Geographic Information System Application to Perform Run Calculations in Watershed

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Abstract

The uArcViewtilization of geographic information systems (GIS) is very important, especially in the field of hydrology bbecause GIS can assist in hydrological analysis. One of the hydrological analysis processes is to perform runoff calculations which are very important to determine how much water discharge in a watershed is usually still done manually, namely with the help of analog maps, so it takes a long time to calculate the total runoff and present information about the map. Through this application that is built, it is hoped that it can help in the runoff calculation process that does not need to spend a long time.

The development of this GIS application was built using the VB.Net application as a system interface, maps using ArcView 3.3 and map Object 2.4 as a liaison between visual basic and ArcView.

The result of this research is an application that can facilitate the user in performing runoff calculations that do not need to spend a long time in presenting information about the map.

Keywords*: Runoff, Map Object, Information System, Geographic, Application, Watershed*

I. INTRODUCTION

The current use of GIS has covered various fields, one of which is the field of Hydrology. The existence of GIS, can assist in Hydrological Analysis which is very necessary to support Planning, Development, Research and Operation of Water Resources as well as the necessary facilities and infrastructure related to water problems. One of the most important things in carrying out hydrological analysis is the calculation of runoff in a watershed. The watershed that will be discussed is the Upper Cimanuk River area which is precisely located in Garut Regency, West Java province.

The Runoff calculation method in general still uses various parameters related to the characteristics of the land and its watershed and these parameters are still more widely available within the boundaries of analog maps. So that the presentation of information and the runoff calculation process that is done manually will take a long time

II. LITERATURE REVIEW

2.1. Geographic Information System (GIS)

GIS is a computer system used to store, analyze, and display data related to positions on the earth's surface [1] . Geographic Information System is used because GIS is a powerful tool for handling spatial data that is managed in digital format so that the data becomes smaller in storage space than in the form of paper maps, tables, or other conventional forms. Large amounts of data can also be managed and manipulated at high speed a low cost.

2.1.1. Data

The input data used in GIS is a digital map. This digital map will later be combined with information from other data for the analysis process to provide information, divided into types, namely:

a. Spatial Data

Data that describes the features of a geographic location. For example, points, lines, polygons are usually used to describe geographical features such as roads, rivers, lakes and others [2]

Spatial data has two types, namely vector and raster. Vector data models display, locate, and store spatial data using points, lines or curves, or polygons and their attributes. Raster data models display, and store spatial data using a matrix structure or pixels that make up a grid. The utilization of these two spatial data models is adjusted to their designation and needs.

The data model used in making this application is a raster data model. The raster data element unit is usually called a pixel, the element is an extraction from an image that is stored as a digital number (DN). Reviewing the structure of a raster data model is identical to that of a matrix form. In a raster data model, a matrix or array is ordered according to its column (x) and row (y) coordinates.

b. Non Spatial Attribute Data

Data that describes information such as street names, the salinity of rivers, soil composition of a particular plain [2].

2.1.2. Ways of Working GIS

GIS can represent the real world on a computer monitor as map sheets can represent the real world on paper, but GIS has more power than flexibility than paper map sheets [3]. A map is a graphic representation of the real world, the objects represented on the map are called map elements or map features (for example, rivers, plants, gardens, roads, and others). Maps can organize elements based on their locations; maps are very good at showing the relationships or relationships that the elements have GIS stores all descriptive information of its elements as attributes in the database. Then, the GIS create and store them in relational tables. After that, the GIS can link the elements above with the related tables. Thus, these attributes can be accessed through the locations of map elements, and conversely, map elements can also be accessed through their attributes, therefore, these elements can be searched and determined based on their attributes.

GIS relates a set of map elements with their attributes in units called layers. Rivers, buildings, roads, seas, administrative boundaries, plantations, and forests are examples of layers. The collection of these layers will form the GIS database. Thus, database design is essential in GIS. The database design will determine the effectiveness and efficiency of the GIS input, management, and output processes.

2.2. Digitizing

Digitizing is the process of converting geographical features on an analog map into digital format by using a special digitizing device called a digitizer, which functions to connect to a computer [4]. Location specifications or coordinates (x,y) for each feature that has been built, will automatically be recorded and stored as spatial data.

2.3. *Dereferencing*

Dereferencing is the assignment of a known coordinate system, such as latitude and longitude, Universal Transverse Mercator (UTM), or state plane, to raster (image-map) or planar map coordinates [5]. Raster data from Dereferencing can be used in queries, or geographic analysis with other geographic data. The following is a coordinate system that is commonly used:

a. Geographic Coordinate System (GCS), is a reference system that uses latitude and longitude to indicate a location on a horizontal or spherical surface layer.

b. Projected Coordinate System (PCS), is a coordinate system shown on a flat surface. In contrast to the GCS, PCS has fixed lengths, angles and areas across two dimensions. In PCS, the location is known as the x,y coordinate on the grid, with the starting point centered on the center point of the grid.

2.4. Hydrological Analysis.

Hydrological analysis was used to test the consistency of the rain data obtained using the double-mass curve technique [6]. Inconsistent rain data is usually caused by changes or disturbances in the environment around where the rain gauge is installed, for example, rain gauge protected by trees, located close to tall buildings, changes in the method of measuring and recording, moving the dosing location and so on, thus allowing deviations to occur. against the trend again. The benefits of the hydrological analysis itself are used to support planning, research, development and operation of water resources as well as the necessary facilities and infrastructure related to water problems.

2.5. Runoff

Runoff is where waterfalls to the earth as rain, which then partially flows over the land surface, and reaches rivers without reaching groundwater [7]. There are 2 factors related to runoff, namely meteorological elements which are represented by rainfall and drainage area elements which indicate the physical characteristics of the drainage area.

2.6. ArcView

ArcView is a desktop geographic information system and mapping software that has been developed by ESRI [8]. With ArcView, users can have the ability to visualize, explore, answer queries (both spatial and non-spatial databases), analyze data geographically and so on. To be clearer, the capabilities of this ArcView GIS device in general can be described as follows:

1. Data exchange: read and write data from and into other GIS software formats.
2. Perform statistical analysis and mathematical operations.
3. Displays spatial and attribute information (database).
4. Answering spatial and attribute queries.
5. Perform basic GIS functions
6. Create a thematic map
7. Customize the application by using a scripting language
8. Perform other special GIS functions (using extensions intended to support ArcView GIS software users).

There are 2 extensions used in making DEM for this application, namely: 3D analyst, and Spatial Analyst. The following is a brief description of each extension.

a.3 D Analyst

3D Analyst is an extension that is sold separately from its parent software (ArcView). This extension is distributed in the form of a CD (Compact Disk) and to add it to the ArcView software an installation process is required as well as installing software in general. This extension is needed to create 3D files, surface modeling and create perspective viewing of spatial data. Concerning the preparation of spatial runoff data, this extension together with the spatial analyst extension is used in contour data processing to produce slope spatial data .

b.Spatial Analyst

Like the 3D analyst, the spatial analyst extension is a separate extension from the ArcView software, distributed on CD. In general, this extension is needed to know and understand spatial relationships based on spatial data. With the addition of this extension, ArcView software can be used to compose, process and analyze spatial data in raster format which in ArcView terminology is called a grid theme. Based on the grid theme, spatial slope data can be compiled from contour data, and with the reclassification facility in the extension, the slope data can be classified according to the slope classification.

2.7. MapObject 2.4

MapObject is a third party component that can be used in Visual Basic, Visual C++, Delphi, and others, to display maps along with navigation, and other mapping functions [9]. Because it is a component, the GIS application created with MapObject can be made more flexible, can be combined with applications, and can be free to create views. Here the author uses MapObject Version 2.4, and will be used in Vb.Net.

III. RESEARCH METHOD

3.1. Stages of The Process

The stages of the process are:

1**. Analysis and definition of requirements.**

At this stage, the author analyzes and defines the requirements regarding the runoff calculation process manually by using an analog map and the calculation process that will be used in building a new system. This requirement analysis and definition aim to understand the old system to be able to define system problems so that it can determine the system requirements in outline as preparation for the next process.

2. System and software design

At this stage the activities to be carried out are designing the system to be built, including data structures, databases, operations/processes that are involved in performing runoff calculations, and user interface design.

3.Implementation and unit testing

At this stage the activities to be carried out are implementing the results of the design/coding into the application using the VB.Net programming language, MapObject and a database using ArcView 3.3.

4. System integration and testing

At this stage the activity to be carried out is testing, at this stage the author will test the application that has been built whether it is by with the needs that have been defined at the beginning.

5. Operation and maintenance

The last stage is maintenance, but this stage is not documented, only evaluates applications that have been submitted to the user, the results of the evaluation can be made possible to make changes according to developments and needs so that they can still be used.

3.2. The General Runoff Calculation Method

The general runoff calculation method is usually as follows:

1. Use of analog maps

Usually in doing runoff calculations, they still use the help of analog maps, where the data needed for these calculations are slope, elevation, soil type, land use and postal position to determine the value of rainfall. Using analog map media still contains weaknesses or limitations. Information that is stored, processed and presented in a certain way, and usually for a specific purpose. A map always provides an image or symbol of a geographical element with a fixed or static shape even though it is needed for different needs. So to do runoff calculations and in the presentation of information can take quite a long time.

2. Formation of flow accumulation

To produce an accumulation of flow in a watershed, several processes are needed. That is the flow direction process wherein determining the previous flow direction we must have an elevation value in the watershed. Later we can only generate slope values on each grid, and the slope value data can be used to determine a flow direction. While the next process is the flow accumulation process, which we can generate when we get the data flow direction. So that we can generate flow accumulation which can later be used to add up the total runoff value.

3. Data Storage

The data needed to perform runoff calculations are recorded or stored in Microsoft Excel. For example, the type of soil, and the use of the soil will be combined and produce a value by looking at the curve number table, which will be stored in Microsoft Excel. So if we need data to perform runoff calculations, we have to look at the data one by one in Microsoft Excel, which will take quite a long time, and there is no place to store historical data.

Perform runoff calculations require:

1. Database that can accommodate the data needed for the calculation.
2. An easy-to-use (user friendly) GIS application to calculate runoff per grid and total runoff.
3. Information about the data contained in each map.

The results of the analysis for the development of Geographic Information Systems to perform runoff calculations using ArcView 3.3 and VB.Net:

1. Mapping

a. The type of map built is a thematic map

b. The reference coordinate system used is the Projected Coordinate System (PCG).

c. The data model used is a raster data model.

2. Outcome (goal)

The information that is the goal of the application is the total runoff value in the Cimanuk Hulu watershed.

3. Interface (interfacing).

The components that will be used are map control, legend control, toolbars.

IV. IMPLEMENTATION SYSTEM

The system developed is an application specifically designed for use in a hydrological environment. The system to be developed is equipped with a map that can function to display rainfall maps, flow accumulation maps and curve number maps in the upstream Cimanuk area and on the map there are rainfall values, curve number values, and flow accumulation directions. . This system is also equipped with a database that functions to accommodate the data needed to perform runoff calculations. The system to be developed has guidelines and messages for each process so that it is easy to use.

The system to be developed is a software which is expected to be a medium that can improve the old system in:

1. Provide information on rainfall value, area name and curve number in the Upper Cimanuk watershed.
2. Knowing the direction of flow accumulation in the Upper Cimanuk watershed.
3. Generate runoff on each grid.
4. Generate the total amount of runoff.

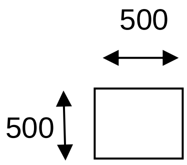
4.1. Model Design

One of the analyzes carried out to carry out a hydrological analysis is to use the Digital Elevation Model (DEM). This DEM was created by interpolating contour digital data. DEM is raster or grid data that represents the height above sea level. From these data, various kinds of data can be derived. Namely, slope, flow direction, and flow accumulation.

a. Slope

The slope of a place is the ratio between the height difference between two points and the horizontal distance. The equation used to calculate the slope is as follows ;

$$Gradient\ y = dy = \frac{\partial z}{\partial y} \qquad Gradient\ x = dx = \frac{\partial z}{\partial x}$$



$$Diagonal = \sqrt{dy^2 + dx^2}$$
$$\sqrt{500^2 + 500^2}$$
$$= \sqrt{(2(\llbracket 500 \rrbracket^2))}$$
$$= 500\sqrt{2}$$

500

67	56	49
52	48	37
58	55	52

500

67	56	49
52	48	37
58	55	52

$$S_u = \frac{(67-48)}{500\sqrt{2}} = 0{,}02687 \qquad S_u$$
$$= \frac{(67-52)}{500} = 0.03$$

b. Flow Direction

Flow direction is a function that can calculate the flow direction from the data grid. The values in the grid cells indicate the direction of the lowest of each cell. To determine the lowest direction is calculated based on the slope of each grid cell. Based on Figure 1, the direction of the largest flow indicates the flow is going to that place, and in this case the flow will go to Slope 0.03.

In the ArcView program, the value of each flow direction starts from 1 to 128. This value is the value of the coding system implemented in acrview. The code in each cell is the value that will be used as the flow direction. The coding system is carried out as shown in the image below:

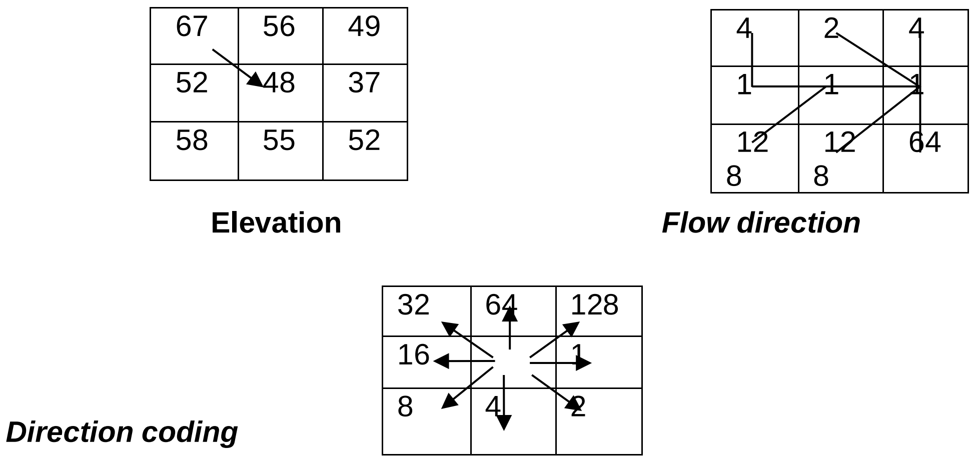


Figure 1:
Direction Flow Process

C. Fill sinks

Fill sinks are one of the functions available in the DNR Hydro tool, this tool is almost available in every tool related to hydrology. This function is useful for modifying the elevation of the grid-type DEM to be adjusted based on the lowest elevation data around it. Fill sinks are performed if the elevation of the grid cell is lower than the elevation of the surrounding cells, so that the water will be stagnant and there will be no flow. To anticipate these problems, fill sinks will be carried out. For more details, see the image below as an illustration of fill sinks.

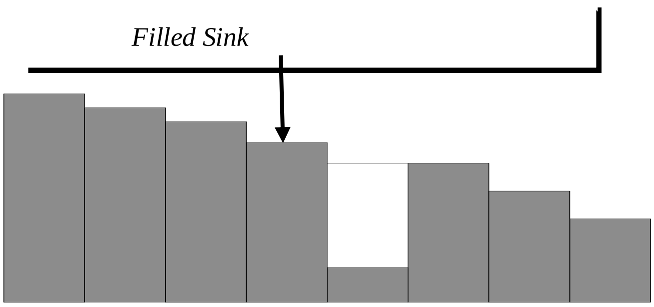


Figure 2: Fill Sinks Illustration

D. Flow Accumulation

The accumulated flow is calculated as the accumulation of the number of cells flowing towards each cell with the lowest height. If the weight of each cell is expressed as 1 unit, then the accumulated flow of each cell is the contribution area of the cell flow. For example, the accumulation of flow at a watershed outlet represents the area of the watershed (catchment area). Cells that have accumulated flow mean no flow enters the cell and are associated with valleys or hilltops. For surface accumulation, the value of each cell represents the total number of cells flowing towards it. Cells that have a high accumulation are areas where the flow is concentrated so that they can be used to identify river networks

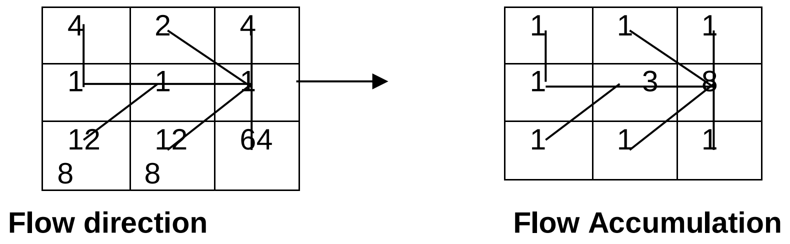


Figure 3:Accumulation Flow Process

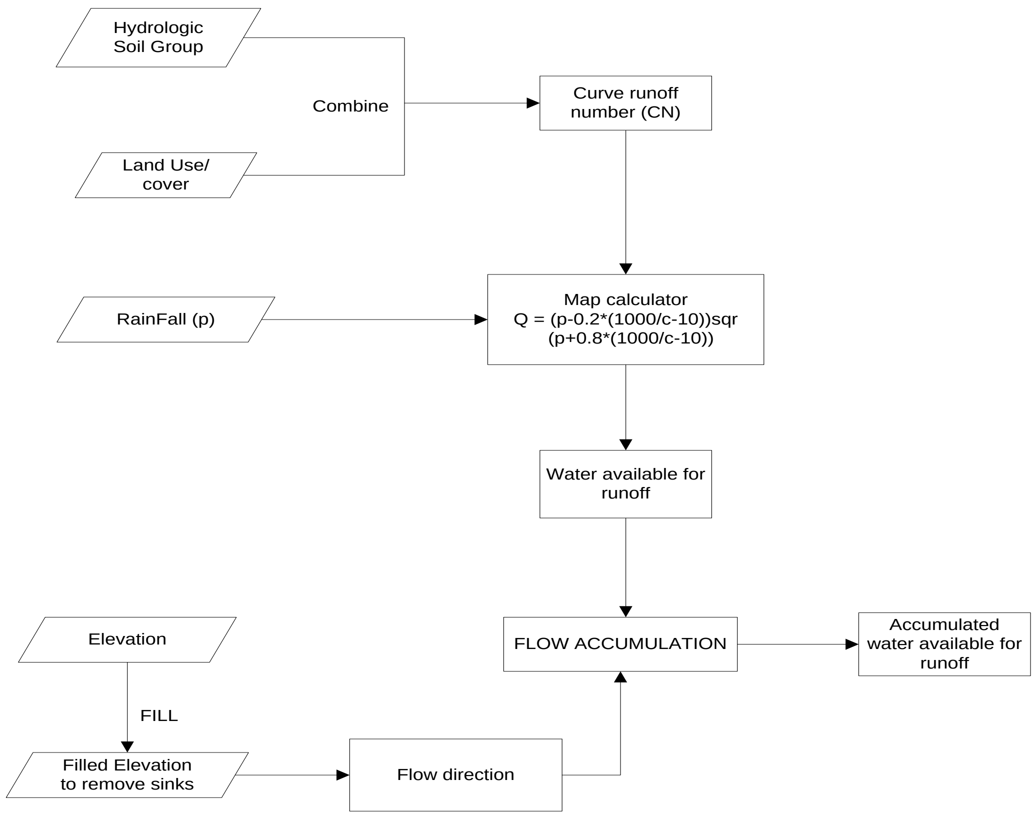


Figure 4: Flow Acumulation & Flow Direction Illustration

4.2. Meteorological Elements

Factors belonging to the group of meteorological elements are the type of precipitation, rainfall intensity, duration of rainfall, distribution of rainfall in the drainage area, direction of movement of rainfall, previous rainfall and soil moisture, and other meteorological conditions.

4.3. Drainage area Elements

The factors that affect the elements of the drainage area are land use conditions, drainage areas, topographical conditions in the drainage area, soil types, and other factors such as watershed characteristics parameters.

A watershed is a land area that is topographically limited by mountain ridges that accommodate and store rainwater to then channel it to the sea through the main river. While the Watershed Characteristics is a specific description of the watershed which is characterized by several parameters, one of which is hydrology.

Determination of flow accumulation requires a sequenced flow direction grid and elevation grid. The procedure is as follows:

1. Each cell weight from the flow accumulation grid is stated to be worth 1 unit
2. Repeat for each cell in order from lowest to highest (in this case the cell with the highest elevation to the cell with the lowest elevation)
3. Make the current cell the source cell
4. Determine with the flow direction grid, the direction from the source cell that flows to other cells. That other cell will become the target cell
5. Add the accumulated flow value from the source cell to the target cell.

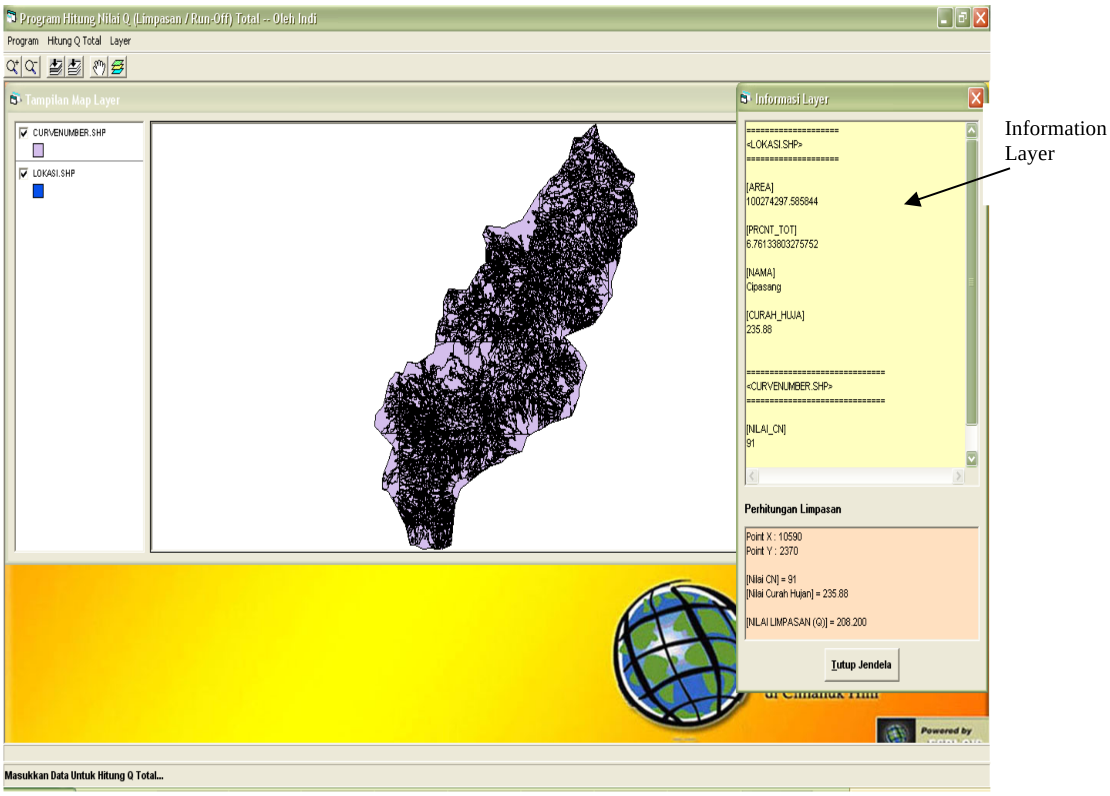


Figure 5:Information Layer

V. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Based on the results of the implementation of the final project and the process of developing this GIS application from the analysis, design, to system implementation stages, the authors draw the following conclusions:

1. This application can assist in the runoff calculation process, including displaying a map of Cimanuk upstream, providing information on rainfall values, curve number values and flow accumulation. From this information, it can generate runoff values for each grid or total runoff.
2. This application can speed up and make it easier for employees to calculate runoff Suggestions

5.2. Recommendation

The development of this application does not test the accuracy of the total runoff value, because there is no data from the total runoff calculation in the field as a comparison. It is hoped that future developers will be able to test the accuracy level.

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