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The Use of GIS to Identify and Analyze the TIN and DEM in Stream Ordering

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Abstract: *Geographic Information System is process of collecting, manipulating, analyzing, and storing as well as displaying all geographical data for geospatial purposes, used to solve most of our environmental abnormalities emanating from the hydrological phenomena. It is very important to realize that water from the rivers or streams can be identified using Triangulated Irregular Network (TIN), and Digital Elevation Model (DEM). The quantity and volume of water can be simulated using appropriate data of steam flow and it directions. The software Arcgis 10.0 has an application specifically for hydrological modeling. However, the application of TIN and DEM IN stream ordering is useful in mitigating flooding in our environment. Important progress has been made during the last four years in the availability of comprehensive spatial data sets which support hydrologic modeling. The distribution of low cost or free data sets via Internet and CD-ROM for digital elevation data, soils, land use, and climate data has stimulated the development of procedures for processing the data into useful forms for hydrology.*

Keywords: *GIS, Hydrology, Modeling, TIN, DEM, Environment*

I. Introduction

Water is one of the most natural resources. Without it, there would be no life on earth. Hydrology has evolved as a science in response to the need to understand the complex water system of the earth and help solve water problems. Hydrology is the science that encompasses the occurrence, distribution, movement and properties of the waters of the earth and their relationship with the environment within each phase of the hydrologic cycle, Robert (2007). The water cycle, or hydrologic cycle, is a continuous process by which water is purified by evaporation and transported from the earth's surface including the oceans to the atmosphere and back to the land and oceans. Hydrologists apply scientific knowledge and mathematical principles to solve water-related problems in society: problems of quantity, quality and availability. They may be concerned with finding water supplies for cities or irrigated farms, or controlling river flooding or soil erosion. Or, may work in environmental protection: preventing or cleaning up pollution or locating sites for safe disposal of hazardous wastes. Geographic information systems (GIS) are a useful tool for analysis of spatially distributed features on and under the earth surface. Considering the inherently spatial character of components of the hydrologic cycle, GIS is increasingly used by hydrologists to analyze, simulate, and understand hydrologic processes. Representation of the essential physical characteristics of a hydrologic process in terms of parameter maps raises issues not generally considered by hydrologists before the advent of the technology and spatial data.

Spatial resolution, scale, attribute uncertainty, surface interpolation, error propagation, and aspects related to the linkage or integration of spatially distributed data within a GIS and a hydrologic model. Water makes up at least 97 percent of our bodies it also covers 80 percent of the earth surface Alexandria (1994)

II. Developing A Spatial Hydrology Model

Hydrology is concerned with study of the motion of the earth's waters through the hydrologic cycle, and the transport of constituents such as sediment and pollutants in the water as it flows. GIS is focused on representing the landscape by means of location referenced data describing the character and shape of geographic features. A spatial hydrology model is one which simulates the water flow and transport on a specified region of the earth using GIS data structures. Suppose the boundary of this region is represented by a polygon, such as a river basin boundary or an aquifer boundary. Because both vertical and horizontal water flow can be taking place within the region, hydrologic processes need to be defined over a volume of space rather than an area. Such a volume can be constructed by projecting vertically the lines making up the polygon boundary into the atmosphere and into the earth, and closing the top and bottom of the volume by horizontal planes. Such a volume is called a control volume in fluid mechanics and the surface which surrounds it is called the control surface. Chow et, al (1988).

III. Objectives

To understand the concept of stream order and its importance in hydrology
To generate stream network from a given surface elevation data
To use GIS function in generating a stream order
To analyze the limitation of such automated approach as compared to manual

Variable Lake Levels

Water levels in the Great Lakes fluctuate on both a seasonal and long-term basis. On a seasonal basis, the lowest levels are during the winter when much of the precipitation is held on land as snow and ice. The highest seasonal levels are during the summer. Long-term variation of lake levels depends on precipitation and evaporation trends in the Great Lakes watershed. The water volume of the Great Lakes is large and outflow from natural outlets is limited. Flow regulation structures exist in Lakes Ontario, Michigan and Superior, but their influence is limited by their size and the need to regulate water levels for multiple interests including shipping. Lake levels rise when net water supply exceeds outflow and above average lake levels can persist for extended periods even after the conditions that caused them have ended. Table 1 shows characteristics of recent high lake levels in Lake Michigan and Table 2 shows characteristics of recent low lake levels. (Wisconsin Coastal Management Program 1992)

Table1. Recent Lake Michigan High Lake Level Periods

High Lake Level Periods	Peak Monthly Average	Peak Month
1996-1998	177.19 m	July 1997
1983-1987	177.50 m	October 1986
1972-1976	177.32 m	July 1974
1952-1953	177.28 m	August 1952

Source: COE, Detroit District

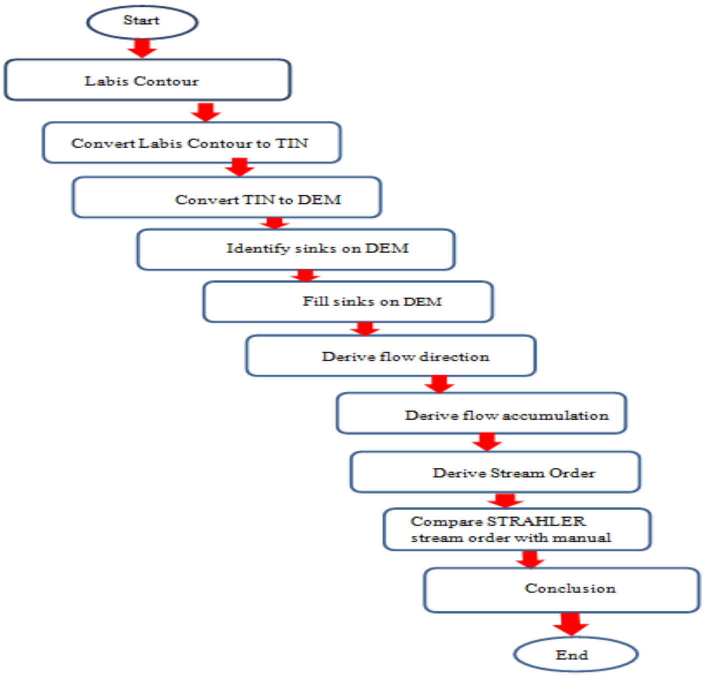
Table2. Recent Lake Michigan Low Lake Level Periods

Low Lake Level Periods	Peak Monthly Average	Peak Month
1999-present	175.87 m (provisional)	February 2000
1963-1968	175.67 m	March 1964
1932-1938	175.67 m	Feb/Mar 1934

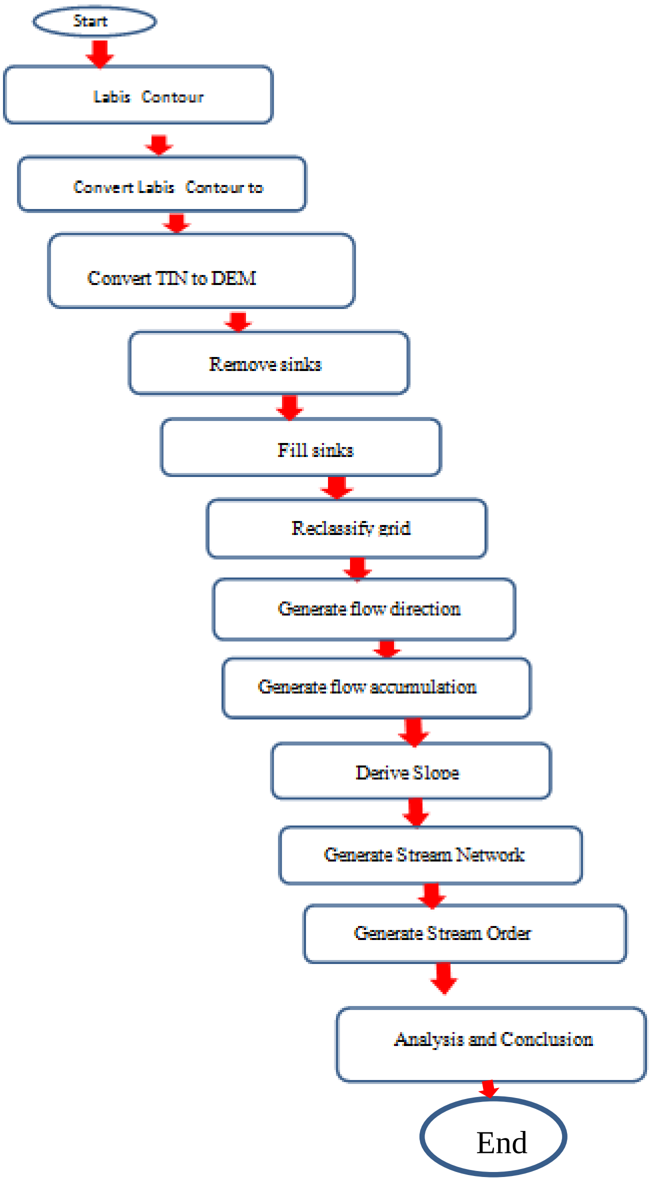
Source: COE, Detroit District

IV. Methodology

The data source is Labis contour (UTM) Using ArcGIS 10.0 to determine TIN and DEM



Using ArcView 3.3 to determine the TIN and DEM



V. Results

ArcGIS 10.0

In order to generate stream network and stream order the given contour is converted to TIN which is Triangular Irregular Network and DEM which is the Digital Elevation Model. In hydrologic modeling, the elevation grid is important to be filled. It must have no sinks. Sinks are areas of internal drainage which is areas that do not drain off the edge of the grid; they may attempt to drain into each other, which will lead to an endless processing loop.

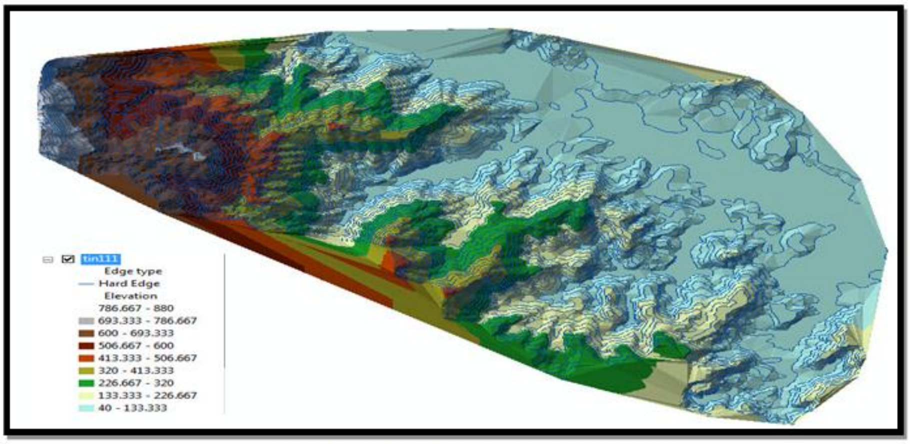


Figure 1.0: ***TIN (Triangular Irregular Network)***

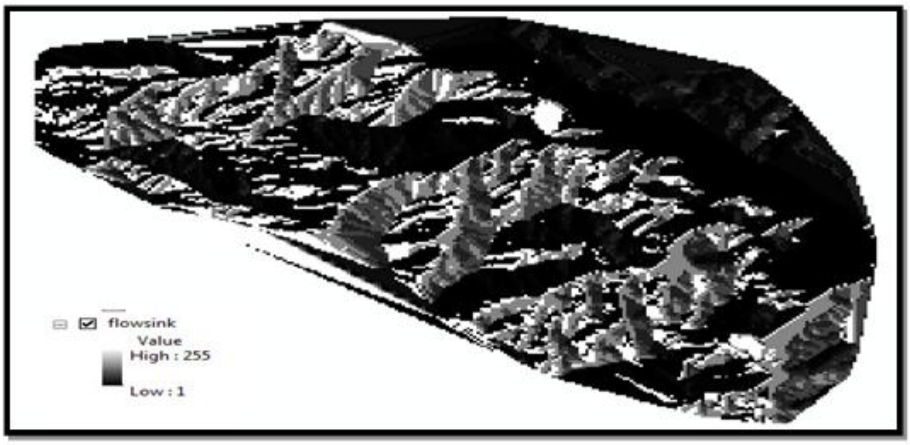


Figure 1.2: ***Sink DEM***

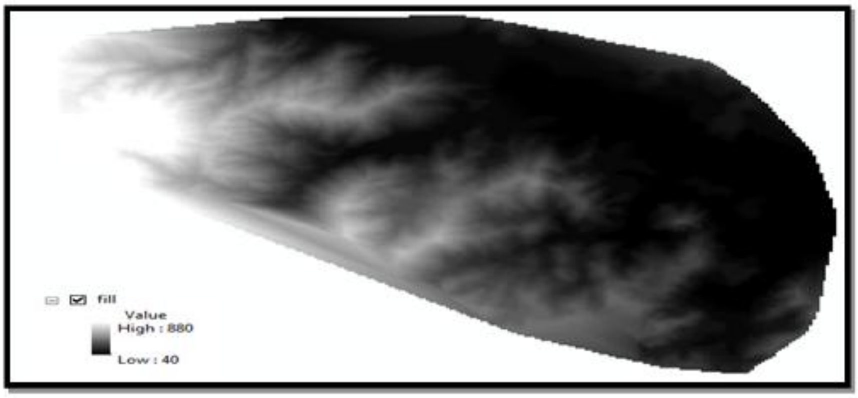


Figure 1.3: ***Fill DEM***

Flow direction shows the direction which the water will flow out of each cell of a filled elevation raster. It should be performed on grids that are free of sinks. A perfect flow direction should only contain eight values: 1, 2, 4, 8, 16, 32, 64, and 128, representing the eight adjacent cells into which water would flow. For example, for a cell with a value of 16, the water is flowing to the left (i.e. west).

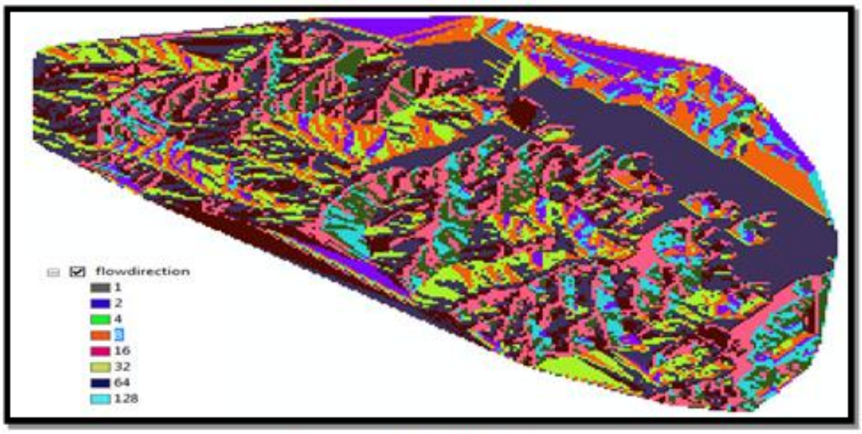


Figure 1.4: ***Flow Direction***

Stream networks can be delineated from a digital elevation model (DEM) using the output from the Flow Accumulation function. Flow accumulation in its simplest form is the number of upslope cells that flow into each cell. By applying a threshold value to the results of the Flow Accumulation functions using the Con tool in geoprocessing, a stream network can be delineated. By selecting cells with the greatest accumulated flow, it will be able to create a network of high-flow cells. These high-flow cells should lie on stream channels and at valley bottoms. Higher-flow cells will have a larger value, and in the data frame below. The deeper white represents the higher stream flow.

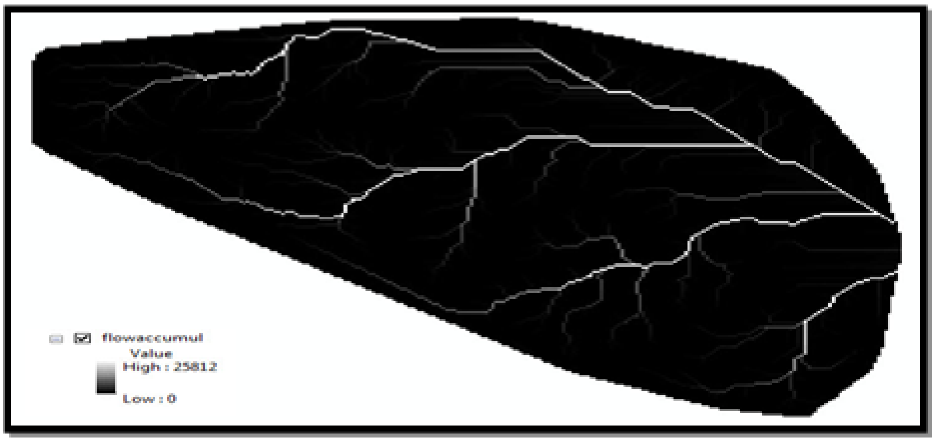


Figure 1.5: ***Flow Accumulation***

Stream ordering is a method of assigning a numeric order to links in a stream network. This order is a method for identifying and classifying types of streams based on their number of tributaries. To represent the order of each of the segments in a network, the STRAHLER techniques are applied. In the STRAHLER order method, all links with no tributaries are assigned an order of one and are referred to as first order. When two first-order links intersect, the downslope link is assigned an order of two. When two second-order links intersect, the downslope link is assigned an order of three, and so on. When two links of the same order intersect, the order will increase. This is the most common method of ordering.

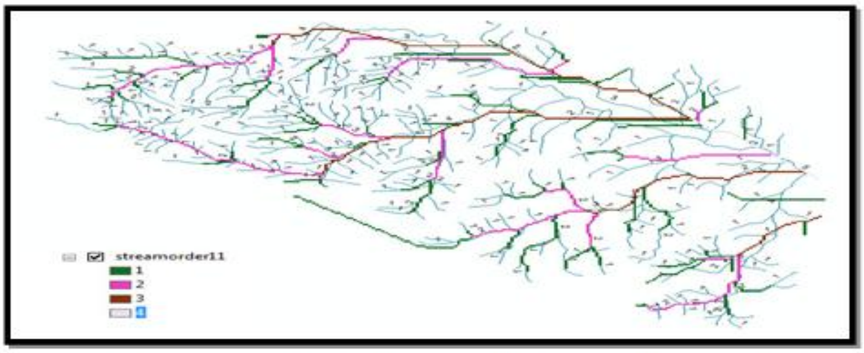


Figure 1.6: ***Stream Network with Threshold value > 100 overlay with Labisriver.shp data***

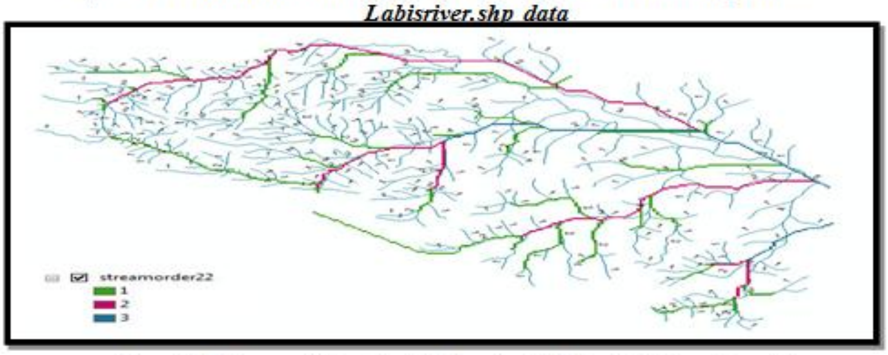


Figure 1.7: ***Stream Network with Threshold Value > 200 overlay with Labisriver.shp data***

In Figure 1.7, the stream network has 4 stream orders, while in Figure 1.6; the stream network has 3 stream orders. Figure1.6 apply threshold value > 100 while Figure 1.7 applies threshold value > 200. The stream order for both figures also some are not the same with the stream order done manually.

VI. Arcview 3.3

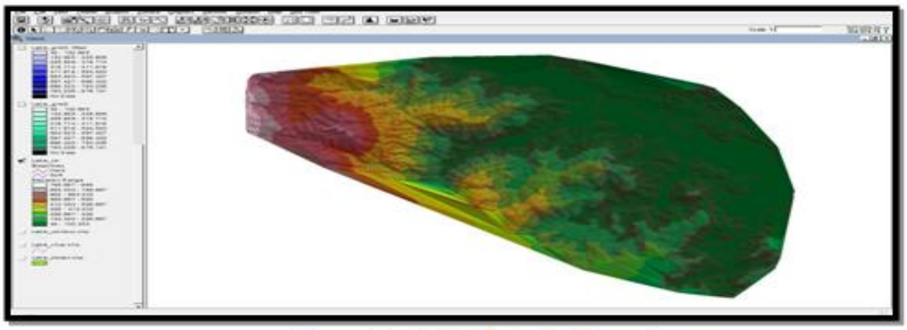


Figure 2.0: ***TIN (Triangular Irregular Network)***

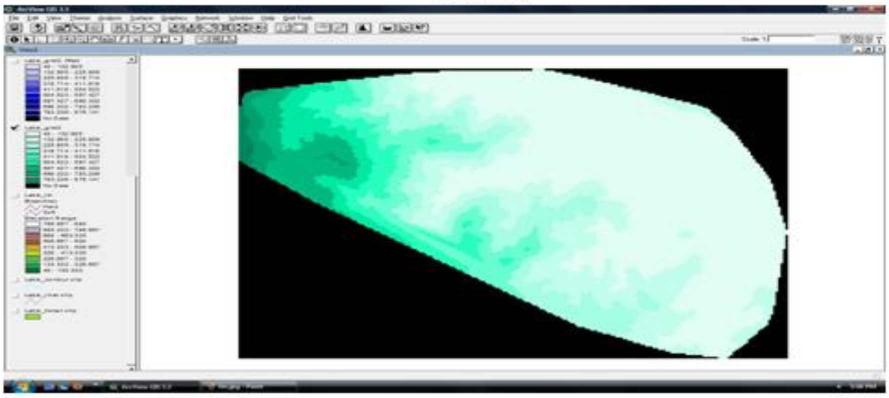


Figure 2.1 ***DEM converted to Grid***

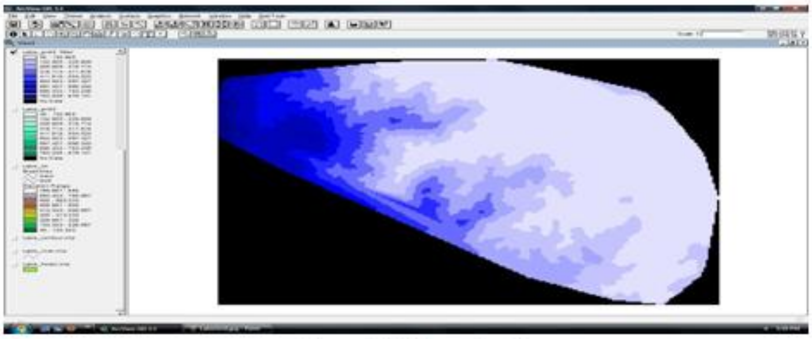


Figure 2.2: ***Depresionless Grid (DEM)***

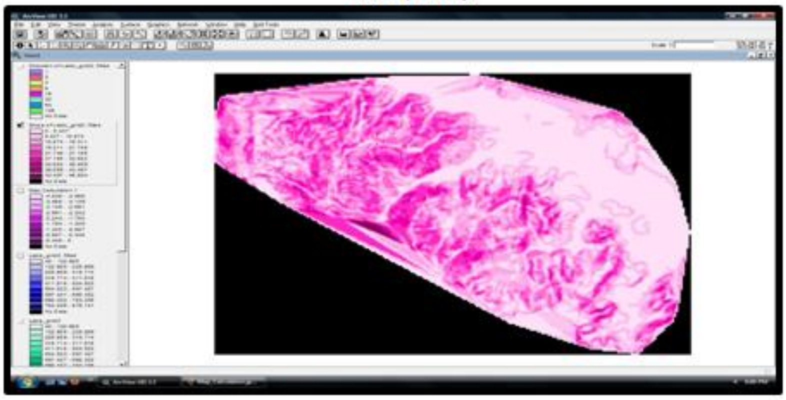


Figure 2.3: ***Slope generation***

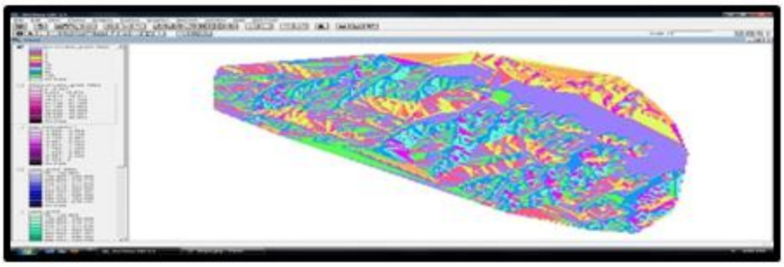


Figure 2.4 ***Flow Direction***

There was an error while trying to generate the flow accumulation. It could not find the yield. dll in the particular folder.

VII. Gis In Surface Water

It is possible to access real time streamflow data via the Internet. Embedded within a GIS are layers with stream locations and gage or monitoring measuring sites. It's also possible to link radio transmitted and remotely sensed data that is(Remote Sensing) in GIS.The real time or historical data are available from the United States Geological Survey (USGS) in the form of gage height and streamflow or discharge in cubic feet per second. Within a GIS, it's possible to direct link via the Internet to real time data. Other sources of data for flood information and water quality come from the National Weather Service (NWS) and United States Environmental Protection Agency (EPA). All these data are available for analysis within GIS, providing a spatial representation of what would otherwise be data in a table type format. Hart et, al (1995). GIS is much more capable of displaying data spatially than temporally. Within one GIS, ESRI's ArcGIS for example, is it possible to delineate a watershed. Digital elevation model (DEM) data are layered with hydrographic data so that the boundaries of a watershed may be determined. Watershed delineation aids the hydrologist or water resource manager in understanding where runoff from precipitation or snowmelt will eventually drain. In the case of snowmelt, snowpack coverage may be determined from ground stations or remotely sensed observers and input into GIS to determine or predict how much water can be counted on to be available for use by cities, agriculture, and environmental habitat.A digital elevation model (DEM) from which a watershed may be delineated within a GIS Another useful application for GIS regards precipitation, but other hydrologic data (evapotranspiration, infiltration, and groundwater) may be treated similarly. Precipitation is an area event measured using data from point locations. The difficulty in using point data lies in extrapolating these point measurements to areas. One useful method to extrapolate data is to construct Thiessen polygons which assess the distance and geometry of points in a plane and determines representative areas for which to assign precipitation values. GIS applications like ArcGIS are capable of constructing Thiessen polygons, and other methods of determining area precipitation are viable with GIS as well.

Shoreline Engineering, Managing Coastal Hazards

The following methods for coastal erosion hazard reduction were listed in the 1990 report by the National Research Council titled Managing Coastal Erosion.

Offshore Breakwaters

Offshore breakwaters are designed to reduce wave energy reaching the shore and promote sediment deposition on the protected side of the structure. Breakwaters can also be constructed that do not extend above the water surface and absorb most but not all the wave energy. Breakwaters are expensive to construct (NRC 1990, p 60-61). Keillor and Miller. (1987). Building a hydrologic model involves writing equations that relate the rates of change of water properties within the control volume to flow of those properties across the control surface. For example, a simple soil water balance model for a control volume drawn around a block of soil is:

$$S(t+1) = S(t)+P(t)-E(t)-Q(t)$$

in which S(t) represents the amount of soil moisture stored at the beginning of the time interval t, S(t+1) the storage at the end of that interval, and the flow across the control surface during the interval consists of precipitation P(t), evaporation, E(t), and soil moisture surplus, Q(t), which supplies streamflow and groundwater recharge. Solving this equation requires dealing with time series of the four variables: S, P, E, Q, and possibly of other variables related to them. Maidment, D.R. (1993).

VIII. Conclusion

From the above analysis, it is learned that GIS plays an important role in hydrology. The source of the data is also important aspects which have to be taking in order to have a more accurate result. The contour was given which have 20m interval. It would be more accurate if the interval value were smaller which can improve the accurateness of the DEM generated which will lead to a more accurate stream network and stream order. The threshold value applied also influence the accurateness of the stream network which also influences the stream orders accurateness. The stream order generated by automated means is about 40-50 percent accurate compared to the manual stream order. This order is important as for identifying and classifying types of streams based on their number of tributaries.The tools are different for ArcGIS 10 and ArcView 3.3, but the functions are just similar. ArcGIS 10 is more comfortable to be used for the tools and interface is easy to understand compared to the hydrology tools in ArcView 3.3.

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