INTRODUCTION TO SLOPE GEOHAZARD

By

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1.0 Introduction - Definition

A natural hazard has been defined by UNESCO (see Varnes, 1984) as the probability of occurrence within a specified period of time and within a given area of potentially damaging phenomenon

(*Suatu bencana alam di takrifkan oleh UNESCO (lihat Vernes, 1984) sebagai keberangkalian suatu kejadian dalam tempoh masa dan di suatu kawasan yang mana fenomena kejadian tersebut berpotensi untuk merosakkan*)

Hazards- Hazards implies a degree of risks, but the degree of risk varies according to what is being risked.

Collapsed Bridge, Guatemala

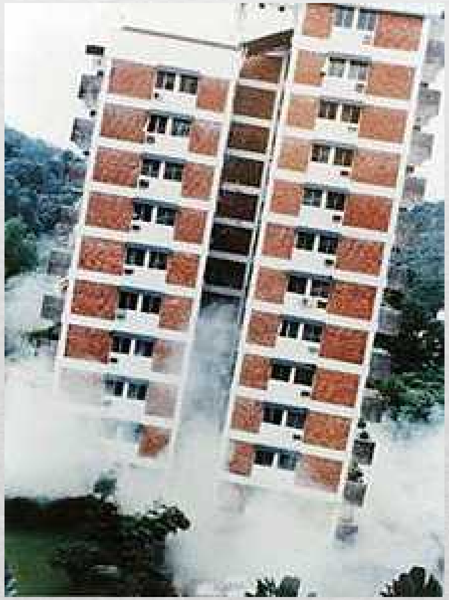
Marina District, San Francisco, 1989

Introduction

Hazards involves of risk, the degree of risk the element at risk being life, property , possessions and the environmental

Risk Assessment – Magnitude of the hazards and the probability of the occurrence

Hazard map- any special aspect of hazard can be mapped, providing there is sufficient information on it distribution



11 Dec 1993 – Highlands Tower -48 died

A steel-fortified railroad lies twisted like a toy after a 7.2-magnitude earthquake rocked Kobe, Japan, in 1995.

The Great Hanshin Earthquake Disaster of 1995 was one of the worst in Japan's history, killing 6,433 people and causing more than $100 billion in damages.

2.0 Type of Geohazard

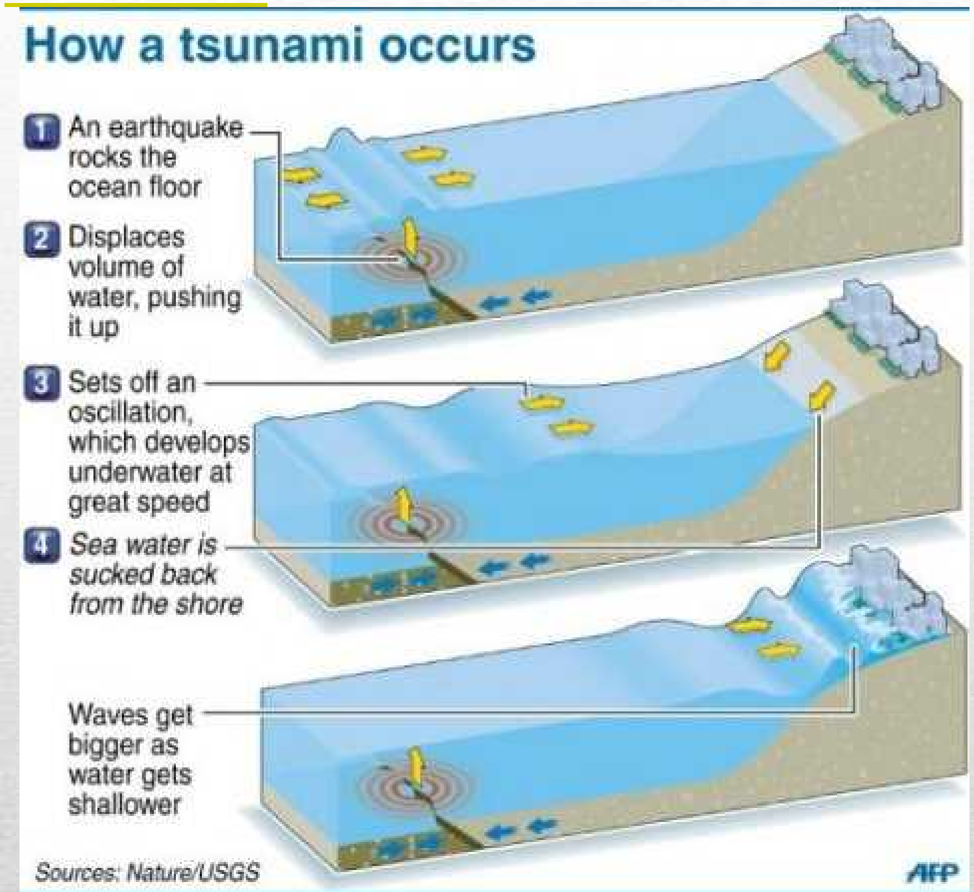
Earthquake

A sudden release of energy in the earth's crust or upper mantle, usually caused by movement along a fault plane or by volcanic activity and resulting in the generation of seismic waves which can be destructive

Gempa bumi adalah getaran atau goncangan yang terjadi di permukaan bumi akibat pelepasan tenaga dari dalam secara tiba-tiba, biasanya disebabkan oleh pergerakan satah sesar atau aktiviti volkanik yang menciptakan gelombang seismik..

7 Dec 2016- Acheh

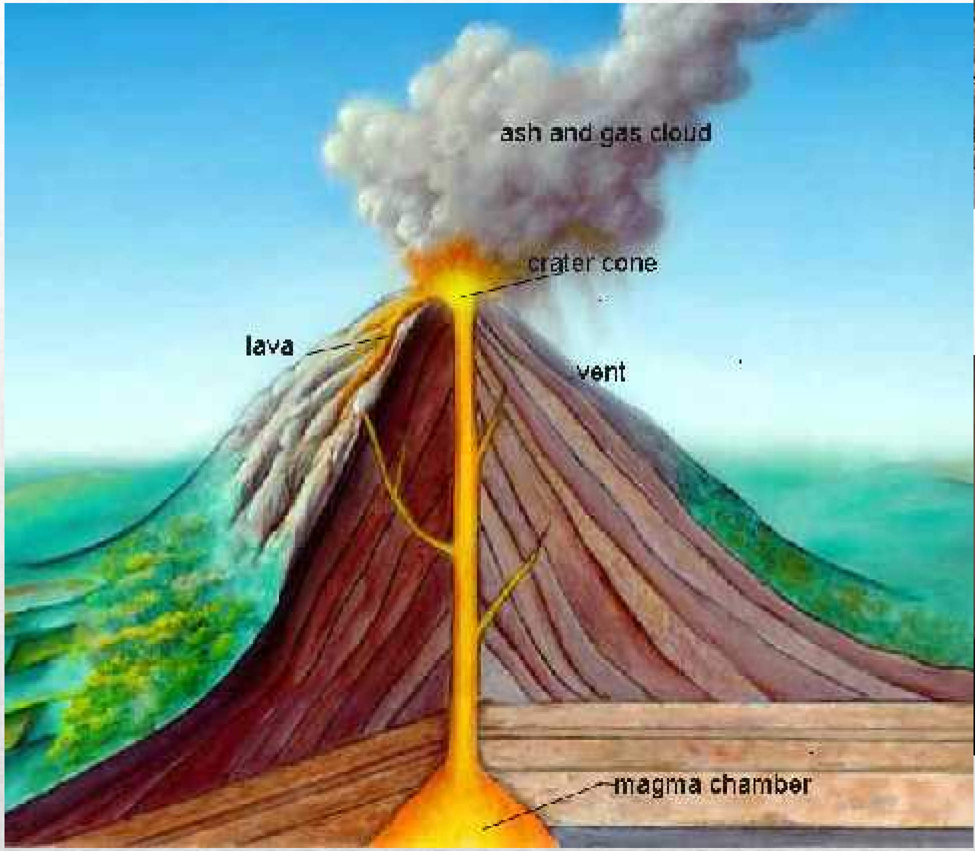
Tsunami



Tsunami is a series of waves produced by sudden movement of great volume of water due to tectonic activities in the ocean floor.

Tsunami can produced up to 100 km of wave length and height more than 2 m.

Volcanic



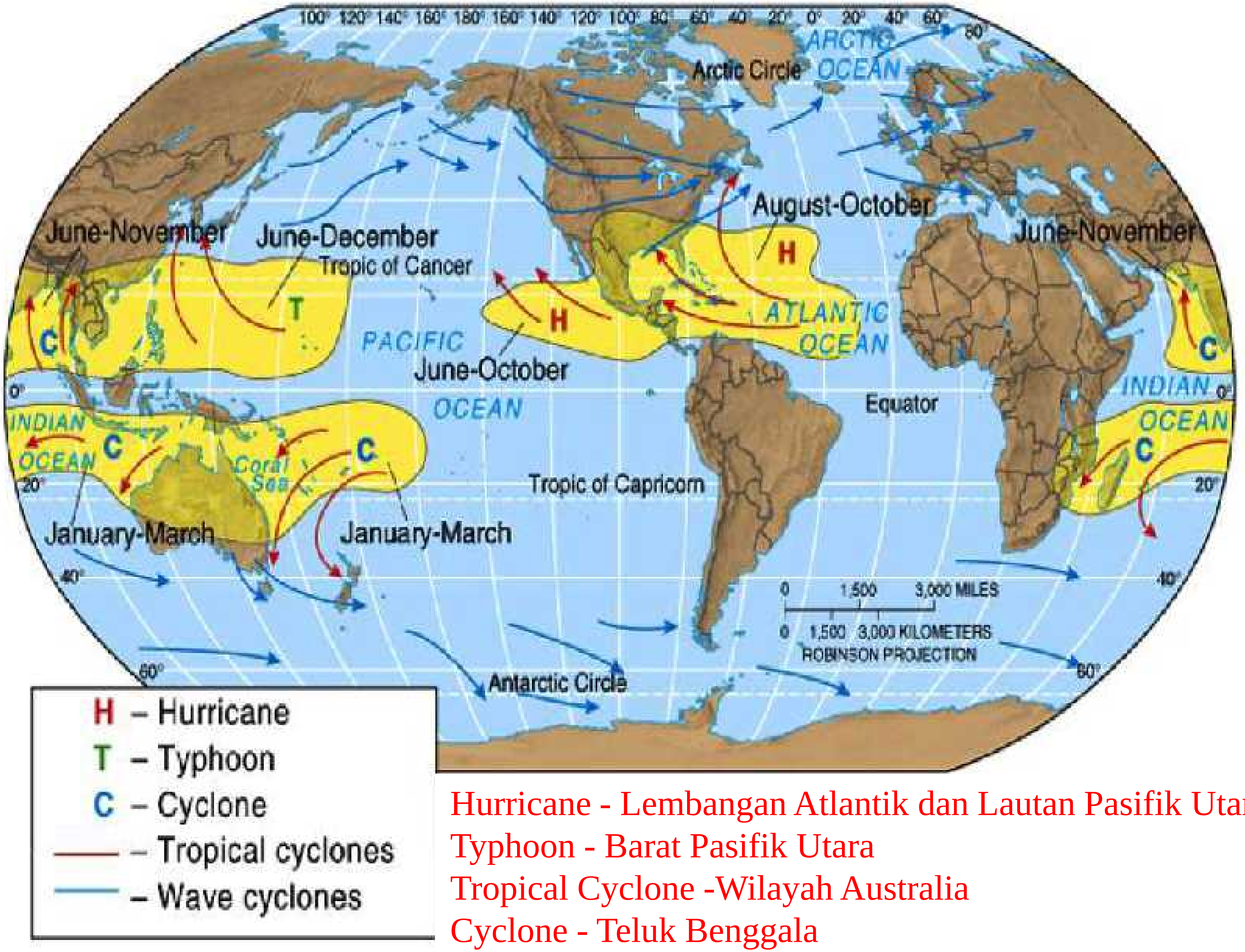
A volcanic eruption is a rupture in the crust of a planetary-mass object, such as Earth, that allows hot lava, volcanic ash, and gases to escape from a magma chamber below the surface

Letusan volkanik merupakan pembukaan atau perekahan, pada permukaan atau kerak bumi, yang membenarkan magma panas, abu vulkanik dan gas .

High wind velocities

Ortley Beach in an aerial view of devastation along the barrier islands of Ocean County after Hurricane Sandy wreaked havoc on the Jersey Shore. 10/31/12 (Andrew Mills/The Star-Ledger

Ribut merupakan gangguan terhadap atmosfera planet, terutamanya yang mempengaruhi permukaan dan menghasilkan cuaca buruk.



Hurricane - Lembangan Atlantik dan Lautan Pasifik Utara.
Typhoon - Barat Pasifik Utara
Tropical Cyclone -Wilayah Australia
Cyclone - Teluk Benggala

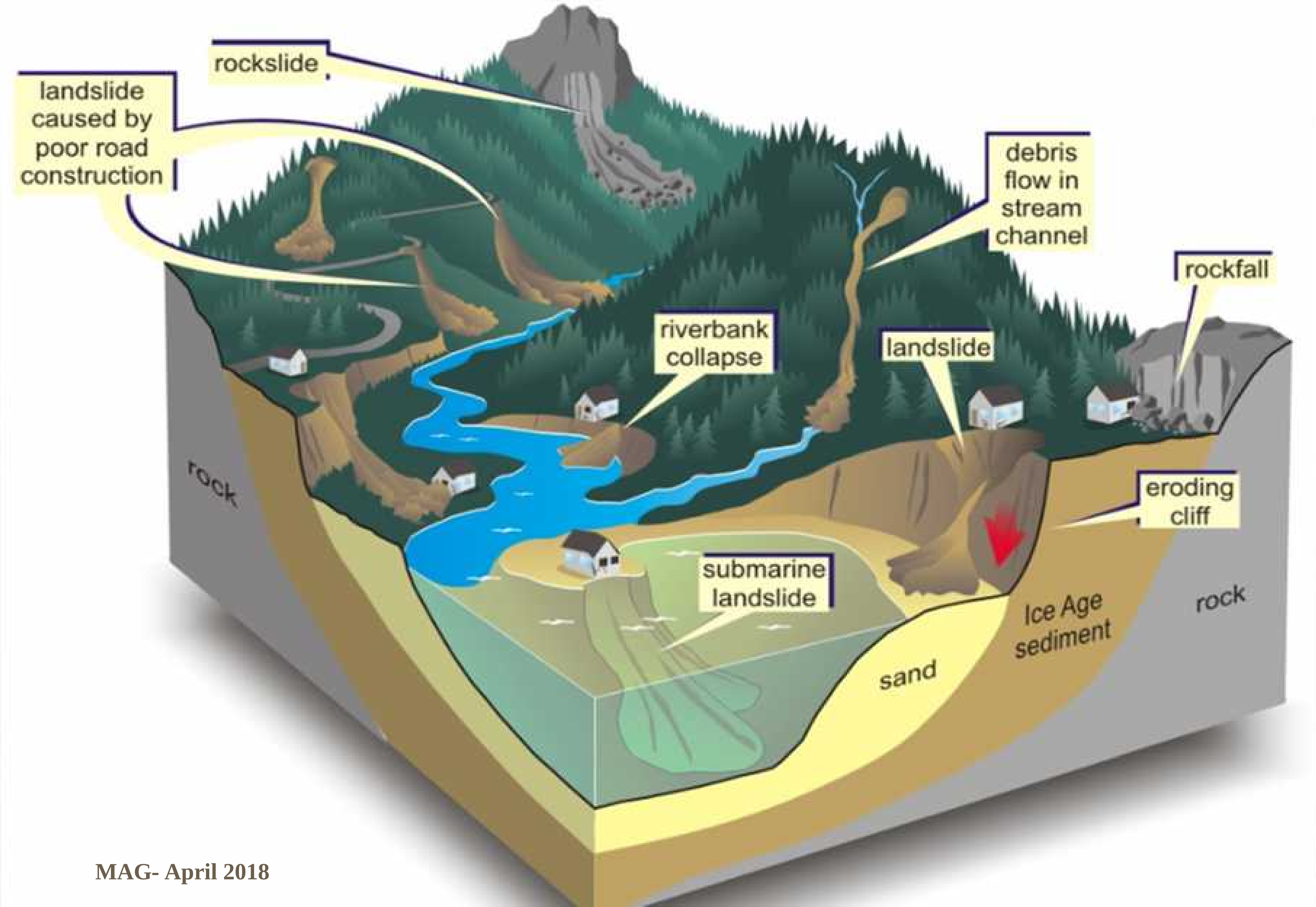
Floods

Flood is a condition where an area is entirely covered by water body.

Flood occurence can be divided into:

- Downstream Flood
- Flash Flood

Mass Movement (Landslides)



Definition & Background – “Landslide”

Hazard analysis is the process of identification and characterization of the potential landslides together with evaluation of their corresponding frequency of occurrence

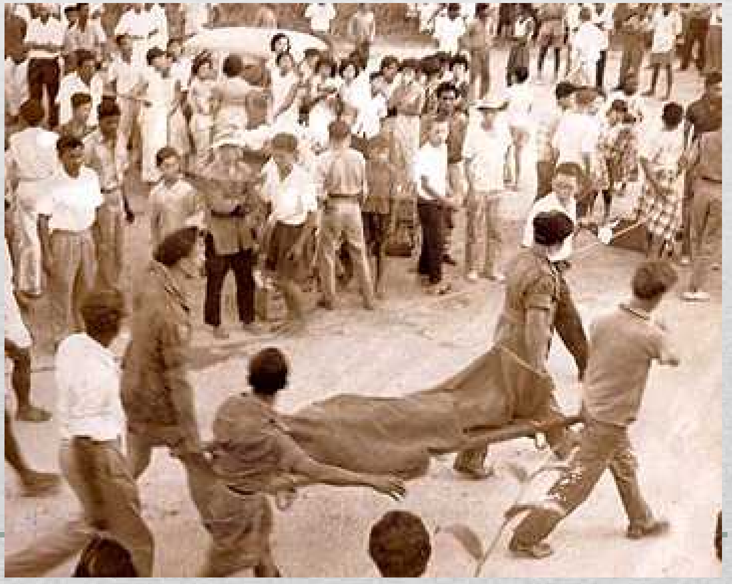
Hazard (landslide) identification requires an understanding of the slope processes and the relationship of those processes to geomorphology, geology, hydrology, climate and vegetation

Landslide = The movement of a mass of rock, debris or earth flowing down a slope (Cruden,1991)

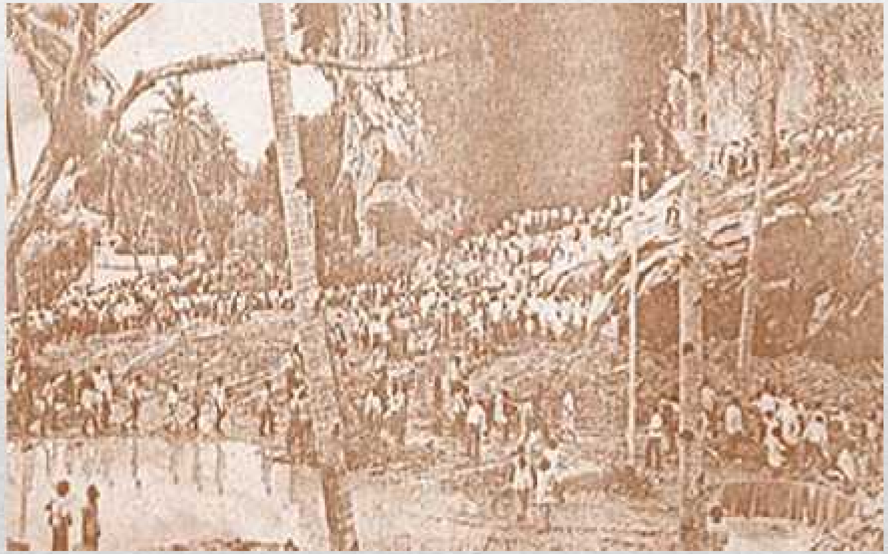
- Major landslides have occurred, since 1993, in residential areas and along highways, resulting in loss of lives and economic hardship to the public.
- From 1973 to 2007, some 440 landslides were reported. Of these, 31 cases involved fatalities. There have been slightly less than 600 deaths.
- In addition there are thousands more 'unreported' minor slope failures and landslides.

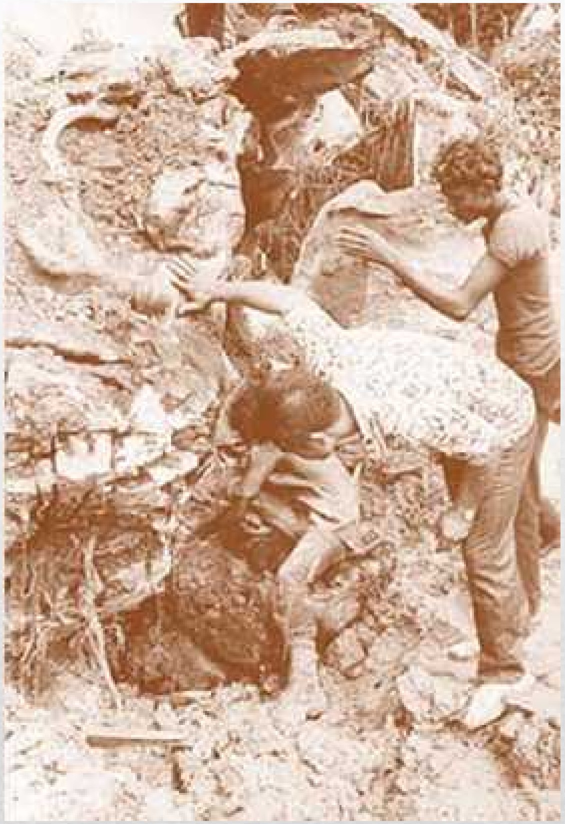
LANDSLIDE HISTORY

- Ringlet Tragedy, Cameron Highlands, Pahang
  - 11 May 1961
  - 700 people and 2 bulldozers assisted
  - 30 rescued (2hrs/4hrs)
  - 16 fatalities
  - 10 houses immediately replaced



- Kampung Kacang Putih (Gunung Cheroh) Ipoh, Perak
  - 18 October 1973
  - 42 fatalities (only 12 retrieved)
  - 60 cows & goats also buried
  - 120 occupants relocated





- Highland Tower, Ampang, Selangor
  - 11 Dec 1993
  - Block 1, 14 storey condominium collapsed
  - 2 rescued
  - 48 fatalities (all recovered)

- Keningau, Sabah
  - 26 Dec 1996
  - Tropical Storm Gregg
  - 302 Fatalities
  - 4925 houses destroyed





Bukit Lanjan, NKVE Highway
- Nov 2003

Precinct 9, Putrajaya
22 Mar 2007
27 cars buried
1,200 evacuated

Apartment Mewah, Pandan Mewah

- End of 2011

ENVIRONMENT INSTITUTE OF MALAYSIA (EiMAS), UKM, SELANGOR.

- 11 November 2012

BUKIT NANAS, JALAN DANG WANGI, KUALA LUMPUR.

- 7 May 2013
- Road closure for all vehicle at Jalan Ampang off Jalan Dang Wangi.

KM 23, JALAN RINGLET SG. KOYAN, RAUB, PAHANG.

- 2014
- Partially road closure

TNB TASIK KENYIR POWER PLANT

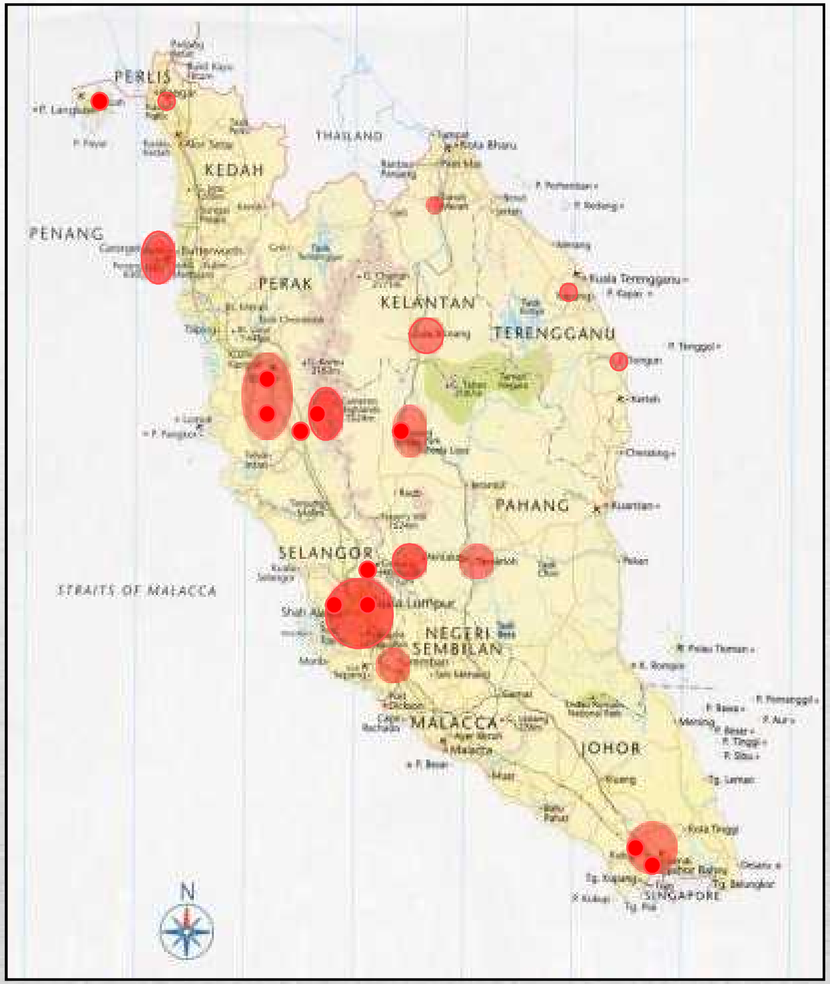
- 2014

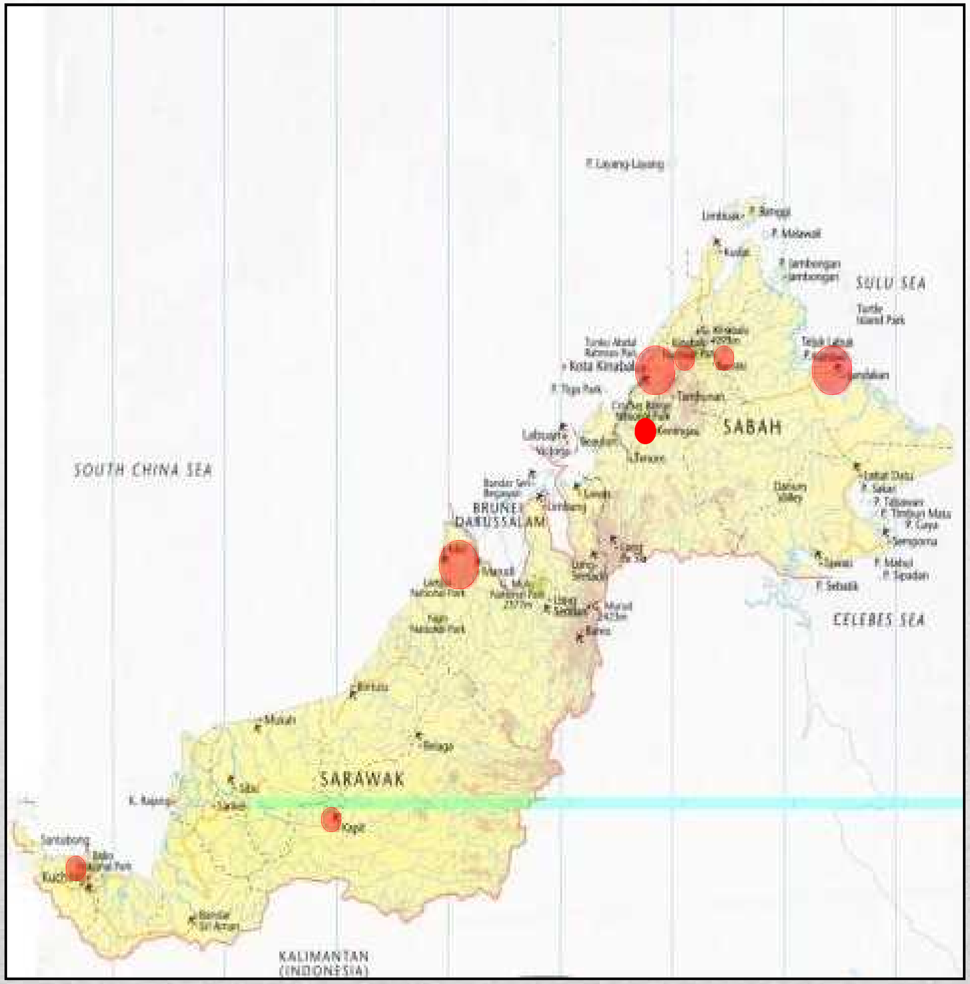
KM 139.9 Jalan Gerik – Jeli
27th September 2017

Incident Background

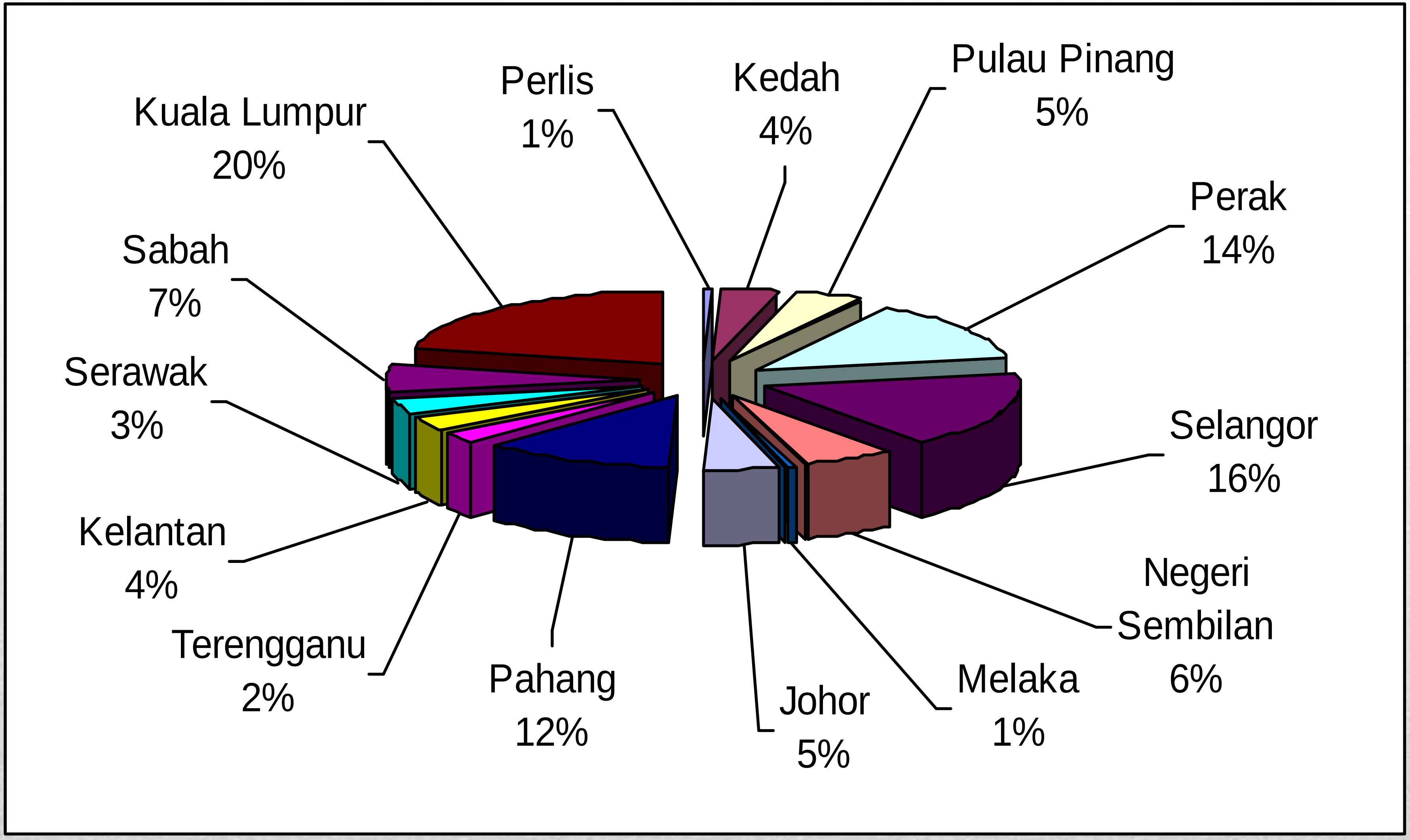
- Location: FT004 Lebuhraya Timur Barat Gerik-Jeli, Seskyen 139.9 (101.280707, 5.527906), 30km Gerik town, 12km from Tasik Banding.
- Date of Incident: 27 September 2017.
- Area of Landslide: 6600.00 M^2

Landslide distribution (1961-2007)



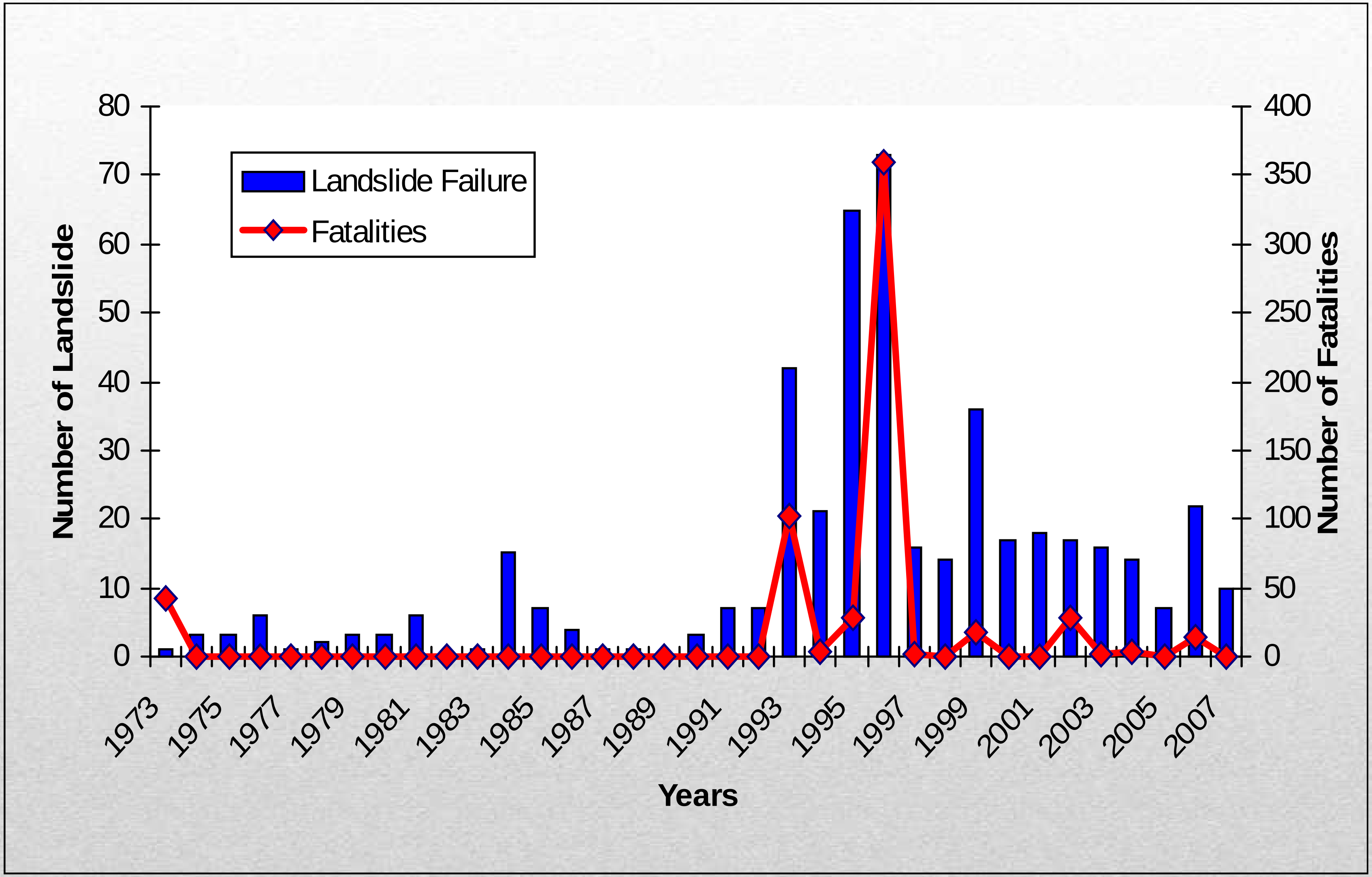


Source: National Slope Master Plan



Landslide Distribution in Malaysia (from 1961 – 2007)

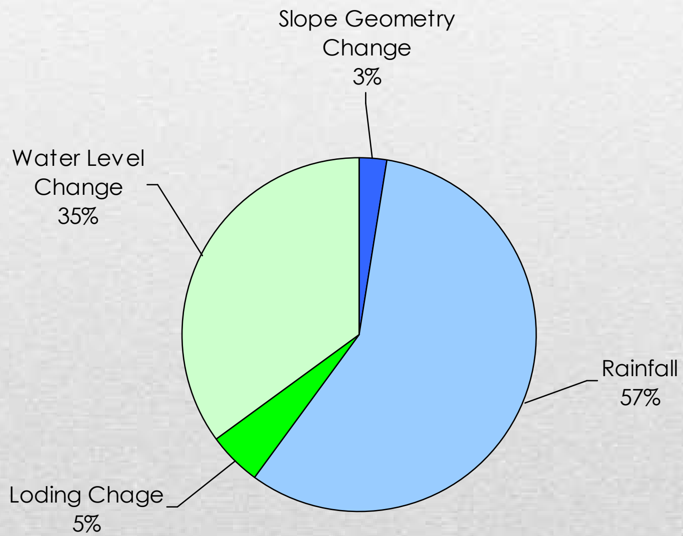
Landslide Event



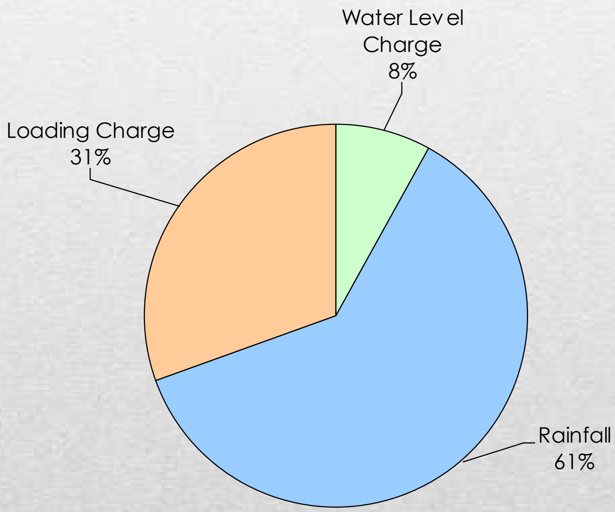
Current Status

Triggering Mechanism for Slope Failure

World



Malaysia



Source: National Slope Master Plan

Classification of landslide

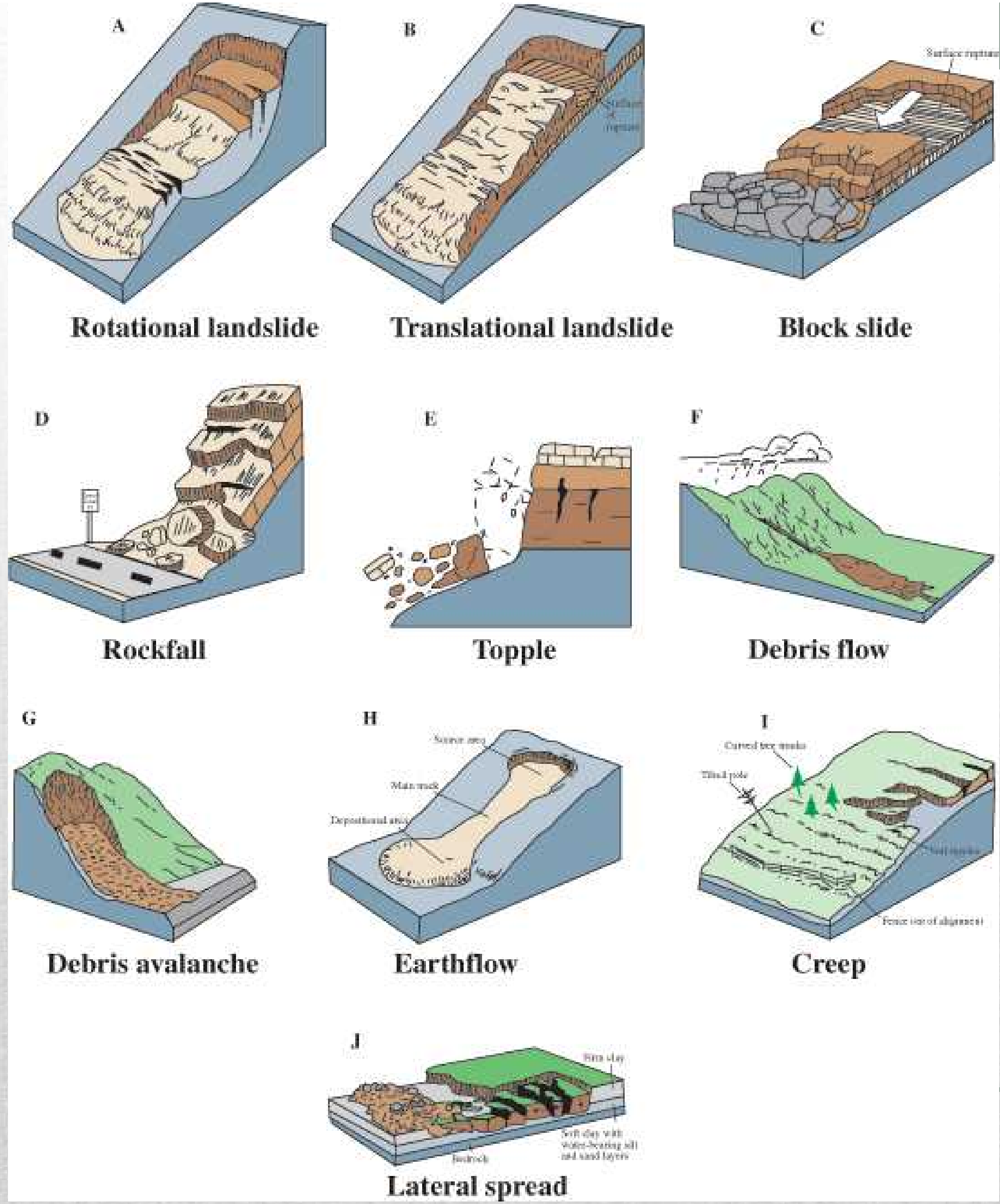
TYPE OF MOVEMENT		TYPE OF MATERIAL		
		Bedrock	ENGINEERING SOILS	
			Predominantly coarse	Predominantly fine
Falls		Rock Fall	Debris fall	Earth fall
Topples		Rock Topple	Debris Topple	Earth topple
Slides	rotational	Rock Slump	Debris slump	Earth slump
	translational	Rock Block slide	Debris block slide	Earth block slide
		Rock slide	Debris slide	Earth slide
Lateral Spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flow (deep creep)	Debris flow	Earth flow (soil creep)
Complex		Combination of two or more principal types of movement		

Classification of landslides (Varnes, 1978)

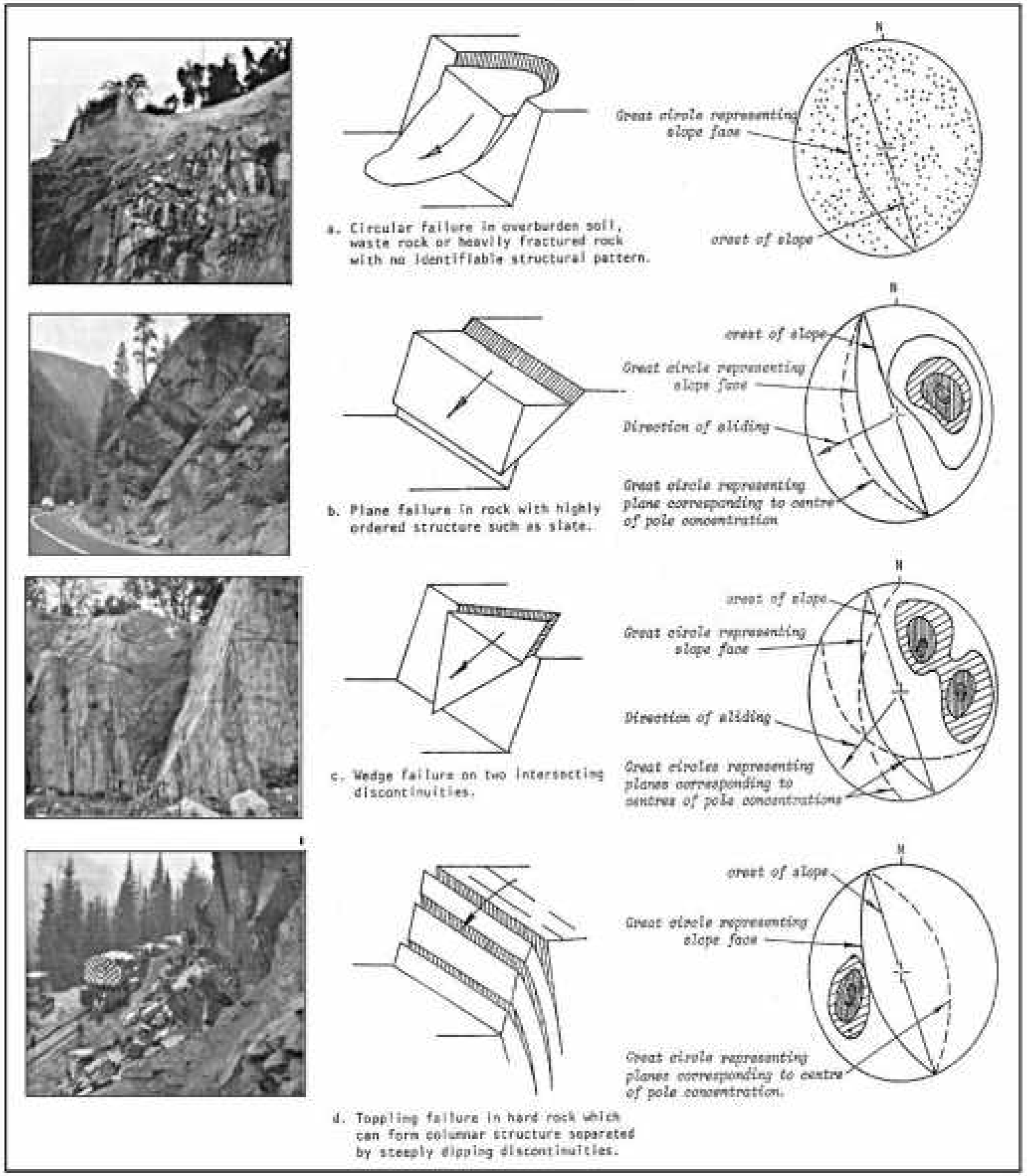
Geologists also describe the type of movement of a landslide as either:

1. Translational (where movement occurs along a flat surface);
2. Rotational (where sliding material moves along a curved surface); or
3. Wedge (where movement occurs on a wedge-shaped block formed by intersecting planes of weakness, such as fractures, faults and bedding)

Source: National Slope Master Plan



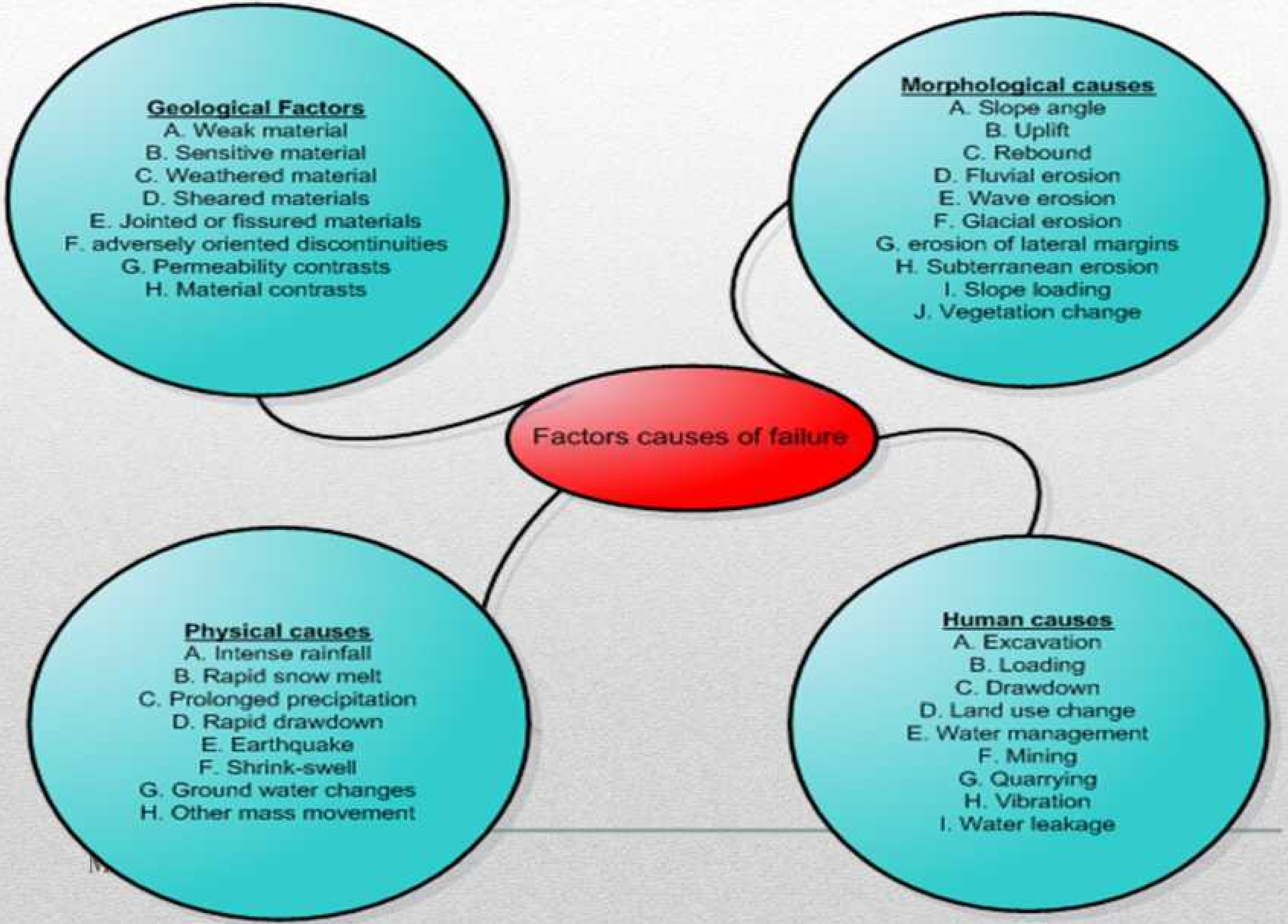
- Main type of soil slope failure



Main type of rock slope failures and the respective stereoplots of the discontinuities.
(After Hoek & Bray, 1981).

Factors causes of failure

Source: National Slope Master Plan



3.0 Landslide Hazard Assessment Method and Analysis

In general, hazard maps can be developed in a number of ways, ranging from simple qualitative or historical assessment, to varying degrees of site mapping and scientific analyses involving statistical and other numeric software packages

The common landslide hazard assessment or classification can be divided into 4 main categories,

a) Heuristic Method (Expert Judgment approach)
b) Statistical Method (Discriminant Analysis)
c) Deterministic Method (common slope stability analysis approach).
d) Spatial Method (Geological Information System (GIS) approach)

The methods for preparing hazard maps have been categorized by Hutchinson (1992) into three groups, namely:

- **Geotechnical method** : This approach involves sampling, logging and testing, and is generally considered too expensive for regional studies.
- **Direct Methods.** These methods are based on geomorphological mapping, geological mapping and remote sensing (primarily aerial photography).
- **Indirect Methods.** The simplest indirect methods involve univariate and bivariate analyses to identify single parameter or pairs of parameters that cause or contribute to slope instability.

Definition – Hazard Map

- **Hazard maps have been used throughout the world to identify areas of either existing or potential slope instability. Such maps have been applied to land development projects, new and existing highways, and mining works (Hurley et l 1995).**

a) Heuristic Method (Expert Judgment approach)

- The heuristic, instability factors are ranked and weighted according to their assumed or expected importance in causing mass-movement.

- In heuristic model, the contribution of the factors to landslide is evaluated by the experts and then the landslide hazard is forecasted (Barredo et al., 2000; Esmali and Ahmadi, 2003).

- In heuristic methods the expert opinion of the earth scientist making the survey is used to classify the hazard. These methods combine the mapping of mass movements and their geomorphologic setting as the main input factor for hazard determination.

b) Statistical Method (Discriminant Analysis)

- In the statistical (or probabilistic), the role of each factor is determined on the basis of the observed relations with the past/present landslide distribution.

- In statistical landslide hazard analysis the combinations of factors that have led to landslides in the past are determined statistically, and quantitative predictions are made for areas currently free of landslides but where similar conditions exist.

- Overlying of parameter aps and calculation of landslide densities form the core of the analysis.

- Most of the analyses are based on the relationship between the landslide densities per parameter class compared with the landslide density over the entire area, and then the result are used to predict future landslides [Clerici et al., 2002; Dai and Lee, 2002; Donati and Turrini, 2002; Gupta and Joshi, 1990].

- This model is suitable for medium scales. Each method has its own specific rules for data integration required to produce the total hazard map.

c) Deterministic Method (Common slope stability analysis approach).

- Deterministic model was often used in a large scale area and the hazard in absolute values in the form of safety factors, or the probability of failure could be provided [Jibson et al., 2000; Luzi and Pergalani, 1996; Miles and Ho, 1999; Refice and Capolongo, 2002].

- In deterministic analysis, the landslide hazard is determined using slope stability models, resulting in the calculation of factors of safety.

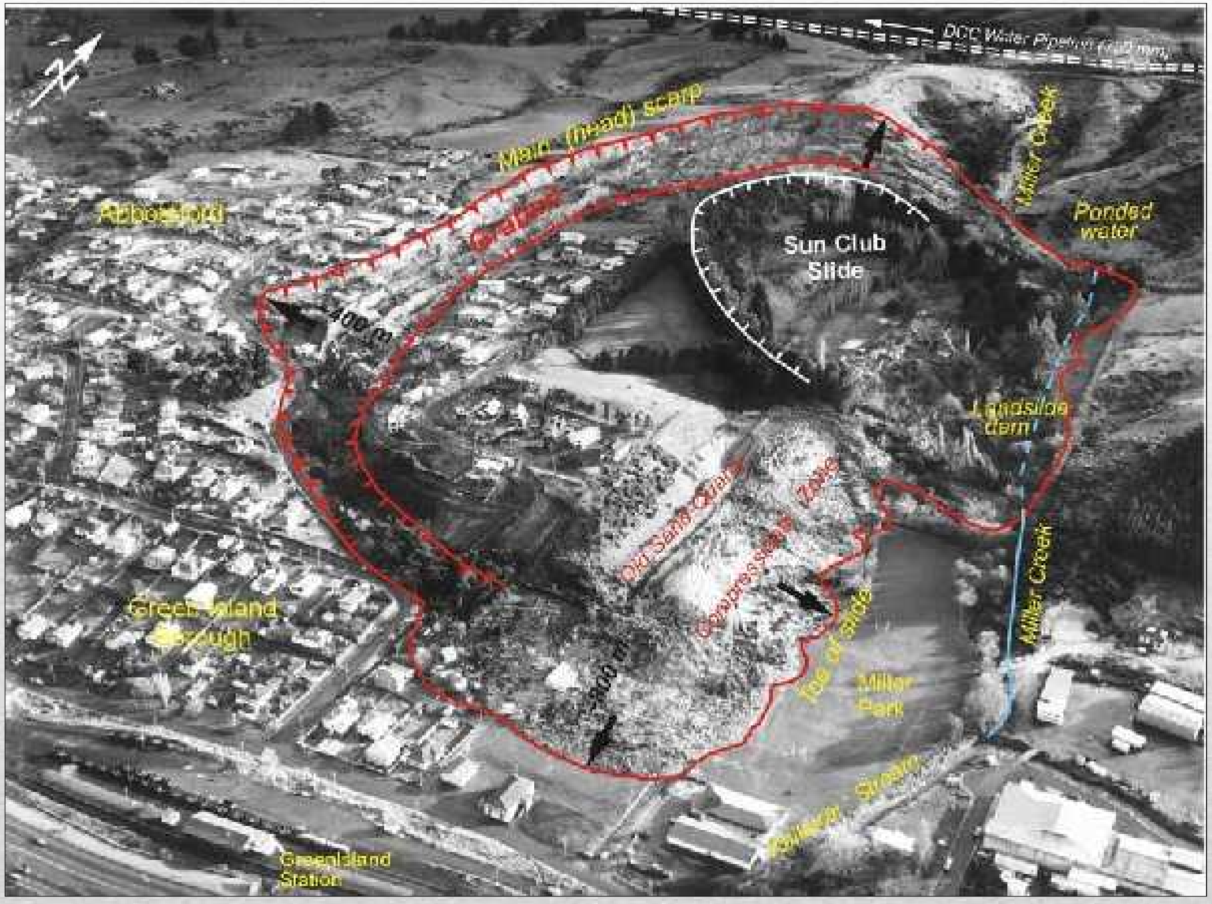
- Deterministic models provide the best quantitative information on landslide hazard that can be used directly in the design of engineering works, or quantification of risk.

- However, they require a large amount of detail input data, derived from laboratory tests and field measurement, and can therefore only be applied over small areas at large scales.

d) Spatial Method

<u>1) Aerial Photographs</u>

Aerial photography is used in cartography (particularly in photogrammetric surveys, which are often the basis for topographic maps) land-use planning and others fields**.**



d) Spatial Method

2) Satellite Images

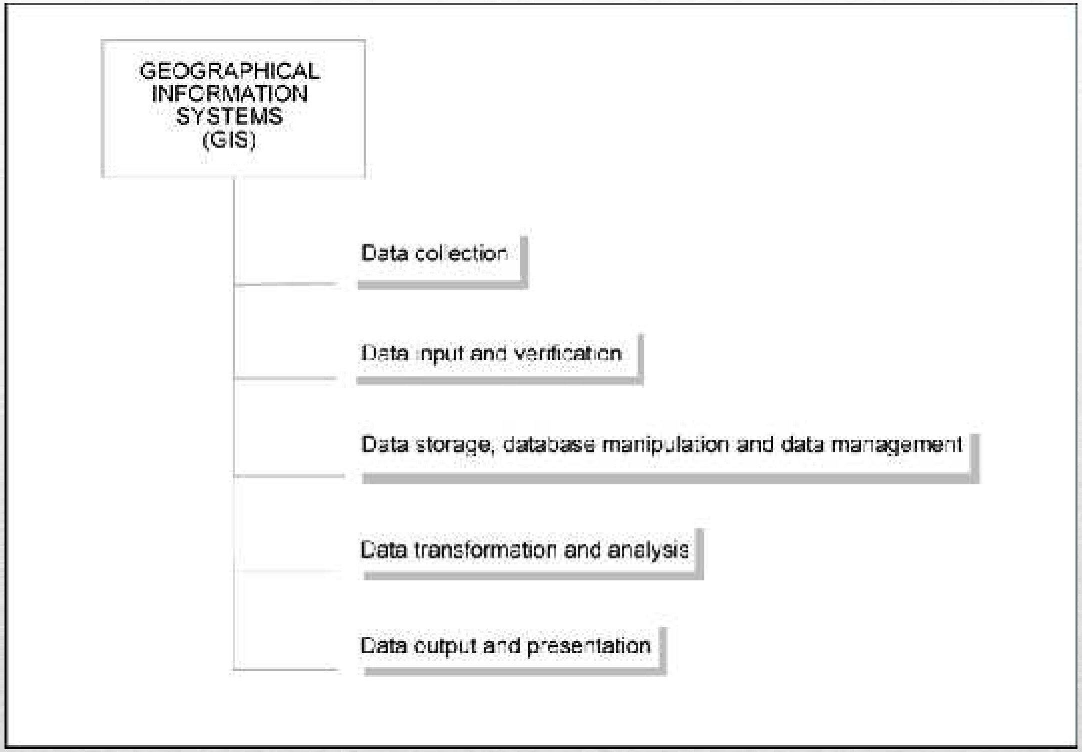
- The applications with space born images are quite new compared to the others.
- They are generally defining the landslides indirectly by mapping out other parameters such as land cover.

d) Spatial Method

3) Geographical Information System (GIS)

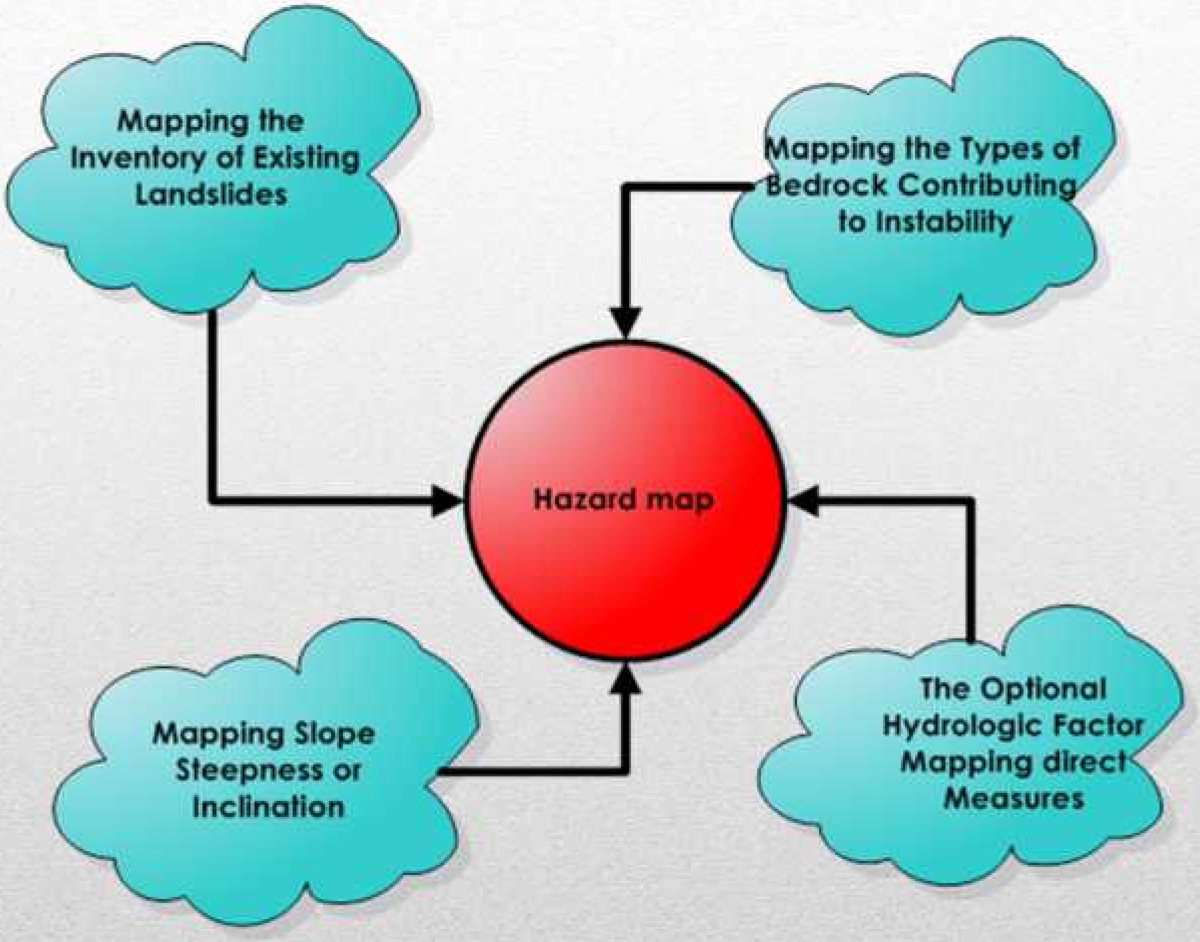
- A GIS is defined as a "powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for particular set of purposes" (Burrough, 1986).

- A more specific definition is given by Bonham-Carter (1996) as follows: "a geographic information system, or simply GIS, is a computer system for managing spatial data.

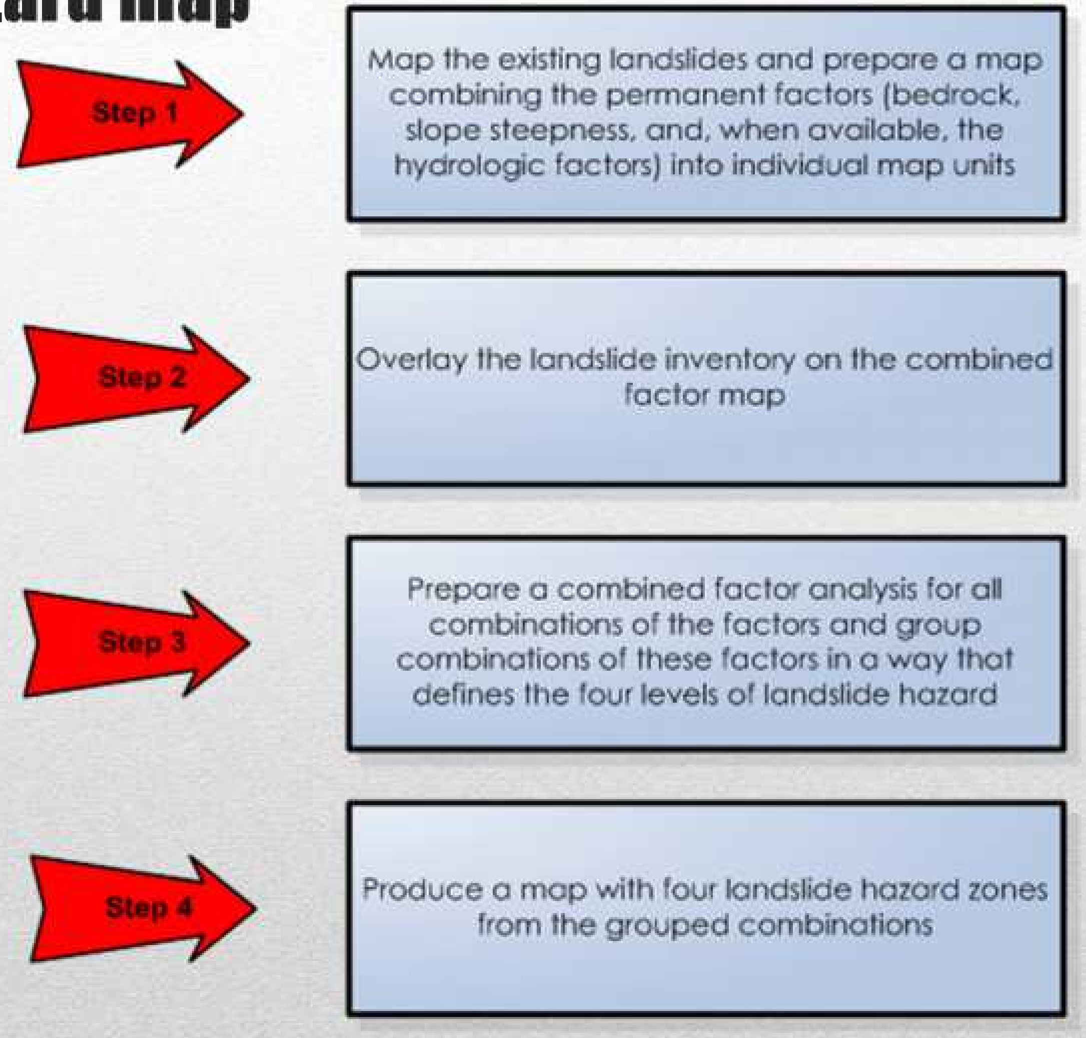


Phases of a GIS

Landslide Hazard Map Preparation



Produce a hazard map



5.0 Landslide Risk

- Varnes (1984) describes risk as the expected number of lives lost, persons injured, damage to property, or disruption to economic activity because of a particular natural phenomenon.

- To quantify risk, Varnes (1984) gave the following factors and definition:

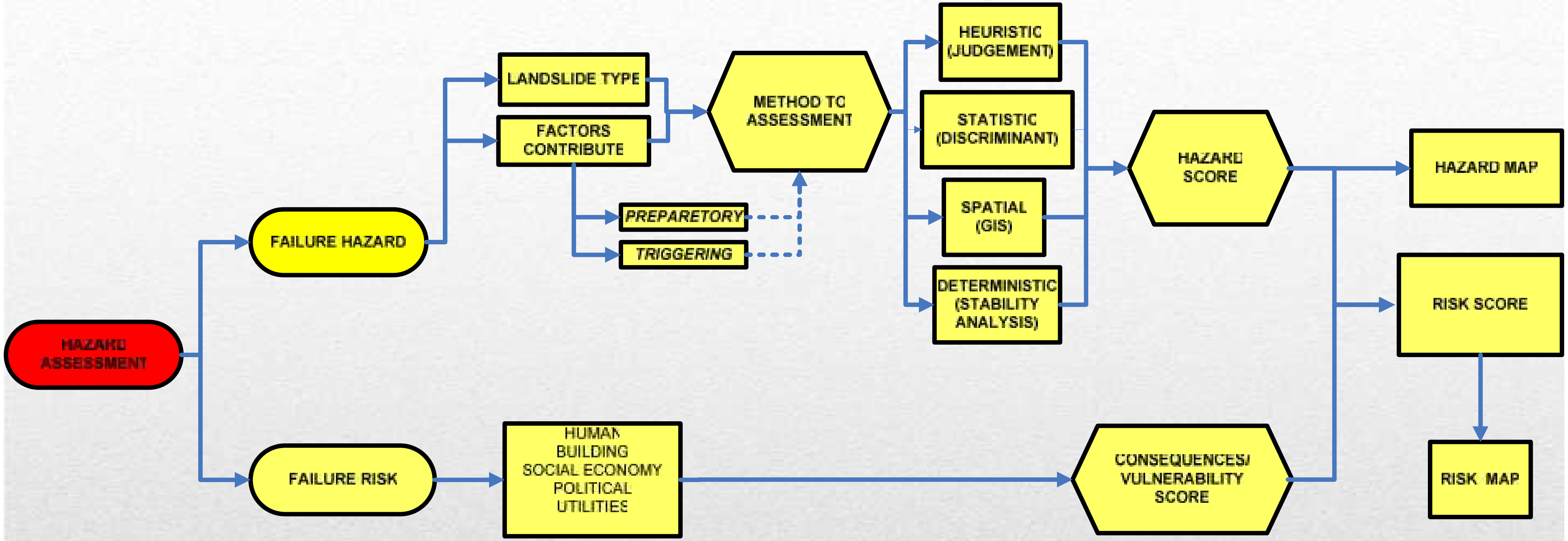
1) <u>Vulnerability</u>
degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude.

2) <u>Element of risk</u>
population, properties, economic activities and so on at risk in a given area.

3) <u>Specific risk</u>
expected degree of loss to a particular phenomenon.

4) <u>Element at risk</u>
population, properties, economic activities including public services etc at risk in a given area.

5) <u>Total risk</u>
Expected number of lives lost, person injured, damage to property or disruption of economic activity due to a particular phenomenon,



General landslide hazard and risk assessment methodology

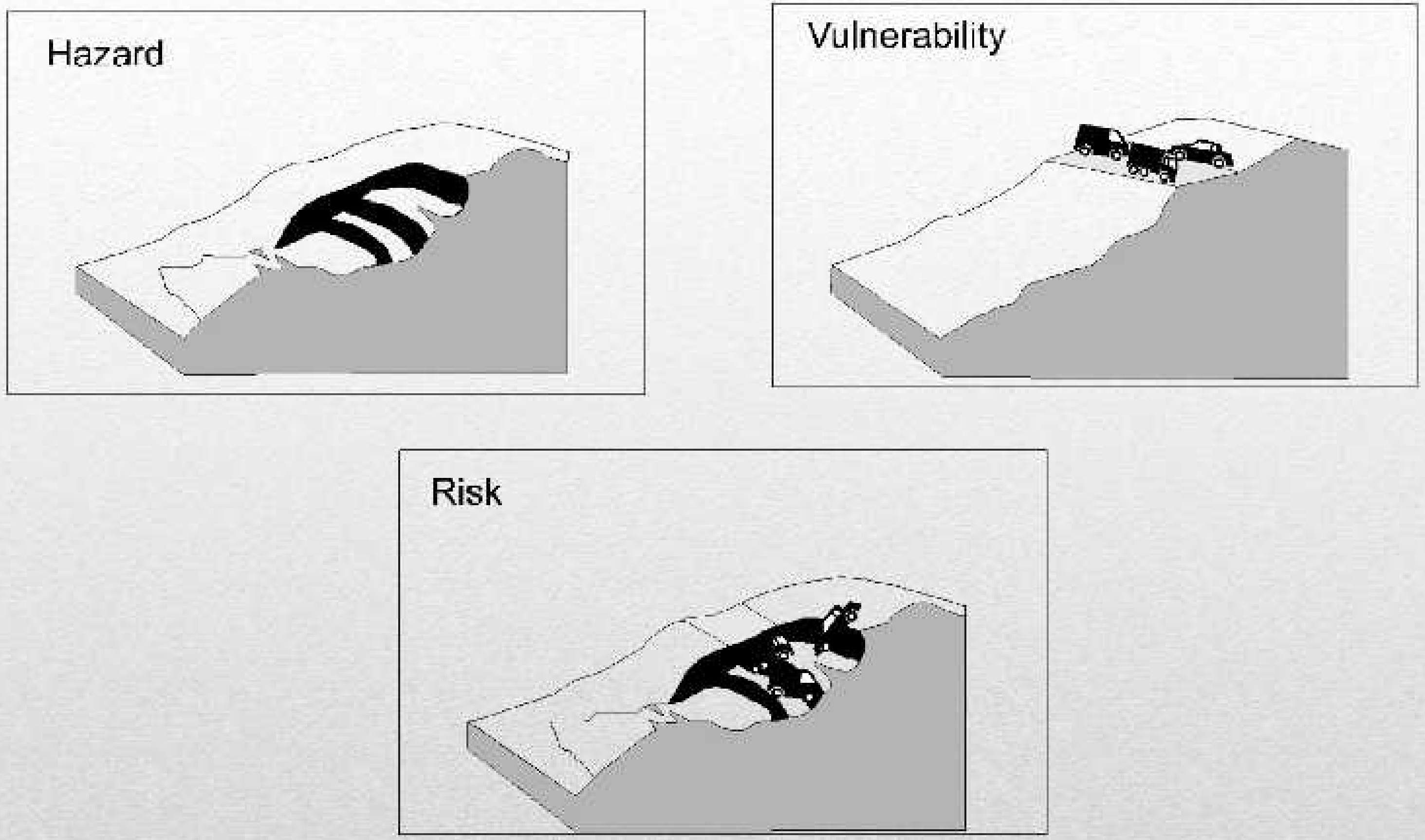
- Elements at Risk. The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by the landslide hazard

- Vulnerability. The degree of loss to a given element or set of elements within the area affected by the landslide hazard

- **Risk:-**

Varnes (1984) describes risk as the expected number of lives lost, persons injured, damage to property, or disruption to economic activity because of a particular natural phenomenon. (Risk = Consequence x Hazard)

  - Specific risk – expected degree of loss to a particular **phenomenon (Specific risk = *Hazard* $\times$ *Vulnerability*)**
  - Total risk – expected number of lives lost, person injured, damage to property or disruptionof economic activity due to a particular phenomenon, which is a product of specific risk and element at risk.
  - **Total risk = Hazard $\times$ *Vulnerability* $\times$ *Element at risk***



Graphical representation of hazard, vulnerability and risk

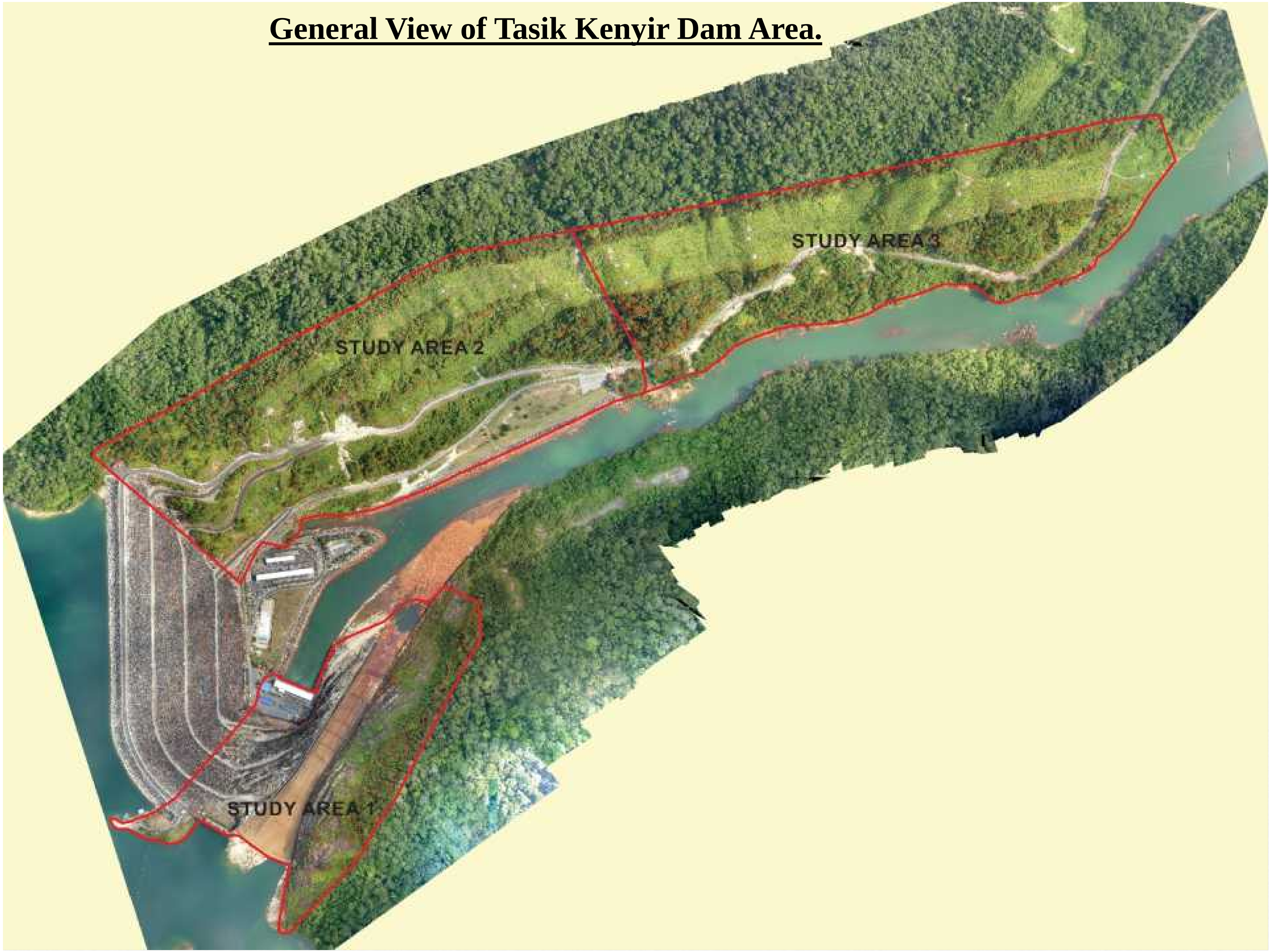
Case Study (i.e. : Stesen Janaelektrik Sultan Mahmud, Tasik Kenyir, Terengganu)

- The Study area is divided into three sites, that are:
  - ✓ Site 1 is the study of rock slope.
  - ✓ Site 2 is along the road to power approximately 1km of rock and soil slope.
  - ✓ Site 3 is covered by hilly area and rock slope.

- Area for each Sites as follows:
  - ✓ Site 1: 37.02 ha
  - ✓ Site 2: 57.03 ha
  - ✓ Site 3: 35.08 ha

- General geology of study area shows major rock distribution in Tasik Kenyir Dam area as medium to coarse-grained biotite granite. At certain place it was formed as sheared biotite granite. The zenolith found within granite body is interpreted as basic igneous rock, namely as gabronorite pyroxene-hornblende to gabronorite olivine. It was older and heritage from previous volcanic activity in the area.

General View of Tasik Kenyir Dam Area.



TYPE OF SURVEY

1

LAND SURVEY

2

UAV LIDAR

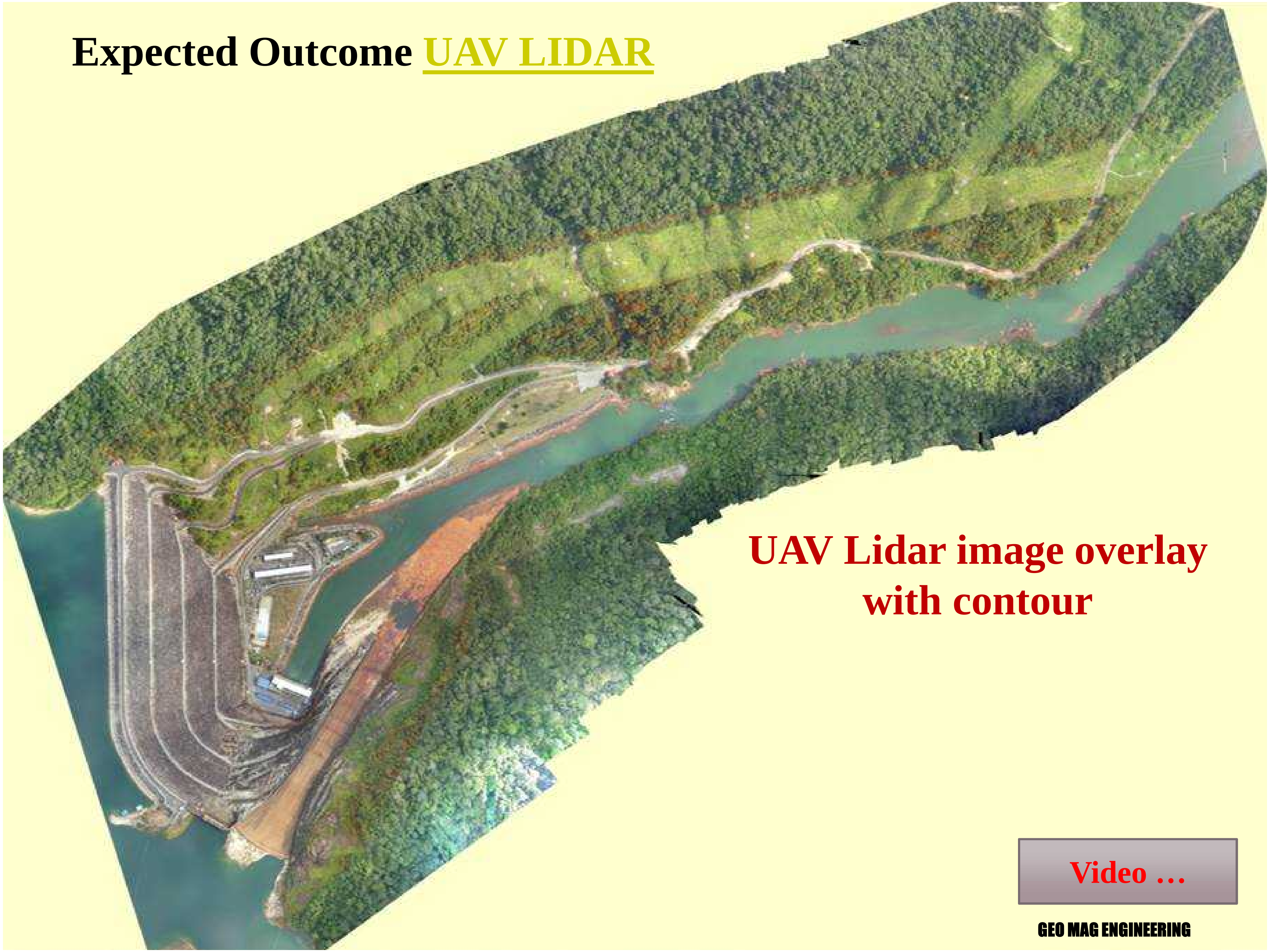
3

BATHYMETRIC

4

LIDAR

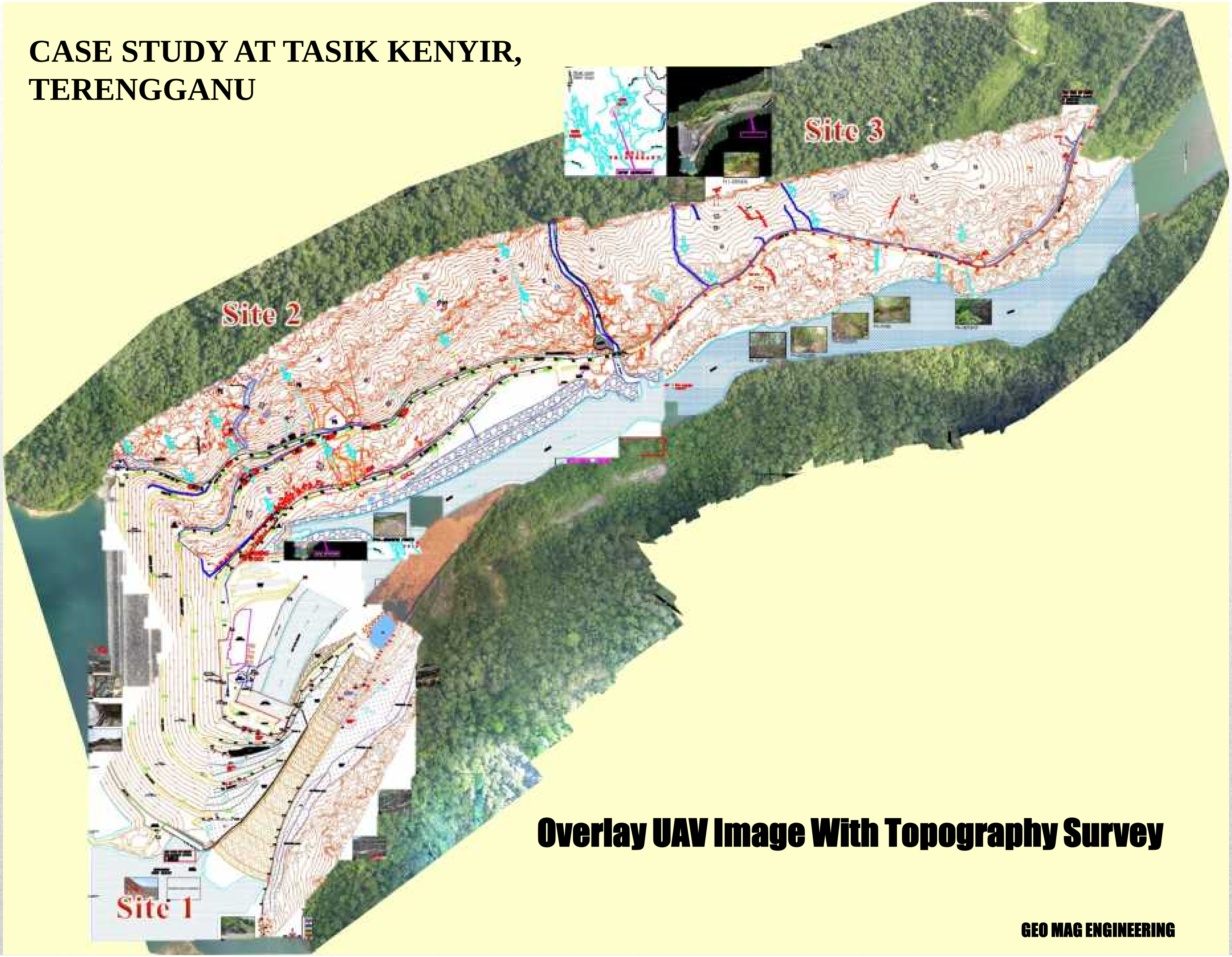
Expected Outcome UAV LIDAR



UAV Lidar image overlay with contour

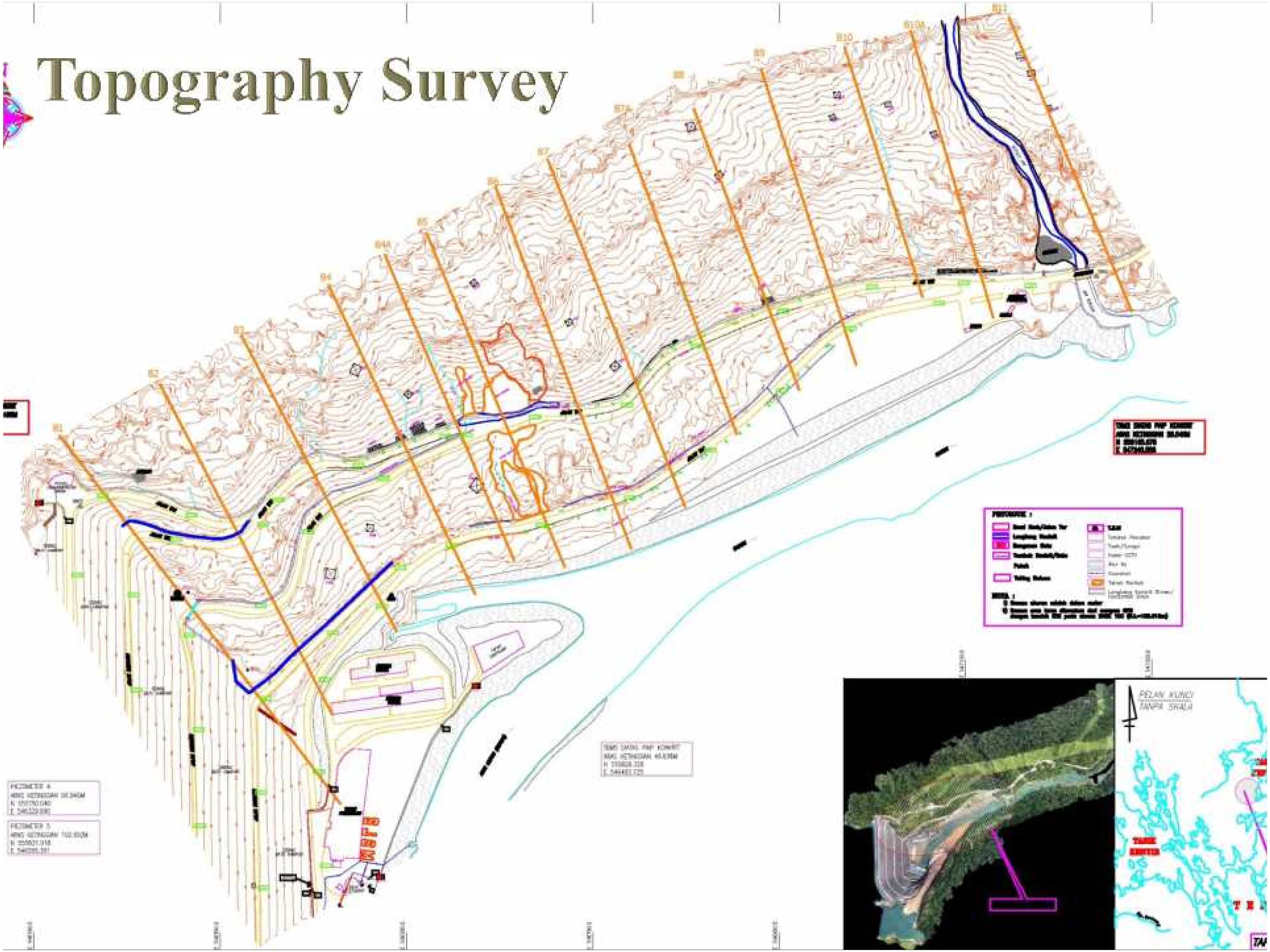
Video …

CASE STUDY AT TASIK KENYIR, TERENGGANU

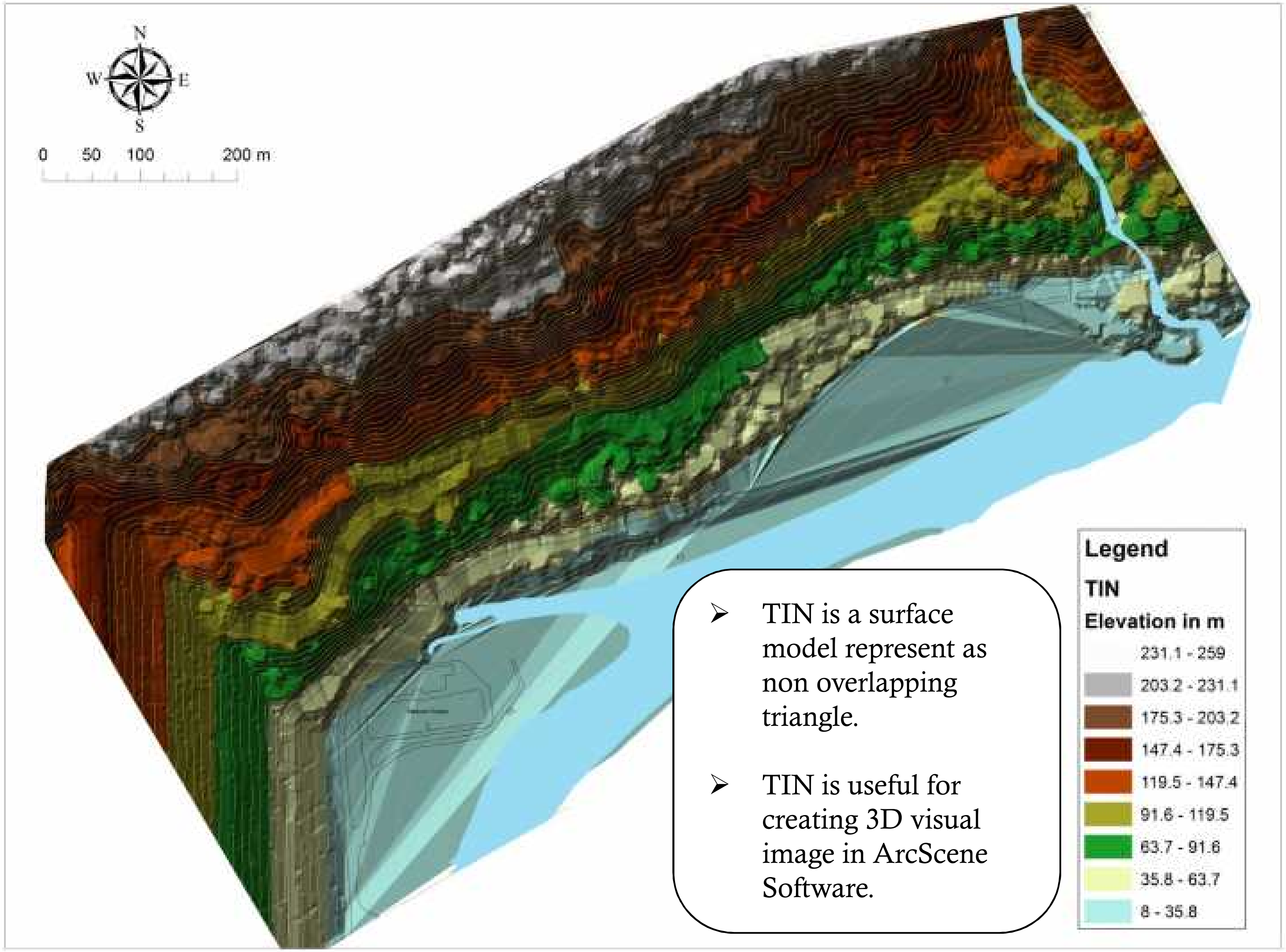


Overlay UAV Image With Topography Survey

Topography Survey

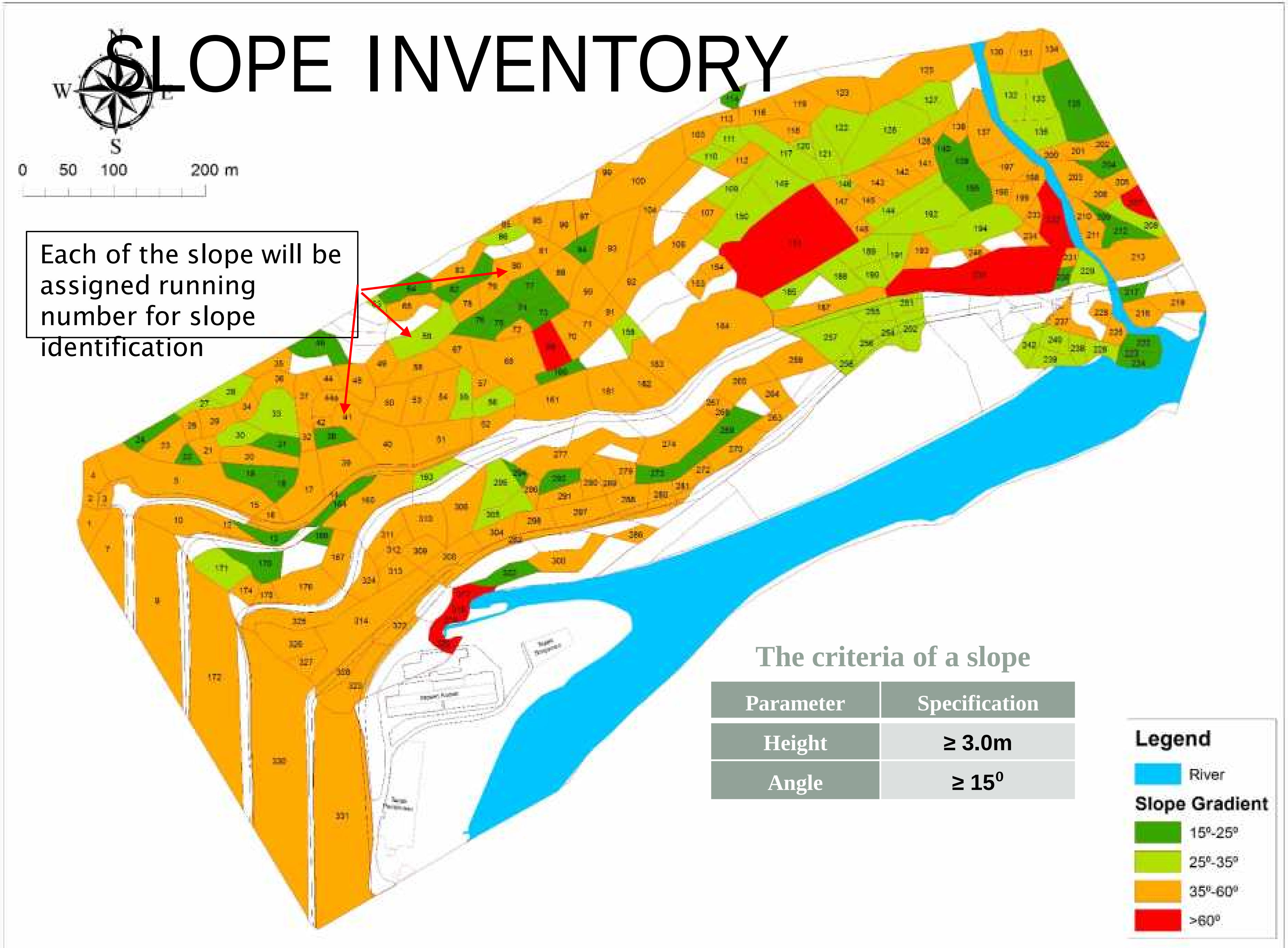


5) Triangulated Irregular Network (TIN)



- TIN is a surface model represent as non overlapping triangle.
- TIN is useful for creating 3D visual image in ArcScene Software.

SLOPE INVENTORY

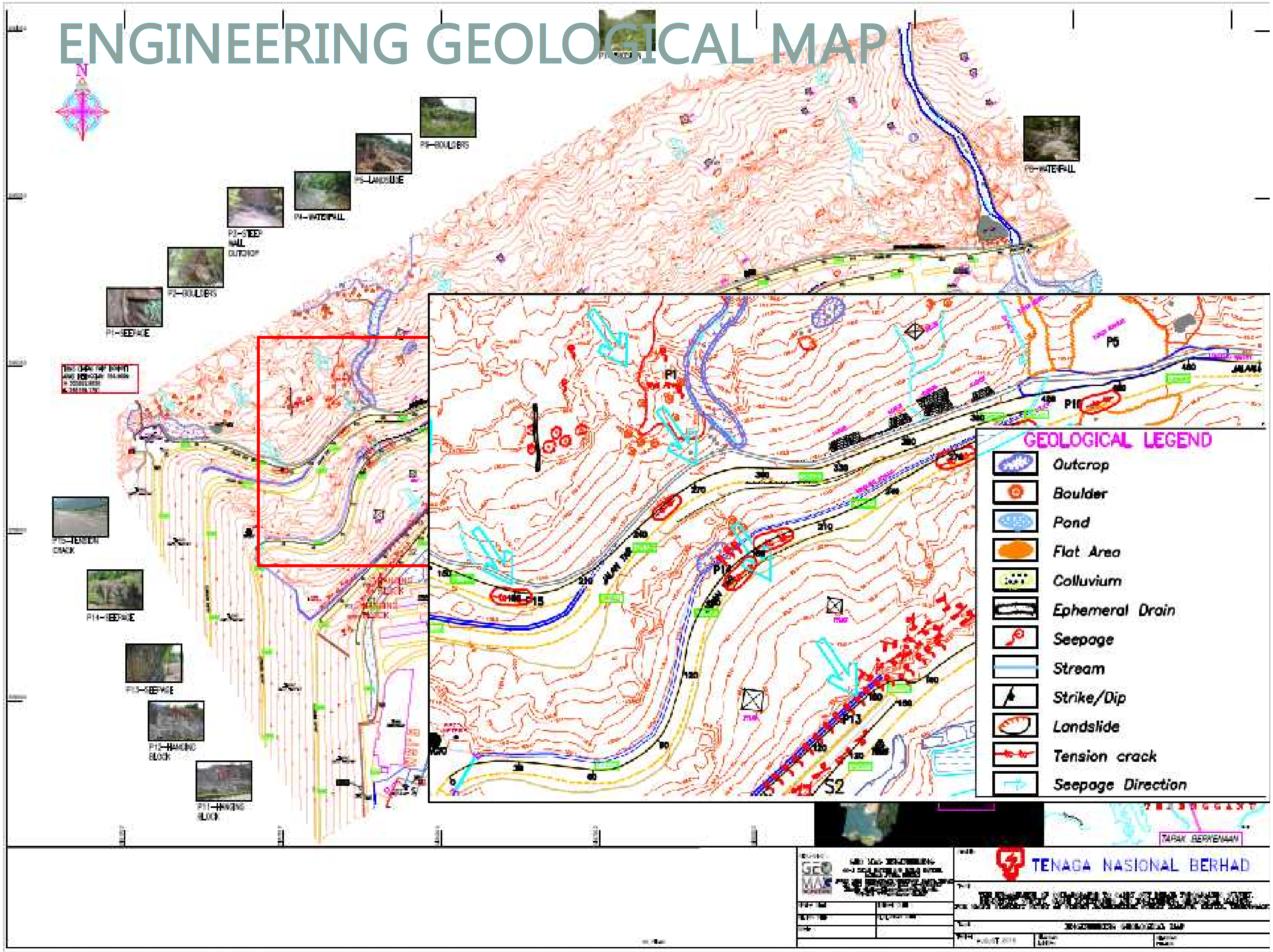


Each of the slope will be assigned running number for slope identification

The criteria of a slope

Parameter	Specification
Height	≥ 3.0m
Angle	≥ 15^0

ENGINEERING GEOLOGICAL MAP



SMR Rating	Class	Color (Alert Type)
81-100	Class I	Blue
61-80	Class II	Green
41-60	Class III	Orange
21-40	Class IV	Purple
0-20	Class V	Red

Terrain Mapping

JMG

SUITABILITY CLASS	SUITABILITY FOR DEVELOPMENT	GEOTECHNICAL LIMITATION
Class I	High	Low
Class II	Moderate	Moderate
Class III	Low	High
Class IV	Probably Unsuitable	Extreme

Hazard Mapping (Methods)

SMR

ROMANA

SAS-B

PWD

INSTABILITY SCORE	HAZARD RATING
2.137 to 2.653	Very High
1.620 to 2.137	High
1.005 to 1.620	Low
0.389 to 1.005	Very Low

LHEF

ANBALAGAN

HAZARD ZONE	RANGE OF CORRECTED TEHD VALUE	DESCRIPTION OF ZONE
I	TEHD <3.5	Very low hazard (VLH)
II	3.5 ≤ TEHD <5.0	Low hazard (LH)
III	5.0 ≤ TEHD <6.5	Moderate hazard (MH)
IV	6.5 ≤ TEHD <8.0	High hazard (HH)
V	TEHD >8.0	Very high hazard (VHH)

Terrain Mapping

This method is used to classify the slope into Class I, Class II, Class III and Class IV

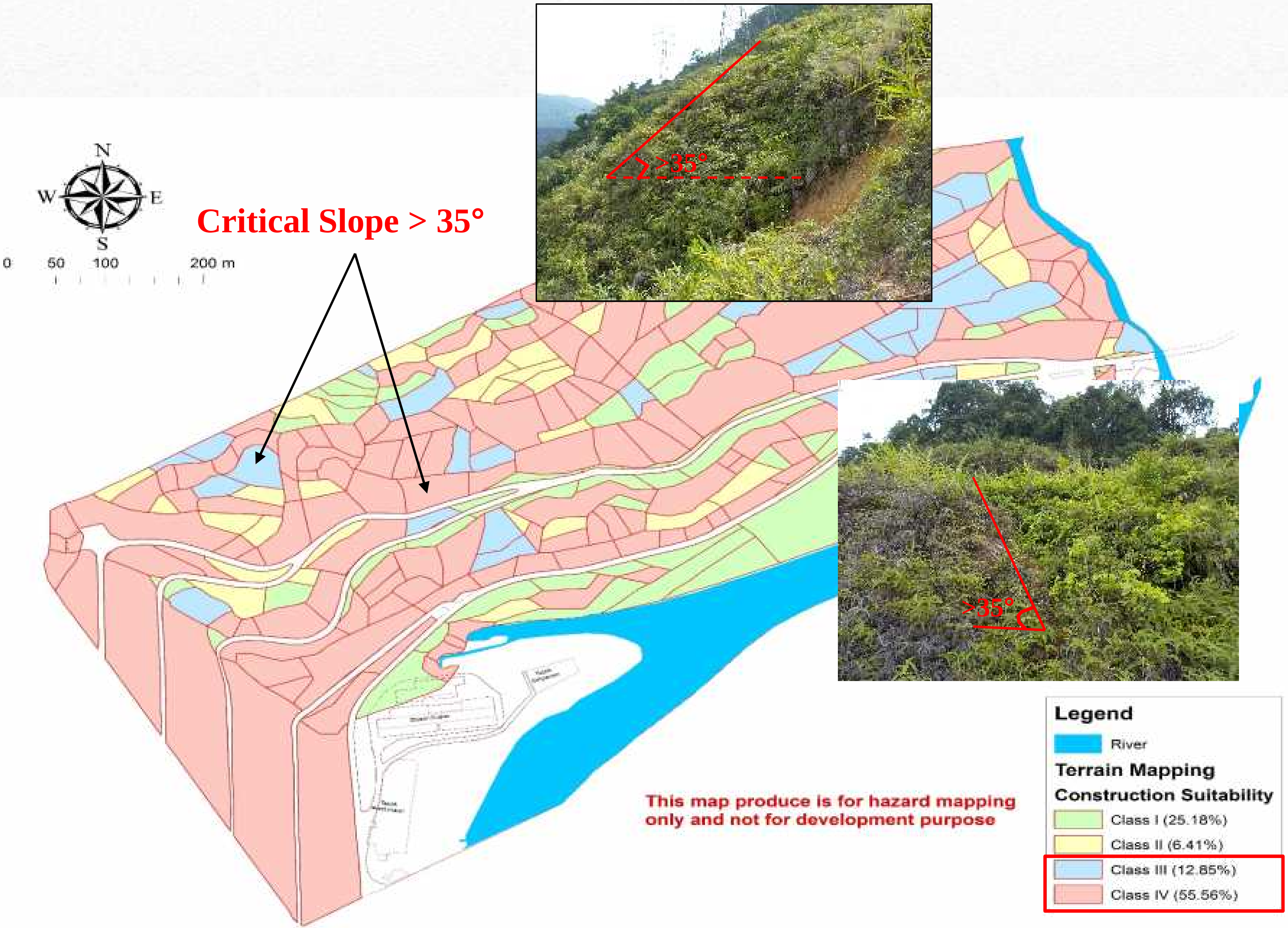
The classification is based on slope attributes:

- Slope gradient
- Terrain component
- Terrain activity
- Erosion and instability

Suitability Class	Suitability for Development	Geotechnical Limitation
Class I	High	Low
Class II	Moderate	Moderate
Class III	Low	High
Class IV	Probably Unsuitable	Extreme

Class III and Class IV are classified as high hazard

Geohazard Map - Terrain Mapping



Slope Assessment System Model B (SAS-B)

This method is used to classify the slope based on hazard rating:

- **Very low**
- **Low**
- **High**
- **Very high**

Site inspection is done in the study area to calculate the instability score for the given parameter

How to calculate the instability score?

Using this formula

$$Y = 0.111(angle) + 0.138(feat\_area) + 0.076(dst\_ridg) - 0.048(slp\_shp) + 0.097(uncover) + 0.102(rexp) + 0.171(bench\_d) + 0.086(hori\_d) + 0.172(erosion) + 0.159$$

Where
angle is slope steepness in degrees
feat_area is the slope location
dst_ridg is the slope distance to crest in metres
slp_shp is the slope shape
uncover is uncover portion of the slope in percentages
rexp is the rock exposure of the slope in percentages
bench_d and **hori_d** is the drainage near the slope
erosion is the presence of erosion process at the slope

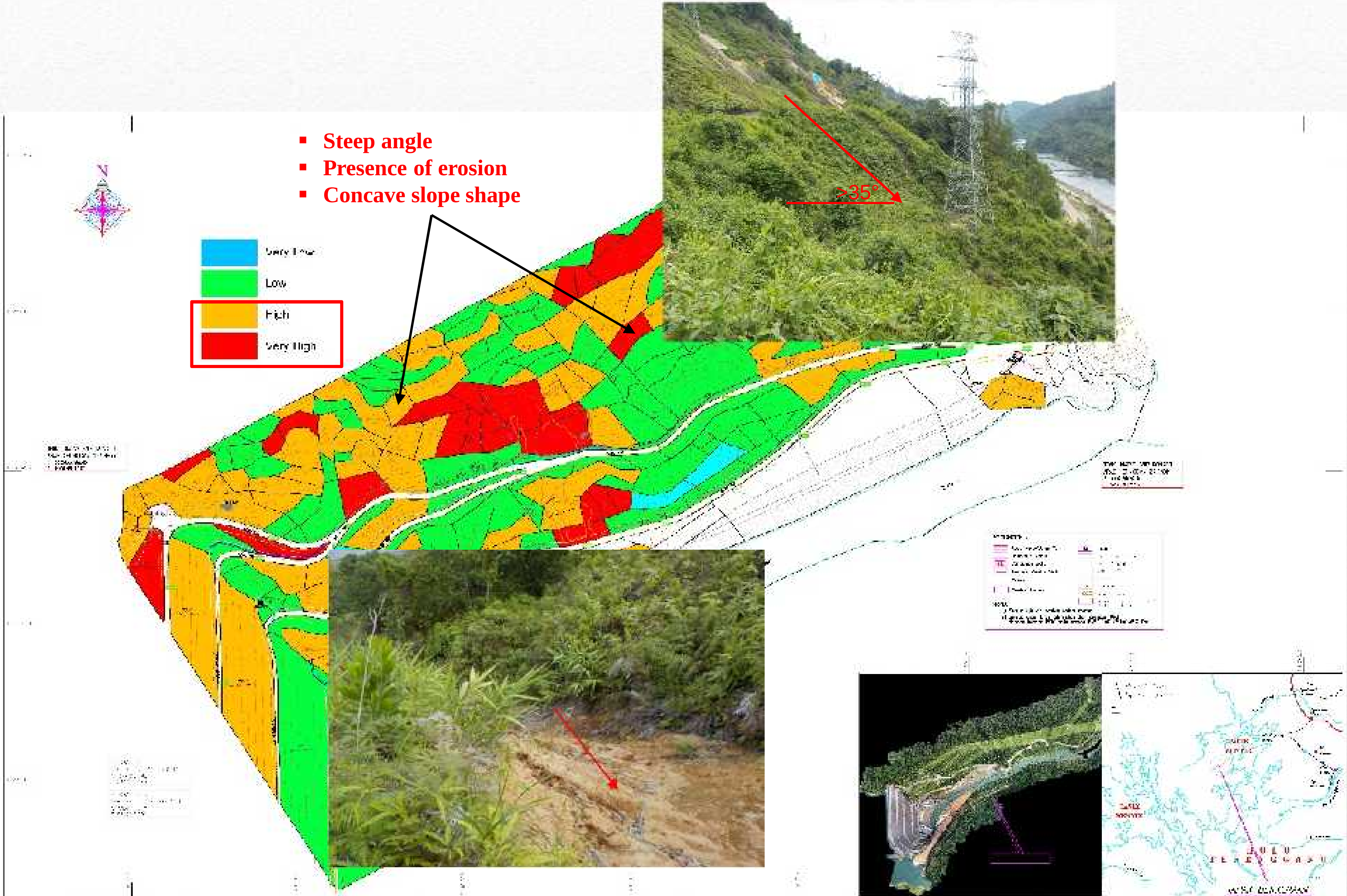
Parameters to inspect at site

INSTABILITY SCORE	HAZARD RATING
2.137 to 2.653	Very High
1.620 to 2.137	High
1.005 to 1.620	Low
0.389 to 1.005	Very Low

Critical slope !

Geohazard Map - SAS-B

- Steep angle
- Presence of erosion
- Concave slope shape



Landslide Hazard Evaluation Factor (LHEF)

To classify the hazard rating into 5 classes:

- **Very low hazard**
- **Low hazard**
- **Moderate hazard**
- **High hazard**
- **Very high hazard**

Site inspection is done in the study area to calculate the total estimated hazard (TEHD) for the given parameter

How to calculate the total estimated hazard?

Using this formula

CALCULATION OF **TOTAL ESTIMATED HAZARD (TEHD)** FROM LHEF RATINGS

TEHD = a + b + c + d + e + f + g + h

Where, a = Rating for lithology
b = Rating for structure
c = Rating for slope morphometry
d = Rating for relative relief
e = Rating for land use and land cover
f = Rating for hydrological factor
g = Correction for external parameters (seismicity and rainfall)
h = Occurrence of slope failure

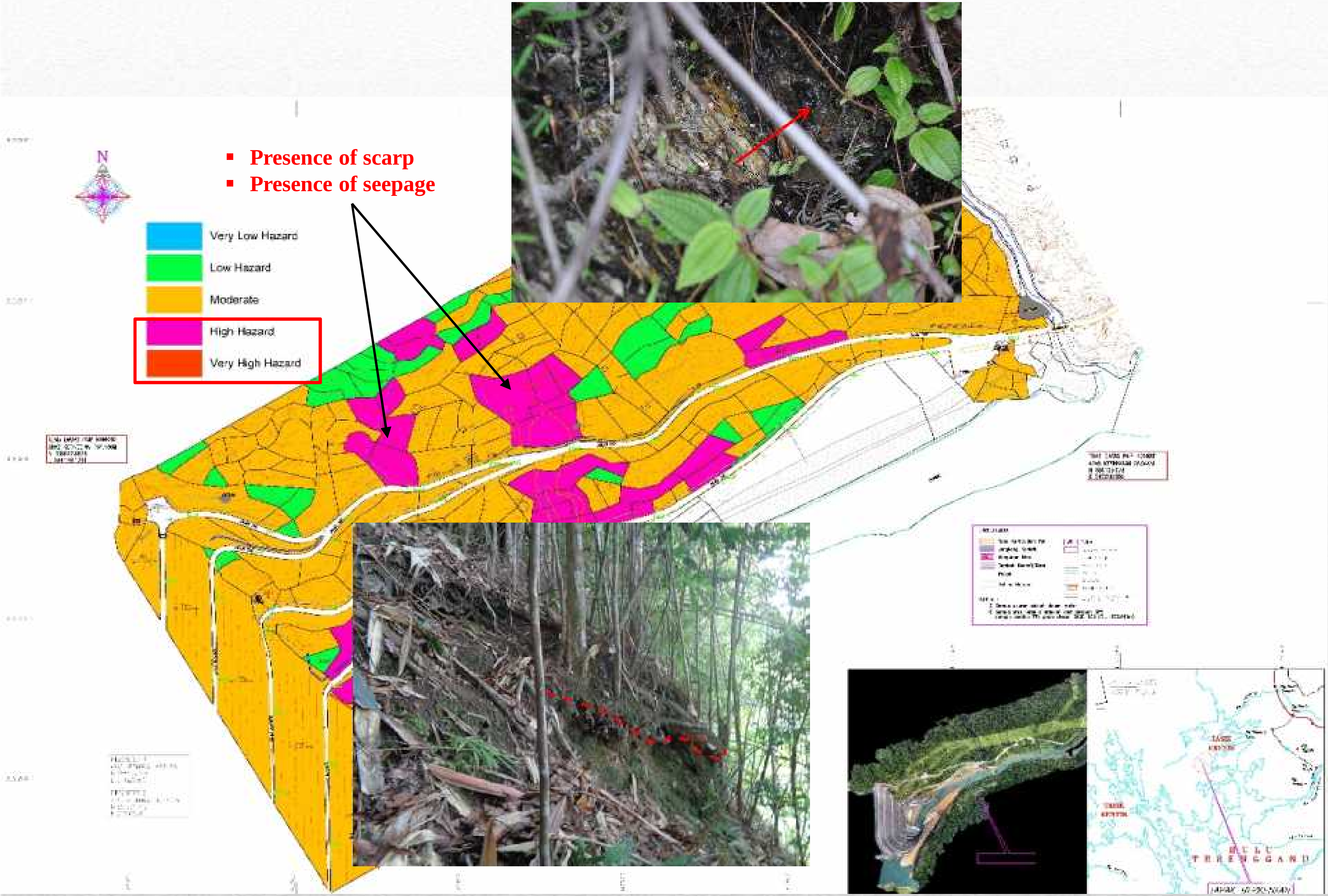
Parameters to inspect at site

Hazard Zone	Range of corrected TEHD value	Description of zone
I	TEHD <3.5	Very low hazard (VLH)
II	3.5 ≤ TEHD <5.0	Low hazard (LH)
III	5.0 ≤ TEHD <6.5	Moderate hazard (MH)
IV	6.5 ≤ TEHD <8.0	High hazard (HH)
V	TEHD >8.0	Very high hazard (VHH)

Critical slope !

Geohazard Map - ANBALAGAN

- **Presence of scarp**
- **Presence of seepage**



Slope Mass Rating (SMR)

This method is to calculate the hazard rating only at rock slope

Geologist is required to obtain the data for

- Strength of intact rock
- Rock Quality Designation
- Water inflow
- Spacing of discontinuity
- Condition of discontinuity
- Orientation of discontinuity

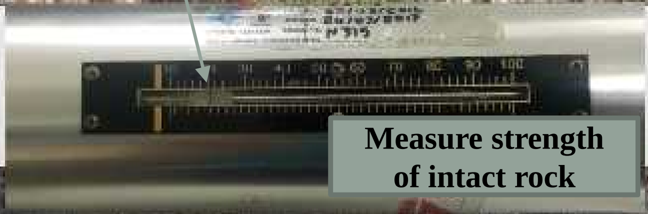
Can be obtained during discontinuity survey

Formula to calculate SMR

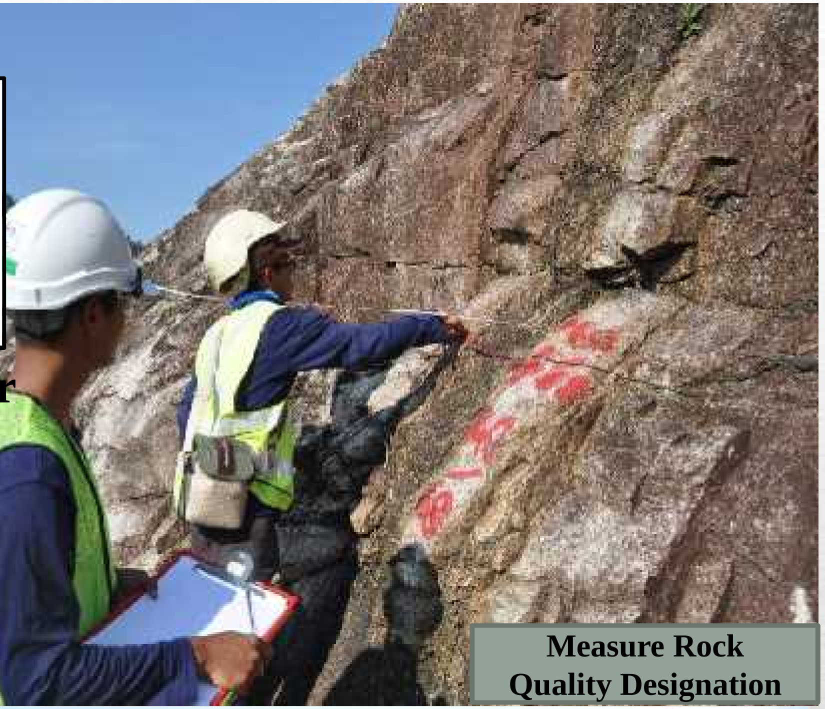
$$\boxed{SMR = RMR_B + (F_1 \times F_2 \times F_3) + F_4}$$

Field Method

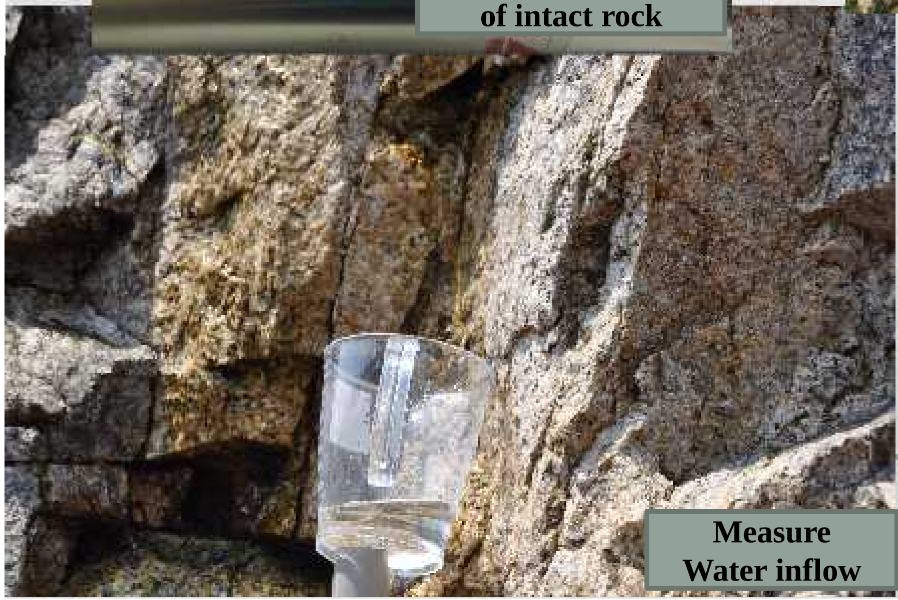
Schmidt hammer



Measure strength of intact rock



Measure Rock Quality Designation



Measure Water inflow

Discontinuity survey

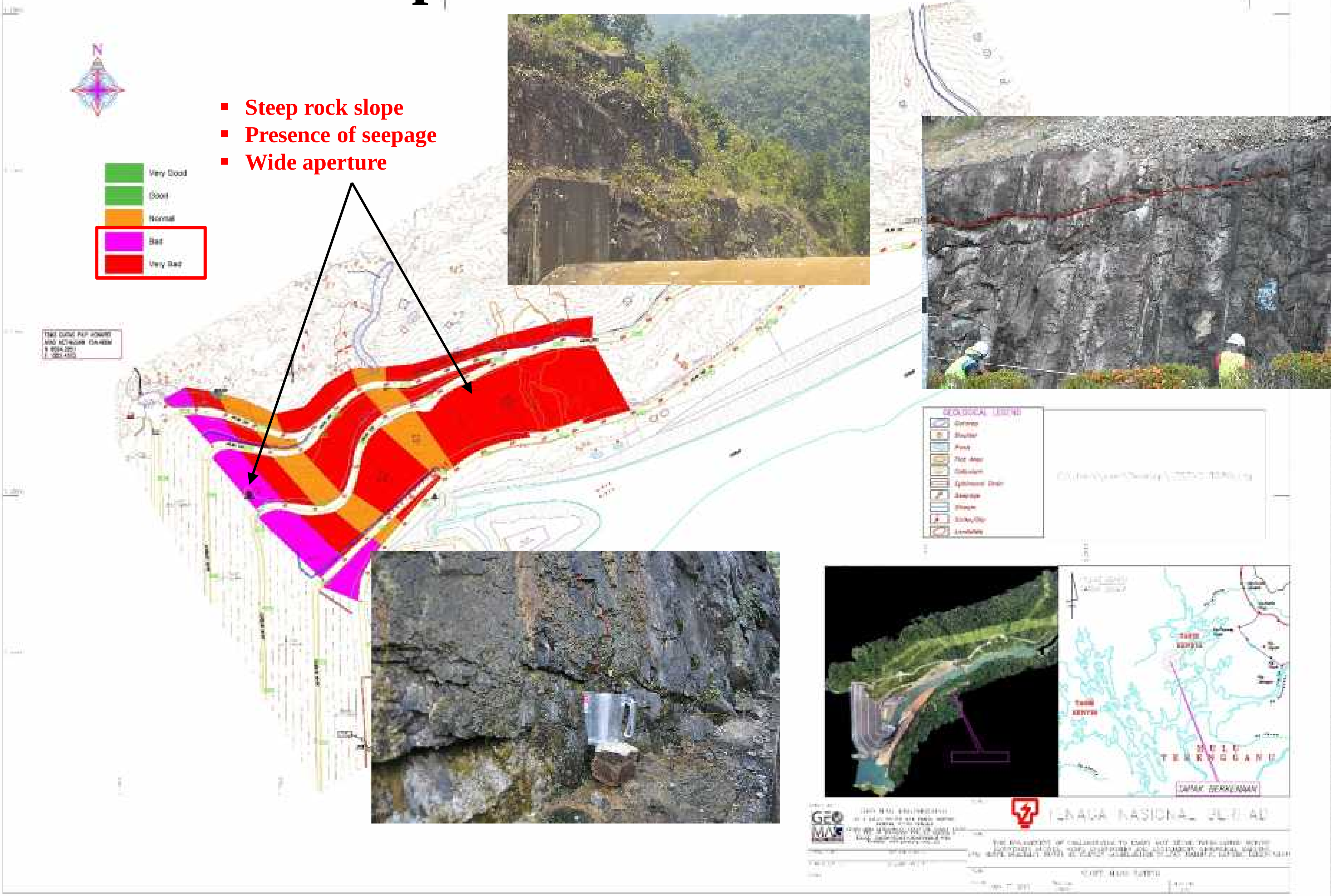
Classification of SMR Rating

SMR Rating	Class	Color (Alert Type)
81-100	Class I	Blue
61-80	Class II	Green
41-60	Class III	Orange
21-40	Class IV	Purple
0-20	Class V	Red

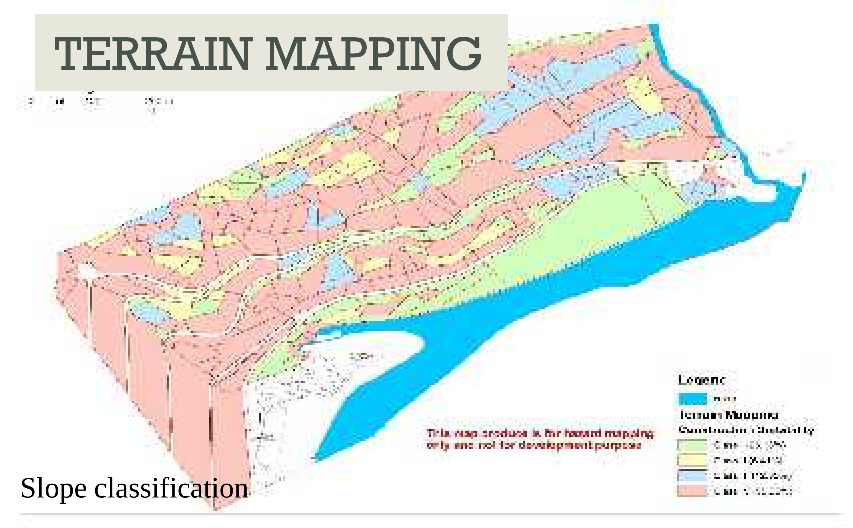
High hazard zone

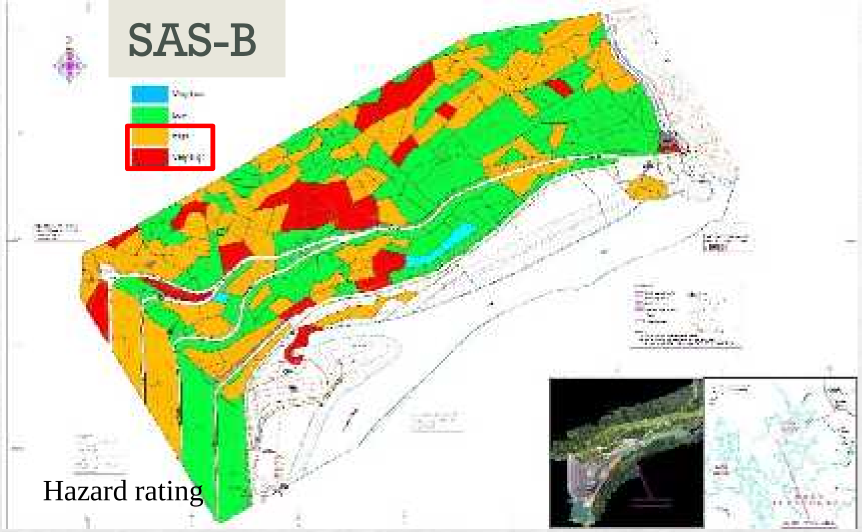
Geohazard Map - SMR

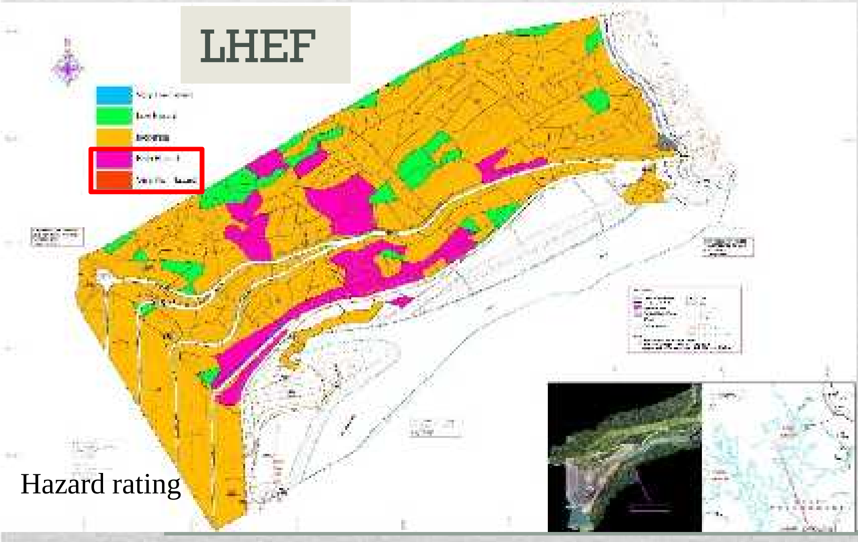
- Steep rock slope
- Presence of seepage
- Wide aperture

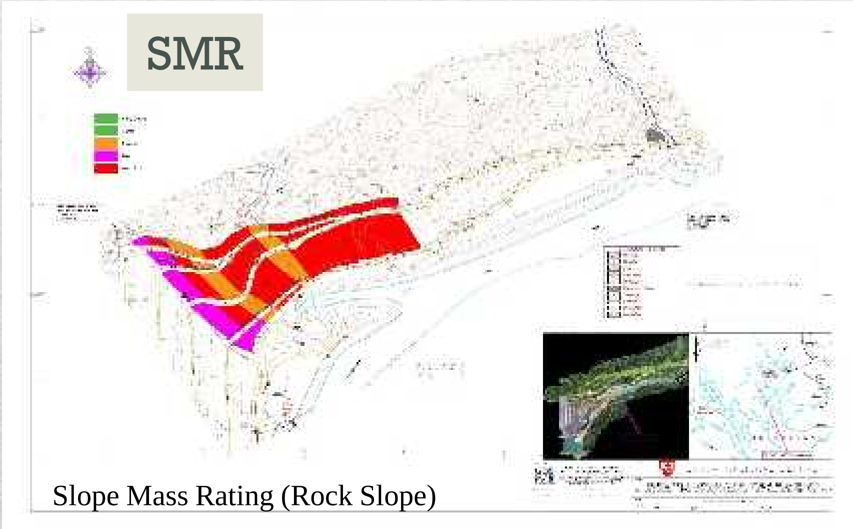


We can overlay these map…

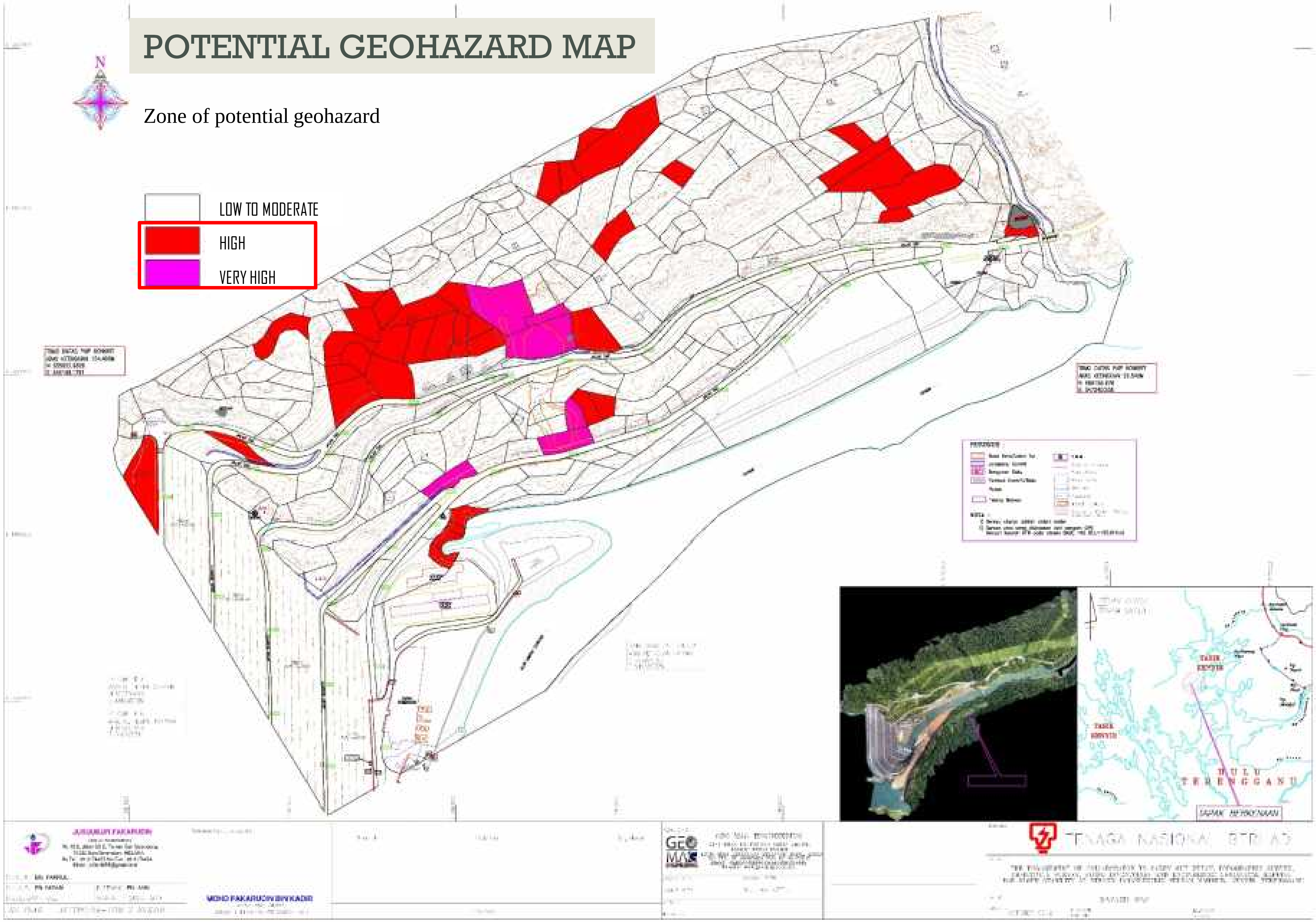








…to produce


POTENTIAL GEOHAZARD MAP
Zone of potential geohazard
N
LOW TO MODERATE
HIGH
VERY HIGH
TENAGA NASIONAL BERHAD
HULU TERENGGANU

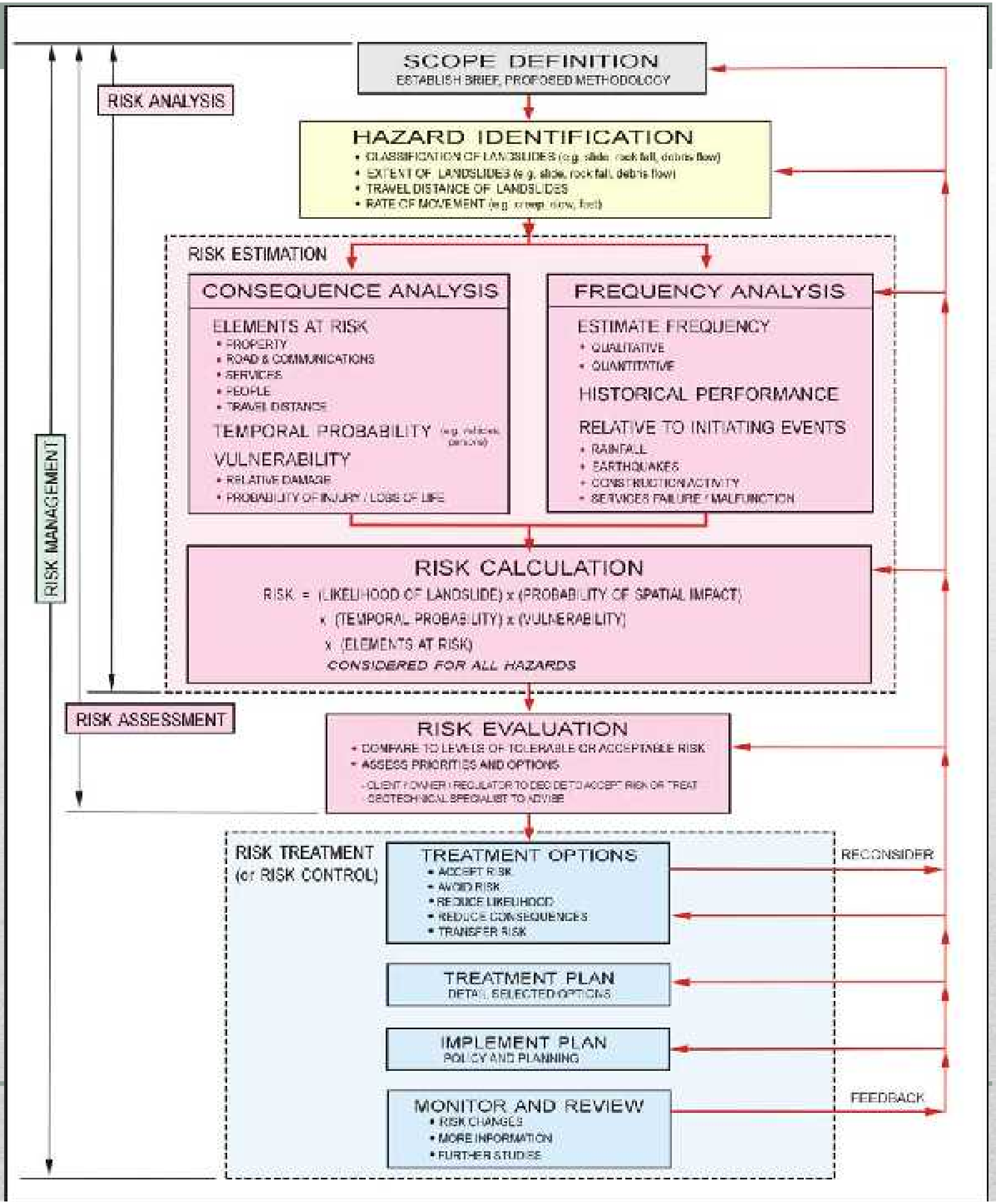
Discussion

Can we forecast?

Can we avoid?

Can we minimize the risk?

Conclusion



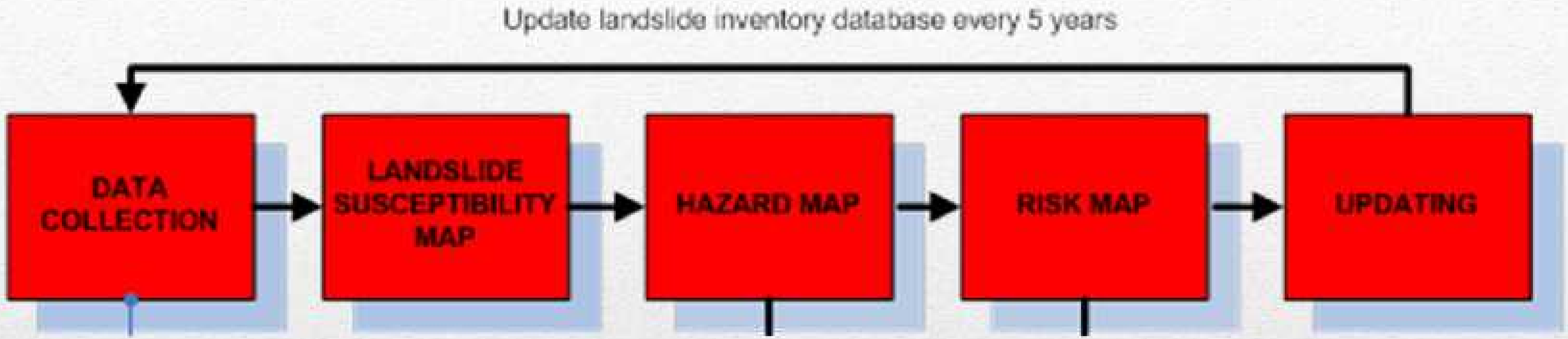
RISK MANAGEMENT
RISK ANALYSIS
RISK ASSESSMENT
SCOPE DEFINITION
ESTABLISH BRIEF, PROPOSED METHODOLOGY
HAZARD IDENTIFICATION
• CLASSIFICATION OF LANDSLIDES (e.g. slide, rock fall, debris flow)
• EXTENT OF LANDSLIDES (e.g. slide, rock fall, debris flow)
• TRAVEL DISTANCE OF LANDSLIDES
• RATE OF MOVEMENT (e.g. creep, slow, fast)
RISK ESTIMATION
CONSEQUENCE ANALYSIS
ELEMENTS AT RISK
• PROPERTY
• ROAD & COMMUNICATIONS
• SERVICES
• PEOPLE
• TRAVEL DISTANCE
TEMPORAL PROBABILITY (e.g. vehicles, persons)
VULNERABILITY
• RELATIVE DAMAGE
• PROBABILITY OF INJURY / LOSS OF LIFE
FREQUENCY ANALYSIS
ESTIMATE FREQUENCY
• QUALITATIVE
• QUANTITATIVE
HISTORICAL PERFORMANCE
RELATIVE TO INITIATING EVENTS
• RAINFALL
• EARTHQUAKES
• CONSTRUCTION ACTIVITY
• SERVICES FAILURE / MALFUNCTION
RISK CALCULATION
RISK = (LIKELIHOOD OF LANDSLIDE) x (PROBABILITY OF SPATIAL IMPACT)
x (TEMPORAL PROBABILITY) x (VULNERABILITY)
x (ELEMENTS AT RISK)
CONSIDERED FOR ALL HAZARDS
RISK EVALUATION
• COMPARE TO LEVELS OF TOLERABLE OR ACCEPTABLE RISK
• ASSESS PRIORITIES AND OPTIONS
- CLIENT / OWNER / REGULATOR TO DECIDE TO ACCEPT RISK OR TREAT
- GEOTECHNICAL SPECIALIST TO ADVISE
RISK TREATMENT (or RISK CONTROL)
TREATMENT OPTIONS
• ACCEPT RISK
• AVOID RISK
• REDUCE LIKELIHOOD
• REDUCE CONSEQUENCES
• TRANSFER RISK
TREATMENT PLAN
DETAIL SELECTED OPTIONS
IMPLEMENT PLAN
POLICY AND PLANNING
MONITOR AND REVIEW
• RISK CHANGES
• MORE INFORMATION
• FURTHER STUDIES
RECONSIDER
FEEDBACK

Risk analysis involves acquiring knowledge of the slope stability hazards, as well as consideration of the consequences of land sliding if person and/or property are impacted by failure

The assessment of landslide hazard and risk requires input from a number of disciplines and areas of knowledge such as geosciences, hydrogeology, geotechnical engineering, geomorphology, and meteorology and communications technology.

Understanding geological processes and the development of landforms is always very valuable. Basic controlling factors for slope stability must be recognised, identified and, where feasible, quantified.

Recommendation



→ Historical data

→ Ground Survey

→ Aerial survey


THANK YOU FOR
YOUR ATTENTION


THANK
YOU!