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MANUAL

Banjir Bandang Disaster Management

Manual for Making Map of Landslide and Banjir Bandang Prone Area Caused By the Collapse of Natural Dam

MINISTRY OF PUBLIC WORKS

version final draft

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Foreword

Manual of Researching Banjir Bandang Hazardous Area contains technical guidance of stages for analysis and mapping an area prone to landslides and banjir bandang.

This manual refers to the results of research and literature regarding banjir bandang in Japan but has been adapted to the situation in Indonesia.

Technical procedures that are written in this manual require some type of software to perform its functions, so users who use this manual is expected to have ability to run some software required to use this manual.

With this guideline, it is expected the central government and local government throughout Indonesia could define an area prone to landslides and banjir bandang, as a disaster mitigation efforts.

Introduction

Indonesian territory is located at the equator so will receive much of sun's heat and have highly rainfall, therefore, Indonesia has become vulnerable to hydro-meteorological disasters such as floods, droughts, large ocean waves, and so forth. National Disaster Management Agency (BNPB) record from the total hydro-meteorological disasters that most often happens in Indonesia is the catastrophic floods and followed by landslides.

Condition of Indonesia's morphology that has varied landscape relief and has many rivers, causing flood will always occur every rainy season in Indonesia. One type of flooding that often occurs in Indonesia and resulted in substantial losses are banjir bandang. For example in 2006 there was banjir bandang in Jember - East Java, which caused 92 people died, 1900 people were displaced and about 2500 buildings damaged.

Japan International Cooperation Agency (JICA) in cooperation with the Ministry of Public Works of Indonesia organizes various efforts and implementation to enhance mitigation capabilities of a region in Indonesia in facing flood catastrophe.

This manual contains the technical phases of procedure that aims to help identify a region prone to banjir bandang. The method that is used to analyze or identify areas prone to banjir bandang is based on methodology in accordance with the conditions of ability and availability of data at local government level in Indonesia.

Manual for Making Map of Landslide and Banjir Bandang Prone Area Caused By the Collapse of Natural Dam

1. Scope

This manual contains the technical procedures for analyzing or identifying an area prone to landslides and banjir bandang.

This guidelines is made with the intention that the central government can use these guidelines to support local governments in identifying landslide and banjir bandang prone in the region as a disaster mitigation effort

Flash floods can be caused by the rapid concentration of heavy rain, the collapse of natural dams that occurred in the upstream river, as well as the collapse of dam and/or artificial embankment. This manual only presents identification techniques of landslide prone areas to banjir bandang prone area based on factors of the collapse of natural dams that occurred in the upstream river.

2. Normative references

This guideline cannot be implemented without using a reference document below.

PSN 08:2007, *Pengembangan Standar Nasional Indonesia..*
PSN 03-1:2007, *Adopsi standar internasional dan publikasi internasional lainnya menjadi Standar Nasional Indonesia – Bagian 1: Adopsi standar ISO/IEC.*
Standar Nasional Indonesia – Bagian 1: Adopsi standar ISO/IEC.
ISBN 978-979-8763-09-0, *Panduan pengoperasian Sistem Peringatan Dini – Banjir debris berbasis masyarakat di sungai Jeneberang*.
ISBN 978-602-96989-1-6, *Petunjuk pekerjaan SABO – Pengenalan bangunan pengendali sedimen*.
ISBN 978-602-96989-3-0, *Petunjuk pekerjaan SABO – Perencanaan bangunan pengendali sedimen*.

3. The introduction of banjir bandang

3.1 Banjir bandang description

Banjir bandang is a flood that occurs suddenly and powerful. Banjir bandang formed in the range of a few minutes to several hours after a heavy rain in a short time on the watershed or on a narrow river channel on the upstream. The flow the river has a short time of concentration, so that runoff can quickly accumulate in the river channel.

Banjir bandang characteristics:
- has a peak discharge which jumped suddenly and subsided again quickly;
- has a big volume and high flow rate;
- has a very big flow transport capacity and erosion power, so can bring the material erosion toward downstream direction;
- the flow that bring debris material can lead to catastrophic sediment in downstream areas after the apex point.

The causes of the occurrence of banjir bandang are:

- Accumulation of heavy rainfall that fell in a short time duration on river upstream watershed, where then the volume of water collected in a short time into the river channel, causing a large spike and sudden discharge exceeds the capacity of the flow path downstream.
- The collapse of dam, levee or natural dam that occur because of the accumulation of landslide material on river channel.

3.2 Natural dam

The collapse of natural dams is one of the main causes of banjir bandang, therefore the following will be discussed more about the formation process and the cause of collapse of natural dams.

The formation process of natural dams:
- because of the landslide;
  landslide material in the form of soil, rocks, or trees, can fall into the river and immediately form a dam. In other cases, the landslide material can be carried away by the flow and clog the river flow on the bottleneck pattern that will gradually form a dam.
- because of illegal logging in the uplands.
  logs with irregular size accompanied by the roots and branches of trees that are the result of illegal logging, it can slowly drawn into river upstream, so can block the river flow naturally.

The cause of the collapse of natural dams:
- Overtopping;
  the river water that is blocked by natural dam, slowly increase the water level. When the water level has reached the upper limit of the dam, the water will begin to spill over the dam as well as grinding dam material until all dam material eroded. This incident caused the river water becomes turbid.
- Piping;
  air sungai yang terbendung oleh bendungan alam, dapat mengalir ke dalam tanah menyusur dasar dan dinding bendungan alam. Jika mencapai kecepatan kritis, butiran tanah akan terbawa sehingga terjadi peristiwa piping sehingga akhirnya bendungan alam dapat runtuh. Kejadian ini sering menyebabkan air sungai menjadi keruh.
- Liquefaction;
  is the phenomenon of loss of soil strength due to soil saturation and (earthquake) vibration. At the time of vibration, pore water pressure within the layer of soil/sand can be increased, approaching or exceeding the vertical stress so that the force of friction between the sand particles becomes lost. This resulted in soil strength decreases drastically. At this time, a layer of soil/sand can turn into a liquid that cannot sustain the burden of dams in or on top of it. This event often occurs because of heavy rainfall or a discharge that causes a large vibration or rumbling sound which heard as the signs.

3.3 Landslides

Natural dam generally formed by landslide material. The characteristics of landslide prone areas and their cause factors will be explained below.

In principle, a landslide occurs when the driving force on slopes greater than anchoring force. Anchoring force is generally influenced by the strength of rock and soil density, while the driving force is influenced by the magnitude of the slope angle, water, heavy loads and types of soil/rock.

Characteristics of landslide prone areas:
- Has high rainfall intensity;

Long dry season caused the large numbers of evaporation water on the soil surface. This resulted the pores or cavities of land and thus the land surface to crack and fissure. When the rain falls with a high intensity, water will infiltrate into the cracks to make the soil becomes saturated in a short time and can accumulate at the bottom of the slope, so create the lateral movement and landslide occur.

- Classified as a slope area/steep cliffs;
  Slope or cliffs that would enlarge the driving force can trigger the landslides.
- The content of the soil is less dense and thick;
  The type of less dense soil is clay with thickness of more than 2.5 m. This soil type is very susceptible to ground movement because it's easy to become mushy when exposed to water and easily broken when the weather is too hot.
- Have a less strong rock;
  In most cases the less strong rocks are volcanic rocks and sedimentary rocks which have sizes such as sand and a mixture of gravel, sand, and clay. The rock will easily become the soil when undergoing a process of weathering, thus generally prone to landslides.
- A land use type that prone to landslide;
  Many landslides occurred in rice fields and cultivation areas. In rice field areas, the roots is less strong to bind the soil grains so the soil becomes soft and saturated with water, therefore on this land use type, landslides will easily happen. Whereas for cultivation areas, the tree roots can not penetrate the deep field of landslide and and it's generally occurs in old landslide area.
- The erosion;
  Erosion is mostly done by river water towards the cliff. In addition, deforestation around the bend of the river causing a steep cliff and become prone to landslide.
- Is a former area of the old landslide;
  The former area of the old landslide characterized as follows :
  - the existence of a long steep cliffs which curved shape of a horseshoe
  - generally there are springs and trees are relatively thick because the soil loose and fertile
  - the existence of small landslides, especially on cliffs of the valley
  - the cliffs are relatively steep
  - presence of grooves and found the cracks on the ridge of the valley and small landslides
- Is a discontinuities plane (plane that are not aligned);
  This plane is a weak plane and can serve as a glide landslides plane and has the characteristics as follows :
  - the plane of bedding rock
  - the contact plane between the ground cover and the bed rock
  - the contact plane between the cracked rocks and a solid rock
  - the contact plane between the rocks that can pass water and the rocks that cannot pass water (waterproof)
  - the contact plane between the soft soil and a solid soil.

4. Terms and definitions

Here are some terms used in these manual.

4.1 debris flow

a type of mass movement flow of debris material with a very large transport content, coarse grained, non-cohesive, composed of small to large grained material such as sand, gravel, small rocks and large stones.

4.2 apex
the location of inflection point steepness riverbed from upstream to downstream which became more gentle.

4.3 flood (banjir)
the event of overflowing river water exceeds the riverbed.

4.4 banjir bandang
big flood that occurs suddenly, because of the overflow discharge that exceeds the flow capacity of rivers by the rapid concentration of high-intensity rainfall and often brings debris flow or the collapse of the natural dam, that formed of deep-seated landslide material in the upstream area of the river.

4.5 dam
buildings in the form of barrow, stone barrow, concrete, and/or masonry built in addition to detain and hold water, can also be built to hold and accommodate mine waste, or accommodate mud that formed the reservoir.

4.6 natural dam
dam that formed naturally, generally derived from the results of landslide material that has a large enough volume, and stem the flow of a river.

4.7 catchment area / watershed
is an area of land, which is a unity with the river and its tributaries, which serve to accommodate, store, and stream water originating from rainfall to the lake or the sea naturally, where the boundary on land is topographical separators and the boundary at sea until the waters are still affected land activities.

4.8 attribute data / non-spatial data
data in the form of graphics and text or numeric; data that tangible number, is the number / numeral system.

4.9 geospatial data
data about geographic location, dimension or size, and / or characteristics of natural objects and / or man-made under, at, or above the earth's surface.

4.10 raster data
data generated from Remote Sensing system. In raster data, geographic object is represented as a grid cell structure called a pixel.

4.11 vector data
is the shape of the earth represented in the collection of lines, areas (the area bounded by the line that starts and ends at the same point), point and nodes (a point of intersection between two lines).

4.12 Digital Elevation Model (DEM)
digital data describing the geometry of the earth's surface shape or part of it which consist of a set of sampling results coordinate points from the surface with a defined surface algorithm using the set of coordinates. (Tempfli, 1991)

4.13 digitations
the process of converting analog data into digital format. Objects on high-resolution satellite imagery such as roads, houses, fields and others that were previously in raster format, can be converted into digital format by the process of digitization.

4.14 contour line
imaginary line connecting points having the same height.

4.15 geo-reference
align geographic data so that it can be precisely located at the exact coordinates so the data can be seen, be queried, be analyzed and compared with other geographic data that have the same coverage area.

4.16 geospatial information
geospatial data that are processed so that it can be used as a tool in policy formulation, decision making, and/or implementation activities associated with terrestrial space.

4.17 lineament
a straight topographic feature of regional extent, which is thought to represent crustal structure. A fault, line of sinkholes, straight stream stretch or a line of volcanoes can be considered linear features.

4.18 lithology
the study and description of rocks, including their mineral composition and texture. Also used in reference to the compositional and textural characteristics of a rock.

4.19 landslide
a mass transfer process of soil or rock with obliquity from its original position (so apart from a solid mass), because of gravity, the current attack, earthquake, etc., with the kind of rotation and translational motion.

4.20 deep-seated landslide
among the slope failures such as landfall and cliff failure, a comparatively large-scale landslide phenomenon, in which the sliding plane occurs at the layer deepen than in the case of the surface failure, and, not only the surface soil but also the ground in the deep layer becomes the decayed clod of earth. The volume of deep-seated landslide material generally greater or equal to 10^5 m^3.

4.21 micro-topography
A description of the surface features of a material, of the earth, or other body, on a small or microscopic scale.

4.22 river morphology
river channel form and circumstances in connection with the flow.

4.23 ortho-rectification
geometric correction methods to reduce geometric distortion satellite imagery from the effects of Earth's surface topography.

4.24 fault
a fracture or zone of fractures in the rock due to the occurrence of a movement.

4.25 digital map
certain maps in digital format that can be accessed by using the hardware and some software.

4.26 topographic map
base map that provides information specifically for the land.

4.27 rectification
transformation process of imagery or aerial photos by specific mathematical equations to obtain planimetric images or aerial photographs.

4.28 spatial resolution
size of the smallest object that can be recorded by a sensor system. In other words, spatial resolution reflects the detail information that can be served by a sensors system.

4.29 Geographic Information System (GIS)
a component that consists of hardware, software, geographic data and human resources that work together effectively to enter, store, refine, update, manage, manipulate, integrate, analyze and display data in a geographic-based information.

4.30 scale
rate ratio between the distance in a geospatial information with the actual distance on earth.

4.31 river
a channel or containers of natural and/or artificial water in the form of water drainage network along with water in it, ranging from upstream to the estuary, with limited right and left by a line of demarcation.

4.32 levee flood
construction to prevent flooding behind the levee.

4.33 pour point
A pour point is the point at which water flows out of an area. This is usually the lowest point along the boundary of the drainage basin.

4.34 Triangulated Irregular Network (TIN)
vector-based topological data model that is used to represent the earth terrain. TIN represent form of the earth's surface obtained from sample points that are scattered irregularly and form a triangular irregular networks that are interconnected. Each triangle consists of three vertices have the coordinates x, y and elevation (z). [http://gis-indonesia.blogspot.com]

5. Data

Here are described some of the data required for making landslide potential map and banjir bandang hazardous area. These data are the data source and there is also a derivative of data that results from the data source.

The main data are: imagery data, contour data, river data, geological maps and climate maps. While the secondary data are: past landslide events data, geological and micro-topography features data, DEM data, slope data, flow direction data, flow accumulation data, watershed data, and sub-area data.

Flow chart of the acquiring data process can be seen in Figure A.1.

5.1 Imagery

- is used to interpret the landslide area or micro-topographic features;
- in color or black n white;
- can use the images at different times, but still give priority to the latest image;
- have a minimum spatial resolution of 30m, with recommendation resolution of 5m;

- the types of imagery data that exist in Indonesia with the features and price estimation, are described in Table C.1;

5.2 Flow accumulation data

- raster data that results from flow direction data processing;
- raster data type with pixel size of 50 m;
- the value contained in a pixel shows the total flow of all the pixels in the region that includes the flow direction data.
- data can be interpreted also as a pressure or level of ground water saturation.

5.3 Flow direction data

- raster data that results from DEM data processing;
- raster data type with pixel size of 50 m;
- the value contained in a pixel showing a particular direction according to the index value of the flow direction.

5.4 DEM data

- is the result of contours or TIN data processing;
- raster data type with pixel size of 50 m (horizontal resolution).

5.5 Data of geological and micro-topography feature

- line data (vector data type);
- geological feature data is the result of digitization of geological maps;
- micro-topographic feature data is the result of interpretation and digitization of imagery data or from field survey results;
- information and a clearer description of the shape and character of each micro-topographic element, contained in Appendix E.

5.6 Past landslide events data

- polygon data (vector data type);
- is the result of interpretation and digitization of landslide area from satellite imagery or from field survey results;
- a clearer description of the shape and character of deep-seated landslide, contained in Appendix D.

5.7 Slope data

- raster data that results from DEM data processing;
- raster data type with pixel size of 50 m;
- the value contained within a pixel is the maximum height change between pixels by 8 pixels around it.

5.8 Contour data

- line data (vector data type) which cover a study area;
- contour data derived from 1:50.000 minimum scale map (with vertical resolution of 25m);
- contour data is processed using GIS software to obtain TIN and DEM data;
- topographic map in Indonesia can be obtained at Bakosurtanal.

5.9 Morphology river data

- line data (vector data type);
- useful in various purposes of making a landslide potential map and banjir bandang hazardous area using river flow position.

5.10 Sub-area data

- vector data type in the form of square grid with size of 1 km2 (1000 mx 1000 m) which covers study area;
- this data is the smallest area unit to illustrate the landslide potential value.

5.11 Geological map

- in the form of raster maps that can be the result of scanning, which has geo-referenced and then digitized;
- is used for interpretation and digitization process of geological elements such as faults or lineaments in the study area;
- is used to determine the boundaries of study areas, where the study area should have the same geological or lithological and climate or rainfall character;

5.12 Climatic map / rainfall distribution map

- is used to help determine the boundaries of study areas, where the study area should have the same geological or lithological character and climate or rainfall character.

6. Terms and condition

6.1 The tools that are used

6.1.1 Software

These manual are made by using the software with the following specifications:

6.1.1.1 GIS software

The software has the following capabilities:
- can create, edit, process the data vector,
- can create, edit, process raster data,
- can create, edit, process attribute data,
- can process the contour data to produce DEM data,
- can generate slope data, and
- can generate the data flow direction.

6.1.1.2 Spreadsheet tool software

The software has the ability to compute large amounts of data, aided by a mathematical formula in a column or table.

6.1.2 Hardware

Minimum specifications required of the hardware are Dual Core Processor 2GHz, Memory 2GB, VGA Card 256 MB.

6.2 Requirements for determination of the study area boundaries

The study area should have a common character of geological/lithological and climatic/rainfall characters. Determination of the study area boundaries should be done by using geological maps and climate maps by overlay these maps and look for areas that have a common position of the both character.

6.3 Requirements for interpretation and digitations of the landslide area using imagery data

Imagery data used for the interpretation of landslide areas should have a uniform resolution throughout the target area. Landslide areas that are digitized only the deep-seated landslide type area, which has a volume greater or equal to 10^5 m^3 (one hundred thousand cubic meters). The calculation method to find the amount of deep-seated landslide material volume based on the area data, using the formula: volume = 0.074 * (the width of landslide area)$^{1.45}$.

6.4 Requirements for interpretation and digitations micro-topographic elements using imagery data

Imagery data used for the interpretation of micro-topographic elements should have a uniform resolution throughout the target area. There are five types of micro-topographic elements, which each element should be made in each type of vector data. Information and better description of shape and character of each elements that will be used for interpretation and digitations process, contained in Appendix E.

6.5 The concept of designing stages of banjir bandang based on river bed slope

Flash flood stage depends on many factors. In an effort to prepare the draft map of banjir bandang hazard area by using topographic data, based on “Guideline for Survey of Debris-Flow-Prone Stream and Survey of Debris Flow Hazard Areas” published of SABO Division, SABO Department, River Bureau, Ministry of Construction, Japan, April 1999, there are two criteria in determining the banjir bandang stage based on river bed slope, namely

1) Volcanic area; banjir bandang hazard area occurred on the river that has a slope range of 2°-10°
2) Non-volcanic area and says that banjir bandang hazard area occurred on the river that has a slope range 3°-10°.

6.6 Requirements of banjir bandang hazard areas determination

In establishing banjir bandang hazard area, the following factors should be considered:

- Topography;
- Distribution of accumulated sediment caused by banjir bandang;
- Past record of flooding by banjir bandang;
- Neighboring banjir bandang prone streams and neighboring topography;
- Status of floods of banjir bandang of banjir bandang streams which are similar in terms of geography and other features;
- Land-use and demography.

7. The steps

The basic principle of this manual is to make a map of landslide and banjir bandang hazard area. Map of landslide hazard area is used to view and determine areas prone to natural dam forming on the upper river, so automatically it will be assumed that the area is prone to banjir bandang. After determining the river or area that prone to banjir bandang, to see or to predict areas that prone to banjir bandang runoff, which is needed next is a map of banjir bandang hazard area.

This concept diagram can be seen on Figure A.2.

7.1 Defining the study area

The initial step that should be done is to define the boundaries of study area that would be analyzed by reference to Chapter 6.2.

7.1.1 Making sub-catchment

1) Process DEM data to generate sub-catchment data using GIS software;
2) The result is sub-catchment data of raster data type;
3) Convert the raster data into polygon data (vector data type). (Figure B.3)

7.1.2 Making catchment area

1) Use river spatial data as a guide in selecting the position of sub-catchment that will be merged to create a catchment area. The boundaries must be located outside the catchment area of a river and its tributaries; (Figure B.4)
2) Set the limits of the watershed downstream by using slope data as a reference, ie at the location when the slope of the terrain began low (Figure B.5 and B.6)
3) The process result is catchment area data vector data type that describes multiple watershed in study area. (Figure B.7)

7.1.3 Making sub-area

1) Create a square-shaped object of 1 km2 (1000 m x 1000 m) area by using GIS software;
2) Copy and paste the object into the nearby square where the corners coinciding with the corners of the square next to it;
3) All square objects (sub-area) must cover or overlap the catchment area data of study area;
4) Each sub-area must have attribute data of identification number (ID). (Figure B.8)

7.2 Analysis of landslide potential based on past landslide data

Sometimes, deep-seated landslide occurs close to the place where once the deep-seated landslide has occurred. From the fact, it is considered that possibility of occurrence of deep-seated landslide is high in the area close to the place, where once the deep-seated landslide occurred.

This stage is the first step in creating the landslide potential map. In this first stage, the analysis is done only based on past landslide data.

Flowchart of this analysis can be seen on Figure A.3.

7.2.1 Make an information table about intersection of sub-area and past landslide data

1) Overlay sub-area data and past landslide events data by using GIS software;
2) Perform analysis to determine whether a sub-area is intersected/overlapped with the landslide area;
3) Generate a new data that is spatial data of analysis results from the overlaid of sub-area data with past landslide events data;

For simplicity and for the purposes to the next stage of analysis, the analysis can also be done using spreadsheet tool software with the following stages:
1) Extract the attribute data of sub-area data and past landslide events data;
2) By using spreadsheet tool software, create a table with the following specifications:
   - The first column, containing the sub-area ID;
   - The second column, contains the number of landslide events in one sub-area, where the value in this column is obtained from the attribute data of spatial data from analysis results of intersection between sub-area data with past landslide events data;
   - The third column contains the value that indicates whether a sub-area is overlap with landslide area. The values are "1" for sub-areas that is overlap and "0" for sub-area that is not overlap;
   - The table example can be seen in Table C.2.

7.2.2 Make a landslide potential map based on past landslide data

Landslide potential map based on past landslides events, is obtained by knowing the sub-areas which is overlap with landslide area. Sub-areas that is overlap with landslide area is sub-area that prone to landslide based on past landslide events data.

The another way is to use the value in the third column of the table from Chapter 7.2.1, which is by entering the value in the attribute data in accordance with the sub-area ID.

The example of landslide potential map based on past landslide events data can be seen in Figure B.9.

7.3 Analysis of landslide potential based on geological element and micro-topography data

It is considered that geological conditions play an important role in generation of deep-seated landslide. In addition, it is also considered there is a high possibility that the micro-topographic elements such as the rock creep or the linear depression contour represents deformation of the rock, which is considered a signal that the deep-seated landslide would occur.

On this second stage, the data required are data of geological elements, micro-topographic elements, as well as past landslide data events. In the case of Kabupaten Jember, the geological elements are fault and lineament, whereas the micro-topographic elements are circular arc crack and ancient deep-seated landslide.

The flowchart of this analysis process can be seen in Figure A.4, whereas the position of geological features map can be seen in Figure B.10.

7.3.1 Make an information table about intersection of sub-area and geological elements or micro-topographic elements

1) Overlay sub-area data with geology/micro-topography data;
2) Perform analysis to determine whether a sub-area is overlap with geological/ micro-topographic elements;
3) Generate new data that is spatial data of analysis results from the overlap of sub-area data with geological/micro-topography data;
4) Extract the attribute data of the new data;
5) By using spreadsheet tool software, create a table with the following specifications:
   - The first column contains sub-area ID;
   - The second column contains a value that indicates whether a sub-area overlap with landslide area. The value of "1" for sub-areas that overlap and the value of "0" for sub-areas that don't overlap;
   - The third column indicate the number of overlapped fault elements in a sub-area, where the value in this column is obtained from the attribute data of overlap analysis results between sub-area data with fault element data;
   - The fourth column contains a value that indicates whether a sub-area overlap with fault element. The value of "1" for sub-areas that overlap and value of "0" for sub-areas that don't overlap;
   - The fifth column contains a value that indicates whether a sub-area overlaps with landslides area and also overlaps with fault element. The value of "1" for sub-areas that overlap with both and the value of "0" for sub-areas that overlap with just one or even not overlap with both.
6) The third, fourth, and fifth column in the table above is the analysis for the fault element. For the purposes of analysis of other elements, namely lineament, circular arc crack, and ancient deep-seated landslide, each element will require three columns.
7) For more details, see the examples of Table C.3.

7.3.2 Finding two elements that most correlated with past landslide events

1) Select two elements of geology/micro-topography that are analyzed on the previous stage, based on the elements that most correlated with the landslide events, which are calculated by using hitting ratio and cover ratio method (Appendix E);
2) The resulting table in chapter 7.3.1 (Table C.3) yields values of the parameters needed to calculate the hitting ratio and cover ratio;
   - Total value of the second column is the value of S1 parameter that is the number of sub-areas that experienced landslides events;
   - Total value of the fourth column is the value of S3 parameter for fault element that is the number of sub-areas that overlap with fault element;
   - Total value of the fifth column is the value of S2 parameter for the fault element that is the number of sub-areas that experienced landslides events and overlap with fault element;
   - Similar to the next parameter value of S2 and S3 for others elements.
3) By using the values of these parameters, calculate the hitting ratio and cover ratio for each element;
4) Calculate the value of hitting ratio and cover ratio of past landslide events where the value of S2 is the total of sub-area that experience landslide, and value of S3 is the total of sub-area.
5) Choose two elements that have higher hitting ratio value than the hitting ratio value of past landslide events, and also have the highest value of cover ratio.
6) Examples of calculation results can be seen in Figure B.11.

7.3.3 Finding combination of the two selected elements

This stage is to find the best combination of two elements selected from the previous stage, which are the elements that most correlated with the landslides events.

1) If the two elements is assumed by A and B, then the combination option of the two elements are: only A, only B, A and B, A or B;
2) Each combination has a parameter value of S2 and S3, while the parameter value of S1 is still obtained through overlapped sub-areas data with landslide events data; (Table C.4)
3) Choose one combination of elements that have the highest value of hitting ratio and cover ratio;
4) Examples of calculation results can be seen in Figure B.12.

7.3.4 Making landslide potential map based on geologic and micro-topographic elements

1) Perform overlap analysis between sub-areas with the two elements based on the best combination. For example, if the combination chosen is "A or B", then the sub-areas that overlap at least with element A or element B or even with both elements, that sub-area is potential or prone to landslides;
2) Mark the potential sub-areas and plot them to create landslide potential map based on geological and micro-topographic elements.
3) Examples of maps can be seen in Figure B.13.

7.4 Analysis of landslide potential based on topography

There are two relations between topographic factor and occurrence of deep-seated landslide: the steeper the inclination, the more the slope gets unstable, then deep-seated landslide is likely to occur; the larger the catchments area, the more underground water gets gathered, then deep-seated landslide is likely to occur.

In the third stage of analysis, the required data are slope data, flow accumulation data, and past landslide events data.

Flowchart of this analysis process can be seen in Figure A.5.

7.4.1 Converting raster format of slope data to vector format of point data

1) Convert slope data and flow accumulation data that both in raster format into point data (vector format) using GIS software;
2) The purpose of the conversion is to extract values contained within a pixel to be insert to the attribute data of point data;
3) The conversion results are point data that has attribute of slope values and point data that has attribute of flow accumulation values;
4) The sample data of conversion result can be seen in Figure B.14.

7.4.2 Merge the two attribute value from two point data into a single point data

1) Merge the two attribute values (i.e. slope value and flow accumulation value) from two point data into a single point data;
2) The merger is a data point that has two attribute values of the slope and flow accumulation value;

7.4.3 Selecting slope and flow accumulation points that are within study area

1) Select the points from the chapter 7.4.2 result, which within the study area;
2) The study area is based on sub-area data;
3) Extract the attribute data of selected point data to obtain: point ID, slope value and flow accumulation value;
4) Input the attribute data into a table using spreadsheet tool software.

7.4.4 Selecting points of slope and flow accumulation which are intersect with landslide area within study area

1) Select the points from chapter 7.4.2 results that overlap with landslide areas within the study area;
2) The landslide area is based on past landslide events data;
3) Extract the attribute data of selected point data to obtain: point ID, slope value and flow accumulation value;
4) Input the attribute data into a table using spreadsheet tool software.

7.4.5 Prepare data table to calculate the landslide ratio

1) Create a new column in both tables from the results of chapter 7.4.3 and chapter 7.4.4, which contains value of the formula: "log(pixel wide x flow accumulation value)", where the pixel wide = 50 x 50 = 2500;
2) The value obtained should be rounded to two decimal places;
3) Example of a table can be seen in Table C.5.

7.4.6 Calculating landslide ratio table

1) Prepare table to count the number of points that have a specific range of slope values and log(pixel wide x flow accumulation value) values. The tabular form are as follows:
   - The first column is the range of slope values. The contents start from the second line downward. The range of slope values are: 0 ˚ -10 ˚, 10 ˚ -15 ˚, 15 ˚ -20 ˚, 20 ˚ -25 ˚, 25 ˚ -30 ˚, 30 ˚ -35 ˚, 35 ˚ -40 ˚, 40 ˚ <.
   - The first line is the range of log(pixel wide x flow accumulation value) values. The contents start from the second column to the right. The range values are: 3.40-3.70, 3.70-3.88, 3.88-4.10, 4:10 to 4:44, 4.44-4.72, 4.72-5.11, 5.40-5.70, 5.70 <.
   - Cells in the table contain value that indicates the number of points that have a specific range of slope values and log(pixel wide x flow accumulation value) values.
   - In total, there will be 9 x 8 = 72 cells in this table.
2) Fill in the data to the format of the table above using data from the stages of chapter 7.4.3; (Table C.6)
3) Fill in the data to the format of the table above using data from the stages of chapter 7.4.4; (Table C.7)
4) Make the division process which are the value of each cell of the second table (using the data chapter 7.4.4) is divided by the value of each cell of the first table (using the data chapter 7.4.3) in accordance with the position of the cells;
5) Enter the division result value into a new table in the same format;
6) Make the division process that is the total number of all points of the second table (using data chapter 7.4.4) is divided by the total number of all points of the first table (using data chapter 7.4.3). This value is the average ratio value.
7) The calculation sample is shown in Table C.8.

7.4.7 Determination of the high potential landslide point based the criteria of slope value and the value of log(pixels wide x value of flow accumulation)

1) Divide all values in each cell of the resulting table in chapter 7.4.6 with the average ratio value;
2) Enter the result value of this division into a new table with the same format;
3) Find the value in each cell of the new table whose value is equal to or more than twice the average ratio value;
4) Mark the cells that have the value of these criteria (Table C.9);
5) Mark/paint all the cells to the right and downward from the previously marked cells;
6) Obtain the final information about the range of slope values and the range of log(pixel wide x flow accumulation value) values that potential to landslides based on the position of all the marked cells;
7) A table example can be seen in Table C.10.

7.4.8 Making a distribution map of high potential points of landslide

1) Select the points within the study area in accordance with the criteria of range of slope values and log(pixel wide x flow accumulation value) values obtained from the previous stage;
2) Plot the points that fit these criteria by using GIS software;
3) An example can be seen in Figure B.15.

7.4.9 Counting the number of landslide potential points in a sub-area

1) Overlay the data or map of data points distribution with sub-area data;
2) Create the overlay result into the new data.

7.4.10 Determining the potential sub-areas of landslides

1) Extract the attribute data from the overlay resulted data of landslide potential point data with sub-area data to obtain sub-area ID, landslides events per sub-area, and the number of landslide potential points per sub-area;
2) By using the spreadsheet tool software, create table with the following specifications:
   - The first column contains the sub-area ID;
   - The second column contains values that indicates whether a sub-area overlap with landslide area. The value of "1" for sub-areas that overlap and value of "0" for sub-areas that don't overlap;
   - The third column contains number of landslide potential points per sub-area. This value is obtained from the results of chapter 7.4.9;
   - The fourth column and so on contains value that indicates whether the number of landslide potential point on one sub-area is equal or more than the multiple value of 50. The value of "1" for the corresponding sub-area and the value of "0" for the sub-are that do not correspond;
   - The table example is shown in Table C.11.
3) Perform the calculation of hitting ratio and cover ratio for each multiple number of points of 50 (e.g. 50, 100, 150, etc.). The parameter value of S1 is the number of sub-areas experienced landslides occurrence. The parameter value of S3 is the number of sub-areas that have a certain number of points. The parameter value of S2 is the number of sub-areas that have a certain amount of points and landslide events;
4) The calculation process is more clearly found in Appendix D.

7.4.11 Making landslide potential map based on topographic factor

1) Based on the results of chapter 7.4.10, it is known that sub-area that are potential to landslide based on the minimum number of landslides potential points;
2) Mark and map the sub-area is to create potential landslide map based on topographic factors;
3) Example of a map can be seen in Figure B.16.

7.5 Making landslide potential map based on combination factor

Combine the analysis results of landslide potential map based on the three factors: past landslide events factor, geological and micro-topography factors, and topographical factors.

Sub-area that has three factor score is the sub-area with high potential of landslides. Sub-area that has two factor score is the sub-area with middle potential of landslides. Sub-area that has one factor score is the sub-areas with low potential of landslides. While the sub-area that has no factor at all, is the sub-area that has no potential of landslides.

This flowchart of analysis process can be seen in Figure A.6. The map examples can be seen in Figure B.17.

7.6 Making a draft map of banjir bandang hazard area using contour data

The purpose of draft map of banjir bandang hazard area is to estimate the areas affected by banjir bandang runoff. Maps generated at this stage can be said is a draft map because the determination of banjir bandang hazard area using assumptions of certain height inundation that might be different or incompatible with the field condition/situation of an area, as well as the analysis using contour data that may not actual or have low resolution.

Data used for the purposes of making draft map of banjir bandang hazard map is the DEM data and spatial data streams.

Flowchart of this process can be seen in Figure A.7.

7.6.1 Selecting main rivers

1) River that potential to banjir bandang occurrence generally is sedimentation segment or can also occur in transportion segment;
2) Based on the elements code information on topographical maps from Bakosurtanal, select the code of main river by looking at the location, the name of river, or by using reference data accumulated flow;
3) By using GIS software, create a new spatial data from the selected river data.

7.6.2 Select and edit the features of the main rivers according to criteria of slope based on study area

1) Based on the river bed slope criteria in chapter 6.3, for the case of Jember district, which is volcanic area, so the slope criteria that is used to limit the banjir bandang hazard area is between 10˚ to 2˚;
2) Use the data slope as a reference to help determine the position of upstream and downstream river boundary in accordance with the range of slope;
3) Edit or cut the spatial data of main river from the previous process results in the upstream and downstream according to the range of slope degree;
4) Make a new spatial data from the edited river data. (Figure B.18)

7.6.3 Convert river feature into 3D river feature

At first the river feature is not 3D feature which is a feature that has elevation information. Next, do the conversion of river data that is still 2-dimensional to 3 dimensional. This conversion can be using GIS software.

7.6.4 Raise the height of river feature by 5 meter

Banjir bandang hazard area is determined by marking the boundaries of flooded areas according to a certain height the inundation. The inundation height of banjir bandang can vary depending on the circumstances and field conditions.

At this stage we can use the initial assumption of banjir bandang inundation height which is 5 meters from the river bed, by adding an elevation value by 5 m in the attribute data of 3D river data.

If the data of past banjir bandang events is available in the area, then the height of inundation can be changed according to the data or information. The height of inundation is also must be checked by field investigations using specific methods such as flood mark surveys to see signs of banjir bandang or a cross-section surveys.

7.6.5 Making river inundation surface

From this step until the next step, the process is carried out on river features one by one, meaning that the process is only carried out on one river object rather than the whole river feature objects at the same time.

1) By using spatial data river that height have been raised by 5 m, create an offset or copy and paste one object stream to the left and right approximately 500 m - 1000 m perpendicular to follow the main river. This process will generate three river objects (Figure B.19);
2) Save this data into a new spatial data;
3) Create TIN and DEM from the new spatial data streams, where the pixel size same with pixel size of the DEM study area data that are used (Figure B.20).

7.6.6 Making comparative analysis between topography from river feature and actual topography

The final goal of this process is to look at banjir bandang inundation areas. The technique used is to compare the topography generated by a river spatial data offset results with the actual topography. This process is done using GIS software that has cut and fill analysis feature. (See Figure B.21.)

Analysis of cut and fill is basically calculating the volume difference between the volume formed by the surface of river spatial data offset by the volume of actual topography. The volume difference will show a difference in the horizontal plane.

The results of the cut and fill process is a raster format, so for further editing, the result must be converted to polygon data of vector format. An example of banjir bandang hazard area is shown in Figure B.22. This figure describes the location of banjir bandang formation as an inundation on the downstream area.

7.6.7 Making a draft of banjir bandang hazard map

Polygon data of inundation boundary then are plotted to create a banjir bandang hazard map. The examples of the results of banjir bandang hazard map can be seen in Figure B.23.

Stage of the process to determine areas prone to banjir bandang like this, repeated again until all the object features of the river is made the area prone to banjir bandang.

7.7 Making banjir bandang hazard map by using data from field survey result

Banjir bandang hazard map that is generated using assumption of inundation height and contour data cannot reflect the field situation/condition and actual topography.

To update the topographic data as well as to improve the quality of banjir bandang hazard maps obtained from the previous analysis, do the field survey to investigate the flood mark, to obtain actual topographic data by cross-section survey, and so on.

7.7.1 Prepare materials and equipments

7.7.1.1 Materials and equipments

Materials and equipments that must be prepared are:

- stationery;
- altimeter;
- field note;
- image data like aerial photograph or satellite image (if available).
- handheld Global Positioning System (GPS) (Figure B.28);
- digital camera;
- clinometers (Figure B.29);
- compasses (Figure B.30);
- rolling scale or disto-meter (Figure B.31);
- ruler;
- topographic map;
- range pole;

7.7.1.2 Analysis and observation of topographic map and imagery data

The following items shall be identified and analyzed using topographic maps and available aerial photo or satellite imagery:

- drainage divide;
- catchment area;
- river length;
- longitudinal profile;
- positions of houses and roads;
- land cover.

7.7.2 Topographic survey

Topographic survey that should be conducted is cross-section survey. The targets that to be measured in this survey is the width of river, riverbed slope, elevation relative to river banks, the distance between river banks with the nearest house, and so forth. If there is sediment in the cross section that is measured, the position and thickness of the sediments should also be measured.

We must pay attention to the location where the slope of the riverbed is gentle and the width of a river suddenly gets wider, since these could turn to a flood point.

From the cross section survey results we can update the topographical maps and also can measure the discharge capacity of the river flow by multiplying the cross section area with the flow rate.

7.7.3 Investigation of past banjir bandang events

7.7.3.1 Investigation of the banjir bandang marks

The banjir bandang marks is a scratch mark, an age of vegetation, and sediment deposit composition, etc. These marks usually can give us information of how high the inundation of previous banjir bandang events. The results of this survey then are plotting its positions on the plan map and cross section.

7.7.3.2 Interview to local residents

We need to perform the hearing from residents in order to grasp the size of the past banjir bandang movement, influence, banjir bandang area, etc. To understand the magnitude, the frequency, banjir bandang area, etc. of past banjir bandang events, an interview to local residents should be executed.

Please obtain the information from residents, especially senior people:

- What kind of disaster occurred?
- When did it occur? And the occurrence date of the disaster.
- Influence area of the disaster
- Maximum water level of the disaster.

7.7.3.3 Investigation of location of houses and roads

Perform an investigation survey of location of houses and roads to see how far their position from the river and how high from the river bed. From the survey results we can know the location/area and the roads that are safe from banjir bandang. The results of this survey can also be used to update the existing topographical maps.

7.7.4 Updating the draft map of banjir bandang hazard area based on field investigation data

By using data and information from field investigation data, we can update the draft map of banjir bandang hazard area by consider the factors that has described in Chapter 6.6.

The updated map of banjir bandang hazard area by using field investigation data can be seen in Figure B.24.

7.7.5 Information on the map

The resulting map should have the completeness of information as follows:

- map legend;
- mapmaker agency name and time of manufacture;
- projection system and coordinate system used;

- source of maps or data used.

7.8 Making a banjir bandang risk map

Making a banjir bandang risk map aims to determine the potential losses of human and materials at a particular location, the whole society, or a larger area.

Banjir bandang hazard map that has been obtained from the previous process, is overlaid the position of various objects that risk for disasters, such as residential areas, public facilities, and so forth.

The example of risk map of banjir bandang is shown in Figure B.25.

7.9 Making map of banjir bandang prone area manually

Under certain conditions, map of banjir bandang-prone area can also be made manually without using a computer, software, and digital data.

The flowchart of making banjir bandang-prone areas can be seen in Figure A.8.

7.9.1 Required data

The required data is (printed) topographical map which covers research area or areas that prone to banjir bandang. Topographical maps can be obtained at BIG. For areas of Java island, maps are available generally have the smallest scale 1:25.000, while for outside Java island, a map of available maps generally have the smallest scale 1:50,000.

7.9.2 Equipments

Equipment used for the manufacture of flash flood-prone area map manually refer to Section 7.7.1.1.

7.9.3 The steps

The basic principle of making banjir bandang-prone area manually same as written in Chapter 7.6.

The stages of process are as follows:

7.9.3.1 Determine the river that will be made the prone area

To create a map of banjir bandang prone area manually, first it must be determined the river that is predicted prone to banjir bandang.

This prediction can be obtained through analysis of historical flood events that have occurred in some river such as the frequency of occurrence within a certain timeframe, the power of flood, inundation area, and so on. This prediction can also be obtained through field surveys to see nature signs of such as natural dams which may be formed in the upstream area.

7.9.3.2 Determine the boundaries of the river from upstream to downstream

The determination of these boundaries based on the topographic slope of the river flow in accordance with the requirements as written on Section 6.5. By using a printed topographical map, the range of topographic slope of river flow can be determined based on the density of contour lines that cut the river flow.

For the 1:25.000 scale topographical map, the contour lines interval on the map is 12.5 m. In determining the topographic slope of river flow for 10˚-2˚, the river flow that has topographic slope of about 10˚, has a length of river segment between the intersections of two contour lines approximately 70 m in the field or about 3 mm on the map. While the river flow that has topographic slope of about 2˚, has a length of river segment between the intersections of two contour lines approximately 360 m in the field or about 14.5 cm on the map.

For more detail, please see Figure B.26.

7.9.3.3 Draw the inundation (prone) area according to the certain height of inundation level

The principles of banjir bandang inundation area delineation refer to Chapter 7.6.4 - 7.6.5, where the height of inundation level that is used is 5 m from the riverbed.

Here are the information or tips how to delineate the inundation (prone) area of banjir bandang on a printed topographic map:

1) The river flow has topographic heights that are decreasing from upstream to downstream. The topographic height information on the river flow is known from the intersection of contour lines with river flow. The height values on other sections of river flow that is not an intersection point with contour lines, obtained by height interpolation between two intersections of adjacent contour lines that has a certain height interval. For example, on a 1:25.000 scale topographical map, the contour interval is 12.5 m.
2) To apply the basic principles of banjir bandang inundation height from river bed as 5 m, the initial stage is focusing on the intersection point of river flow with contour lines. It is known that the point actually has a height value equal to the height of contour lines that intersect the river at that point, but at this initial stage, add the height value to that point as 5 m. For example, if the height value on the intersection point of river flow with contour line is 800 m, then make assumption that the height of that point is 805 m.
3) Draw an imaginary straight line that crossed perpendicular to the river flow that intersect the point of intersection of river flow and contour lines. The line must have an equal length to the left or right side of the river flow. This imaginary line is useful for finding the value of the height of 805 m (corresponding to the example above), to the left or right toward the river flow by elevation interpolation technique.
4) With the assistance of an imaginary line, after it is discovered that the point has a height of 805 m either on the left and right sides of the river, mark those points.
5) Perform steps 3 and steps 4 for each location intersection point of river flow with other contour lines.
6) For others river flow locations that are not the intersection point with the contour lines, look for the height value of the point/location by using interpolation techniques as described on step 1. Next, do the second step that is to add height value by 5 m, then do steps 3 and 4 as before.
7) Connect the points result from step 4 by drawing a line. The lines are distinguished based on the points that exist on the left and the right of the river flow.
8) The tightly the points result from step 4, the more delicate the banjir bandang prone areas.

For more clarify the understanding of the steps to create banjir bandang prone areas by manually as written above, see in Figure B.27.

7.9.3.4 Updating the banjir bandang prone area by using field survey data

Field surveys are conducted same as written in Section 7.7.3.1 that is survey to obtain information of banjir bandang elevation that has ever happened in a particular location. These surveys are a flood mark survey and interviews with local people.

By this information, banjir bandang prone area that was produced before can be updated especially at certain locations or the river low in accordance with the information of banjir bandang elevation obtained from the survey. The techniques for redrawing this banjir bandang prone area, refer to Section 7.9.2.3 earlier.

7.9.3.5 Information on the map

Information or other information that must exist on the map that is produced refers to Chapter 7.7.5.

Appendix A
(normative)
Flowchart

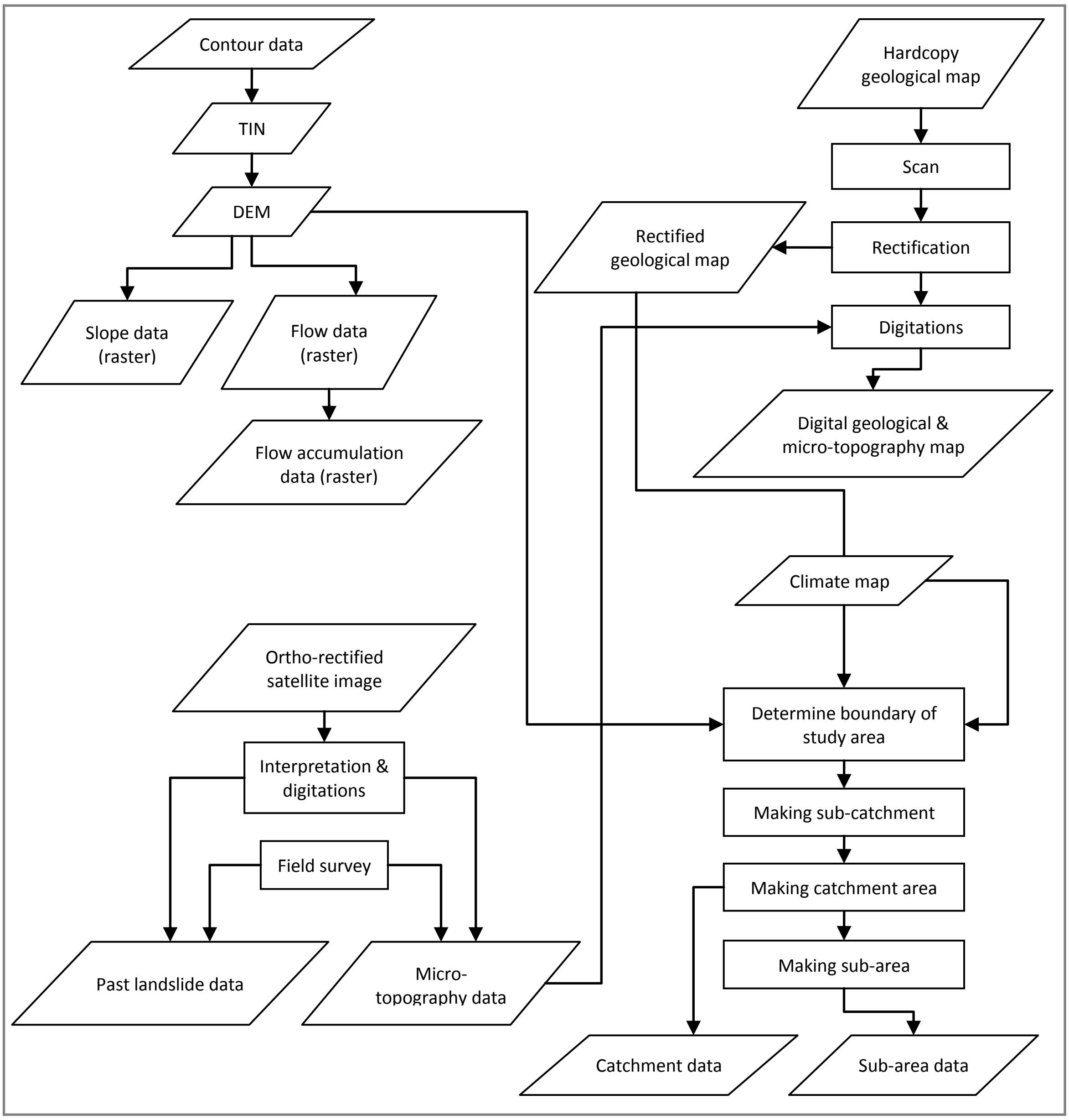


Figure A.1 - Process flow chart of data

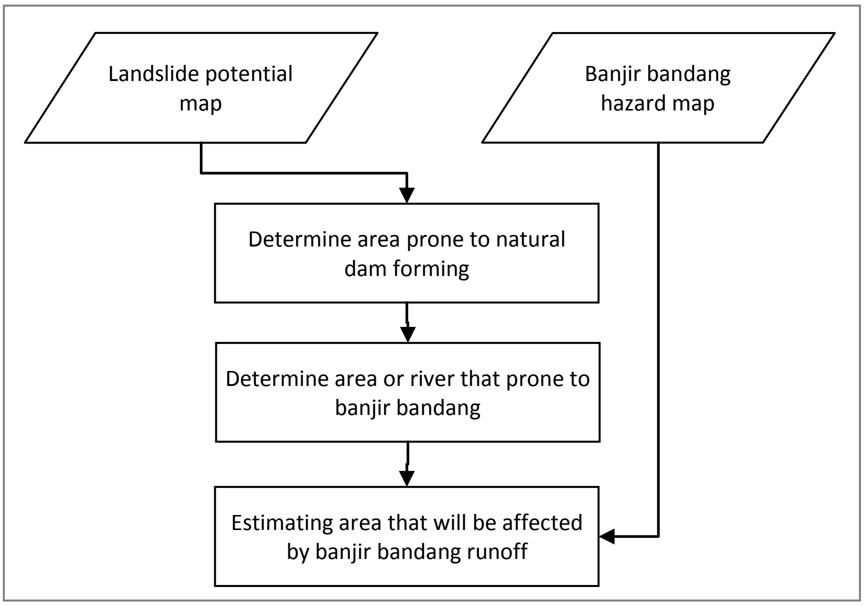


Figure A.2 – The concept of manual of making landslide and banjir bandang hazard map

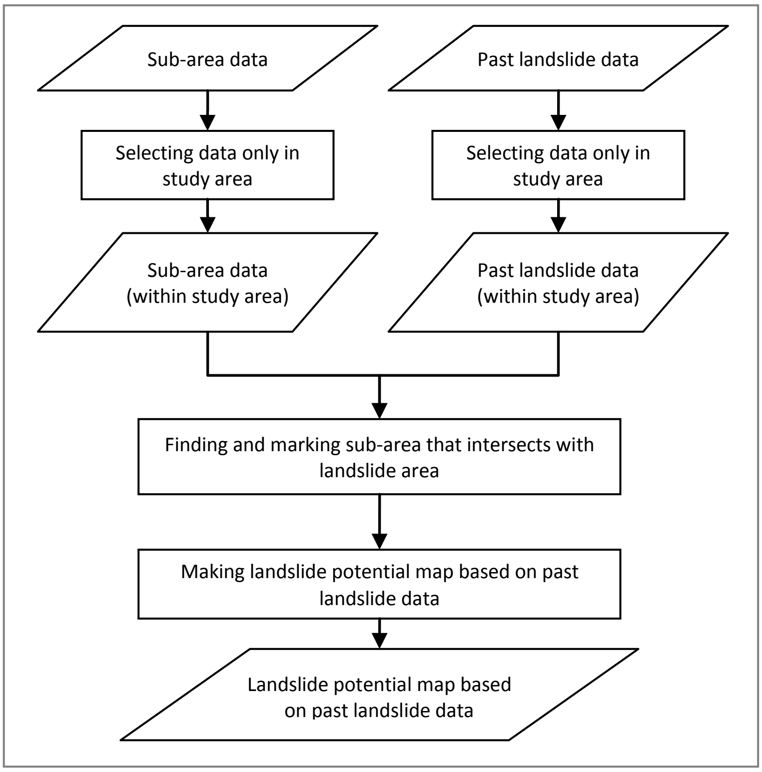


Figure A.3 - Flowchart of making landslide potential map based on past landslide events factor

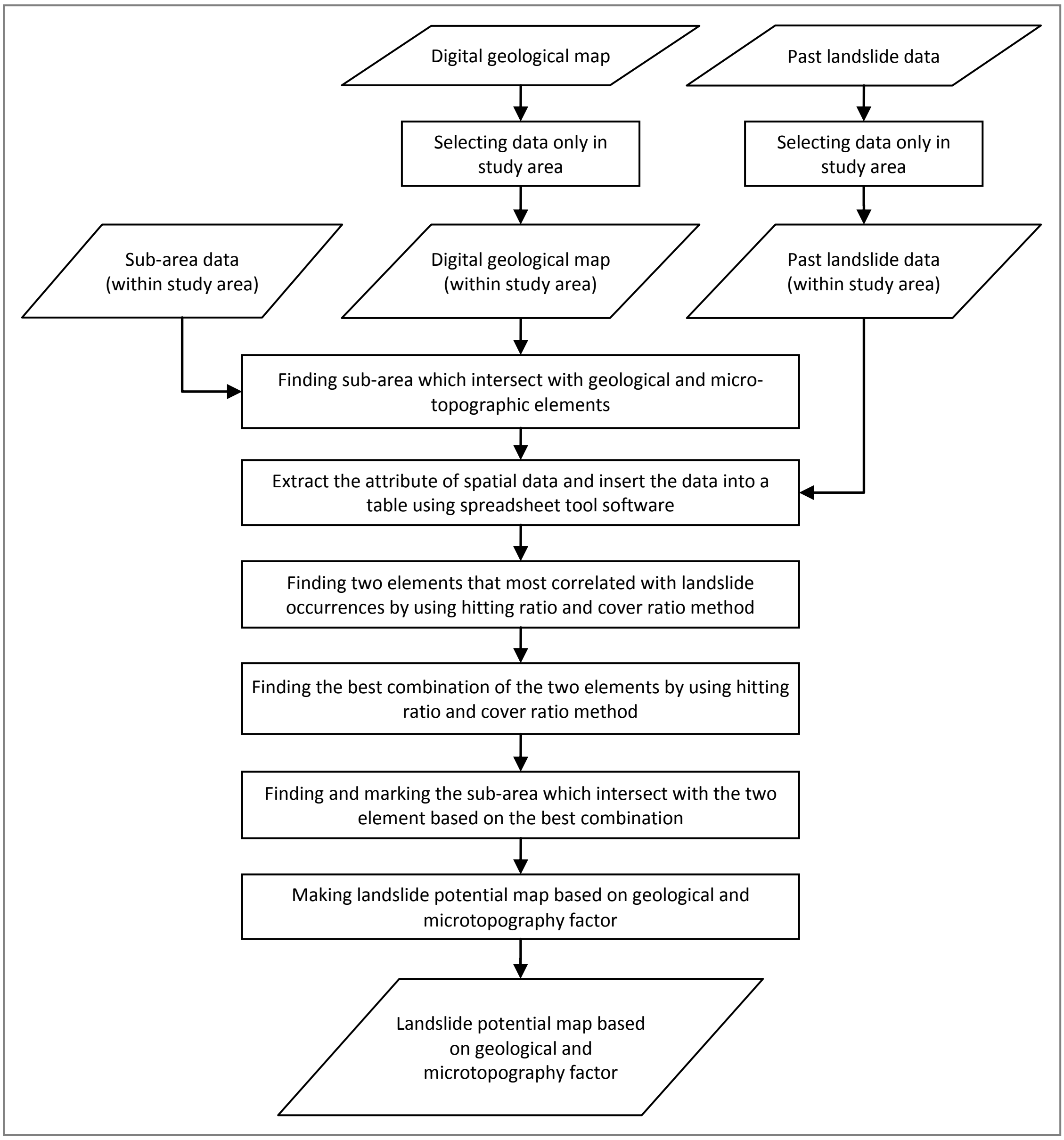


Figure A.4 - Flowchart of making landslide potential map based on geological and micro-topography factor

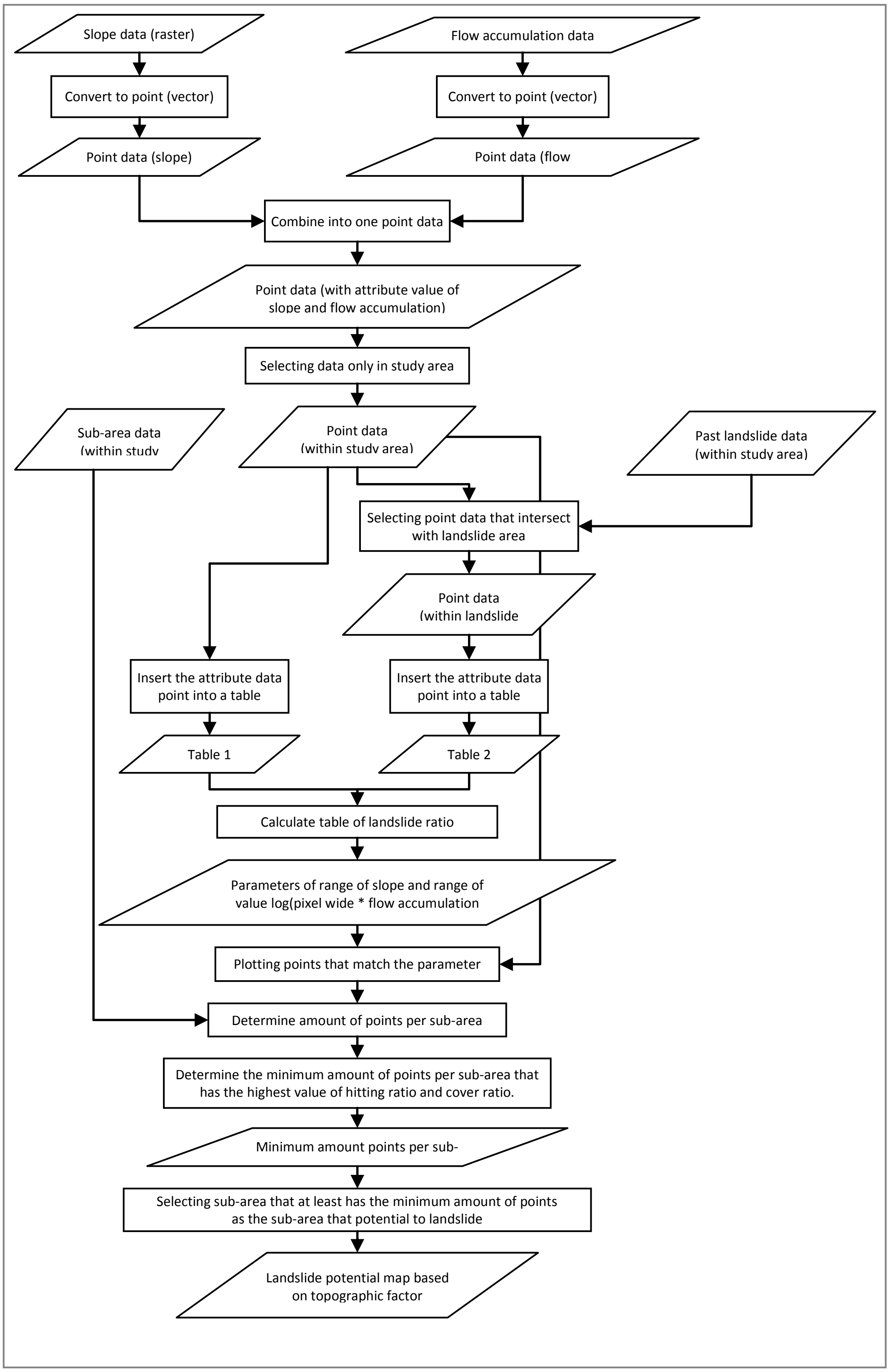


Figure A.5 - Flowchart of making landslide potential map based on topographic factor

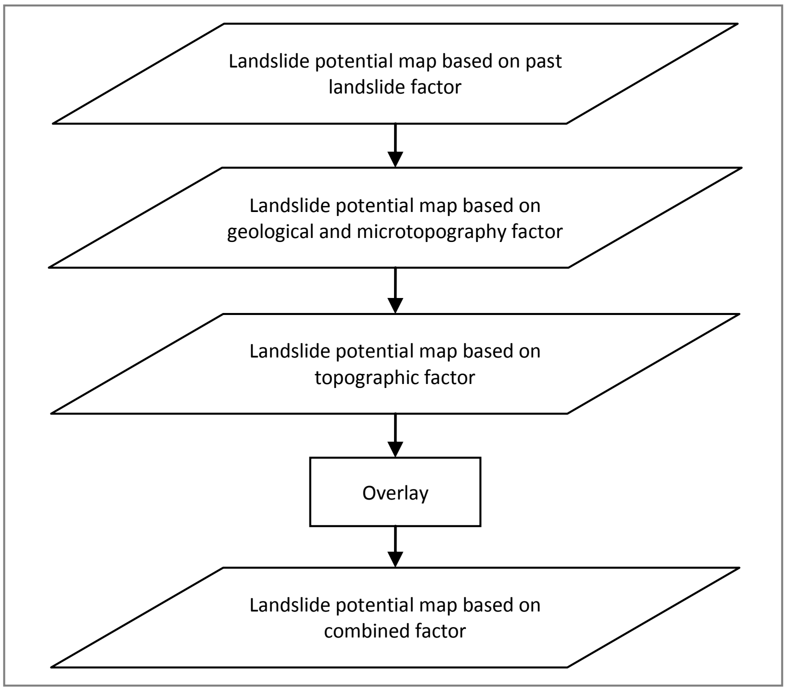


Figure A.6 – Flowchart of making landslide potential map based on combined factor

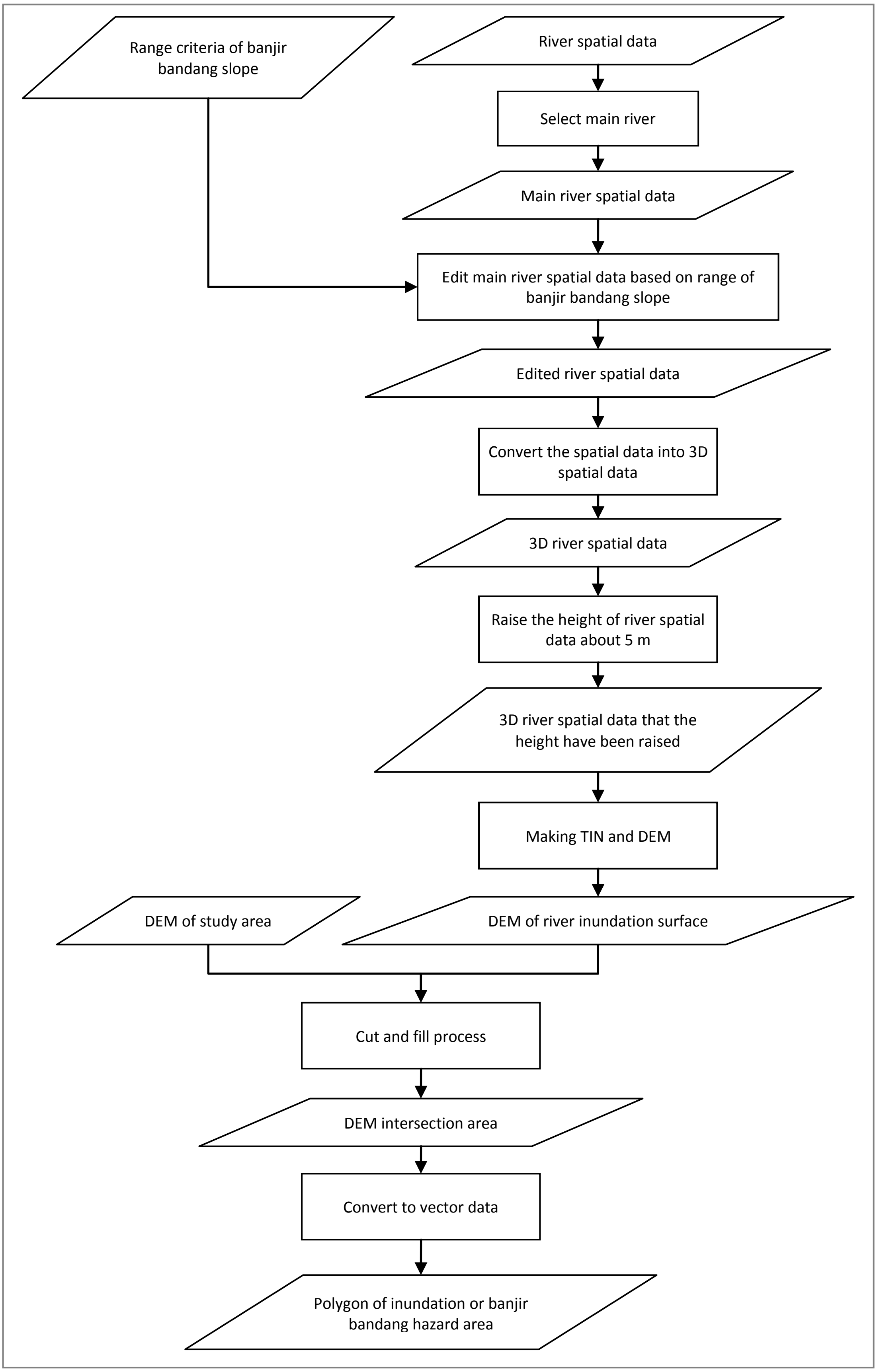
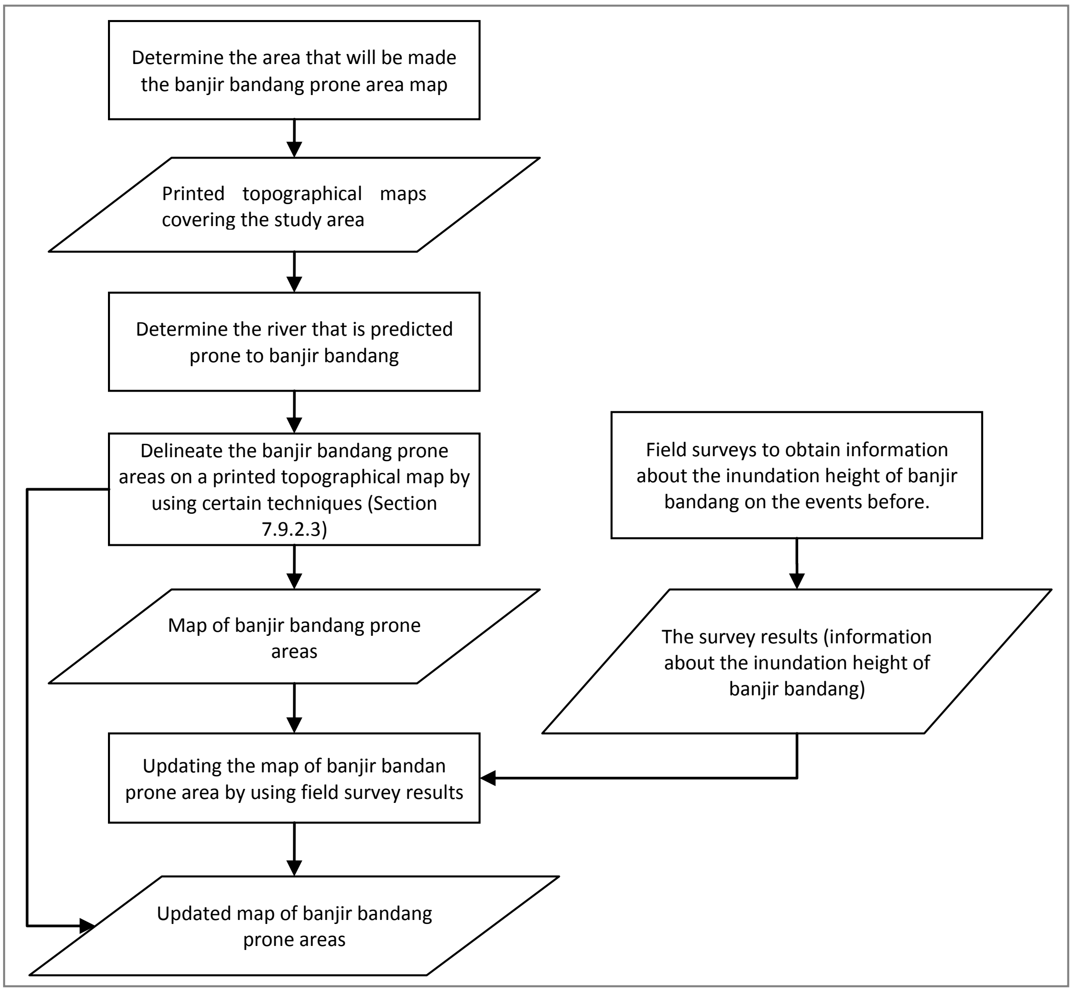


Figure A.7 – Flowchart of making banjir bandang hazard area using contour data



Gambar A.8 - Bagan alir pembuatan peta area rawan banjir bandang secara manual

Appendix B
(informative)
Figure

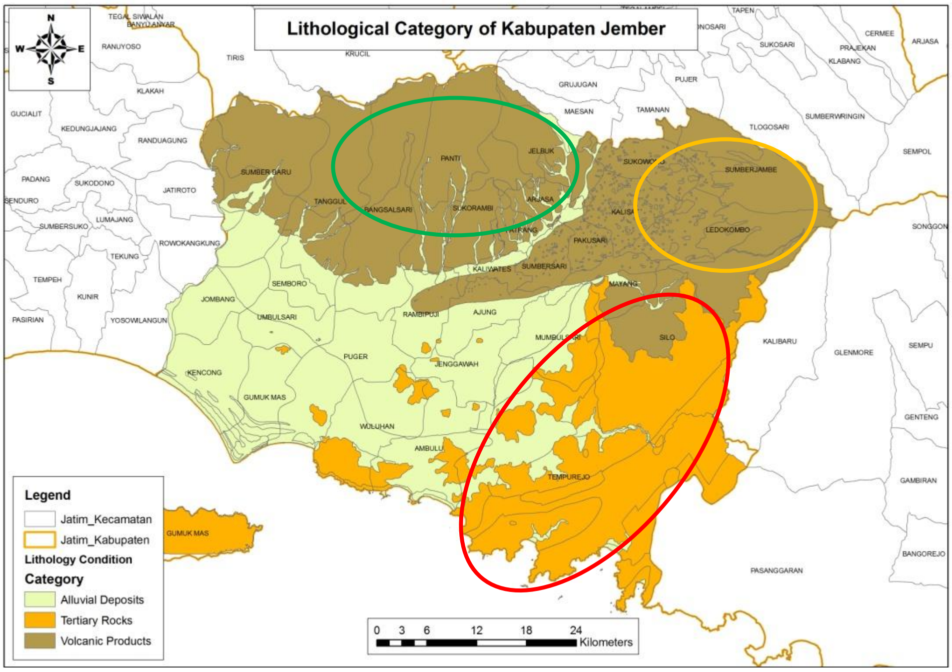


Figure B.1 - Lithological character of kabupaten Jember

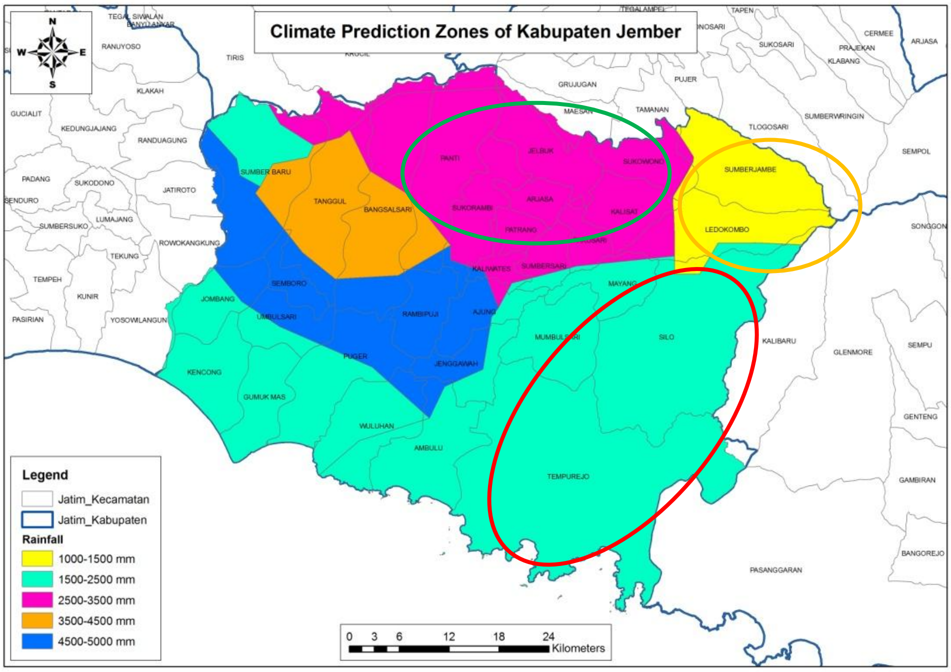


Figure B.2 - Climate prediction zones of kabupaten Jember

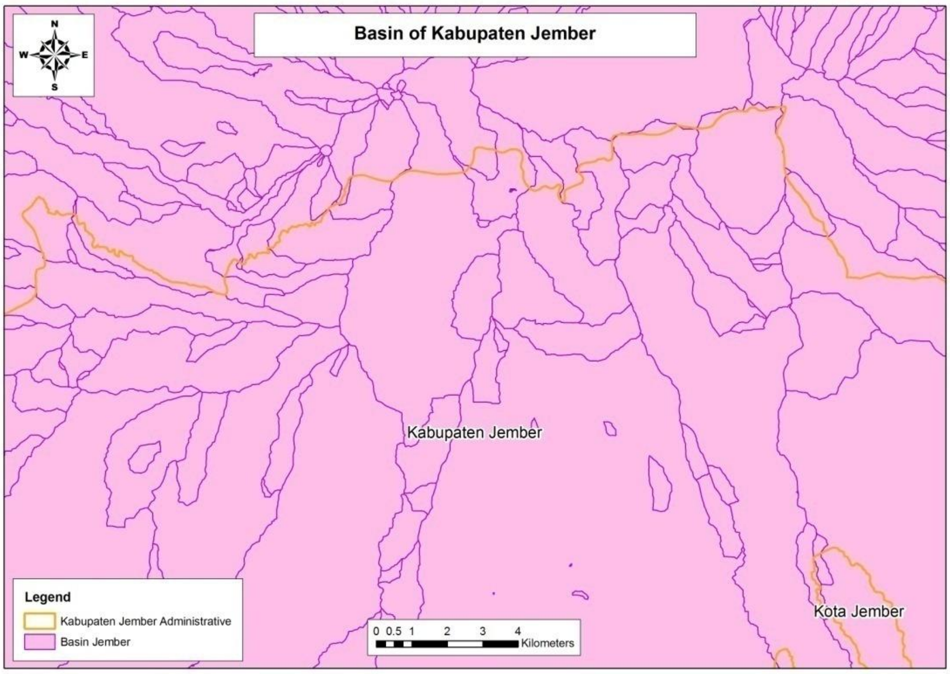


Figure B.3 - Sub-catchment result from DEM data

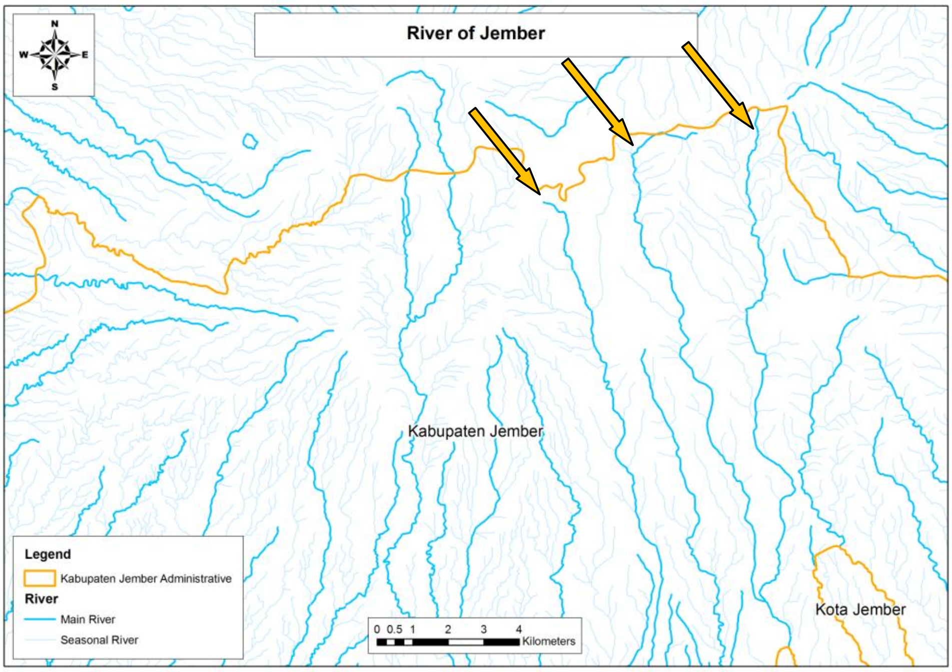


Figure B.4 - Selecting river in a sub-area

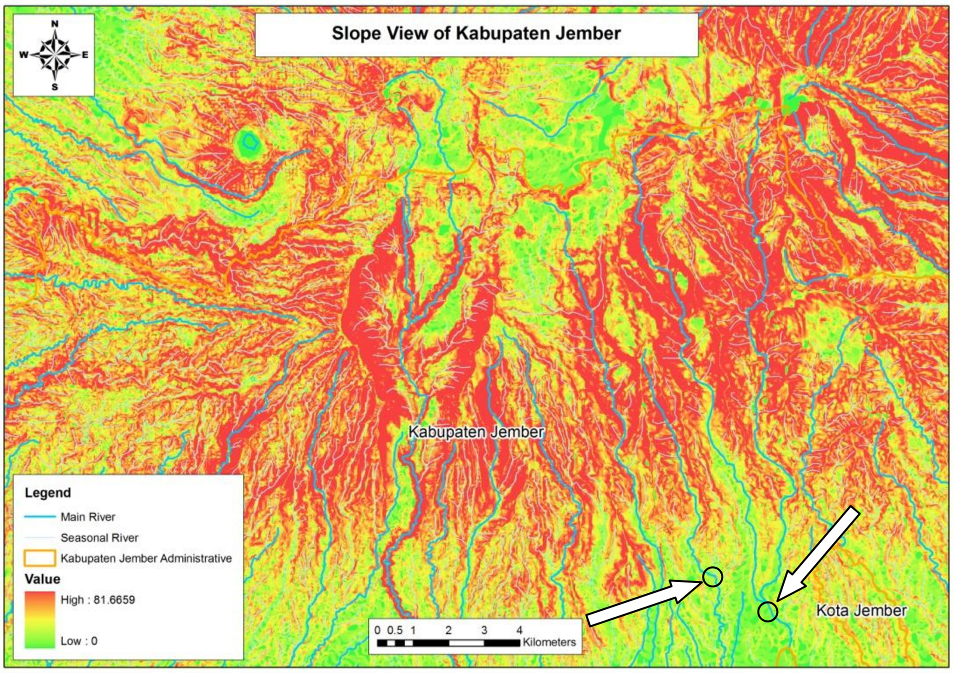


Figure B.5 - Defining the catchment boundary at downstream area by using slope data

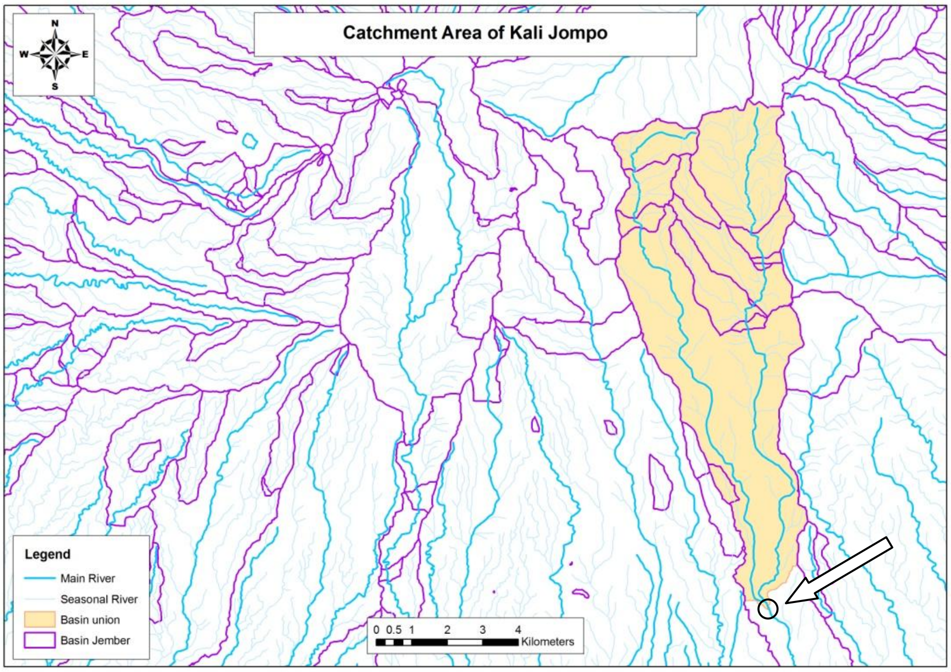


Figure B.6 - Catchment area boundary on downstream area

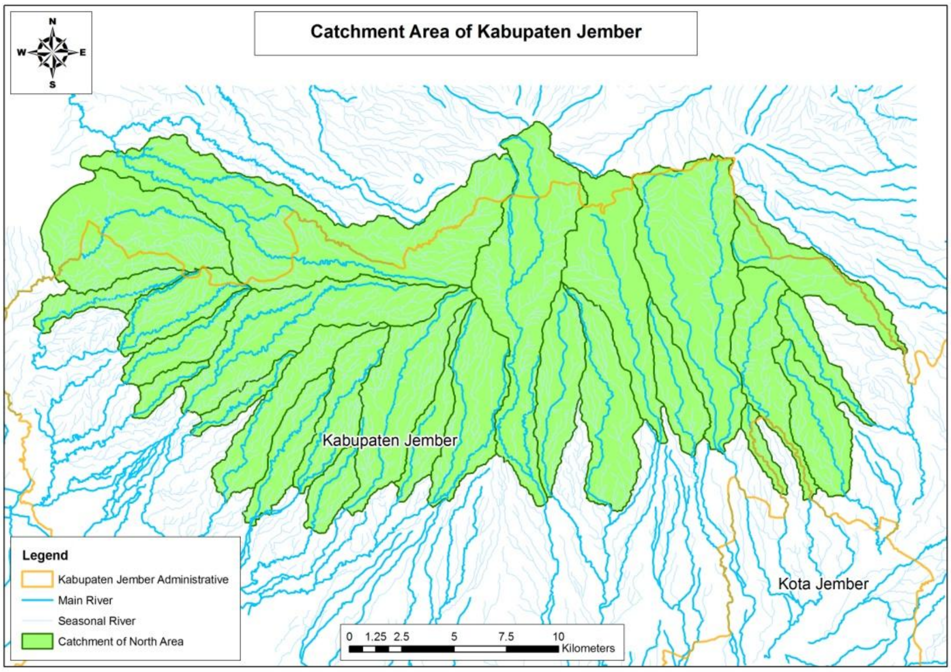


Figure B.7 - Several catchment area in north of kabupaten Jember

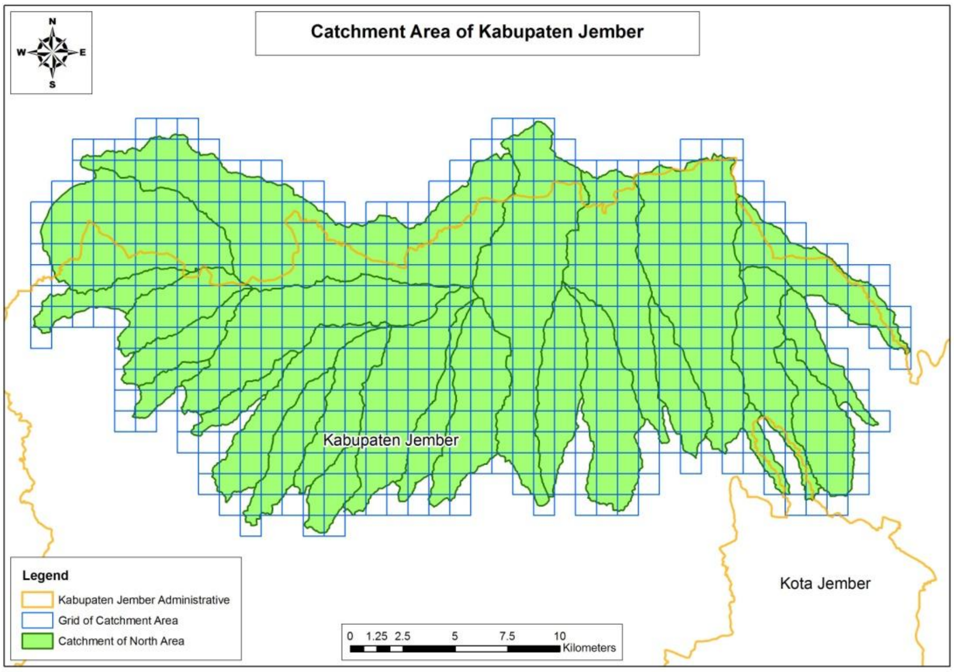


Figure B.8 - Sub-area data results in north of kabupaten Jember

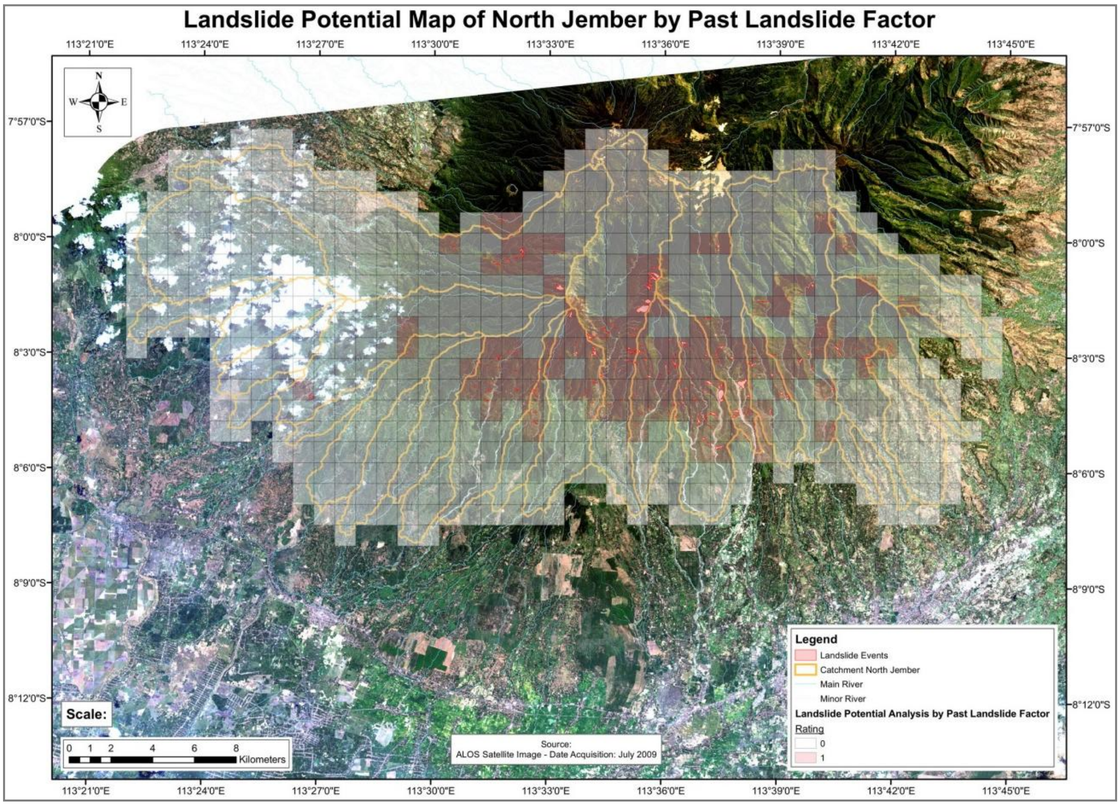


Figure B.9 - Example of landslide potential map based on past landslide data in north of kabupaten Jember

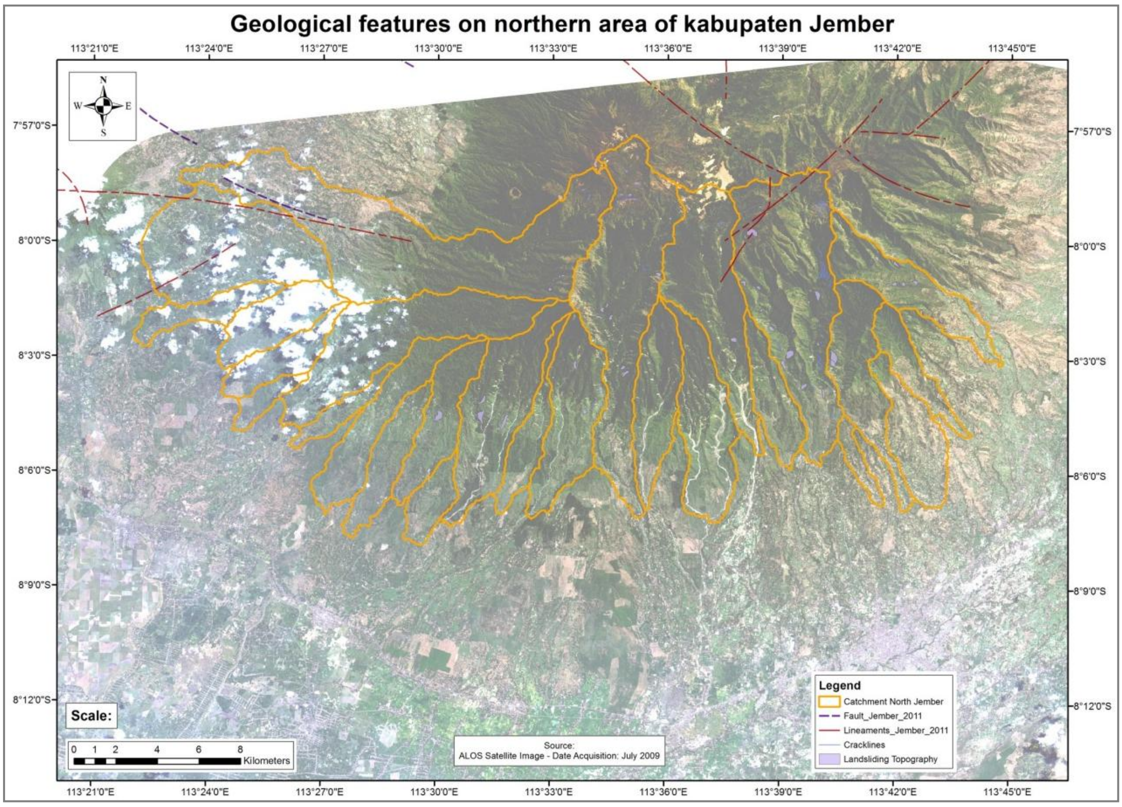


Figure B.10 – Geological features on northern area of kabupaten Jember.

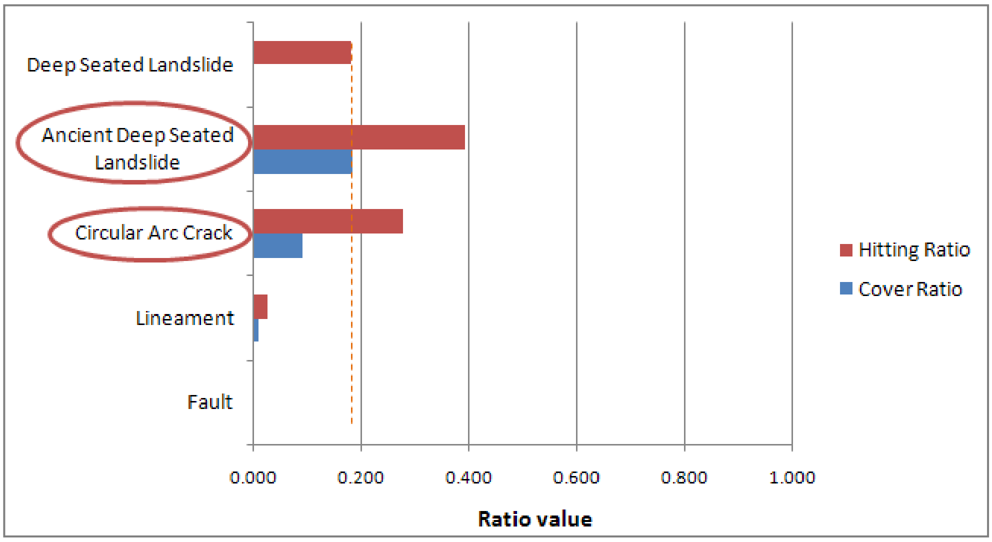


Figure B.11 - Example of the results of selecting two geological or micro-topographic elements that most correlated

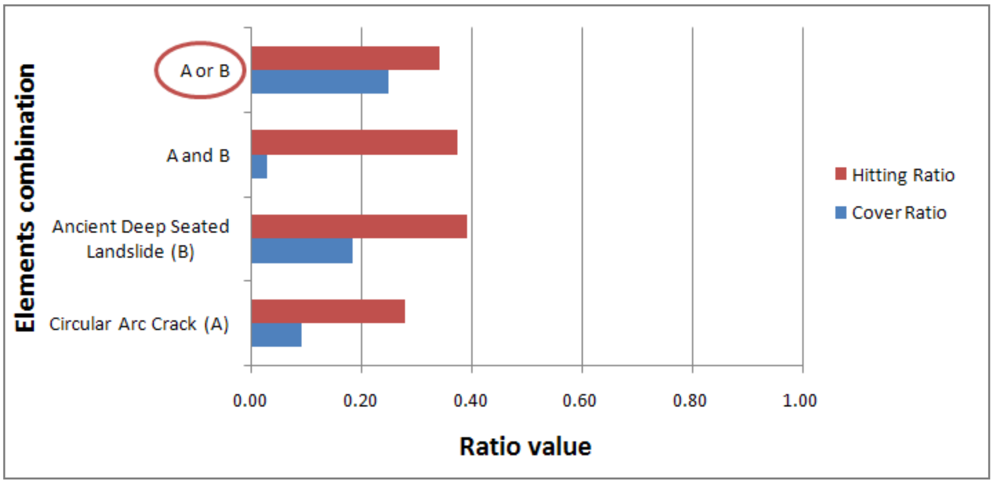


Figure B.12 - Example of the results of selecting the best combination of the two elements that have the highest hitting ratio and cover ratio score