A GIS Based Inundation Model in New Orleans, Louisiana

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Introduction

Floods can cause serious damages to urban areas, threatening industries and people's lives. Researchers have been working on flood models for a long time. Recently, with the help of GIS, it is possible to build 3D flood models. Chen[1], Wang[2] and their fellow researchers have separately built up flood inundation models with GIS, which can be used for reproduction and prediction of flood inundation profile.

The goal of this project is also building up such a model that can be used for prediction. With the help of the model, one could easily tell which part of the city has high risk of flood inundation and which part has lower risk. Besides, the tools provided by the GIS software also make further studies possible.

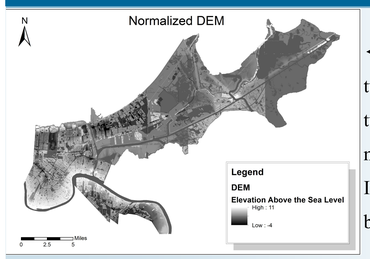
Overview of the Model

The general idea of the model is to treat the interested area as an independent water storage system. The source of the storage comes from precipitation (P), and the storage is reduced via surface runoff (Q), infiltration (F) or drainage system (D). In case of storms, precipitation accumulates rapidly in a short period of time. Capacities of the three outlets, however, is limited. Hence there is a portion of water staying in the system (V). The water balance equation is written as below:

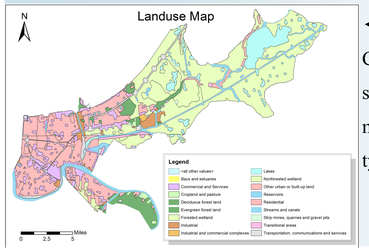
$$V(t)=P(t)-Q(t)-F(t)-D(t)$$

V(t) could be computed by estimating the rest of the terms in the equation. With the Digital Elevation Model (DEM), water surface elevation (WSE) could be found.

Data Preprocessing



◀The DEM with structures. Heights of structures are added to the natural topographic data. It depicts the uneven bottom of the system.

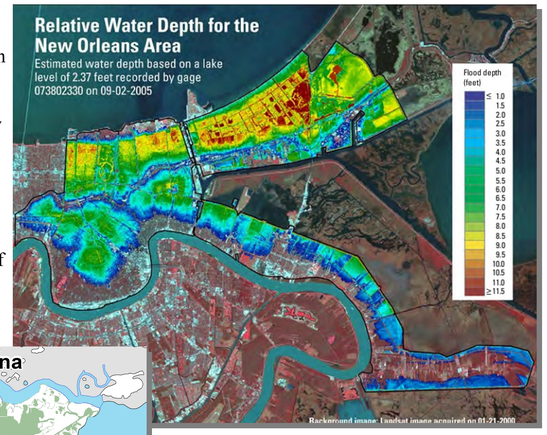


◀The Land Use Map. Curve Numbers are assigned to each cell of the map according to the type of land use.

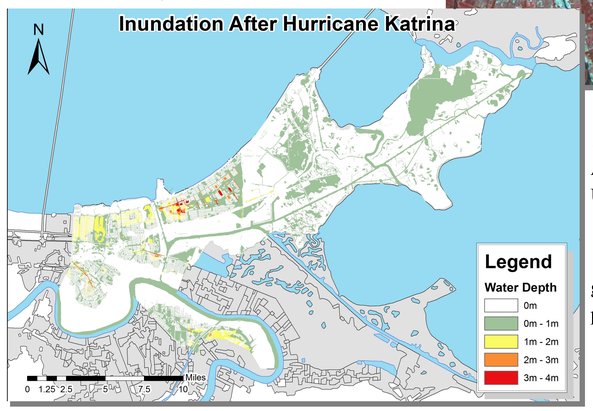
Development of the Model

Precipitation

The area of the system is as large as 207.33 mi^2, which is likely to have an uneven precipitation profile. Precipitation data at several gages around the city of New Orleans are given in a report of the National Oceanic and Atmospheric Administration(NOAA)[3].By using the IDW interpolation tool of ArcGIS, the distribution of precipitation could be obtained. Then the amount of precipitation is averaged to give a depth of precipitation for the whole system, which is 9.45 in. The recording period for the original dataset is from Aug 25th, 2005 to Aug 31th. But the NOAA website shows that the precipitation on Aug 29th is 4.5in. So we may assume that the 7.5 in. came to New Orleans in two days, from Aug 29th to Aug 30th.

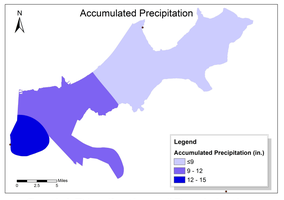


▲Relative Water Depth for the New Orleans Area on September 2nd, 2005, depicted by USGS.[4]



◀Inundation Profile after Hurricane Katrina, generated from the model developed in this project.

By studying the rainfall intensity table for flood design in New Orleans, it could be learned that a large portion of precipitation occurs in the first 6 hours. In order to fit the rainfall intensity curve with this feature, an exponential distribution model is used.



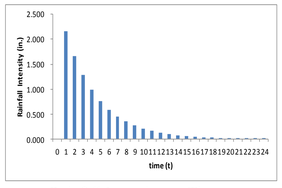
Spatial Distribution of Precipitation

Surface Runoff

The volume of accumulated surface runoff could be expressed as a function of the accumulated precipitation using the unit hydrograph of the system. There are several empirical methods to estimate the unit hydrograph of a watershed, and the Clark's method (TC+R) method is used here:

$$TC + R = C\left(\frac{L}{\sqrt{S}}\right)^{0.706}$$

$$TC = C'\left(\frac{L_{ca}}{\sqrt{s}}\right)^{1.06}$$



Rainfall Intensity vs. Time

HEC-HMS is a software developed by the U.S. Army Corp and is often used for hydrologic simulations. When the parameters are estimated, input them and the precipitation data to the software and a surface runoff curve will be generated.

Infiltration

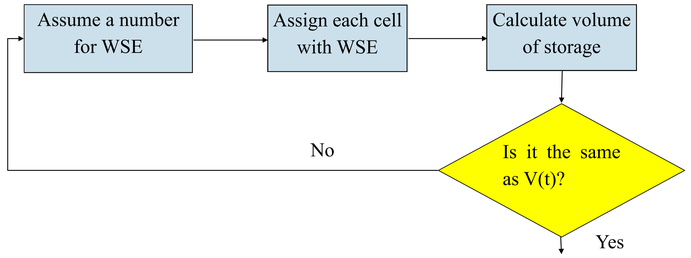
Infiltration can be expressed as a function of precipitation and curve number:

$$F = P - \frac{(P-0.2S)^2}{(P-0.2S)+S} \qquad S = \frac{1000}{10+CN}$$

Drainage

The capacity of the drainage system in New Orleans is 29 billion gallons per day, which is equal to 0.335 inches per hour in the system.[5]

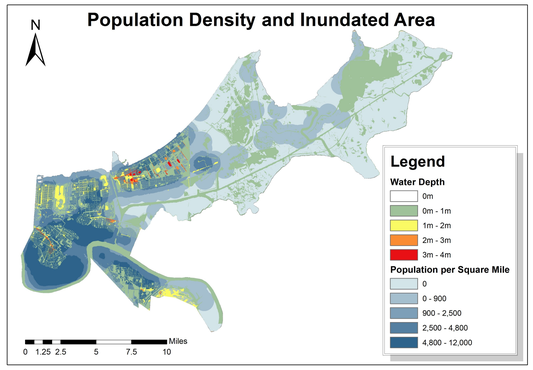
WSE



Application of the Model

Given the time t, the model is able to predict the water depth anywhere throughout the system. It accurately predicts the areas that are most easily to be influenced by floods caused by heavy precipitation. Compared to the GUFIM model developed by Chen, this model requires less data and is more convenient to operate. But it cannot give accurate water depth, which is caused by the limitations of the model.

With the inundation profile, the user could easily figure out those areas with higher risk of inundation, and a serious of spatial analysis could be performed based on the result. One of the example is to examine how many people would be influenced by a flood. Using the "Select by Location" tool of ArcGIS, flooded structures could be figured out, thus the influenced population could be given with population data. Similarly, users could look for schools, hospitals or other public facilities with high risk of flood with available data.



An Analysis of Population Influenced by Flood

References

[1]Chen J., Hill A. A. & Urbano L. D. (2009). A GIS-based model for urban flood inundation. Journal of Hydrology, 2009, 184-192.

[2]Wang C., Wan T. R. & Palmer I. J. (2010). Urban flood risk analysis for determining optimal flood protection levels based on digital terrain model and flood spreading model. The Visual Computer, 26, 1369-1381.

[3]Weather Research Center. New Orleans Rainfall Frequency. Retrieved from: http://http://www.wxresearch.com/newfreq.htm

[4]Axel G. et al. (2005). Hurricane Katrina: A Climatological Perspective Preliminary Report. Retrieved from http://www.ncdc.noaa.gov/oa/reports/tech-report-200501z.pdf

[5]Retrieved from: http://www.swbno.org/history_drainage_facts.asp

Coordinate System: NAD_1983_StatePlane_Louisana_South_FIPS_1702_Feet

Data Resource:

USGS, USGS Digital Elevation Models (DEM) - 24K;

USGS, Enhanced Historical Land-Use and Land-Cover Data Sets of the U.S. Geological Survey;

City of the New Orleans, Department of Information Technology & Innovation