LANDSLIDE HAZARDS

presented during the

TRAINING-WORKSHOP ON DISASTER RISK MANAGEMENT

Rakdell Inn

Virac, Catanduanes

03 July 2008

GEOLOGIC HAZARDS

- the probability of occurrence, within a specific period of time in a given area, of a potentially damaging natural phenomenon
- Events in which natural phenomena such earthquakes, river floods, mass movements, volcanic eruptions, etc. cause the loss of lives and damage to property
- Mainly occur in areas where the natural factors (ie. climate & geology) are unfavorable and where the natural equilibrium has been disturbed by man

IMPORTANCE OF GEOHAZARD STUDIES

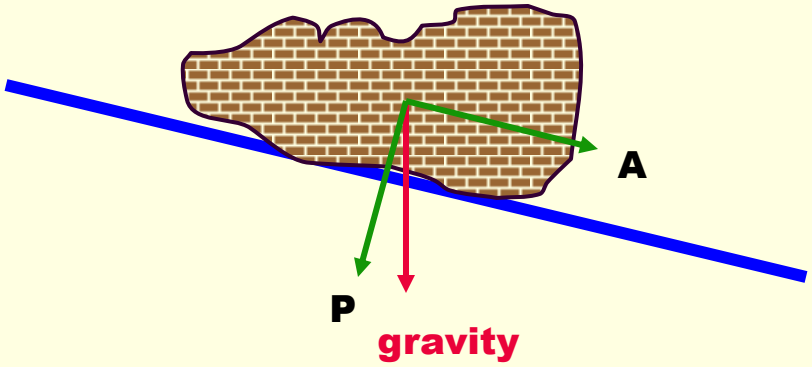
- Landuse planning
- Urban development
- Disaster preparedness & management
  - To minimize loss of life
  - To minimize economic and social disruption

TYPES OF GEOLOGIC HAZARDS

- Mass movements or landslide hazards (pagtiris o pagrasay kan daga o bato)
- Flood hazards (pagbabaha)
- Earthquake hazards (linog)
- Volcanic hazards (pagtuga kan bulkan)
- Accelerated erosion (erosyon)
- Coastal hazards

MASS MOVEMENT

- Is the downslope movement of soil, debris or rock when the shear stress exceeds the shear strength of the material
- Denudational process where soil or rock is displaced along the slope mainly by gravitational forces

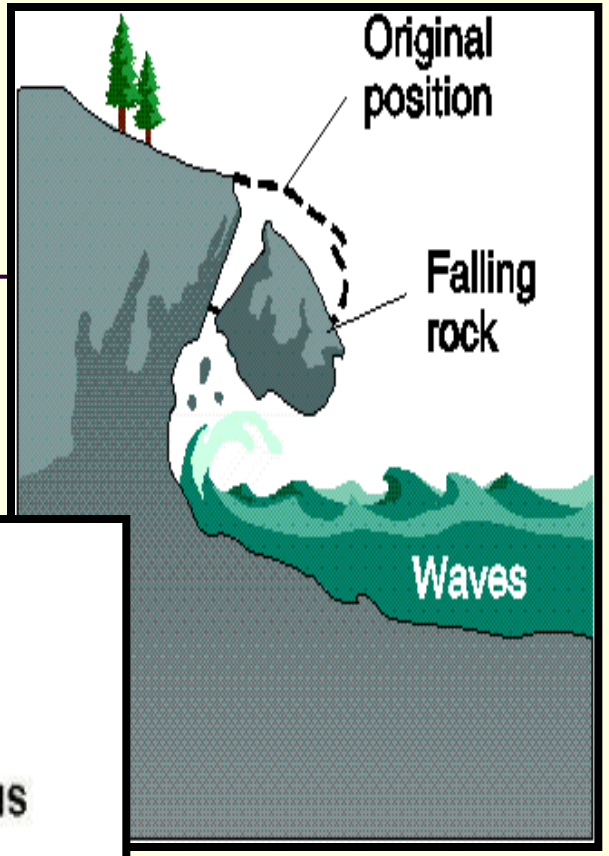


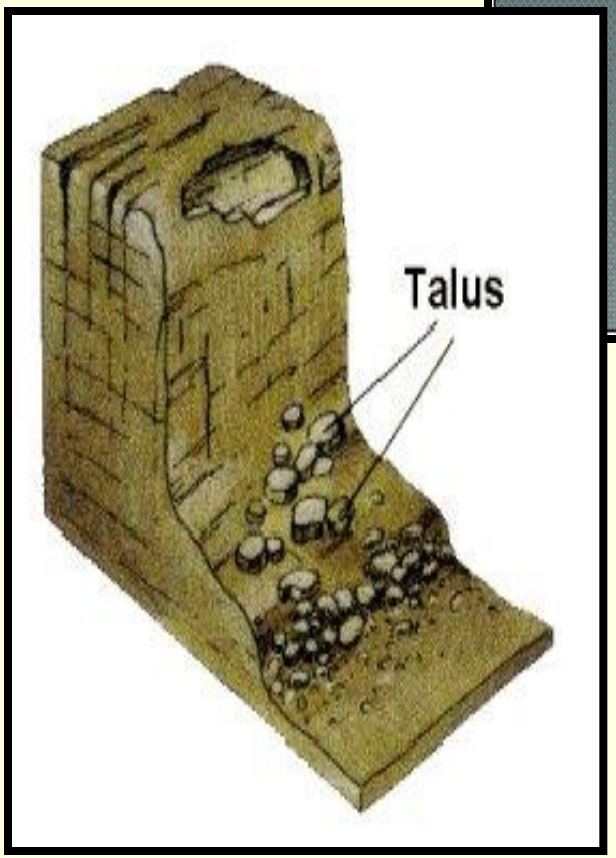
TYPES OF MASS MOVEMENTS:

Type of Movement	***Type of Material***		
	Bedrock	**Engineering Soils**	
		Predominantly Coarse	**Predominantly Fine**
Fall	Rock Fall	Debris Fall	Earth Fall
Topple	Rock Topple	Debris Topple	Earth Topple
Slide	Rock Slide	Debris Slide	Earth Slide
Spread	Rock Spread	Debris Spread	Earth Spread
Flow	Rock Flow	Debris Flow	Earth Flow

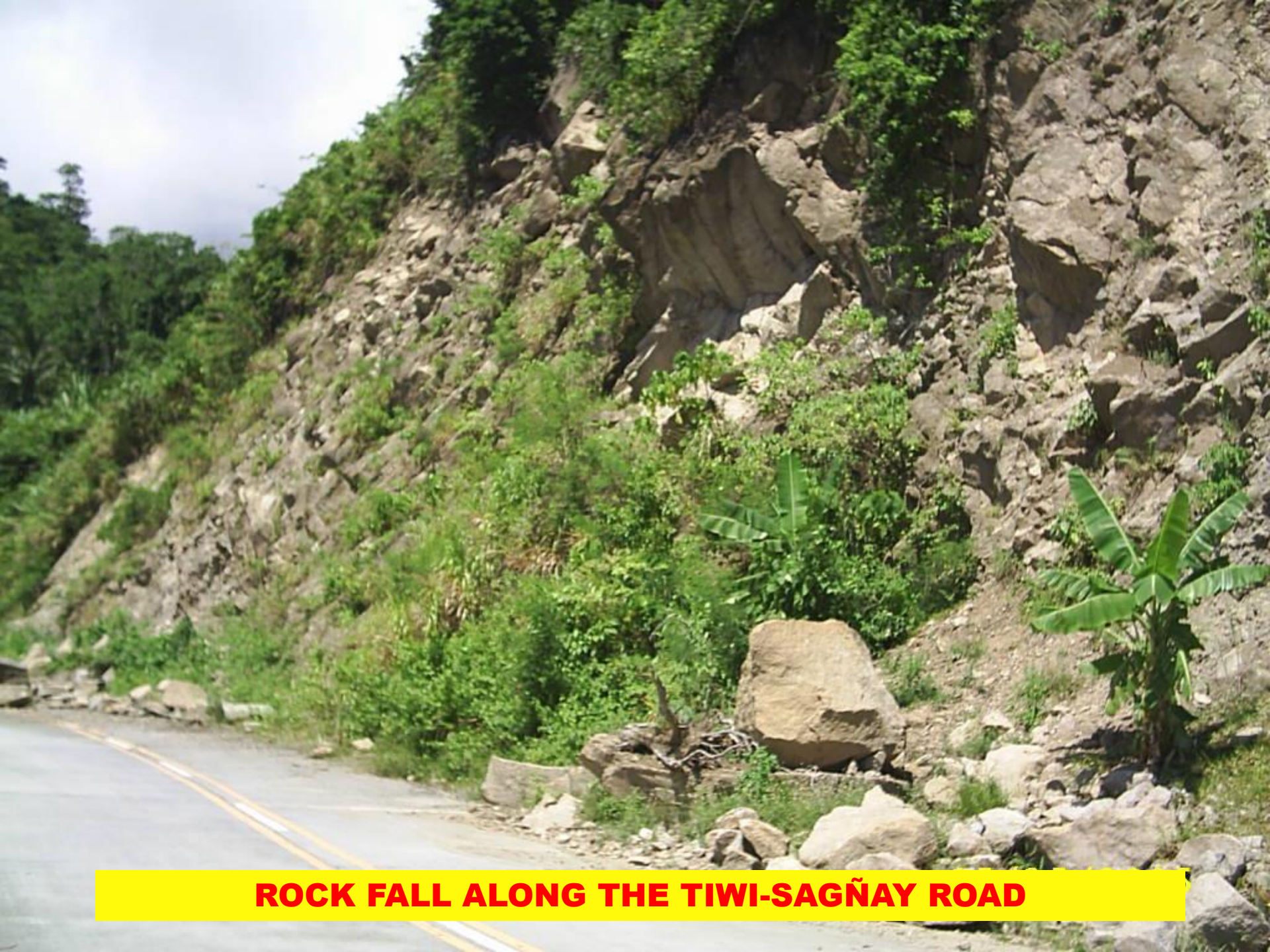
FALL

- consists of the detachment of soil or rock from a steep slope followed by a more or less free and extremely rapid descent of the material.
- the movement is largely through the air, alternated with the bouncing or rolling on the slope.





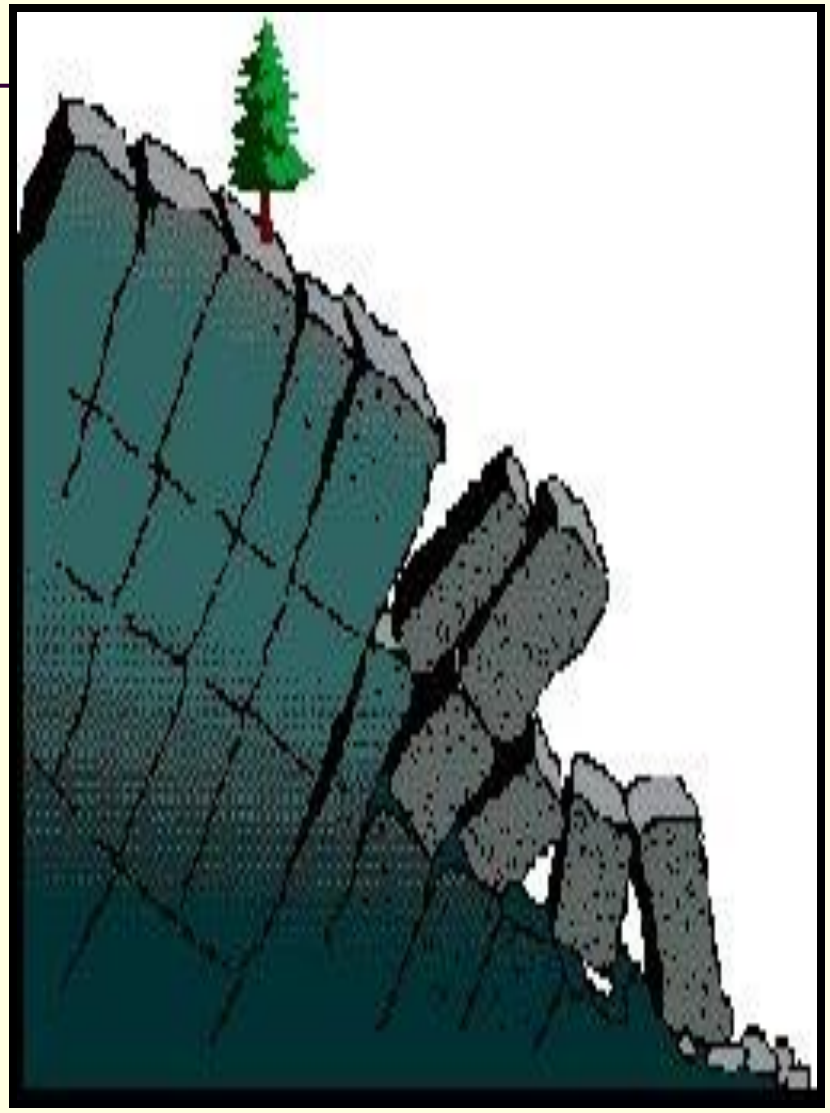
ROAD CUT ALONG THE VIRAC-VIGA ROAD IN SAN MIGUEL IS PRONE TO ROCK FALL AND ROCK SLIDES



ROCK FALL ALONG THE TIWI-SAGÑAY ROAD

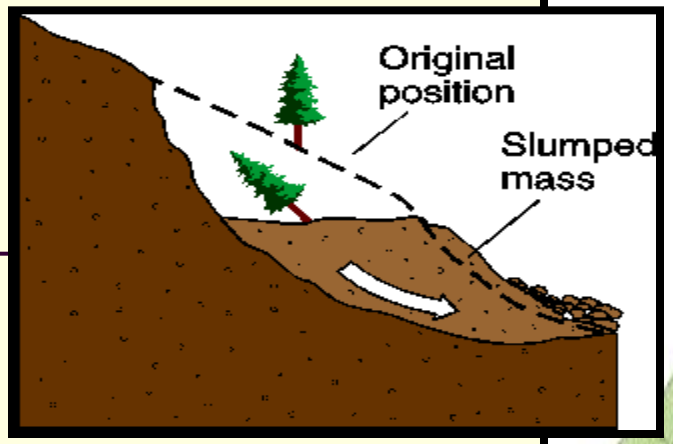
TOPPLE

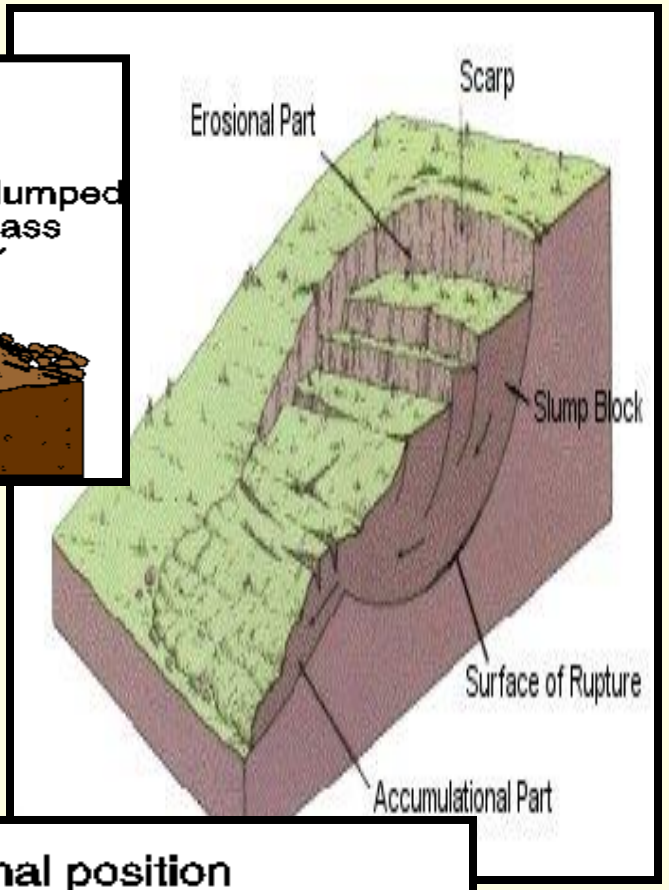
- the end-over-end motion of rock down a slope.
- involves forward rotation out of the slope of a mass of soil or rock a point below the center of gravity of displaced mass.
- mostly occur in combination with fall

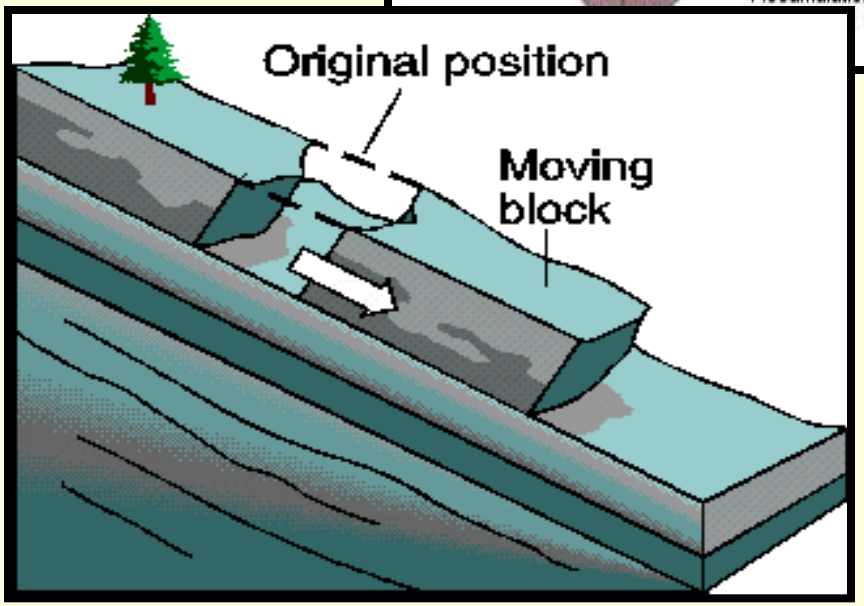


SLIDE

- moving slab of soil or bedrock that moves downslope as a whole, remaining in contact with the underlying material.
- movement parallel to planes of weakness and occasionally parallel to slope







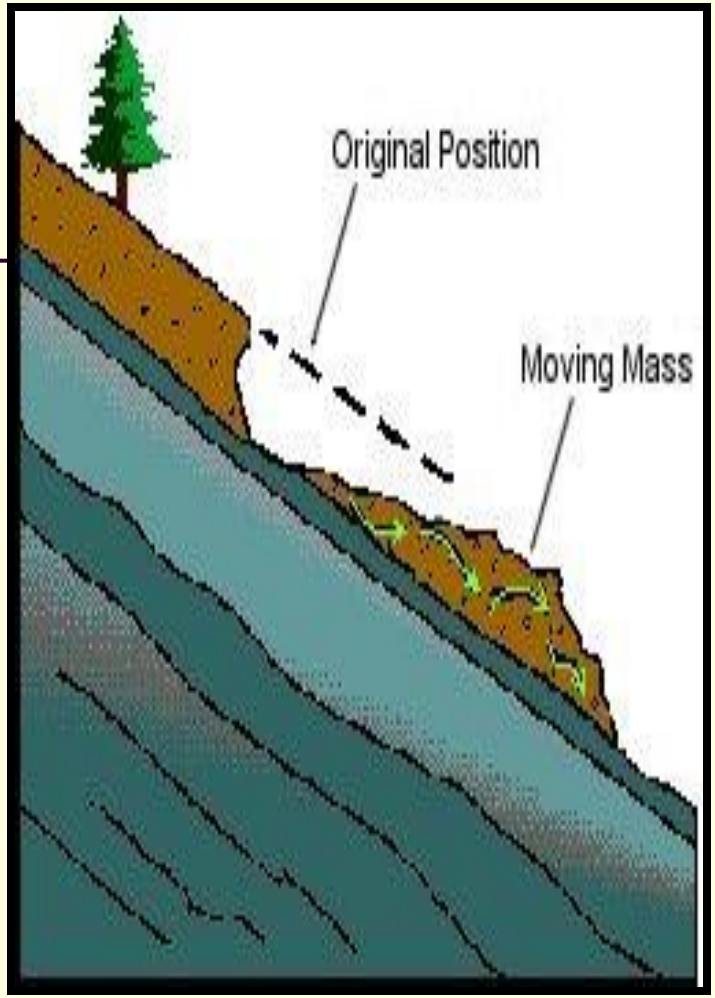
DEBRIS SLUMP ALONG THE VIRAC-VIGA ROAD CUT

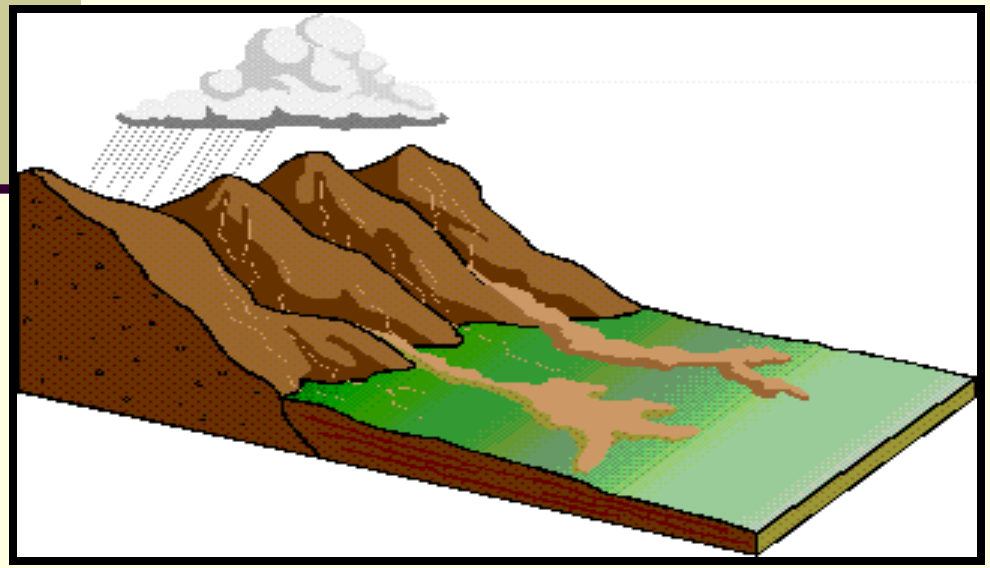
SLIDES ALONG THE VIRAC-VIGA ROAD

HOUSES IN BGY. TOBREHON DAMAGED BY DEBRIS SLIDE

FLOW

- viscous to fluid-like motion of debris
- sporadic and sudden channelized discharge of water and debris
- involves great internal deformation
- Three types: earthflow, mud-flow and debris flow

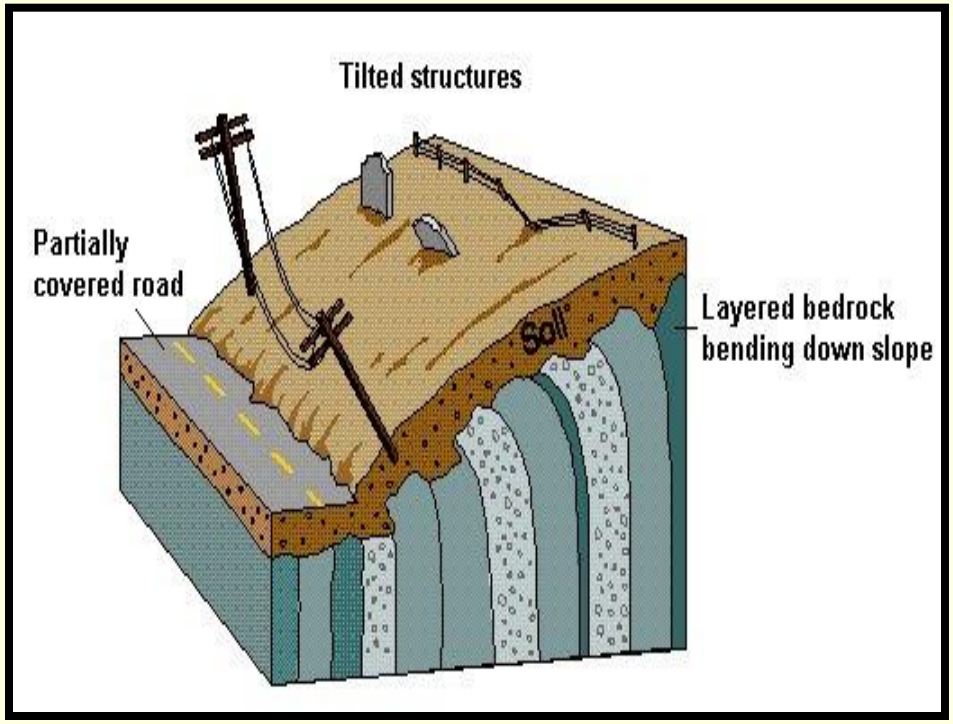





DEBRIS DEPOSIT
WALA RIVER

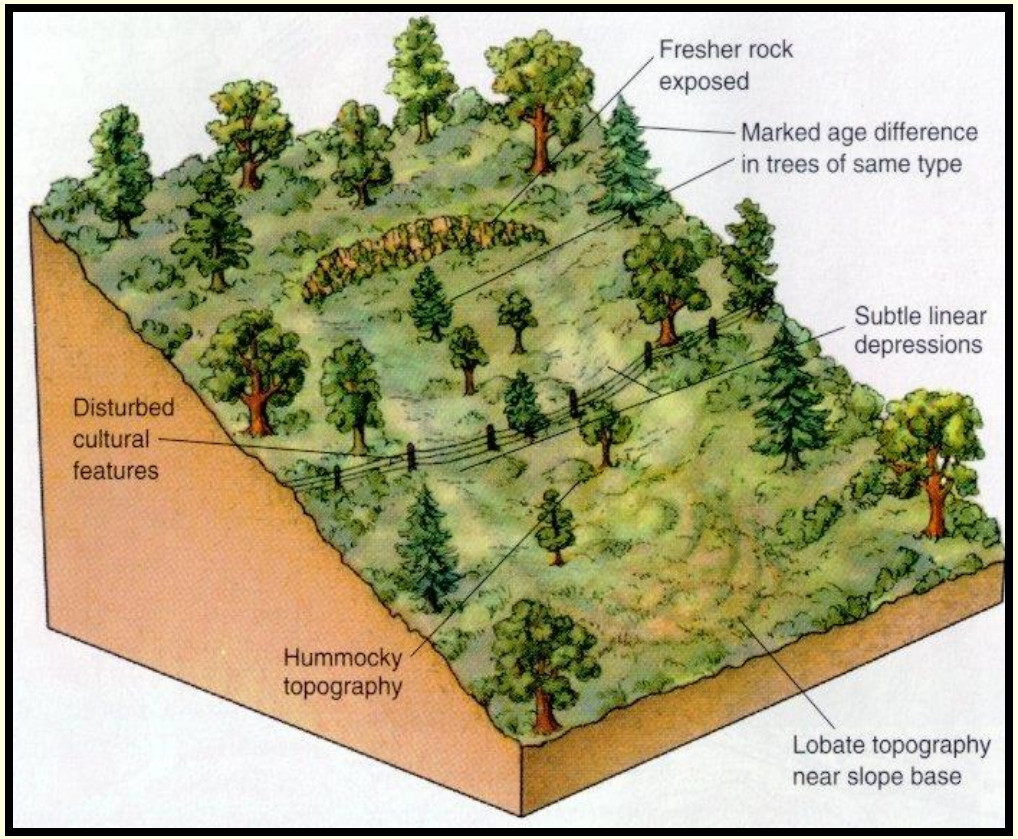
CREEP

- Creep is the slow movement of soil or bedrock down slope
- occurs where the stresses on the slope material are too small to create a rapid failure



MORPHOLOGICAL ASPECTS SUGGESTIVE OF LANDSLIDES:

- Steep backscarps with convex accumulation in the lower slope
- Cracks and depressions
- Morphological steps
- Failure planes and slicken sides
- Backtilting with deranged drainage
- Irregular and hummock relief



LANDSLIDE CAUSES

- Geological causes
  - Weak and sensitive material
  - Weathered material
  - Sheared, jointed or fissured material
  - Adversely oriented fractures
  - Contrast permeability
  - Contrast stiffness
- Morphological causes
  - Tectonic/volcanic uplift
  - Erosion of slope toe
  - Vegetation removal
  - Subterranean erosion (piping, solution)
  - Deposition of load on slope or crest
- Physical causes
  - Intense rainfall/prolonged exceptional rainfall
  - Earthquake/volcanic eruption
- Human causes
  - Excavation of the slope or its toe
  - Deposition of load on the slope or crest
  - Drawdown of reservoirs
  - Deforestation
  - Irrigation
  - Mining
  - Artificial vibration
  - Water leakage from utilities

MITIGATION AND REMEDIAL MEASURES (STRUCTURAL)

- Rock reinforcement such as pattern of rock bolt with wire mesh and shotcrete
- Use of rock sheds
- Use of nets to catch and rock fences to catch falling and sliding rock
- Provide adequate and appropriate slope drainage
- Flatten the slope
- Soil improvement
- Cut or fill solutions
- Rock / soil anchors
- Drainage
- Geofabric
- Grouting
- Use of retaining walls

MITIGATION MEASURES (NON-STRUCTURAL)

- Direct (legal) regulations
  - Landuse zoning
  - Subdivision regulations
  - Building codes
  - Land registration
  - Open space controls
  - Public works and engineering
- Financial incentives
  - Taxation (negative or positive incentives)
  - Insurance and mortgage policies
- Public land development

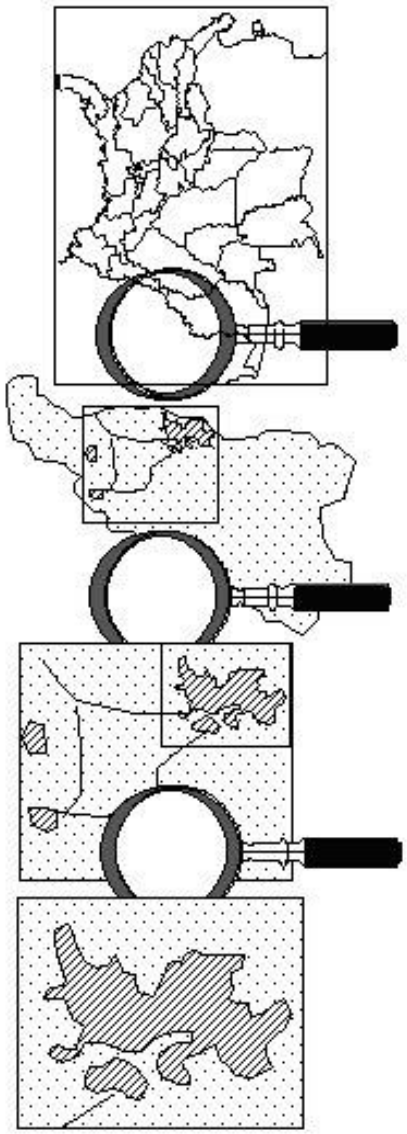
LANDSLIDE HAZARD MAPPING
Landslide Hazard Map Scale

1. National scale
- < 1:1.000.000
- Inventory
- Entire courtries
- Based on records

2. Regional scale
- < 1:100.000
- Regional planning
- Large areas
- Simple methods

3. Medium scale
- 1:25.000 tot 1:50.000
- Local planning
- Areas up to 200 km2
- Statistical methods

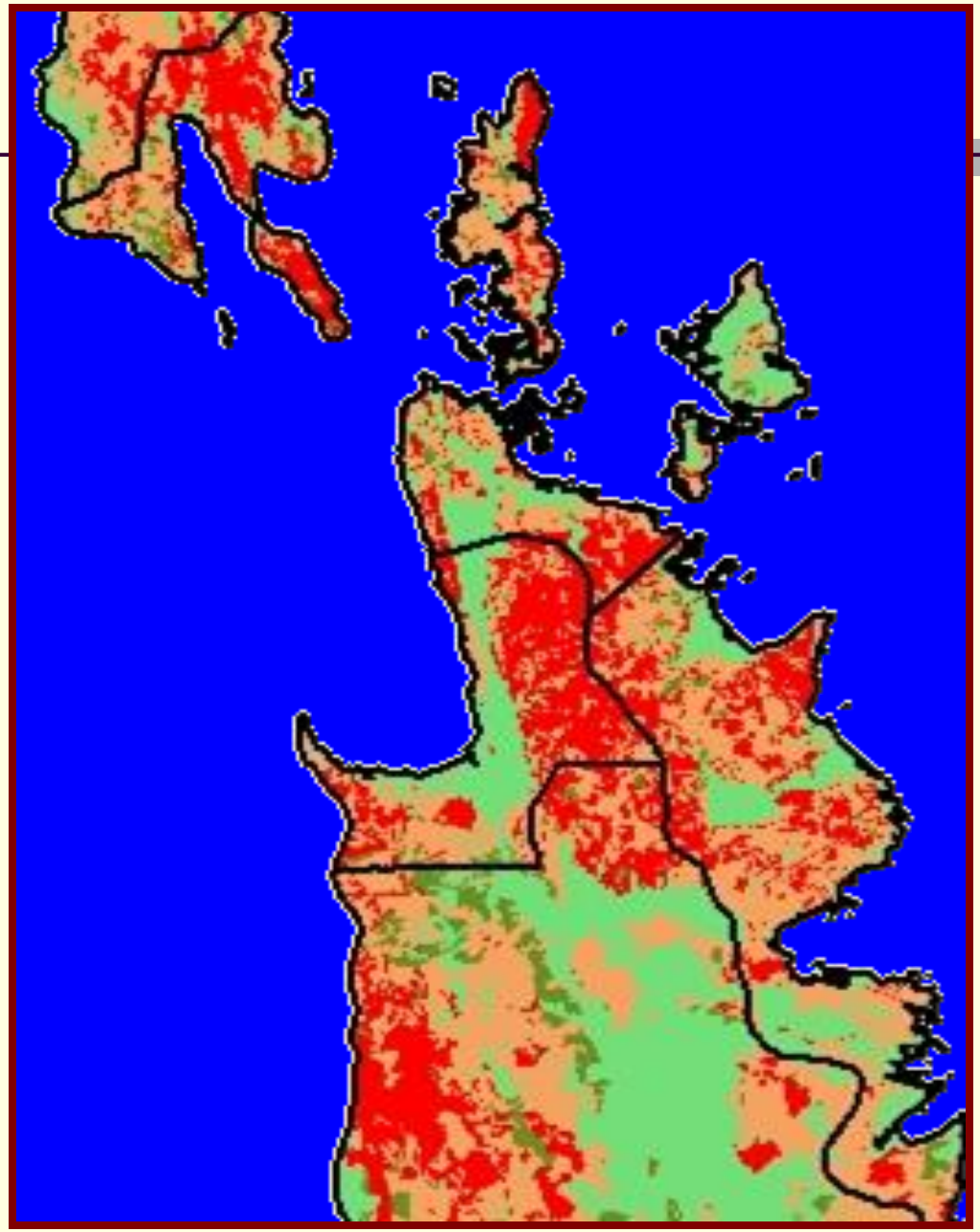
4. Large scale
- < 1:10.000
- Detailled planning
- Small areas
- Stability-analysis



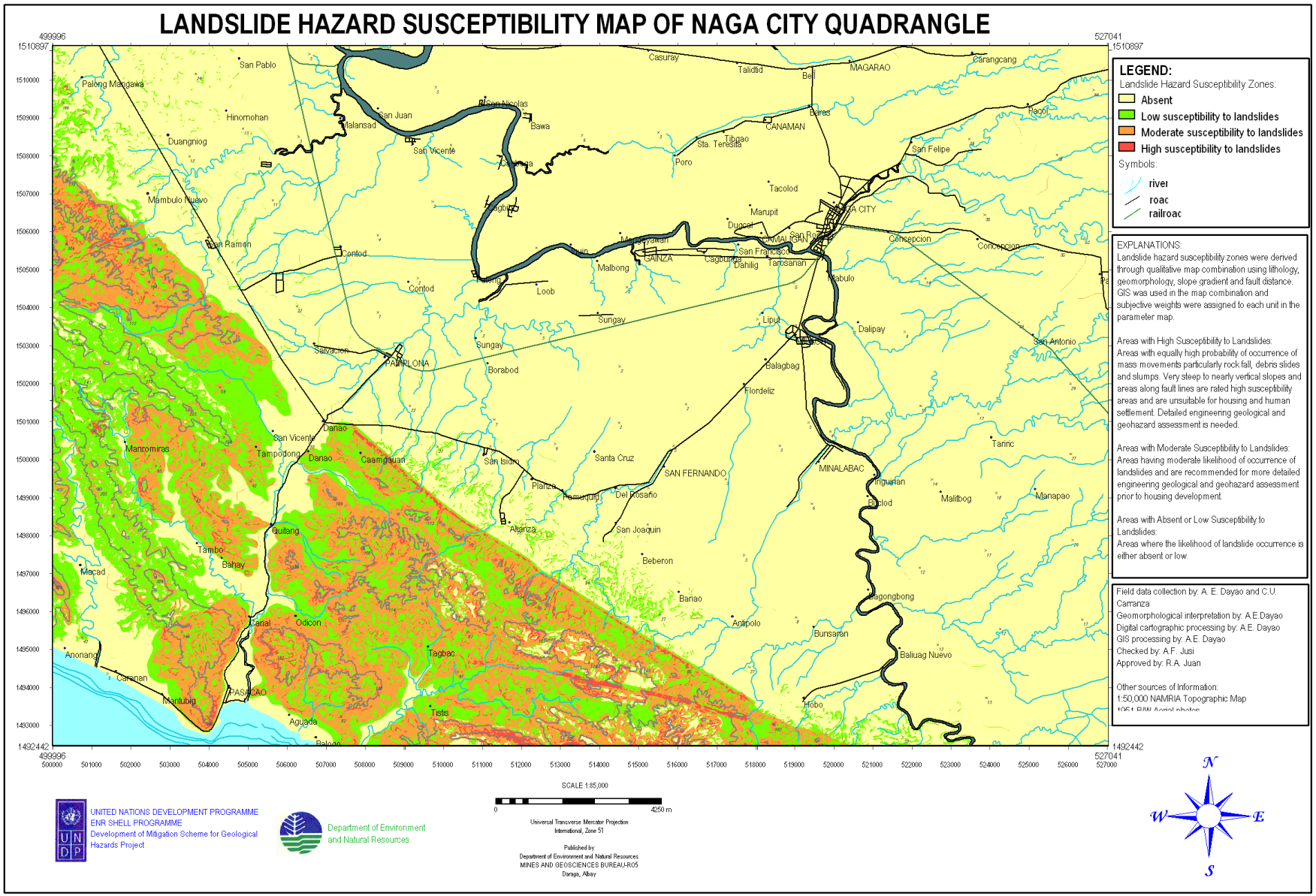
LEVELS OF GEOHAZARD MAPPING

TYPE OF MAP	SCALE	LEVEL OF DETAIL	USUAL DATA SOURCES
National (synoptic)	1:100,000 and smaller	Boundaries of areas containing hazard	Satellite imagery, air photo mosaics
Medium scale	1:25,000 to 1:50,000	Hazard sites	Satellite imagery, air photo mosaics
Large scale	1:10,000 to 1:5,000	Detail of larger hazard areas	Aerial photography, field mapping
Detailed	1:2,000 to 1:5,000	Detail within hazard areas	Aerial photography, field mapping, process monitoring
Site	1:2,000 and larger	Specific hazard	Aerial photography, field mapping, process monitoring, sub-surface investigations

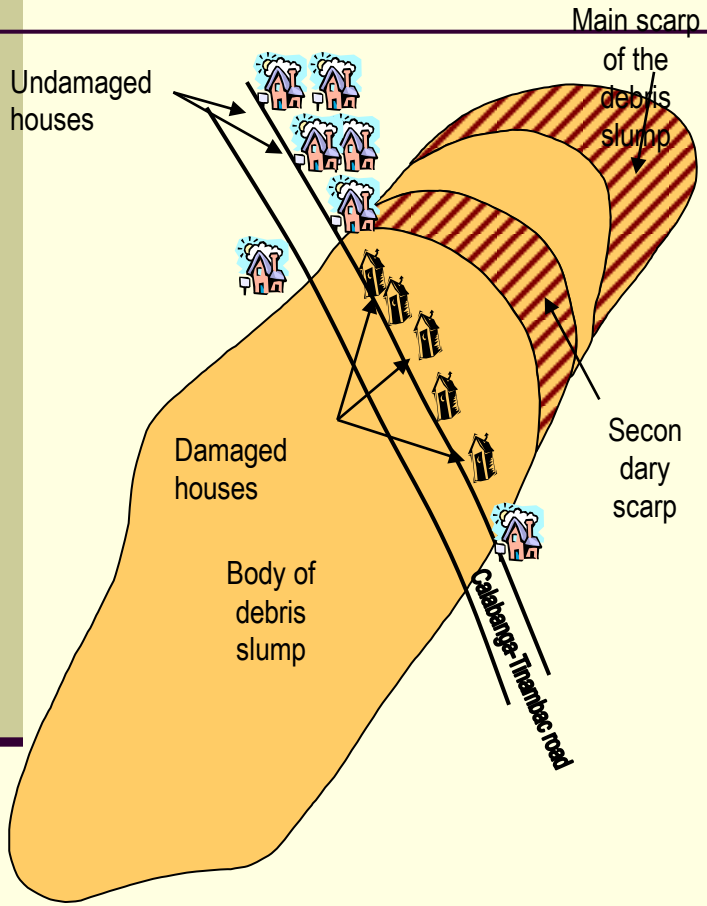
Regional Scale Landslide Hazard Map



Medium Scale Landslide Hazard Map



Large Scale Landslide Hazard Map



GEOHAZARD or NATURAL HAZARD

- the probability of occurrence, within a specific period of time in a given area, of a potentially damaging natural phenomenon
- Key elements:
  - Location
  - Frequency
  - Magnitude

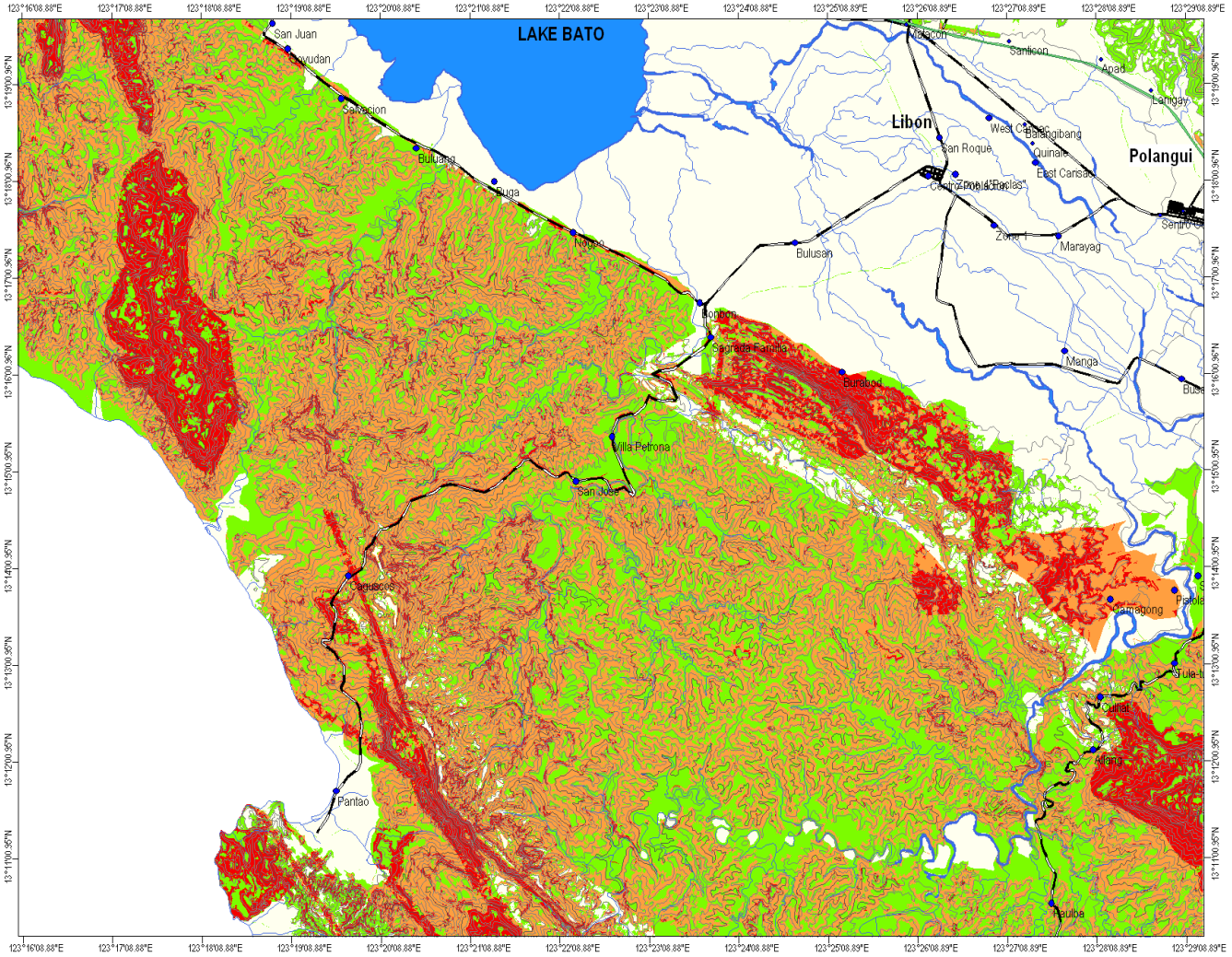
HAZARDS MAPS OF POLANGUI QUADRANGLE, ALBAY

- Mass movement or landslide hazard maps
- Flood hazard maps
- Ground settlement susceptibility map
- Ground subsidence susceptibility map
- Earthquake hazard maps
  - Liquefaction potential

MASS MOVEMENT OR LANDSLIDE HAZARD MAP

- Landslide hazard map was derived through qualitative map combination using a Geographic Information System. Rock type, geomorphology, distance to faults and slope gradients were used in the map combination that resulted in 4 landslide hazard zones.
- Areas of high susceptibility to landslides – areas of high probability of occurrence of mass movements like Rock slumps and debris slides in areas with very steep slopes, along fault scarps and areas underlain by limestone and AGF siltstone-shale
- Areas of moderate susceptibility – areas with steep slopes underlain by AGF siltstone shale

LANDSLIDE SUSCEPTIBILITY MAP OF POLANGUI QUADRANGLE



MAP LEGEND:
Landslide Susceptibility Zones:

- High Susceptibility
- Moderate Susceptibility
- Low Susceptibility to Absent
- Absent
- fault
- river
- road
- railroad

EXPLANATIONS:

Landslide hazard susceptibility zones were derived through qualitative map combination using lithology geomorphology, slope gradient, road distance and fault distance. GIS was used in the map combination and subjective weights were assigned to each unit in the parameter map.

Areas with High Susceptibility to Landslides:
Areas with equally high probability of occurrence of mass movements particularly rock slides, debris slides and slumps. Very steep to nearly vertical slopes and areas along fault lines are rated high susceptibility areas and are unsuitable for housing development and human settlement.

Areas with Moderate Susceptibility to Landslides:
Areas having moderate likelihood of landslide occurrence and are recommended for more detailed engineering geological and geohazard assessment prior to housing development.

Areas with Low Susceptibility to Landslides:
Areas where the occurrence of landslides is low.

Absent:
Areas where the likelihood of landslide occurrence is absent.

Field data collection by: J.M.S.Laud
Geomorphologic interpretation by: J.M.S.Laud
Digital cartographic processing by: E. L. Laguerta
GIS processing by: J.M.S.Laud
Checked by: A.E. Dayao
Approved by: R.A. Juan

Other sources of Information:
1:50,000 scale NAMRIA Topographic Map
1951 B/W Aerial Photographs

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Daraga, Albay
2007

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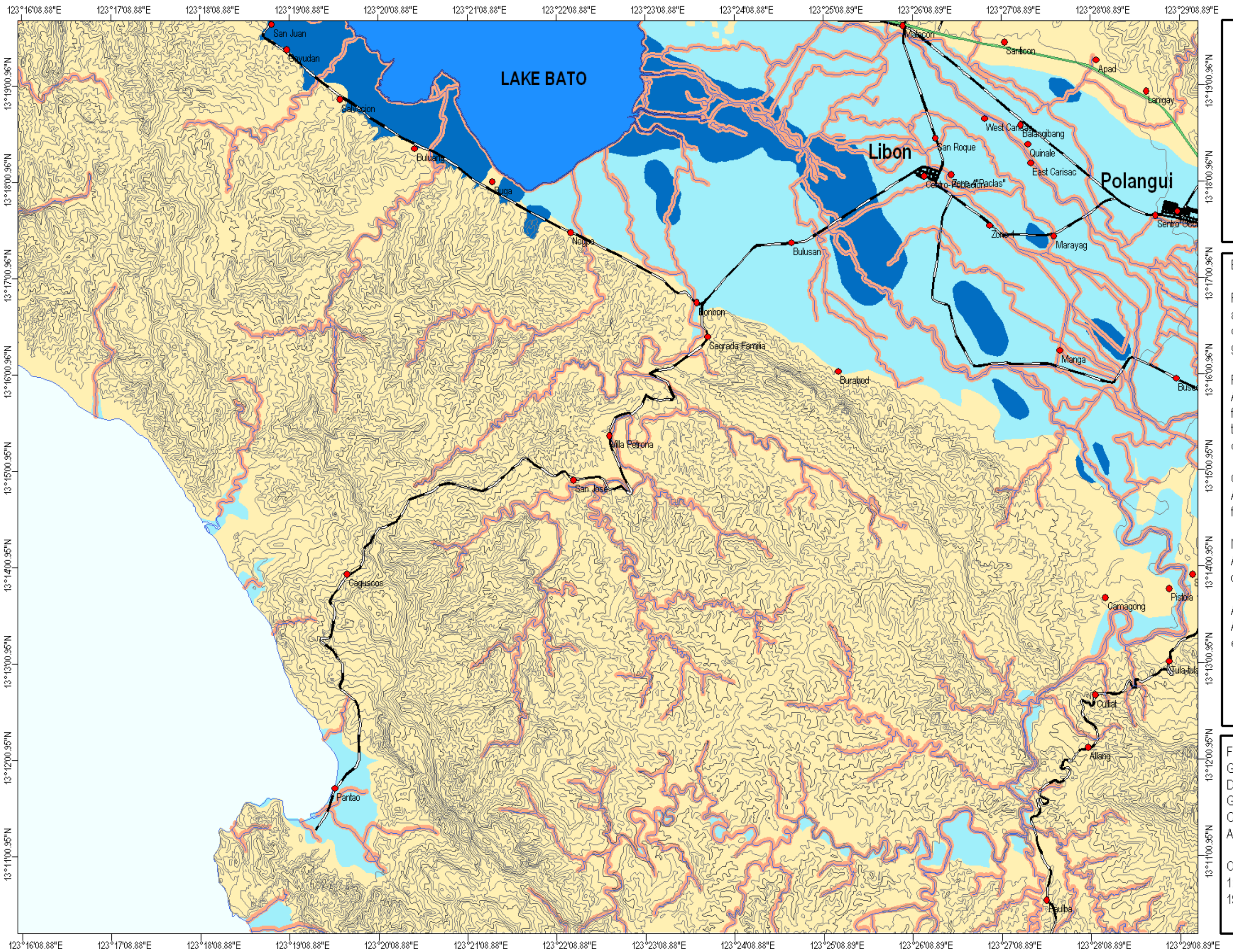
FLOOD HAZARD MAP:

- Derived from the analysis of the geomorphological lay of the fluvial system. Field information on flood occurrences, flood depths, duration and topographic information supported the geomorpho-logic-based flood hazard mapping
- Regularly to frequently flooded areas – moderate to strong typhoons could submerge these areas 0.5 to 2.0 m for a few days to a few weeks.
- Seasonally to rarely flooded areas – areas that become flooded during moderate to strong typhoons from a few centimeters to 1 m deep flood that stays for a few hour to a few days.

FLOOD HAZARD MAP OF POLANGUI QUADRANGLE



MAP LEGEND:

Flood Susceptibility Zones:

- Non flood prone areas
- Occasionally to rarely flooded areas
- Regularly to frequently flooded areas
- Areas prone to bank erosion
- railroad
- river
- road

EXPLANATIONS:

Flood hazard susceptibility zones were derived based on the geomorphological analysis of landforms and the fluvial system. Information on flood occurences, flood depths, duration of inundation as well as topographic information supported the geomorphologically-based flood hazard map

Regularly to Frequently Flooded Areas:
Areas that are frequently flooded. Mere heavy rains of 1 to 2 days could bring about flooding in these areas. Moderate to strong typhoons could submerge these areas 1m to 3 meters or more in flood waters for a few days to a few weeks. Housing development in these areas is not recommended.

Occasionally to Rarely Flooded Areas:
Areas that become inundated during moderate to strong typhoons. Flood depths vary from a few centimeters to 1 m. Floods last from a few hours to a few days.

Non-Flood Prone Areas:
Areas with no reported flood occurrences except low lying areas adjoining rivers or creeks.

Areas Prone to River Bank Erosion:
Areas 0 to 50 m. from river banks of active river channels that are prone to bank erosion.

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Geomorphological interpretation by:J.M.S.Laud
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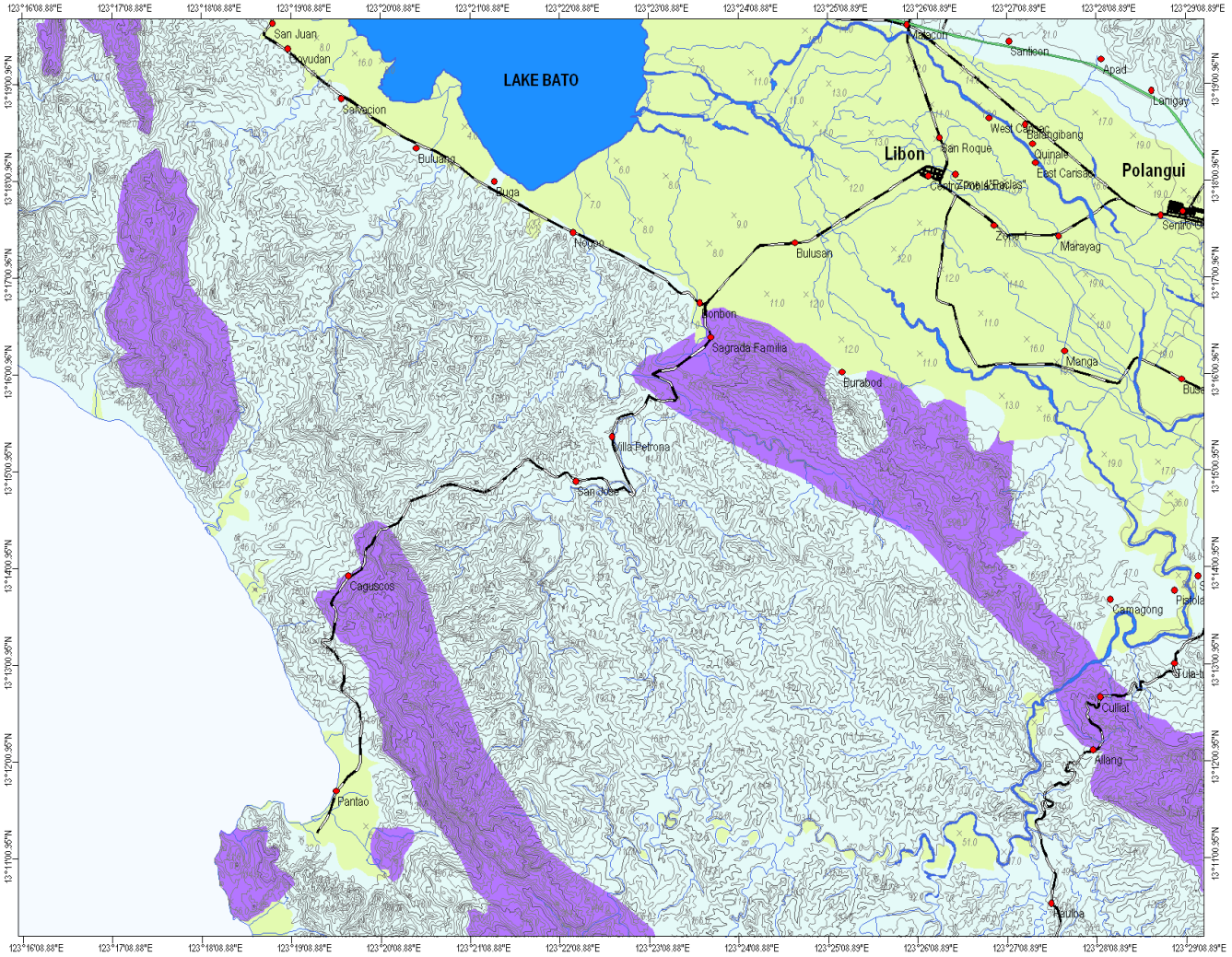
GROUND SETTLEMENT *and* GROUND SUBSIDENCE SUSCEPTIBILITY MAP:

- Ground settlement and ground subsidence susceptibility maps were derived based on the distribution of geologic materials
- Areas underlain by unconsolidated materials particularly soils that are compressible and expansive are the most prone to ground settlement
- Ground subsidence occurs in areas underlain by soluble rocks like limestones and other calcareous rocks. Marked by caves, caverns, sinkholes and underground rivers

GROUND SUBSIDENCE AND GROUND SETTLEMENT SUSCEPTIBILITY MAP OF POLANGUI QUADRANGLE



MAP LEGEND:
Ground Subsidence and
Ground Settlement Susceptibility Zones:

- Areas Susceptible to Ground Settlement
- Areas Susceptible to Ground Subsidence
- Areas not Susceptible to Ground Settlement/Subsidence
- river
- road
- railroad

EXPLANATIONS:

Susceptibility map for ground subsidence due to karst or solution processes was primarily derived based on the rock types of the study area. Field observations on sinkhole occurrences and ground subsidence on concrete roads supported the mapping. Areas of possible ground settlement were delineated through the analysis of the geomorphological lay of the study area, the sub-surface soils and the ground water levels.

Areas Susceptible to Ground Subsidence:
Areas that are prone to ground cavitation, sinkhole formation and ground subsidence in areas underlain by limestone, marl and calcareous sandstone, siltstone and shale.

Areas Susceptible to Ground Settlement:
Area where fluviatile sands, silts and clays coupled with shallow groundwater table are sites of possible ground settlement. Ground settlement maybe reduced through appropriate foundation design. Buildings having 3 storeys or more should be tested for settlement and/or consolidation. Buildings having 5 storeys or more should undergo detailed geotechnical studies.

Areas not Susceptible to Ground Settlement/Subsidence:
Areas where the possibility of ground settlement or ground subsidence is either low or absent.

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Geomorphologic interpretation by: J.M.S.Laud
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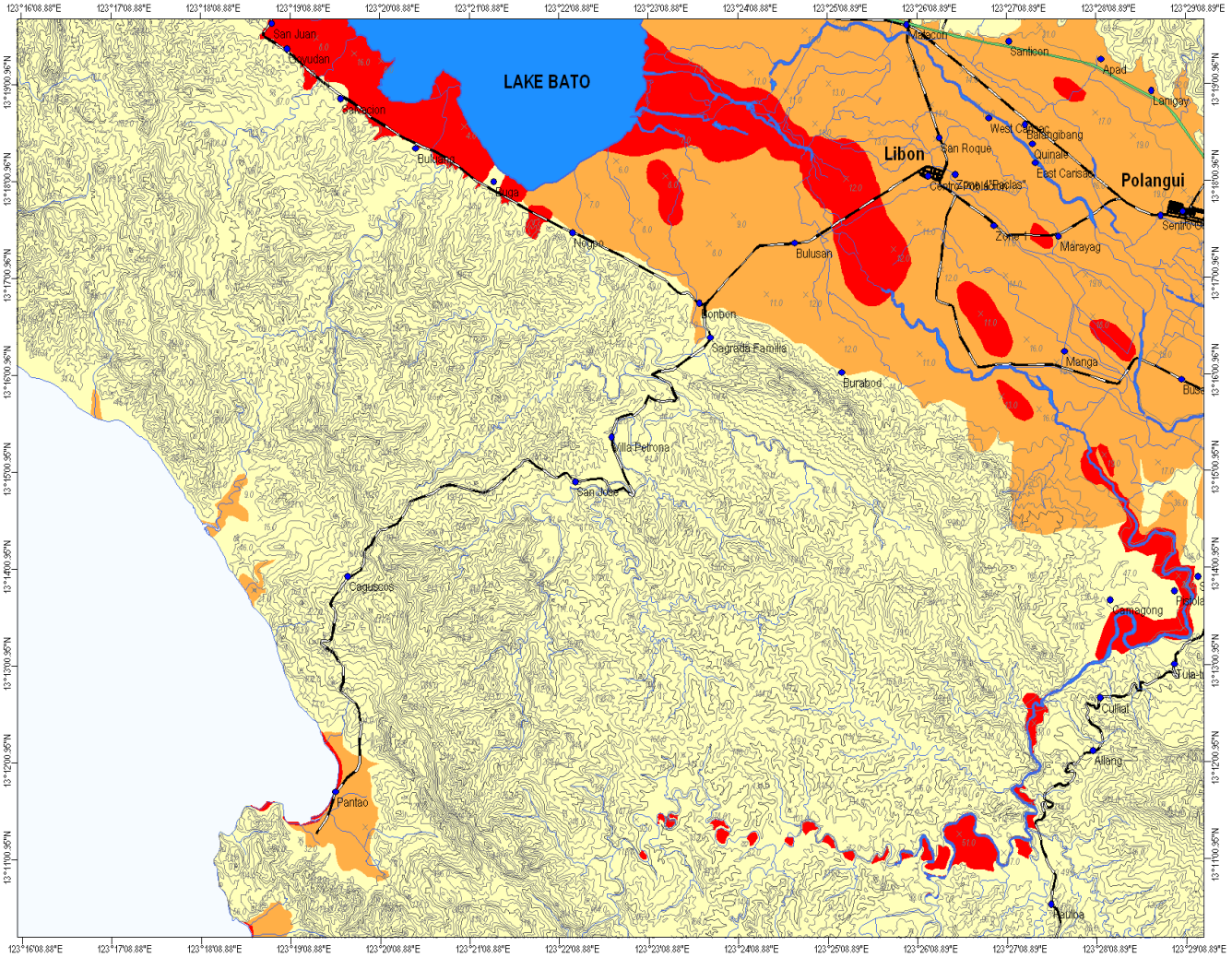
LIQUEFACTION POTENTIAL MAP:

- Hazard zonation for liquefaction potential was based on the geomorphological analysis of the study area following the methodology by Iwasaki and Yasuda
- Areas where liquefaction is likely – include the river bed, abandoned river beds and meanders, river terraces, point bars, swamps and tidal rivers where soils are generally loose and cohesionless and groundwater is very shallow

LIQUEFACTION POTENTIAL MAP OF POLANGUI QUADRANGLE



MAP LEGEND:
Liquefaction Potential Zones:

- Areas where Liquefaction is Likely
- Areas where Liquefaction is Possible
- Areas where Liquefaction is not Likely

- fault
- river
- road
- railroad

EXPLANATIONS:

There are no reported liquefaction occurrences in the study area based on several interviews. However, zones of different liquefaction potential were derived based on the geomorphological lay of the study area following criteria made by Iwasaki and Yasuda.

Areas where Liquefaction is Likely:
Areas where liquefaction is likely to occur include the riverbeds, the backswamps and fluvial basins, the river terraces, the beach, the coastal plain, the lake and the lake fan. These areas are unsuitable for community or urban settlement.

Areas where Liquefaction is Possible:
The likelihood of liquefaction occurrence is less for these areas.

Areas where Liquefaction is not Likely:
Areas where liquefaction is unlikely to occur. Most parts of the Polangui Quadrangle map sheet is not prone to liquefaction because of the presence of underlying bedrock.

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