Geomorphologic Survey for Hazard Mapping and Real-Time GIS, Aided with LiDAR Technology

by

Sotoshi Nakata*, Seiji Ichikawa*, Koji Sango*, Masaharu Tsuzawa*,
Jun-ichi Kisanuki*, and Soichiro Sato*

ABSTRACT

This paper presents the current trend of Geomorphologic Survey for Hazard Mapping by Geographical Survey Institute. This survey has become a combined survey with land-condition survey for flood disasters, land condition survey of volcano for volcanic disasters, and basic mapping of volcano. For the demands of geographic data for real-time hazard mapping, GSI introduce airborne laser scanning and satellite imaging technology to improve thematic mapping..

KEY WORDS
Land-condition Map, Hazard Map, Airborne Laser Scanner, Digital Elevation Model, Digital Terrain Model, Digital Surface Model, Real-time

1. ORIGIN OF SURVEY

1.1 Thematic Mapping for Natural Disasters

On the day 26 September 1959, Typhoon No.15, named "Ise-wan Typhoon" as following disaster, rushed to the coast area of Ise Bay, and generate storm surge by its strong wind and low pressure. The highest tide of Nagoya Port was 3.89m during this event. Most of embankment along bay coast and river streams was overflowed or break, and southern part of Nobi Plain was inundated, 4624 lives were lost.

Just before this largest flood disaster of modern age in Japan, one thematic map sheet was compiled from the national committee of natural resource, organized by Japan's Government. After World War II, geomorphological study was expanded by free utilization of aerial photograph. The thematic map "Geomorphological Map of Nobi Plain for Flood Control" was the result of geomorphological survey by photo-interpretation. Just after the disaster, geomorphologist found obvious correlation between inundation area and detailed landform of plain (Fig.1). Since then, geomorphological survey became principal means for flood control works. Land-condition Map, product from Geographical Survey Institute, hereinafter "GSI", is the one of typical result of geomorphological survey for flood control. Recently, volcanic disaster also became one object of geomorphological survey.

1.2 Hazard Mapping depend on Law

On the day 11 September 2000, Typhoon No.14 generated humid south wind, which brought heavy rainfall to central Japan. River streams overflowed into built-up area of Nagoya City, this flood ruined many properties of the city (Fig. 2).

After that disaster, Flood-Fighting Law was altered to give each obligation on hazard mapping to local government and river improvement office. River improvement office has to publish the result of simulated inundation area and depth. Local government has to announce the inundation area with hazard map. Since then, hazard mapping became national administration matter. In response to this matter, GSI decides to produce geographic information for hazard mapping; one layer is the landform classification by geomorphologic survey for zoning of flood types, the other is detailed digital elevation model surveyed by Airborne Laser Scanner, hereinafter "LiDAR", for the simulation of inundation area.

* Geographical Survey Institute

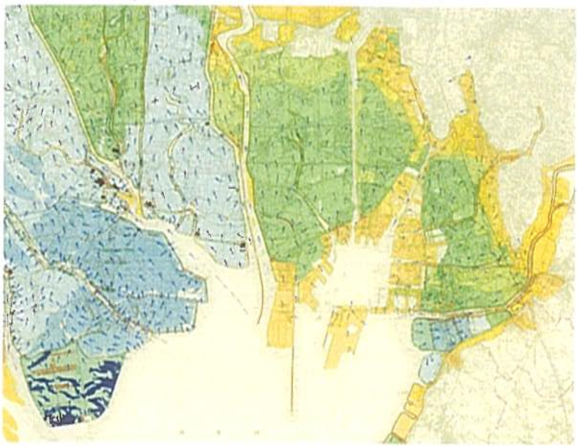

Fig.1: Disaster Map of Ise-wan Typhoon.

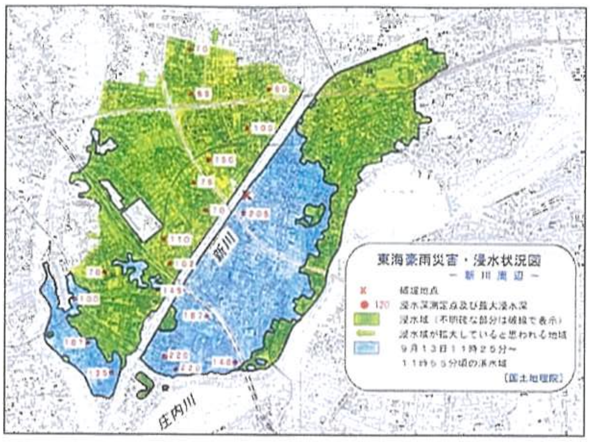

Fig.2: Disaster Map of the flood 2000 in Nagoya City

2. THEMATIC MAPS FOR DISASTERS

2.1 Land-condition Survey

GSI has been carrying out geomorphologic survey to produce thematic map series for disaster prevention, for half century. This map shows landform classification depends upon uniformed legend, and 1m-interval contour of detailed ground elevation of alluvial plane. Landform classification is from photo-interpretation and field survey. Ground elevation is surveyed from levelling and photogrammetry. Results of this survey are printed map-sheet, in scale 1:25,000,(Fig.3) or digital geographic data. Printed map-sheets are published from Japan Map Center.

2.2 Land-condition Map of Volcano

This thematic map series began in 1988. Each map shows landform classification of each volcano, which is reflected by development of eruption or erosion. Objective volcanoes are selected from the list of active volcanoes by the study plan of Working Group for Volcanic Eruption of Japan Science Academic Council.

Printed map-sheets of this series are published from Japan Map Center.

Every volcano has their each characteristic history of its activity, so that legend of landform classification is specialized for each volcano, as followings;

Mt. Bandai (Fukushima-pref.): During its development history, huge collapses and debris-avalanches occurred at least five times. Deposit of debris avalanche formed characteristic landform "Flow Mounds" on foot of the volcano. Land-condition Map shows detailed distribution of them and the relationship between multiple stage of volcanic bodies and debris avalanche (Fig.4).

Mt. Fuji (Yamanashi-pref., Shizuoka-pref.): This is the largest active volcano of Japan, however it has not been recognized as active by the majorities of Japanese nation, for the reason that there have been scarcely any activities without femoral for almost three centuries after huge eruption of 1707. In 2000, low-frequency earthquakes were observed frequently just below the summit crater. That brought new understanding of Mt. Fuji as active. Japanese government establishes Investigation Committee for Hazard Mapping of Mt. Fuji. GSI cooperates this committee by geomorphologic survey for land-condition map of volcano. At this survey, the legend of landform classification of Mt. Fuji emphasizes distributions of debris and corridors of slash-avalanche, which is the most characteristic event of disaster on slopes.

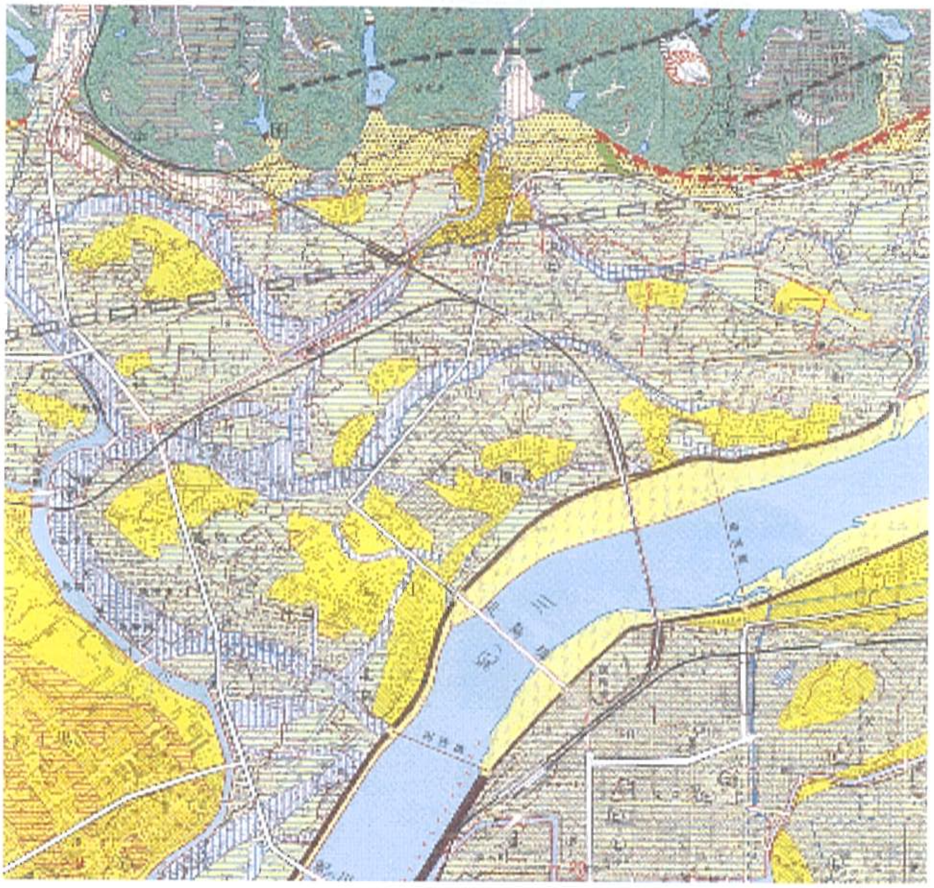

Fig.3: Land-condition Map (1:25,000) "Wakayama"

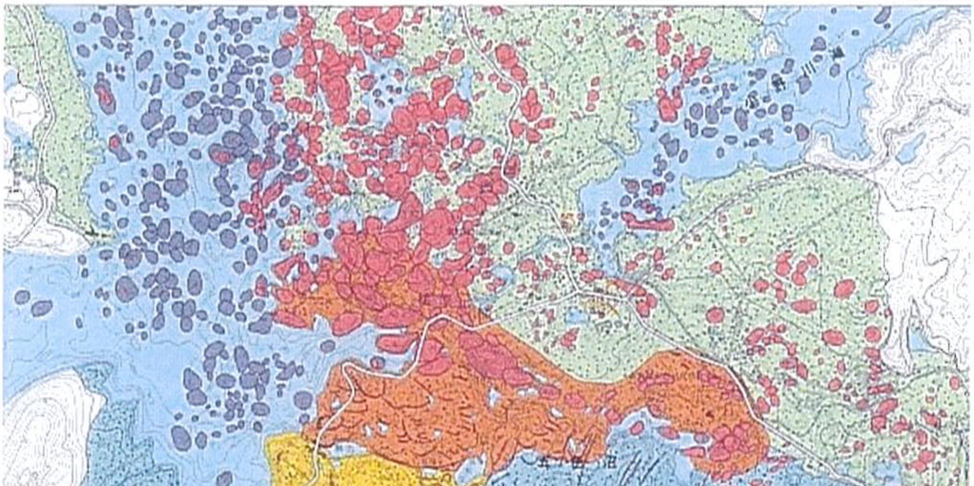

Fig.4: Land-condition Map of Volcano (1:30,000) "Mt. Bandai"

2.3 Volcanic Base Map

This is the kind of basic map series with specialized format for active volcano (Fig.5). Principal data of this series is 5m-interval contour of elevation, which is surveyed by photogrammetry. Printed map sheets are published from Japan Map Center.

2.4 Digital Elevation Model 10m Grid

This digital elevation model is compiled from elevation contour of Volcanic Base Map (Fig.6). CD-ROM is published from Japan Map Center.

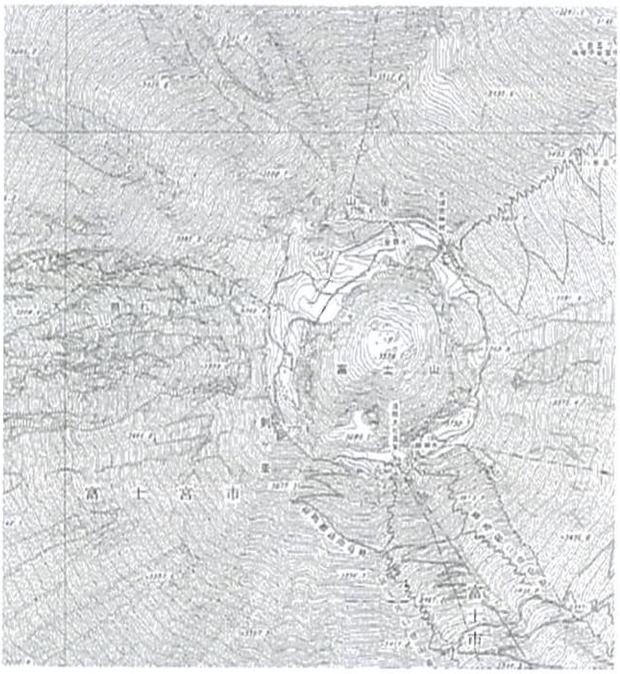

Fig.5: Volcanic Base Map "Summit of Mt. Fuji".

Fig.6: Bird's eye view, calculated from DEM

3. DTM BY LIDAR

3.1 Need for Flood Simulation

In 1975, Ministry of Construction published two types of disaster map; one was the observed inundation area map, the other was a estimation map of flood. This was the first hazard information map of flood, to citizens, as compared with Land-condition map, which was for professional use (Ichikawa, 2001). In 1994, Ministry construction established Guideline for Hazard Mapping for Flood Disaster. In 2001, Flood-Fighting Law was altered to give each obligation on hazard mapping to local government and river improvement office. River improvement office has to simulate inundation area and flood depth for publication.

Simulation of inundation area and flood depth is calculated at each estimated overflow point, by digital elevation model. Map of simulated inundation area shows every maximum depth of each grid (Akagiri, 2001). Standard grid size has been 500m, recently grid size is becoming to 250m.

3.2 Air-born Laser Survey

Principal instrument of this survey is Air-borne Laser Scanner, or LiDAR. Air-borne Laser Scanner is the combined technology with GPS, IMU, and Laser-pulse Profiler. This system enables us to get three-dimensional data in whole surveyed area (Fig.7). Each laser-pulse is reflected at plural points; surface of house or building, canopy of tree, and ground surface (Gig.8).

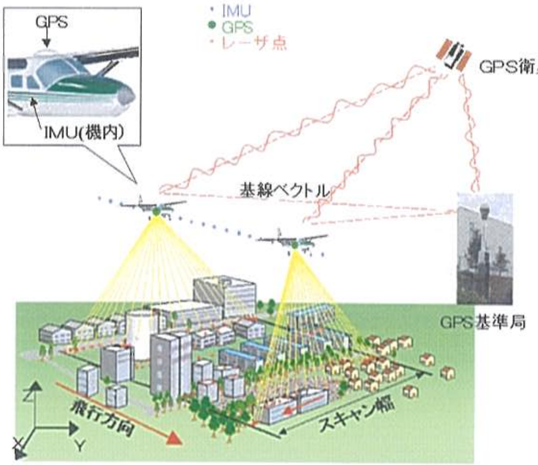

Fig.7: Air-borne Laser Scanning System

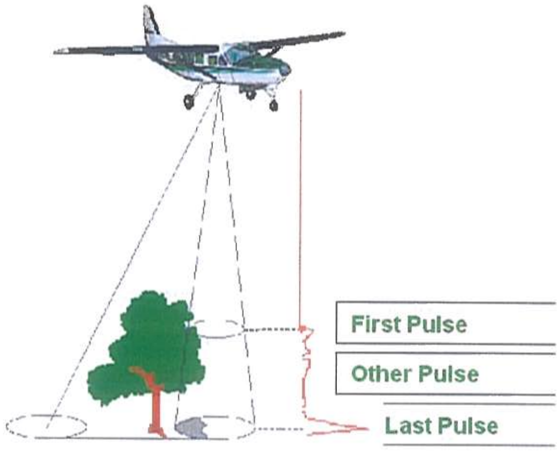

Fig.8: First Pulse, Other Pulse, and Last Pulse

3.3 Digital Terrain Model 5m Grid

This is a new series of digital map from GSI. Such high-density grid data could be obtained by air-born laser survey. Original scanned data is composed of several types of positioning points; surface of man-made structures, canopies of trees, and ground surface, in each grid. Digital Surface Model covers whole surface elevation with buildings and vegetation. Digital Terrain Model is filtered data for representation of ground elevation. Fig.8 shows shading figure of western part of Saitama City, calculated from Digital Terrain Model 5m Grid "Saitama South-East". Compared with Land-condition Map "Ohmiya", blue or green colored area is alluvial plane along Ara-kawa River. Detailed landforms, Natural Levee or Former River Channel could be recognized on both maps.

In case of the Digital Terrain Model 5m Grid "Saitama South-East", air-borne laser survey was done by cooperation between GSI and Ara-kawa River Lower Reaches Work Office. At this river improvement office, flood simulation shall be calculates from 50m mesh in immediate, and it is already possible to get more accuracy for the simulation.

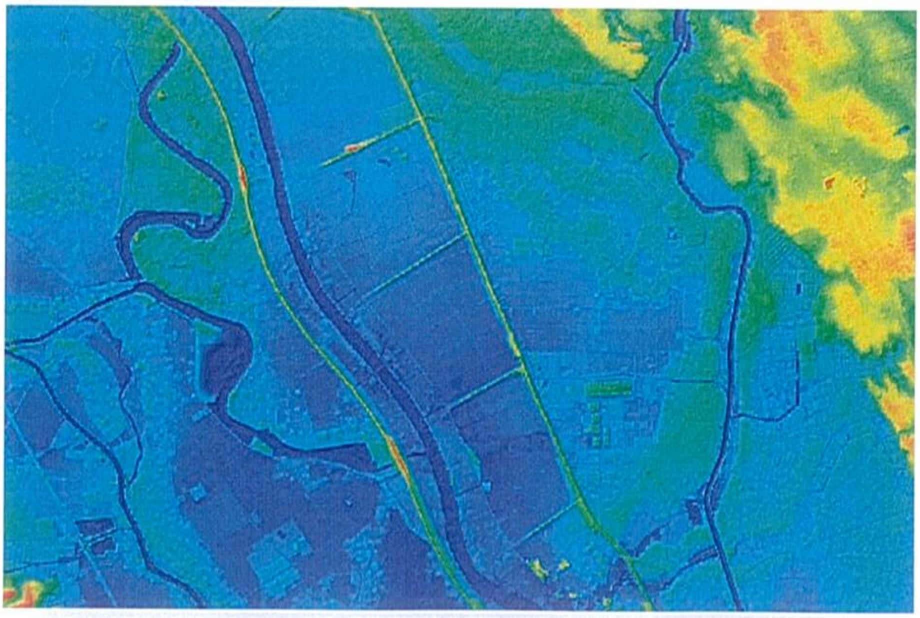

Fig.9: Shading Image of Alluvial Plain along Ara-kawa River in Suburban area of Saitama City.

4. REAL-TIME HZARD MAPPING

4.1 Subject for Improvement of Geomorphologic Survey for Hazard Mapping

Publishing Data of the survey composed from Landform classification and detailed elevation.

The demands for such geographic data will increase rapidly, by two backgrounds. One is the obligation of hazard mapping by each local government, originated from Flood-fighting Law. The other is the mitigation of tsunami disasters along the coastal area. Latest reports of Central Disaster Mitigation Council warn that estimated Tokai, To-Nankai, and Nankai Earthquakes generate large tsunami. For more rapid survey, several new technologies must be use for practical.

Air-born laser survey shall relieve from levelling and photogrammetry for the production of detailed elevation data.

Advanced investigations realize that calculation of digital terrain model is effective for geomorphological analysis; extraction of detailed landform or knick lines (Kamiya et al.).

Advanced Land Observing Satellite (ALOS) is planning to be launched in 2004. Part of objectives of ALOS is as followings; providing maps for Japan and other countries, conducting disaster monitoring around the world. The sensor, Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) produces wide range 2.5-meter spatial resolution with stereo pair, periodically. Printed image of resolution expects to be used as ordinary aerial-photograph, in practical. Especially, nadir view image becomes almost orthogonal projection, so that the results of interpretation could transport on basic cartographic data.

Table. Major Specifications of ALOS/PRISM

Observation Band	0.52 - 0.77μm (Forward-Nadir-Backward)
Base/Height ratio	1.0
S/N	70
Spatial Resolution (IFOV)	2.5m (3.57μrad)
MTF	0.20
Swath Width	35km
Pointing Angle	±1.5° (cross track)

4.2 Needs of Real Time Hazard Mapping

After the occurrence of natural disaster, it needs not only fixed information, but also real time renewal information by circumstantial condition, on GIS, for rescue, refuge, restoration, secondary warning, and reconstruction. GSI and National Institute for Land and Infrastructure Management participate the development project for integrated technology "Real Time Disaster Information". Subjects by GSI are as followings; Real time analysis of crustal movement by GPS, Quick calculation of air-born laser scanning resolution, and standardize of geographic data for common use on GIS. Fig.10 shows the utilization model of Real Time Disaster Information System.

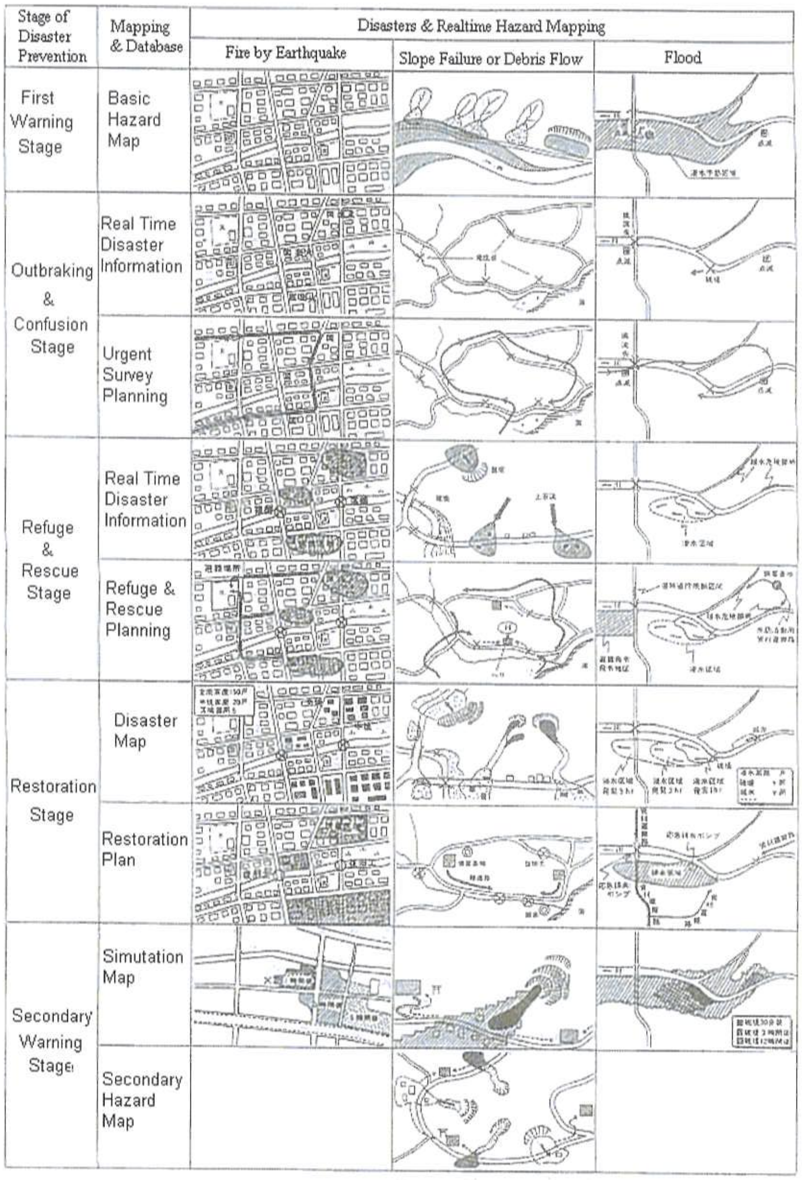

Fig.10: Connectional Timetable for Real Time Hazard Mapping (Tsuzawa, 1992)

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