12

Hydrologic Characteristics, Flood Occurrence, and Community Preparedness in Coping With Floods at Air Dingin Watershed, Padang, West Sumatra

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12.1 INTRODUCTION

The Air Dingin watershed is situated at the confluence of the Air Dingin River, a resource for drainage channel, drinking water, livelihood activities, and also for final disposal of waste- water and solid waste (Abuzar, 2005). It is located in Koto Tangah Subdistrict, Padang, West Sumatra, and covers an area as much as 145.57km^2, which lies on latitude 0°43′44′′–0°54′0′′ and longitude 100°19′38′′–100°30′45′′ (BPS, 2006). More than 99% of settlements and develop- ment areas take place in the lowland (BPS, 2005).

Air Dingin region is constituted by 11 villages, the residence for 119,043 persons or about 28,683 households. Each household consists of 4–5 members. There is an equal sex ratio be- tween males and females. None is more dominant than others. Population density in each village varies from 301 to 3760 persons/km^2 (BPS, 2006).

The socioeconomic and demographic characteristics of the sampled respondents indicates that the occupations of inhabitants vary widely. They are farmers, civil servants, and traders. They grow paddy, coconut, and seasonal crops. They raise goats, carabaos, and buf- faloes. Fourteen percent of residents are classified as poor households. Most of residents are 0–54 years old. Only 0.065% of inhabitants are above 54 years old.

Before structural development of the Air Dingin River was put into operation in 1998, this region was subjected to floods every monsoon season. Extreme flow usually occurs in

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September, October, November, and December, and sometimes continues until January. The highest flow usually comes in November when rainfall exceeds 100mm/24h. The inhabi- tants suffer from 2 to 5 days of flood with 1.5–2 m elevation on average. The Water Resources Agency records that huge and devastating floods occurred in the years 1972, 1979, 1980, 1981, 1982, and 1986, which caused loss of life and property. Distribution of the flood risk area in the Air Dingin watershed is shown in Fig. 12.1. It covers about 37% of the total flood risk area of Padang.

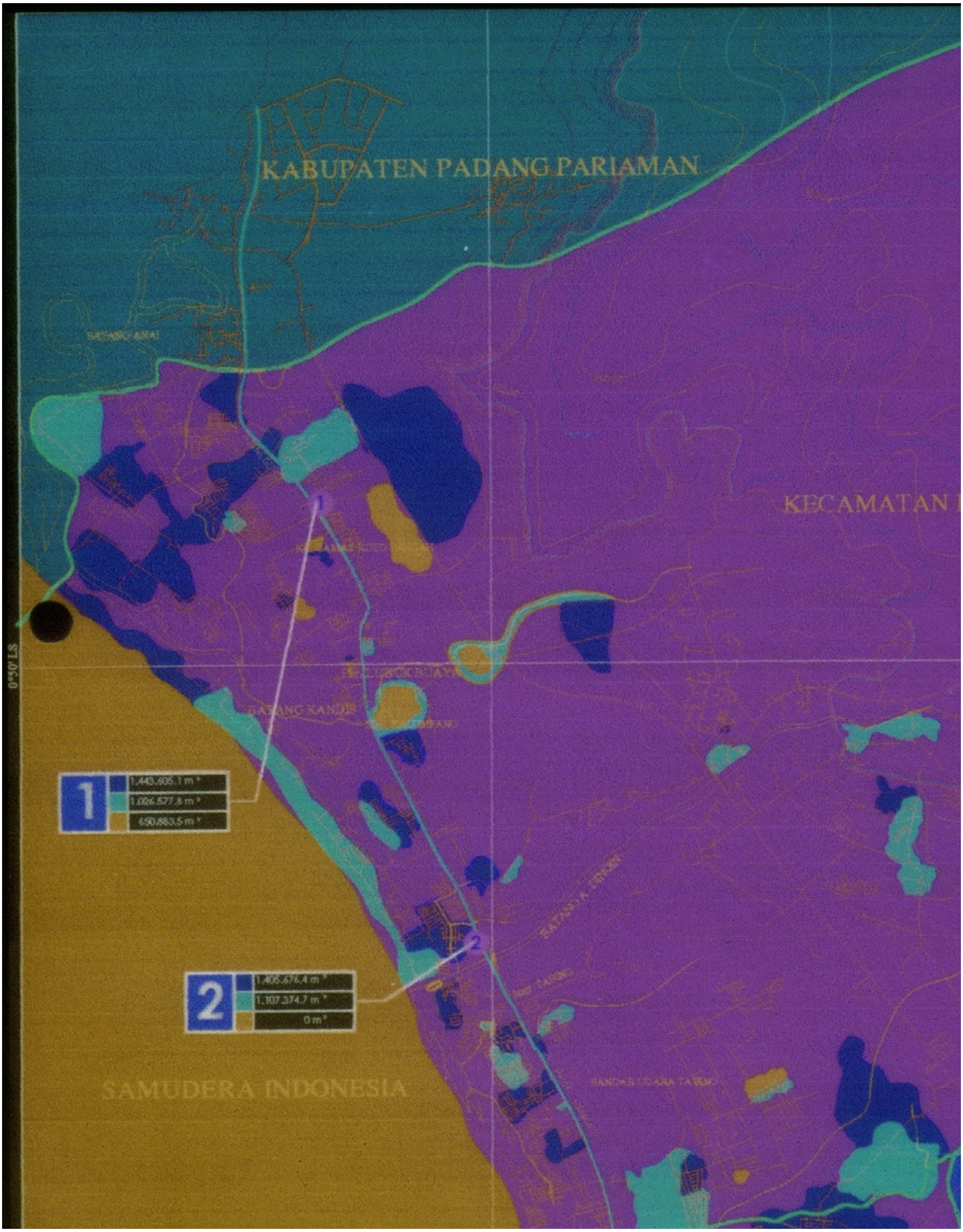

KABUPATEN PADANG PARIAMAN
KECAMATAN
BATANG KANDIS
1
1.443.605,1 m²
1.026.577,8 m²
650.883,5 m²
2
1.405.676,4 m²
1.107.374,7 m²
0 m²
SAMUDERA INDONESIA

FIG. 12.1

Distribution of the flood risk area in the Air Dingin watershed.

Legend: High risk

Middle risk Low risk

The historic reason for floods in the Air Dingin watershed is that rising water levels in the river inundate adjacent areas due to the watershed's shape. The shape is like a bird's feather, narrow and long, extending from the upland area to the estuary, which means a long time is required for the surface flow to reach the ocean. Huge and continuous rainfall needs to flow along this tiny and long watershed creating high peak flow because the upper reaches of the watershed will be contributing runoff to the peak at the same time as the storm is over the outlet of the watershed, enlarging the flood potential. Moreover, the river path is curved in some places, blocking the river flow. On the other hand, high tides block the flow into the ocean, creating a water hammer to the inland. This situation deteriorates further from the addition of dumped solid waste along the river.

Structural development in the Air Dingin watershed was originally set up in 1997. This measure consists of normalization of the Air Dingin River to increase its capacity and the development of a dike. It was designed by the Japanese consultant, Nikken Consultant, in 1983 using limited data on the hydrologic characteristics of the watershed. As consequence, it was based on limited consideration on flood characteristics in the Air Dingin watershed. Even after structural development was completely finished in the year 2000, the region still received 50 cm of periodic monsoon flooding (shallow flooding) in most monsoon months.

An important lesson learned from others is that completion of structural measures alone cannot guarantee safety from flood loss to any region. There will always be possibilities of failure to any structural development. A sustainable, integrated floodplain management plan that relies on community capacities with the help of science, and support from the govern- ment and other stakeholders, needs to be developed. This chapter specifically examines and explores options to improve flood mitigation strategies for the Air Dingin watershed.

The study has been carried out in a number of steps, which include reviewing the existing documents on floods, field visits, exploring hydrologic characteristics of the Air Dingin water- shed, interviews with inhabitants in flood prone areas and responsible governmental agencies, developing a flood forecasting model using PCRaster, calibrating the flood forecasting model, analysis of the flood forecasting model, reviewing current flood management practices by gov- ernment agencies, reviewing current strategies of the community in coping with floods, and the synthesis of an integrated community-based flood forecasting and early warning mechanism.

To measure the success of the research, there is a need to formulate the objectives of the study. They are

i. To assess hydrologic characteristics of the Air Dingin watershed, Padang City. **ii.** To analyze flood occurrence in this watershed.

iii. To assess community preparedness in facing flooding in this watershed. **iv.** To develop an integrated community-based flood forecasting and early warning system.

12.2 METHODOLOGY OF RESEARCH

This study develops a flood forecasting and early warning system for the Air Dingin watershed based on quantitative and qualitative methods. The quantitative method is used in developing the flood forecasting model using PCRaster software. The qualitative method is used in developing the community-based flood early warning system. The general logic of thinking of this study is described in Fig. 12.2.

Local knowledge and capacities in coping with flood

Preserve and enhance

Hydrologic characteristics

Develop flood model

Calibrate the model

Use model to develop real time flood forecasting

Sustainable- integrated flood forecasting and early

FIG. 12.2 General logic of thinking.

12.3 RESULTS AND DISCUSSIONS

12.3.1 Hydrologic Characteristics of the Air Dingin Watershed

12.3.1.1 Digital Elevation Model

Digital terrain data are topographic data, including elevations, slope, and so on. The inter- polation of a derived point into an image surface via spatial interpolation is a crucial process to build a digital elevation model (DEM). A DEM is a function of elevation with respect to a geographic point, $Z = f(X,Y)$ (Aziz, 2001).

Data on a DEM was gained from Gasitech Consultant. A DEM was compiled in the year 2000. The topographic map was derived from photogrammetric techniques (50–100 m spac- ing) and consists of contour lines. The map includes a geographic (latitude/longitude) ref- erence, Universal Transverse Mercator, World Geodetic System 1984 datum Cent. Meridian 99d E. The Air Dingin region has altitude ranging from 0 to 1860 m above mean sea level. The highest place is at the upland area positioned in the east part of the region. The altitude de- creases gradually to the west. There is no extreme variation in slope. The catchment consists of several subcatchments formed by a subriver with a river length of 26.50 km. Subrivers in the upland have steeper gradients than most of the catchment.

12.3.1.2 Precipitation

There is no extreme temperature variation between daylight and night. Temperature ranges from 23°C to 32°C in the daylight and decrease to 22–28°C at night. Average rainfall is

6000 mm/year. Twenty-two years of daily rainfall records from 1979 to 2001 at the four nearest rain gauge stations were collected from the water resource agency and climatology stations. The stations are Tabing (S 0°53′00′′/E 100°22′00′′), Gunung Sagrik

(S 00°53′02′′/E 100°24′24′′), Kasang II (S 00°53′28′′/E 100°25′07′′), and Simpang Alai (S 00°56′04′′/E 100°26′20′′). Blank records were completed by the ratio normal method. Complete data were then checked for quality and consistency by using the double-mass curve technique. Correction will produce consistent rainfall data for the next analysis.

Locations of rain gauge stations were stored to the base map of Padang City using AutoCad Land Development software. The resulting map was exported into ArcGIS software. Here, distribution of rainfall was determined based on real coordinates of rain gauge stations using the Thiessen polygon method. The map was saved in raster form and converted into an ASCII file to be analyzed using PCRaster GIS analysis software. A dynamic model was developed using 30 records of daily rainfall data.

12.3.1.3 Infiltration

Data on infiltration were measured through a field survey using double-ring infiltrometer technique. Sampling points were determined based on a map of soil type produced by Agam Kuantan Watershed Management Body (BPDAS Agam Kuantan). The terrain consists of latosol, podzolic, regosol, litosol, organosol, alluvial, and gleysol. There is no detailed information on spatial distribution of these soil types. The map classifies soil types and their spatial distribution into four classes. Latosol and podzolic is in one single class respectively. Regosol, litosol, and organosol are collected in one other class. The last class consists of alluvial and gleysol.

Land use in this region varies. People use upland area as forests. Agriculture takes place in the form of mix garden in the middle region and rice fields at the lowland along the river. Settlements are distributed along the middle to lowland region. The survey on infiltration took the location in each soil class distribution area with two measurements at each point. It was found that the maximum level of infiltration was 2.098 mm for all soil types and land use, except settlements and wetlands. These two land uses give zero infiltration levels since they are impervious or saturated.

12.3.2 Government Response to Floods

The government has several agencies whose responsibilities are related to floods: the Geophysical and Meteorology Station; the station of river water level; the Water Resources Agency; public works; and the Social Welfare, Flood, and Natural Hazard Mitigation Office. The Geophysical and Meteorology Station provides records on weather data such as rainfall, temperature, evaporation, humidity, and wind velocity. The station of river wa- ter level records average the water level of the river. Some stations measure these parame- ters using manual tools and others use automatic recorders. The records are disseminated to the Water Resources Agency to be analyzed and to produce hydrologic data of this region. Some simple geographical information system (GIS) analysis such as delineation of watershed, digitizing of rain gauge station locations, contour mapping, and mapping of flood prone areas are done. Based on these data, areas that need structural development are determined.

Next, public works is responsible for structural development. In this regard Nikken Consultant, a foreign consultant from Japan, was hired to prepare a feasibility study and design for this structural development. Then the physical construction became the responsi- bility of the public works agency. It was completely finished in the year 2000 but has signifi- cantly reduced floods since the year 1998.

Finally, the Social Welfare, Flood, and Natural Hazard Mitigation Office was responsible for guaranteeing the safety of the community from any hazards, including floods. They be- gan recording floods in 2003 and mapped the flood inundation area in 2005. They provide two boats to evacuate inhabitants from flooded areas. Since 2006, they have had one station located in the flood area to monitor flood elevation and prepare for evacuation.

12.3.3 Community Response to Floods

Data on community preparedness in facing floods were collected through in-depth inter- views with community members in the flooded area. Inhabitants in the Air Dingin watershed are composed of indigenous people who are defined as people who have been living there for generations and newcomers who come from other regions and have lived here since the structural development on flood protection was put into operation in 1998. These indige- nous people inherit knowledge to prepare for floods from their parents, but newcomers do not. Nonindigenous people who lived in this region before the structural development usu- ally moved out to other areas after experiencing one period of monsoon floods. Therefore, there is a crucial difference between community preparedness for flooding before and after the structural development. Before the structural development, communities were aware and being prepared for floods. Floods usually come in the afternoon or early in the morning before school when children are at home. Almost nobody is outside their houses at these two times. Everybody now is alert.

People have various strategies to survive in flood events. Their houses are built with more than one floor or with higher ceilings with a door, used as a safe place of refuge during a flood. They usually track the rain visually, watching upstream if there is potential for a flood. Usually if a hard rain starts or even when there is no rain at all but sounds of swift flow are heard, they have 15min to bring their valuables and survival things such as food, drugs, stoves, and blankets to the ceiling area before the flood. They will stay on the roof during the flood. They cook, eat, and sleep on the roof. Other activities cannot be done. If the water level keeps rising, personnel from the Social Welfare, Flood, and Natural Hazard Mitigation Office will come and bring two boats to evacuate them out of the area. To minimize losses, houses are built with elevated foundations. Each family prepares a table, sized 2×2m^2 with 1 m height, made of wood to save their furniture from a shallow flood. They also prefer to use wood furniture, which is less affected by flood water than is a fabric sofa. Their livestock are kept in elevated stalls. They learn from experience that the most important thing about live- stock is their heads must stay above the water level. When the flooding ends, they clean their houses and all goods affected. Floods often carry stuff away and dumps waste into houses. Each family manages their own things. One family with neighbors coordinate in informing, warning, and sometimes in sharing the roof.

After the structural development, there was no preservation and enhancement of their previous awareness and preparedness in coping with a flood. Loss of local knowledge is

accelerated by the arrival of newcomers who have no experience with a flood. On the other hand, economic development keeps rising and hydrologic conditions are becoming more dif- ficult to predict.

12.3.4 The PCRaster Flood Forecasting Model

12.3.4.1 Synthesis of the PCRaster Flood Forecasting Model

Flood occurrence in the Air Dingin watershed was modeled based on the hydrologic characteristics of this region using PCRaster software, a prototype raster GIS for dynamic modeling that had been developed by Van Deursen (1995) as result of concepts behind the integration of dynamic models and GIS. Those inputs of the model were represented as lay- ers and were analyzed to produce time series flood maps by executing scripts in a PCRaster window. PCRaster also has the capability to store values of a uniquely identified cell or cells written to a time series per time step into the ASCII format.

This capability makes it possible to calibrate and test the accuracy of a model based on the value of the observed water level. Some statistical parameters to evaluate the agree- ment between observations and forecasted flood shows that the mean absolute error (MAE) is −0.044, root mean square error (RMSE) is 0.144, correlation coefficient (CC) is 1.000, and coefficient of efficiency (CE) is 0.999. These parameters show that error of model is relatively small (±14%) and correlation between observed and forecasted water level is high (100%). It is expected that the calibrated model is relatively reliable to forecast dynamic flow of flood at Air Dingin.

Using this model, static maps of maximum flood prone areas for 10, 25, 50, 100, and 200 years of return periods were forecasted. Prediction of rainfall for those return periods were calculated by Gumbel modification, log Pearson type III, and the Iwai Kodoya method. The results of calculation are accepted if the Chi-square test shows that the degree of confi- dence from calculation is less than the theoretical one.

Using daily rainfall from the years 1979 to 2001, it was found that the maximum daily rain- falls accepted are achieved by the Iwai Kodoya method. It showed that maximum daily rain- fall for 10 years is 324mm/24h, 25 years is 406mm/24h, 50 years is 474mm/24h, 100 years is 547 mm/24 h, and 200 years is 625 mm/24 h. Figs. 12.3–12.7 show these maps. These maps present a range of flood depth from zero to hundreds of meters.

12.3.4.2 Interpretation of the PCRaster Flood Forecasting Model

There are several reasons for error in the model. Flood models are developed using limited quantity and quality of hydrologic data on the Air Dingin watershed. The models use the best hydrologic data could be accessed. The results of models are calibrated using 30 daily records of water level at one station in the Air Dingin River.

The most reasonable reason for errors is the lack of a sampling point for calibration of water level data. But, as there is only one sampling point available for total calibration of water level in the entire catchment, accurate calibration for upstream, middle stream, and downstream water levels cannot be done. Moreover, it was found in the field that the quality of water level data is very low. The devices for measurement of the water level were not installed in the right way, water meters did not stand vertically as they should, but

0 45 0 S

0 48 0 S

0 51 0 S

0 54 0 S

FIG. 12.3

100 18 0 E 100 21 0 E 100 24 0 E 100 27 0 E 100 30 0 E

Legend (m)

2–20 0 45 0 S 20–50 50–100 100–300

300–500

100 18 0 E Flood prone areas for 10 years return period (324 mm/24 h).

100 21 0 E

0 100 24 0 E

6400 100 27 0 E

9600

Meters 12,800

100 30 0 E

1600 3200

resembled, dragged along the river flow. No man stood in the station to control the devices. The responsible man only came to the station 4–5 times in a year. In accordance with this, field measurements on water level were only made 4–5 times/year. Daily records were inter- polated from that limited data. Parametric uncertainty occurs as there are errors in the con- fidence intervals around the estimates from models as well as the measurement error in the data used to calibrate models. Improvement on data quantity and quality needs to be done if this data are to be used to produce a reliable flood forecasting model.

These errors need to be corrected before forecasts are calculated. As a result, the next spa- tial analysis needed in developing an warning system, including calculation of areas affected by floods, determination of affected population, affected land use, and so forth, cannot be done yet. To get valuable information for developing a flood warning system in each village, maps of village borders also have to be available.

Because loss of rain through evapotranspiration at the time of a rain event is very small and infiltration would stop after the saturation level is reached at 2.098 mm, it was decided that the main variables in developing a flood forecasting model would be rainfall record, water level record, and DEM.

III. SOCIOECOLOGICAL SYSTEMS AND NEW FORMS OF GOVERNANCE

N WE S

0 48 0 S

0 51 0 S

0 54 0 S

0 45 0 S

0 48 0 S

0 51 0 S

0 54 0 S

FIG. 12.4

 100 18 0 E 100 21 0 E 100 24 0 E 100 27 0 E 100 30 0 E

Legend (m)

2–20 0 45 0 S 20–50 50–100 100–300

300–500

100 18 0 E Flood prone areas for 25 years return period (406 mm/24 h).

100 21 0 E

0 1600 3200 100 24 0 E

6400 100 27 0 E

9600 100 30 0 E

Real time rainfall intensity and duration are a crucial input to developing a flood forecasting model. It should be recorded on an hourly basis or even a minute-by-minute basis. Because there is usually too little time available from the start of rain to a flood occurrence, it would be so much better if rainfall forecasting is available. A preliminary model could be developed using this forecasting.

The matter of climatology development is becoming the responsibility of geophysical and meteorology stations. Analysis of the confidence interval between rainfall forecasting and rainfall field records should be done. Actually, detailed records on the intensity and duration of rainfall are available, but access to them is very limited.

Good quality of rainfall records cannot stand alone to build a reliable flood forecasting model. It should be synchronous with water level records in the Air Dingin River. The mea- surements should produce reliable data. Daily or hourly records should be available. DEM, as one of basic data sources for any kind of structural and nonstructural development, also needs to be improved and made more detailed.

On the other hand, the software package of the forecasting model also needs to be improved. Based on experience, this software package still has many limitations. It is in stages of continuous development by its developer, although many users have used it as part of

N WE S

0 48 0 S

0 51 0 S

0 54 0 S

Meters 12,800

100 15 0 E 0 42 0 S

0 45 0 S

0 48 0 S

0 51 0 S

0 54 0 S

0 57 0 S

FIG. 12.5

100 18 0 E

Legend (m)

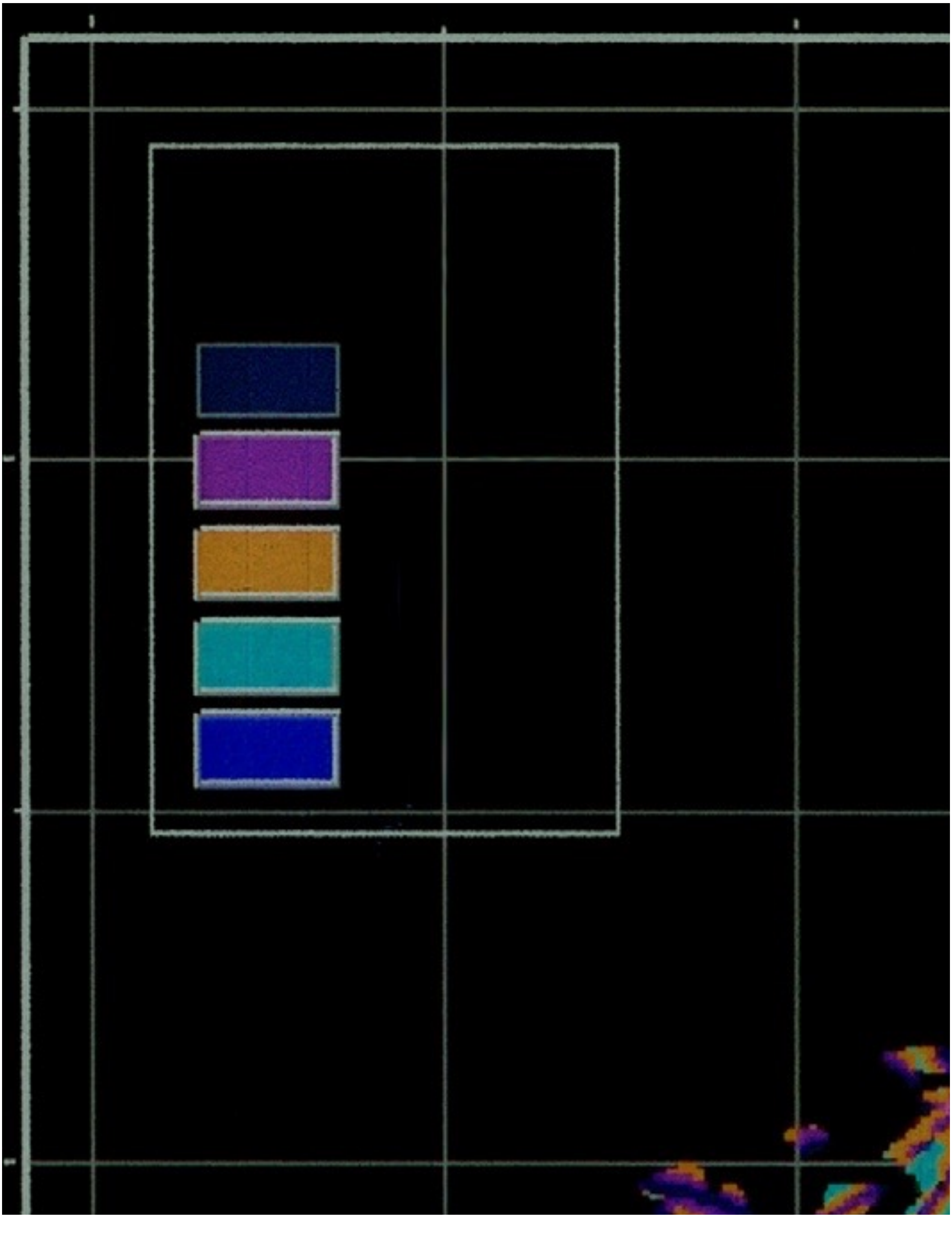
2–20 20–50 50–100 100–300 300–500

100 21 0 E

100 24 0 E

100 27 0 E

100 30 0 E



100 18 0 E Flood prone areas for 50 years return period (474 mm/24 h).

100 21 0 E

100 24 0 E

100 27 0 E

0

2350

4700

9400

14,100

100 30 0 E

their decision support system. Some of the tools provided in the concept are not provided in the manual and cannot be executed. They include "traveltimestate" and "traveltimeflux," which present dynamic simulation in a more sophisticated way. However, the developer of this package provides a mailing list where they can inform and respond to users' questions. Some of other limitations of this software package are:

a. The type of data that could be stored in this software are limited into Boolean, nominal, ordinal, and scalar without possibilities to enter further description of properties for each cell in the raster maps.

b. The software does not recognize a south latitude coordinate system. It only recognizes positive values of coordinates. Tools for handling this case are provided, but unfortunately it does not function.

c. The dynamic model cannot be run in 3-D.

d. Any editing of properties in the legend display cannot be permanently saved for dynamic display. It has to be edited every time you need this information in your own preference classification. The best way of evaluating the result is to verify the model with the real-world situation

when the next flood hits the study area. However, the models are able to predict flood inun- dation areas, although the extent of floods are different.

III. SOCIOECOLOGICAL SYSTEMS AND NEW FORMS OF GOVERNANCE

N WE S

Meters 18,800

100 33 0 E

0 42 0 S

0 45 0 S

0 48 0 S

0 51 0 S

0 54 0 S

0 57 0 S

0 42 0 S

0 45 0 S

0 48 0 S

0 51 0 S

0 54 0 S

0 57 0 S

Legend (m)

2–20 30–50 60–100 200–300 400–500

0 42 0 S

0 45 0 S

0 48 0 S

0 51 0 S

0 54 0 S

0 57 0 S

100 18 0 E

100 21 0 E

100 24 0 E

100 27 0 E

100 30 0 E

100 18 0 E **FIG. 12.6** Flood prone areas for 100 years return period (547 mm/24 h).

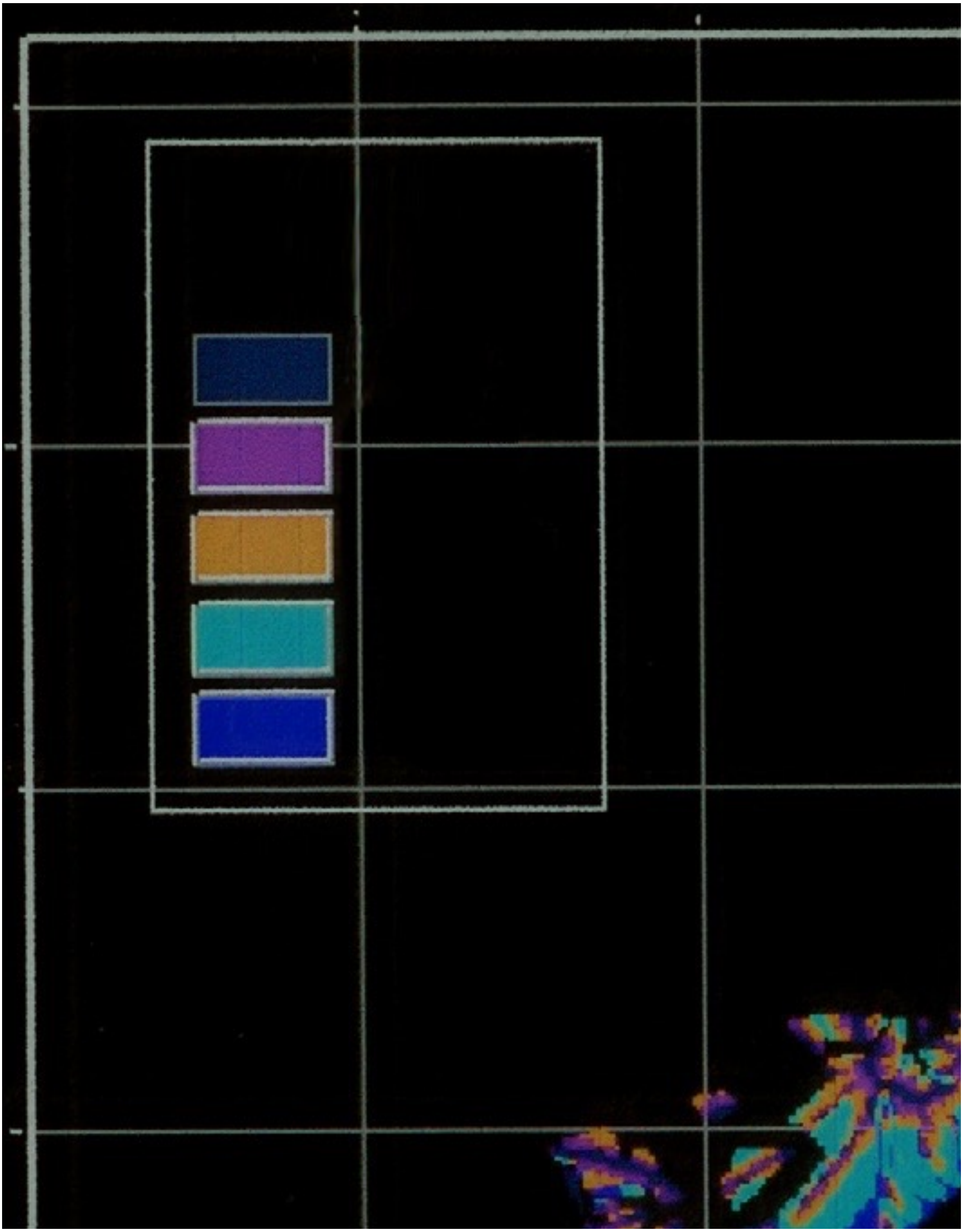
100 30 0 E

100 21 0 E

100 24 0 E

100 27 0 E

12.3 RESULTS AND DISCUSSIONS



12.3.5 Synthesis of an Integrated Community-Based Flood Early Warning System

Because the Air Dingin watershed has more than 0.15 ha of arable area per capita, and scat- tered and low densities of population (<3.760 person/km^2) with low densities of economic development, there are still so many options of flood management strategy that could be taken. The strategies recommended include

a. Raising awareness.

b. Educating and enlarging access to information.

c. Developing community organizations.

d. Preserving local knowledge and strategy on flood preparedness.

e. Disseminating responsibilities to local representatives.

f. Training emergency actors.

g. Rehearsing emergency response.

h. Issuing warnings from hydrologic flood forecasting results.

i. Issuing warnings based on local knowledge.

j. Disseminating warnings to stakeholders,

k. Preparing for evacuation.

l. Providingreliabledataforcontinuousimprovementandhydrologicfloodforecasting.

0 1625 3250

6500

9750

Meters 13,000

100 33 0 E

N WE S

12. FLOODS AT AIR DINGIN WATERSHED, PADANG, WEST SUMATRA

100 18 0 E

Legend (m)

2–20 20–50 50–100 100–300 300–500

100 21 0 E

100 24 0 E

100 27 0 E

100 30 0 E

0 42 0 S

0 45 0 S

0 48 0 S

0 51 0 S

0 54 0 S

0 57 0 S

FIG. 12.7

N WE S

0 42 0 S

0 45 0 S

0 48 0 S

0 51 0 S

0 54 0 S

0 57 0 S

100 18 0 E Flood prone areas for 200 years return period (625 mm/24 h).

100 21 0 E

100 24 0 E 100 27 0 E

0 1875 3750

7500

11,250

100 30 0 E

Meters 15,000

100 33 0 E

All these actions should involve governmental agencies, the media, the community, researchers, and nongovernmental organizations (NGOs). They include geophysics and meteorology stations, the Social Welfare, Flood, and Natural Hazard Mitigation Office, local authorities, police, medical and other emergency services, the media and water level stations, universities, voluntary organizations, an so on. Clear-cut roles and responsibilities, lines of command and control, and communication and coordination among these agencies need to be established. This can be achieved through regular meetings, joint training for emergency management staff, and rehearsals of emergency planning. Awareness and knowledge can be enhanced through public information programs provided by local agencies or NGOs. Publicity campaigns can involve public discussion, radio, and advertising, posters and leaf- lets, bulletins, newspapers, local television programs (Padang TV or TVRI Padang), and mo- bile campaigns by vehicles. A flood mitigation handbook need to be published, explaining about potential flood hazards, the government flood program, strategies before a flood, rec- ommended flood proofing, action needed during a flood, action after a flood, website ad- dresses, important phone numbers, and contacts.

It is required that any information that is made available to the public is in a simple form de- void of any technical jargon to ensure that the community understands and gets the messages. Access to information needs to be opened to as many organizations/institutions/persons

as possible. There should be mechanisms for the public to give input, criticize, and contribute to the program. To achieve this objective the *Balai Pengelolaan Daerah Aliran Sungai* (Watershed Management Body) (BPDAS) needs to set up its own website or create an interactive program through radio and invite the public to participate to enhance continuous improvements on the existing strategies. It will yield transparency about what has been done by government, what agency is responsible for it, why the community needs to participate, and when and where they have to do it, how to do it, who funds it, and so forth.

The local community would know that their government cares about them. Support then will be given to the program. It will create bigger chances for the community to confirm, give input, and contribute to the development. Researchers and academics could get better access to data and improve their research on floods. The community needs to develop their organi- zation called a management agency, where they can communicate, discuss, and set up their planning to cope with the next coming flood. They need to define their role in the program and enhance their capacity in coping with a flood. This management agency should be made up of representatives of those who live on or use the river rather than someone who is respon- sible to the central government and appointed by it. They are accountable downwards rather than upwards. Then, the government could transfer responsibilities related to floods to this catchments management agency; for example, in monitoring the function of existing structural development and issuing warnings if there is a possibility of a flood. Measurement of water level data could also be their responsibility. Gotong Royong (community cooperate and work together) to clean the river from dumped solid waste could also be done to keep capacities of the river in flowing floodwater. What had happened previously are patrols and inspections of any structural development by the responsible governmental agency cannot be done because of the lack of personnel and funds. The solution could be to include the cost of operations and maintenance in the proposed project fund and share responsibility with the community to do the job.

The Social Welfare, Flood, and Natural Hazard Mitigation Office as the emergency actor needs to enhance their capacities and resources. Training includes mobilization of emergency personnel and resources, search and rescue activities, the provision of emergency shelter and emergency feeding arrangements, and/or evacuation. Periodic checking on resources is cru- cial. There may be a tendency for agencies to double count resources available for use in emergencies or to be unaware of resources that could be mobilized. Therefore, careful draw- ing up of inventories of resources (personnel, transport, and supplies) should be a regular part of the preparedness phase.

At the lead time to a flood, warnings have to be delivered to the floodplain occupants affected: businesses, institutions, service providers, and residents. Any warning from hydro- logic flood forecasting or the community should be sent to the management agency. This management agency decides to disseminate or stop the warning. If it will be disseminated, it needs to inform the masjid, radio, and other media, as well as the people and the agency re- sponsible for emergency. Warning could be through telephone or short message service (sms) and siren or public announcement. Some objectives are to

a. Alert people at risk to the need to listen for and seek out further information and advice on the emergency;

b. Encourage organizations and individuals to alert others at risk to the danger.

c. Initiate flood proofing activities on individual properties.

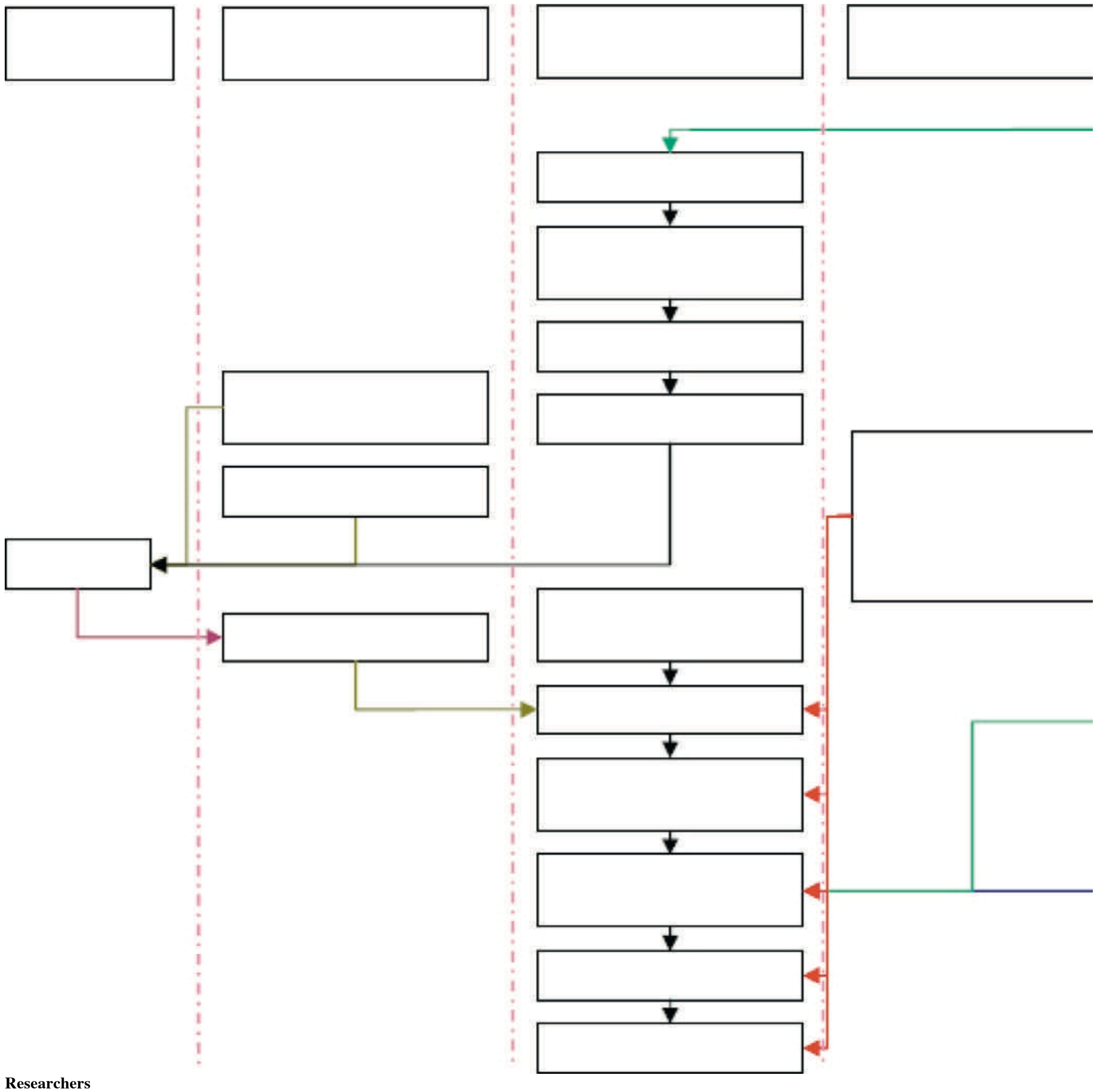
d.Trigger compulsory or advisory evacuation out of the flood risk area.

e. Trigger removal to a safe shelter within the flood risk area, together with emergency supplies such as food, water, clothing, and essential medicines.

f. Stimulate property-saving activities such as moving livestock, business stock, and household effects to a safe place. To some extent, flood management can be included as part of a generic all-hazards

plan in terms of a place for evacuation. Emergency actors should inform people about location, process, and means of evacuation and in the same way to raise their awareness. Emergency planning should be grounded in an understanding of local people's perceptions and needs in an emergency situation. Local people are unlikely to wait passively for official advice but will act on their own initiative. Planning needs to take account of this condition.

Roles, responsibilities, and the proposed mechanism of flood forecasting and early warning are described in Fig. 12.8. This proposed mechanism relies on capacities of the local community and aims to preserve and enhance their knowledge with support from other governmental and nongovernmental parties. An effective and efficient mechanism is orga- nized by minimizing stakeholders involved, because flood forecasting and early warning need real time hydrometeorologic data and needs to be disseminated and transformed into immediate action. The community has the biggest role in participation. However, there is



Researchers

Geophysic and meteorologic stations

Record hydrometeorologic data

Forecast rainfall

Flood forecasting model

Community

Set up organization

Set up planning and strategy

Flood proofing Record water level data

Patrol and inspection of structural development

Forecast flood

Disseminate or stop warning

Being prepared for flood

Action in time of flood Action post flood

Media

Raising awareness and disseminate information a. Public discussion b. Campaign

c. Interactive program

Local authorities

Provide funds and resources

Develop website Raising awareness Educating and inform

Providing shelter, aid, food, and survival resources

Emergency actors

Raising awareness a. Campaign b. Poster c. Leaflet

d. flood mitigation handbook

Being trained

Periodic checking on resources

Rehearsing emergency responses

Being prepared for emergency action

Research

FIG. 12.8

Proposed scheme of roles and responsibilities of stakeholders in managing floods.

some elimination and transfer of roles and responsibilities of governmental agencies. To some extent, some tasks of the BPDAS, whose responsibilities are in developing better wa- tershed management, including flood management, need to be transferred to meteorologic stations. After all, this scheme is not yet set in stone. Some improvement can be made to maximize achievement.

12.4 CONCLUSIONS

This research concludes that

1.The hydrologic condition of the Air Dingin watershed has the potential to monsoon flooding due to its characteristics: a. Time of concentration (time for storm flow to reach the outlet) is long. Huge and continuous rainfall needs to flow along a tiny and long watershed (watershed shape is like the feather of a bird extending from the upland to the estuary), creating high peak flow because the upper reaches of the watershed will be contributing runoff to the peak at the same time as the storm is over the outlet of the watershed.

b. Curved river path blocks the flow, inundating adjacent area with lower elevation.

c. High tide in monsoon months, blocking water flow into the ocean, creating water hammer to the inland.

2.Before structural development was put into operation in 1998, floods frequently came into the Air Dingin watershed in monsoon months. Extreme flow usually occurs in September, October, November, and December, and sometimes it continues to January. The highest flow usually comes in November when rainfall exceeds 100 mm/24 h. Flood levels are 1.5–2 m on average (medium-deep flood) and the areas is inundated for 2–5 days. After structural development completely finished in the year 2000, there was still 50 cm of flood on average (shallow flood) in the monsoon months.

3.Before structural development, the community in the Air Dingin watershed were aware and being prepared for floods. They develop adaptations to their behavior and the structure of their construction. Detailed explanation is provided in Chapter 5. After the structural development, there was no preservation and enhancement of their previous awareness and preparedness in coping with floods.

4.PCRaster, a GIS-based flood forecasting model was developed to make a scientific contribution to the early warning system. It produced dynamic flood models for the Air Dingin watershed with a 100% correlation level between

forecasted and observed water level at the water level station on the Air Dingin River. But, unfortunately, it overestimated the real flood of the entire catchment by hundreds of meters. However, some considerations in the model were   a. Data input to the models were topographic condition (DEM), precipitation (rainfall), and infiltration based on soil type and land use.

b. Topographic conditions represented by DEM were compiled in the year 2000, derived from photogrammetric techniques (50–100 m spacing), consisting of contour lines. The map includes a geographic (latitude/longitude) reference, Universal Transverse Mercator, World Geodetic System 1984 datum Cent. Meridian 99d E.

c. Rainfall was represented by records from two rain gauge stations: Tabing station (latitude 0°53′00′′, longitude E 100°22′00′′) and Kasang II station (latitude 0°53′28′′, longitude 100°25′07′′). Rainfall records were checked for quality by the double-mass curved technique using historical daily rainfall data from the years 1979 to 2001. The Thiessen polygon method shows that the Tabing station only represents 1.43% of total rainfall of this region and the Kasang II stations represent 98.57% of total rainfall of this region.

d.Soil type in the Air Dingin watershed is constituted by latosol, podzolic, regosol, litosol, organosol, alluvial, and gleysol. Latosol and podzolic are classified as till soil. Regosol, litosol, and organosol are classified as outwash soil. Alluvial and gleysol are classified as wetland soil.

e. Land uses in this watershed consist of forest, agriculture land, rice field, and settlements.

f. Infiltration levels for different combinations of soil type and land use type are extremely the same. The maximum level is reached at 2.098 mm.

12.5 RECOMMENDATIONS

Based on the findings, the following recommendations are forwarded:

i. Government needs to enhance and preserve community capacities in coping with floods.

ii.Coordination and clear definition of roles and responsibilities between governmental agencies need to be defined immediately.

iii. Reliability of hydrometeorologic data needs to be increased.

References

Abuzar, S.S., 2005. Potensi Sungai- Sungai Kota Padang sebagai Sumber Air Baku. Andalas University, Padang. Aziz, F., 2001. A Dynamic GIS-Based Flood Warning System. Asian Institute of Technology, Thailand. Statistical Bureau (BPS), 2005. Padang dalam Angka 2005. Statistical Bureau, Padang. Statistical Bureau (BPS), 2006. Padang dalam Angka 2006. Statistical Bureau, Padang.

Van Deursen, W.P.A., 1995. Geographical Information Systems and Dynamic Models Development and Application of a Prototype Spatial Modelling Language. Faculty of Spatial Sciences, University of Utrecht, The Netherlands. http://www.pcraster.nl.