessment of Atmospheric Correction Methods for Hyperspectral Remote Sensing Imagery Using Geospatial Techniques. IOP Conference Series: Materials Science and Engineering.

[5] Aggarwal, S.P., Thakur, P.K. and Dadhwal, V.K., 1991. Remote sensing and GIS Applications in Flood Management. *ISRO, Reserchgate*.

[6] Forkuo, E.K. and Tsawo, V.A., 2013. The use of digital elevation models for water-shed and flood hazard mapping.

[7] Agency, General Authority of surveying. Home, https://mowr.gov.iq.

[8] Kuc, G. and Chormański, J., 2019. Sentinel-2 imagery for mapping and monitoring imperviousness In urban areas. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *42*(1/W2).

[9] Topaloğlu, R.H., Sertel, E. and Musaoğlu, N., 2016. ASSESSMENT OF CLASSIFICATION ACCURACIES OF SENTINEL-2 AND LANDSAT-8 DATA FOR LAND COVER/USE MAPPING. *International archives of the photogrammetry, remote sensing & spatial*

Information Sciences, *41*.

[10] Agency, NASA. (2020). Shuttle Radar Topography Mission: Home, https://earthdata.nasa.gov/learn/articles/nasa-shuttle-radar-topography-mission-srtm-version-3-global-1-arc-second-data-released-over-asia-and-australia.

[11] Du, Y., Zhang, Y., Ling, F., Wang, Q., Li, W. and Li, X., 2016. Water bodies' mapping from Sentinel-2 imagery with modified normalized difference water index at 10-m spatial resolution Produced by sharpening the SWIR band. *Remote Sensing*, *8*(4), p.354.

[12] Woodrow, K., 2014. *Evaluating the effects of DEM properties on the spatial and statistical distribution of hydrological surface attributes* (Doctoral dissertation).

[13] Bengtson, H.H., 2012. Spreadsheet Use for Partially Full Pipe Flow Calculations. *Continuing Education and Development, Inc., Course*, (C02-037).

[14] Taufik, A., Ahmad, S.S.S. and Ahmad, A., 2016. Classification of landsat 8 satellite data using NDVI thresholds. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, *8*(4), pp.37-40.

[15] Liu, Z., Yao, Z. and Wang, R., 2016. Assessing methods of identifying open water bodies using Landsat 8 OLI imagery. *Environmental Earth Sciences*, *75*(10), p.873.

[16] McFeeters, S.K., 1996. The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. *International journal of remote sensing*, *17*(7), pp.1425-1432.

[17] Zhao, G.J., Gao, J.F., Tian, P. and Tian, K., 2009. Comparison of two different methods for determining flow direction in catchment hydrological modeling. *Water Science and Engineering*, *2*(4), pp.1-15.

[18] Vozinaki, A.E.K., Morianou, G.G., Alexakis, D.D. and Tsanis, I.K., 2017. Comparing 1D and combined 1D/2D hydraulic simulations using high-resolution topographic data: A case study of the Koiliaris basin, Greece. *Hydrological Sciences Journal*, *62*(4), pp.642-656.

[19] Vozinaki, A.E.K., Morianou, G.G., Alexakis, D.D. and Tsanis, I.K., 2017. Comparing 1D and combined 1D/2D hydraulic simulations using high-resolution topographic data: A case study of the Koiliaris basin, Greece. *Hydrological Sciences Journal*, *62*(4), pp.642-656.

[20] Brunner, G., W. (2016): "HEC-RAS, river analysis system hydraulic reference manual". *US Army Corps of Engineers*.