



PLUS BERHAD

OBSERVATIONS AND ANALYSIS ON RAINFALL INDUCED SLOPE FAILURES FOR JELAPANG AND GUA TEMPURUNG AREA USING G.I.S.

MAY 2015

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Objectives of Research:

- Understand the trend of slope failures
- Understand the catchment properties
- Rainfall threshold of slope failures for the areas



INTRODUCTION PLUS

PLUS



A member of UEM 

Rest and Service Areas (RSA)



Overhead Bridge Restaurants (OBR)



- Backbone of Malaysian road transport system:
 - ❖ Connects major industrial, commercial & transportation centers
 - ❖ Links major seaports and airports
- States serviced by the NSE make up 81% of population and 89% of GDP in Peninsular Malaysia

		Length
PLUS	North-South Expressway	846 km
ELITE	NSE Central Link	63 km
LINKEDUA	Malaysia-Singapore Second Crossing	47 km
BKE	Butterworth-Kulim Expresssway	17 km
PB	Penang Bridge	13.5km
		986.5 km



PLUS - Assets



Maintenance Management



Pavement

4291 lane-km



Slope

> 5,000 slopes



Drainage

> 4,000 culverts



Bridge

483 bridges



Tunnel

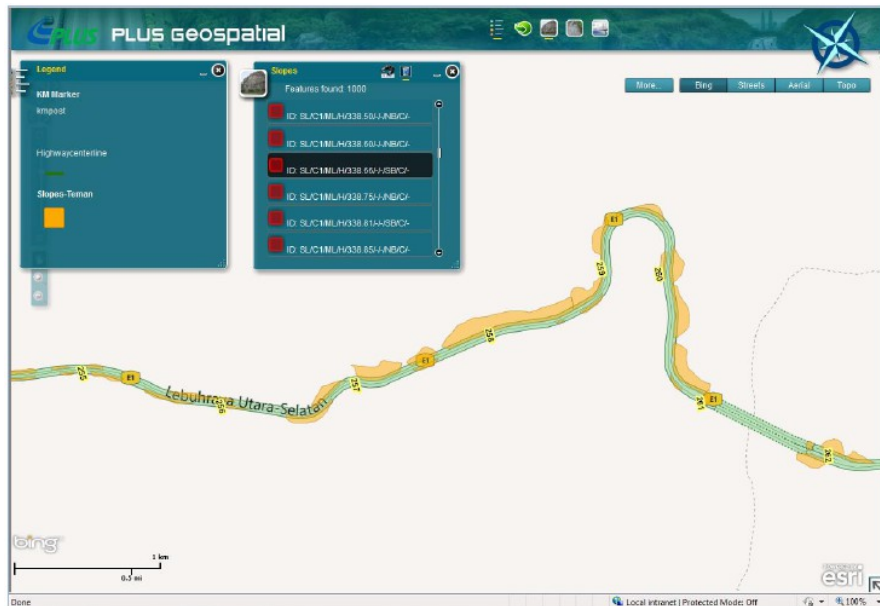
**2 tunnels
(861m & 832m)**



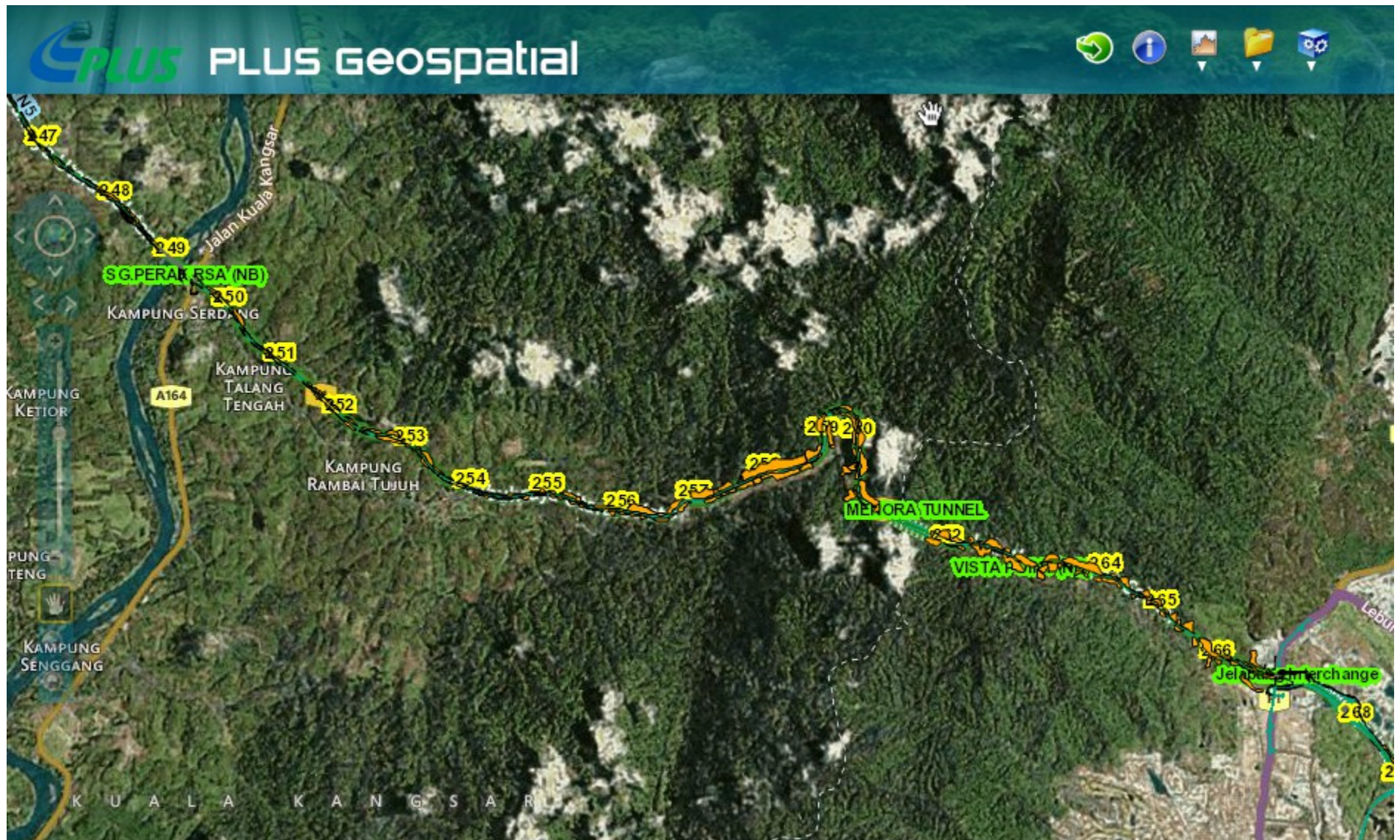
STUDY AREAS: JELAPANG & GUA TEMPURUNG

WHY?

- Back-bone of PLUS
- Small maintenance corridor
- Impact of failure from outside
- Debris flow (2004)



JELAPANG AREA – MAP LAYOUT



JELAPANG AREA – AERIAL PHOTOGRAPH



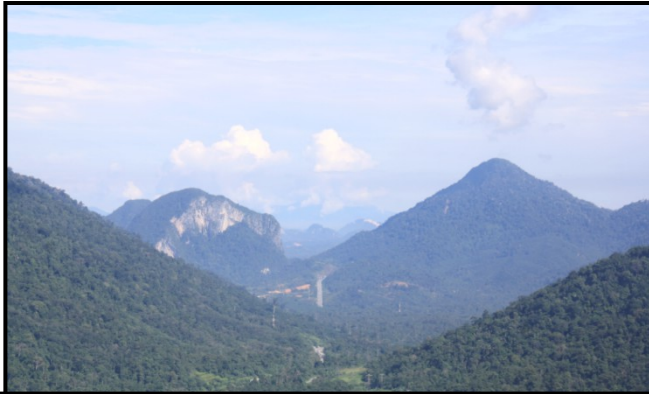
- Mountainous area
- Granitic Formation (part of Kledang Range)
- High cut rock slopes (shallow regolith)



GUA TEMPURUNG AREA – MAP LAYOUT



GUA TEMPURUNG AREA – AERIAL PHOTOGRAPH



- Boundary between Granitic Formation (north-east) and lime stone formation (south-west)
- High cut soil slopes (deep regolith)





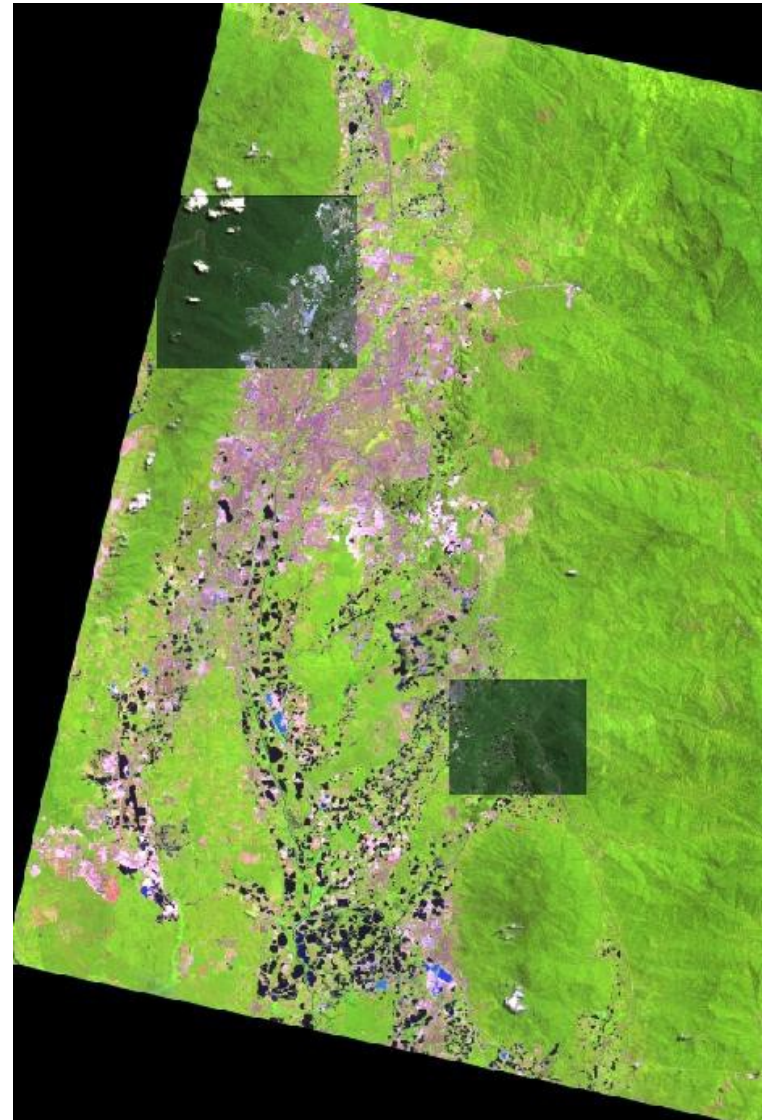
GIS ANALYSIS

- The Trends

Data obtained

- IFSAR data (Inter-ferometric Synthetic Aperture Radar)
- Worldview 2 / Quickbird
- LIDAR

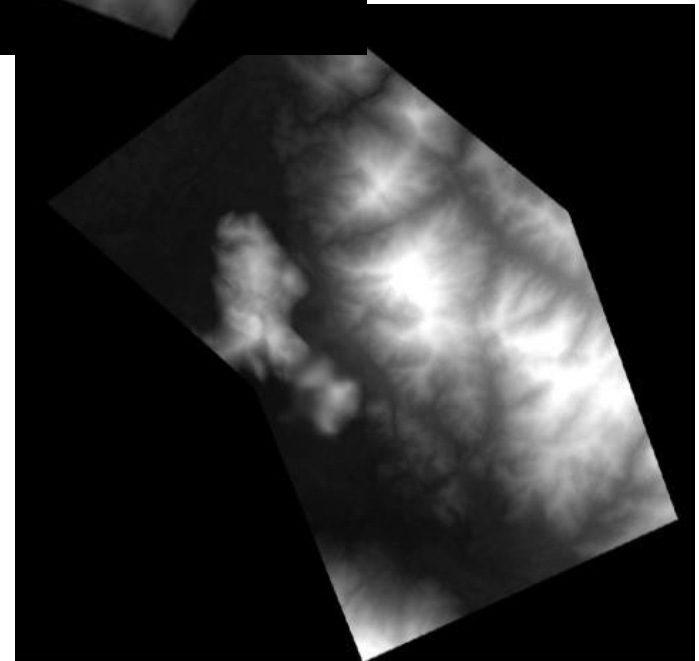
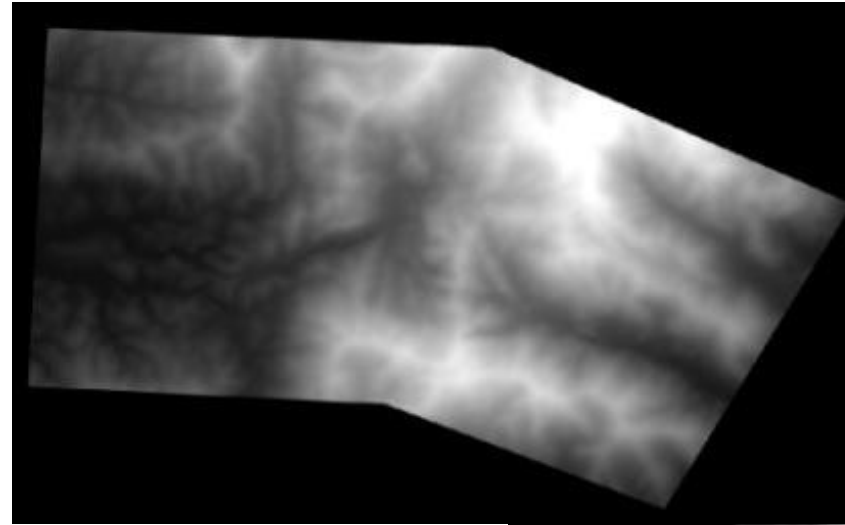
Slope failure records



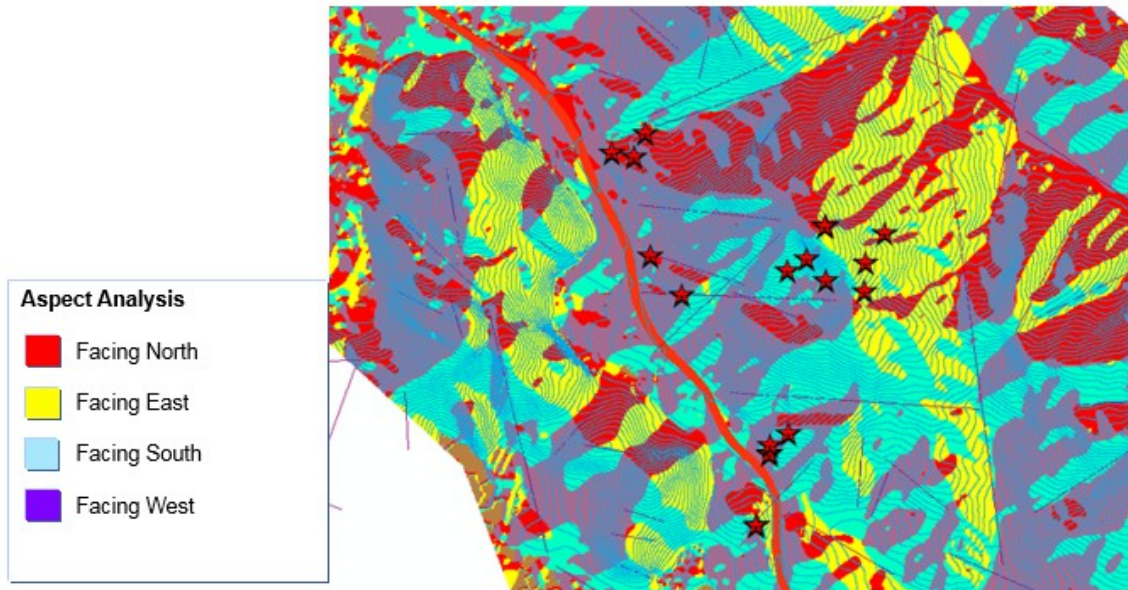
Methodology

- **DSM and DTM**
- **GIS Analysis**
 - **Aspects**
 - **Slope / Inclination**
 - **Curvature**
 - **Hydrology**
 - **Elevation**

(against records of slope failures)

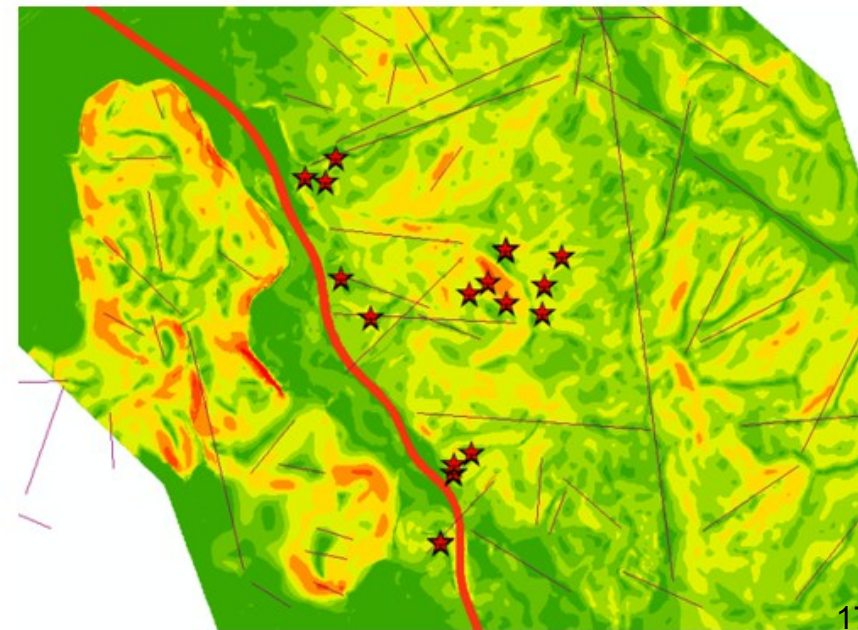
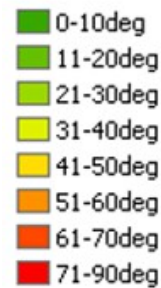


GIS ANALYSIS – GUA TEMPURUNG

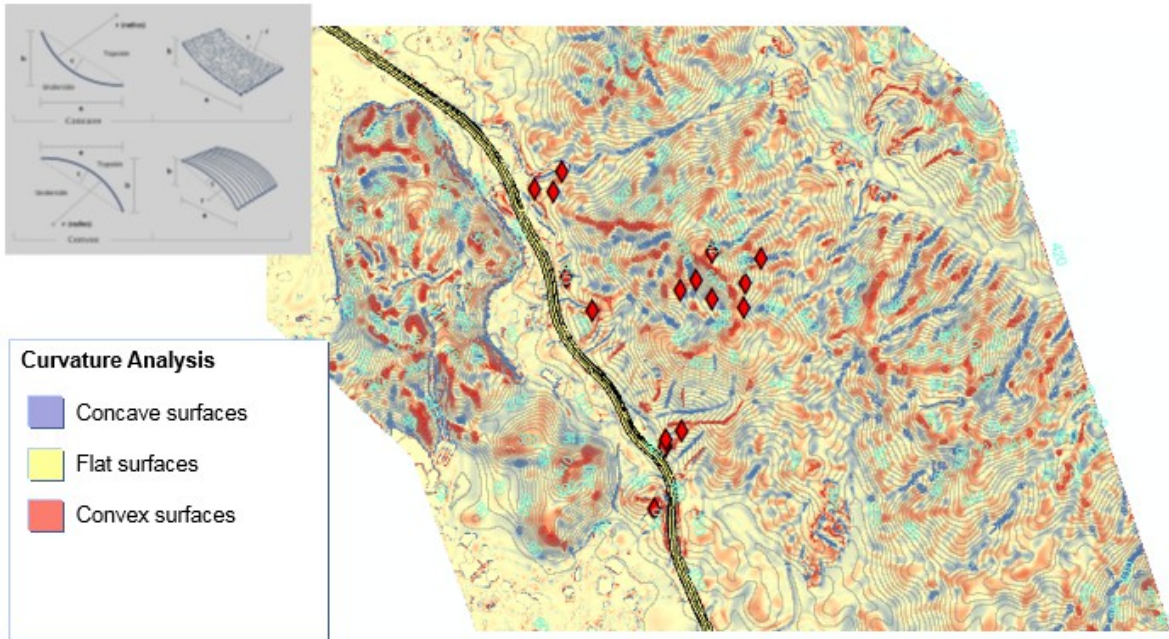


Slope aspect

Slope angle / surface inclination

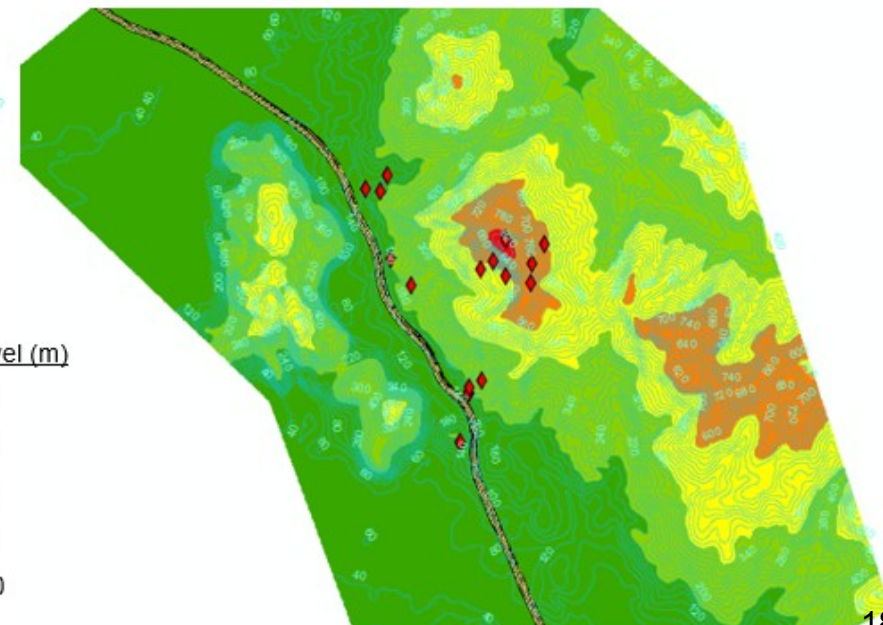


GIS ANALYSIS – GUA TEMPURUNG



Surface curvature

Surface elevation



FREQUENCY RATIO

$$\text{Frequency Ratio} = \frac{\text{No. of failures in Class} / \text{Total No. of failures}}{\text{Area of Class} / \text{Entire Map}}$$

Slope Aspects	Jelapang			Gua Tempurung		
	No of failures	%	Frequency Ratio	No of failures	%	Frequency Ratio
Flat		0.00	0.00		0.00	0.00
North	9	34.62	1.76	5	26.32	1.13
East	5	19.23	0.91	3	15.79	0.86
South	10	38.46	1.19	4	21.05	0.85
West	2	7.69	0.29	7	36.84	1.13
	26	100.00	1.00	19	100.00	1.00

FREQUENCY RATIO

Slope Angle	Jelapang			Gua Tempurung		
	No of failures	%	Frequency Ratio	No of failures	%	Frequency Ratio
0 – 10		0.00	0.00		0.00	0.00
11 – 20		0.00	0.00		0.00	0.00
21 – 30	3	11.54	0.30	3	15.79	0.89
31 – 40	20	76.92	6.29	10	52.63	2.15
41 – 50	3	11.54	14.78	4	21.05	1.35
51 - 70		0.00	0.00	2	10.53	1.60
Total	26	100.00	1.00	19	100.00	1.00

Angle of repose
(earth: 30° - 45°)



Slope Elevation	Jelapang			Gua Tempurung		
	No of failures	%	Frequency Ratio	No of failures	%	Frequency Ratio
600 – 1000		0.00	0.00	6	31.58	5.91
400 - 600	2	7.69	0.28	2	10.53	0.65
200 - 400	23	88.46	2.75	2	10.53	0.38
0 - 200	1	3.85	0.13	9	47.37	0.93
	26	100.00	1.00	19	100.00	1.00



REAL TIME MONITORING SYSTEM (RTMS)

RTMS – CONCEPTUAL LAYOUT

Equipment Installed

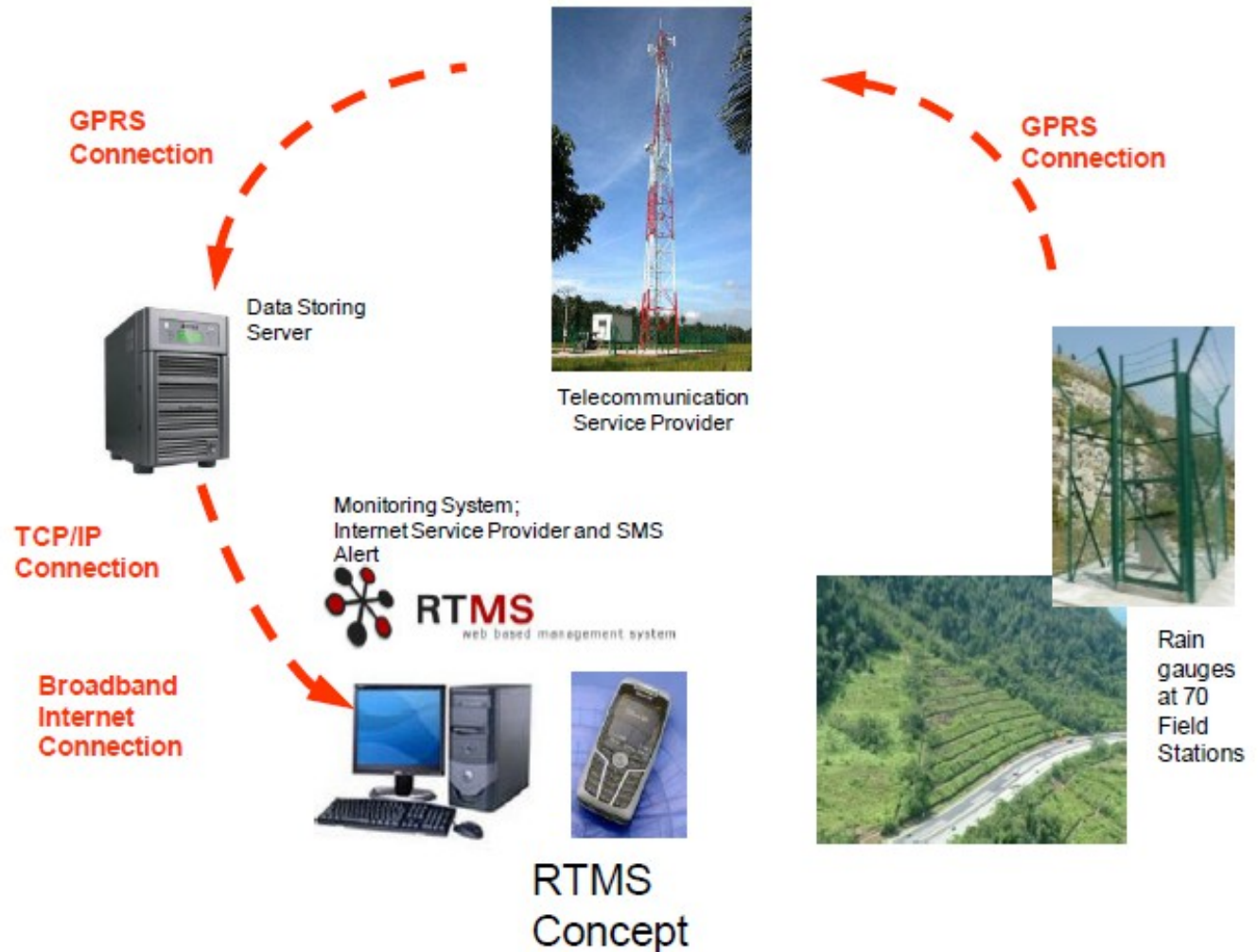
- Server System (HQ)

Slope monitoring

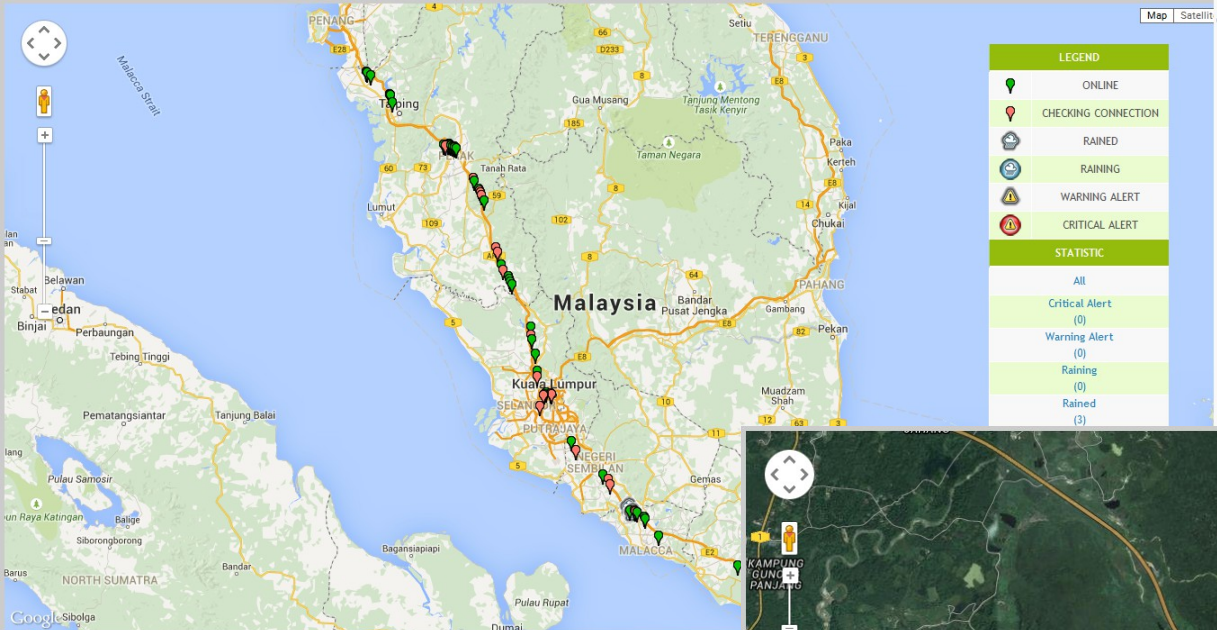
- RG stations (70)
- PM stations (12)

Flood monitoring

- RG stations (3)
- PM stations (5)



RTMS – USER INTERFACE

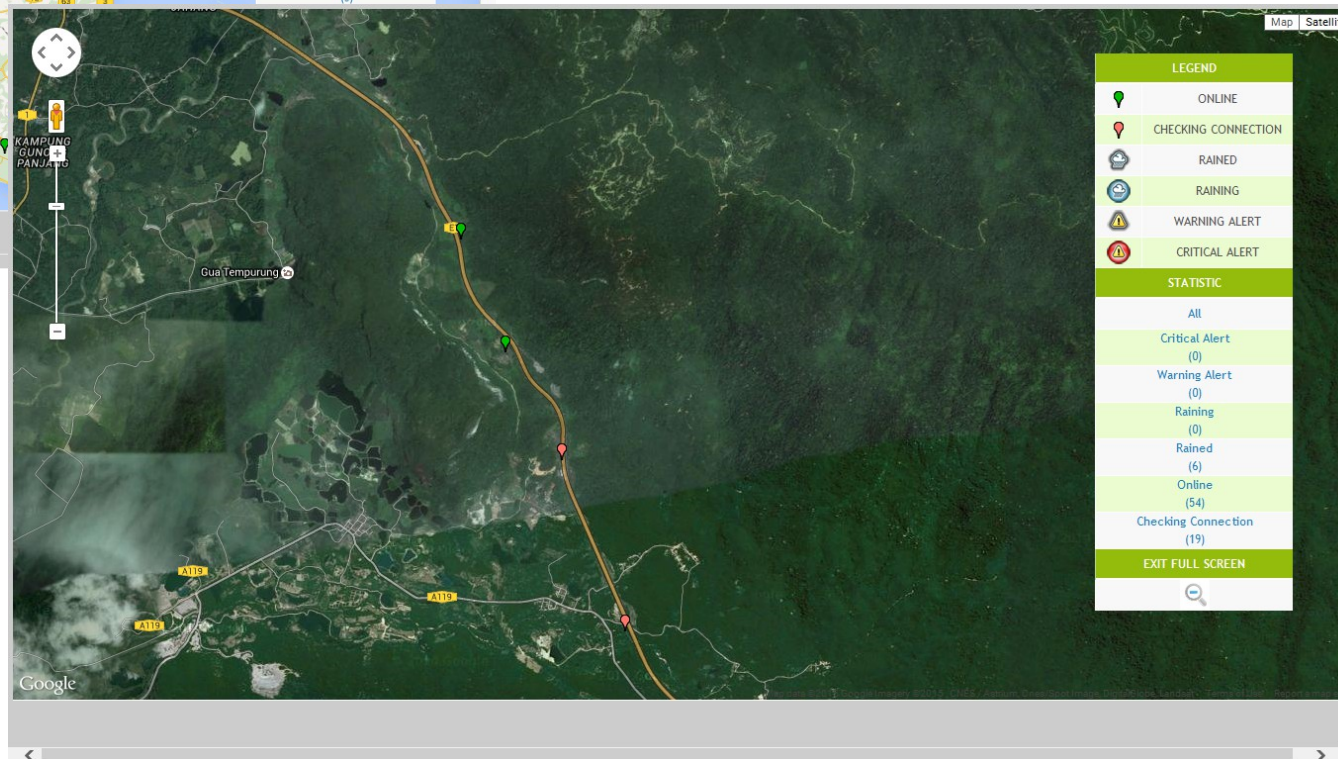


Study area –
Gua Tempurung

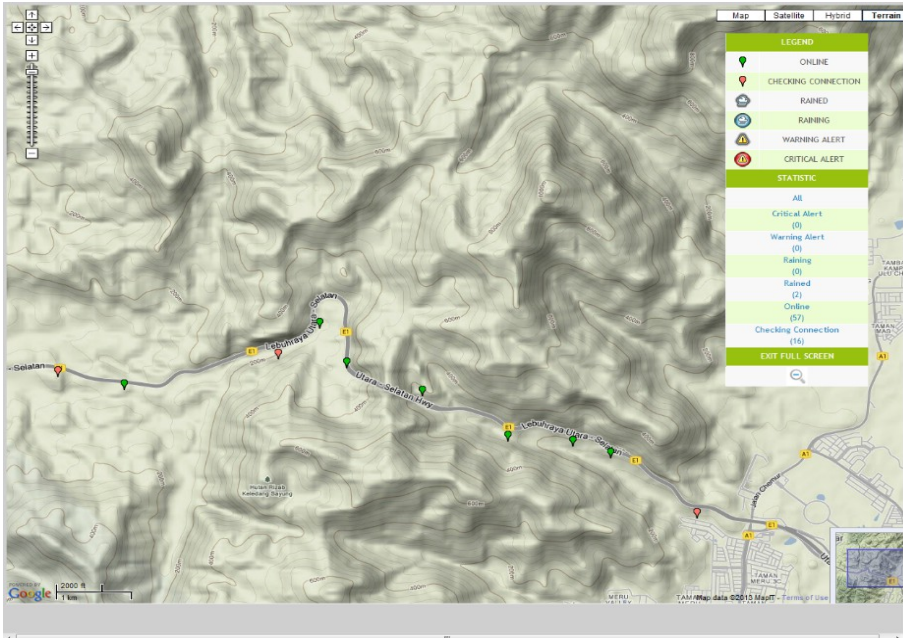
Overall map – NSE

User Interface

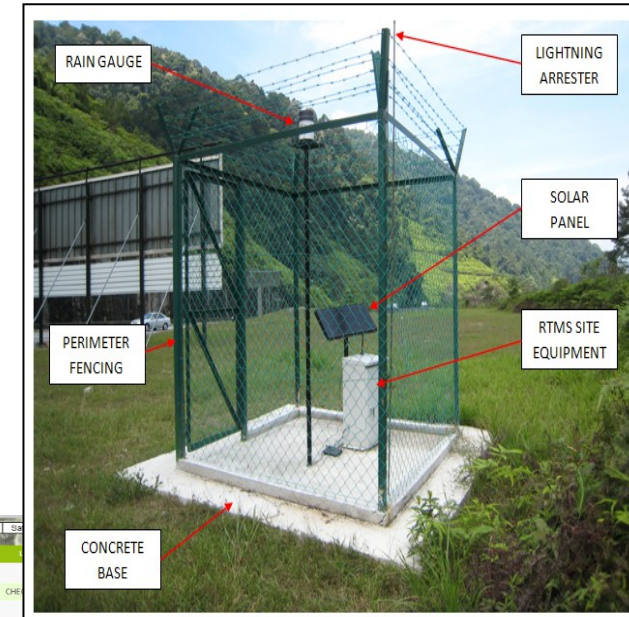
- Intranet
- Internet



RTMS – RAIN GAUGE STATIONS FOR STUDY AREAS



JELAPANG – 10 nos



Typical site layout



GUA TEMPURUNG – 5 nos



CASE STUDY & OBSERVATIONS

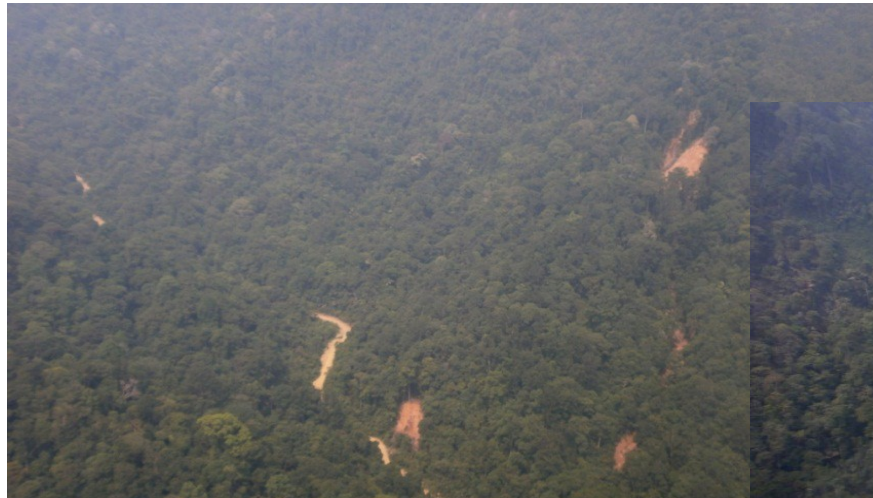
CASE STUDY – GUA TEMPURUNG AREA

Slope failure at Gua Tempurung area.

Seven (7) new failures scars beyond ROW observed during aerial inspection dated 18 June 2012

- The slope failures occurred at steep natural slope (estimated gradient more than 35°)
- Shallow surface failures (estimated between 2 to 3 m deep and wide between 10m to 20m – failures occurs within the root zone of the hill-side slopes)
- The residual soil for the upper region of the natural hill slopes is shallow, between 1m to 3m depth (observed via helicopter visual survey)
- The exposed soil ranges from yellow to reddish soil (normal for granitic residual soil)

CASE STUDY – GUA TEMPURUNG AREA (MULTIPLE SLOPE FAILURES)



2012

2012/06/19

Haversine
formula:

$$a = \sin^2(\Delta\phi/2) + \cos(\phi_1) \cdot \cos(\phi_2) \cdot \sin^2(\Delta\lambda/2)$$

$$c = 2 \cdot \text{atan2}(\sqrt{a}, \sqrt{1-a})$$

$$d = R \cdot c$$

Where

ϕ is latitude, λ is longitude, R is earth's radius
(mean radius = 6,371km)

Failure No.	Latitude	Longitude	RGC1-3 (m)	RGC1-4 (m)	RGC1-5 (m)	RGC1-6 (m)
1	4°24'23.57"	101°12'40.50"	1,845.0	732.9	567.9	2,288.0
2	4°24'26.20"	101°12'44.47"	1,848.0	787.6	665.1	2,339.1
3	4°24'57.74"	101°12'20.89"	633.4	588.2	1,723.0	3,477.0
4	4°25'06.66"	101°12'13.93"	284.4	899.2	2,058.0	3,811.0
5	4°25'30.12"	101°12'05.57"	510.1	1,668.0	2,826.0	4,579.0
6	4°25'34.52"	101°12'12.84"	656.4	1,747.0	2,880.0	4,632.0
7	4°25'29.14"	101°12'10.36"	478.9	1,577.0	2,746.0	4,499.0

CASE STUDY – GUA TEMPURUNG AREA (RAINFALL ANALYSIS)



Monthly rainfall data – Gua Tempurung

LOCATIONS	RG	2012						
		Jan	Feb	Mar	Apr	May	Jun	Jul
KM302.20SB - G. TEMPURUNG	RGC1-3	131.8	182.4	87.2	333.8	76.8	14.2	10.2
KM303.25NB - G. TEMPURUNG	RGC1-4	155.8	310.8	292.4	573.8	134.8	20.4	117.0
KM304.69SB - G. TEMPURUNG	RGC1-5	114.6	291.8	260.4	422.6	137.2	22.6	108.8
KM306.35NB - G. TEMPURUNG	RGC1-6	113.0	258.2	287.0	429.6	111.2	22.2	130.4

Daily rainfall data – Gua Tempurung

Location	Device	Year 2012							
		06-Apr	07-Apr	08-Apr	09-Apr	10-Apr	11-Apr	12-Apr	13-Apr
KM302.20SB - G. TEMPURUNG	RGC1-3	38.6	11.4	0.6	6.8	0.6	26.6	65.8	0.0
KM303.25NB - G. TEMPURUNG	RGC1-4	77.4	13.4	15.2	5.4	0.6	20.0	214.0	37.8
KM304.69SB - G. TEMPURUNG	RGC1-5	48.2	7.0	24.2	6.2	3.6	16.0	97.0	38.4
KM306.35NB - G. TEMPURUNG	RGC1-6	30.8	21.2	13.4	12.8	19.8	14.2	73.6	33.6
		195.0	53.0	53.4	31.2	24.6	76.8	450.4	109.8
Average		48.75	13.25	13.35	7.80	6.15	19.20	112.60	27.45

Area	Highest rainfall recorded (mm/hour)
Jelapang area	56.2 mm/hour
Gua Tempurung area (7 nos. of slope failures)	61.6 mm/hour

Hourly rainfall data – Gua Tempurung

• 1st cycle

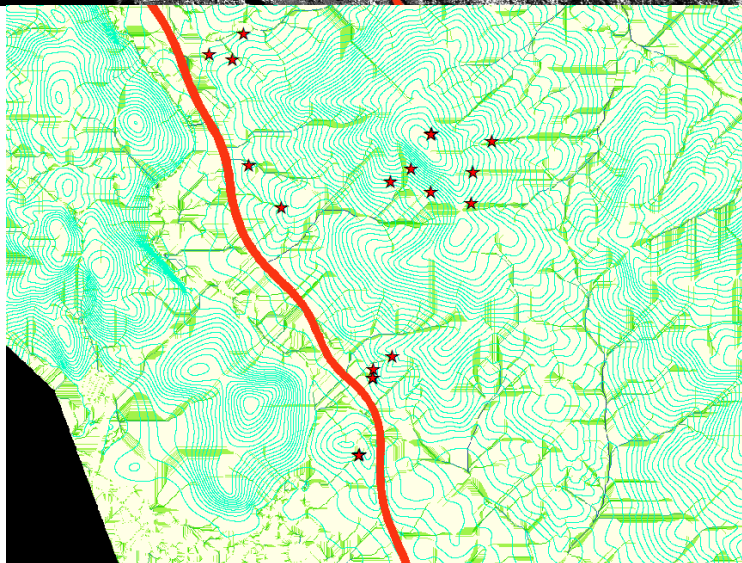
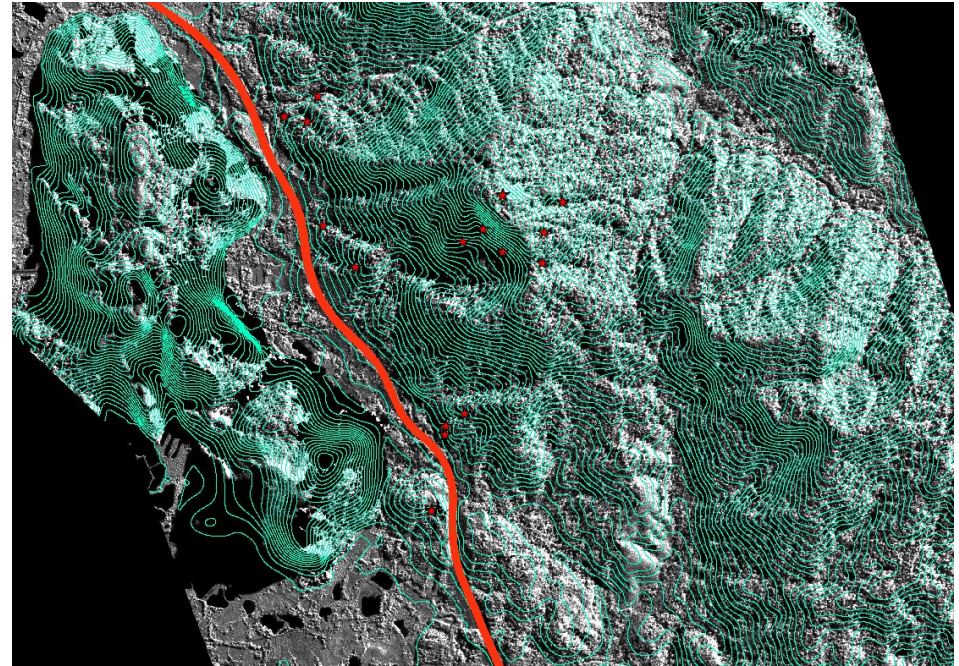
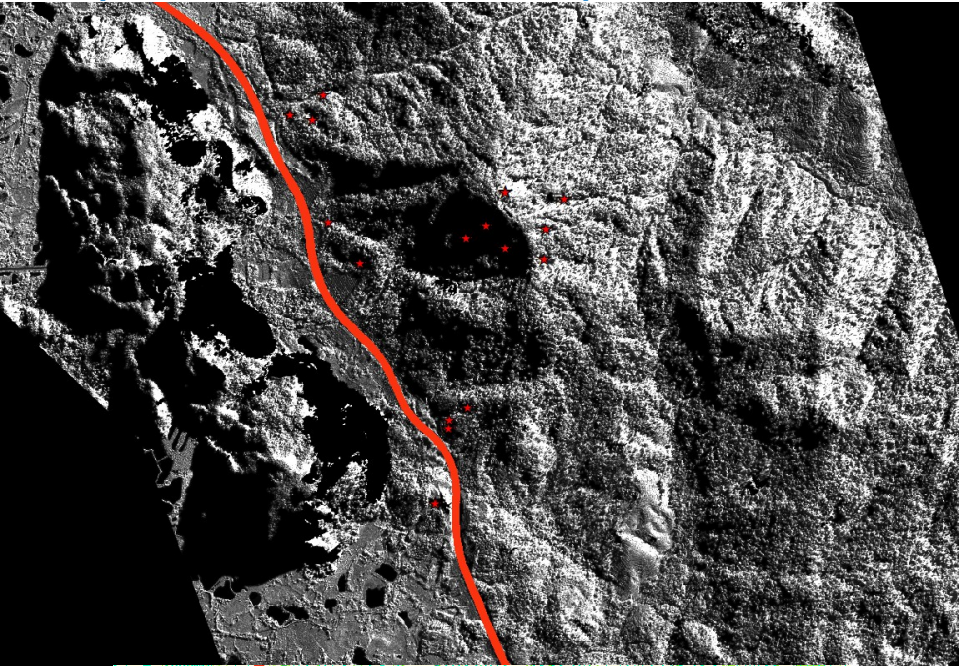
RG	11-Apr-12					12-Apr-12							
	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700
RGC1-3		2.8	4.4	2.8	16.6	20.2	36.4	5.6	2.0	1.0	0.4	0.2	
RGC1-4		1.6	7.6	1.0	9.8	19.6	33.2	7.0	24.2	11.6	21.0	61.6	
RGC1-5			5.2	1.2	9.4	21.8	29.2	6.8	2.8	0.6	0.2		
RGC1-6			7.2	2.6	4.2	21.8	27.8	20.2	2.8	0.4	0.2	0.2	
-		4.4	24.4	7.6	40.0	83.4	126.6	39.6	31.8	13.6	21.8	62.0	-
		1.10	6.10	1.90	10.00	20.85	31.65	9.90	7.95	3.40	5.45	15.50	

• 2nd cycle

RG	12-Apr-12				13-Apr-12			
	2000	2100	2200	2300	0000	0100	0200	0300
RGC1-3								
RGC1-4		5.8	7.2	19.6	30.2	7.0		
RGC1-5		0.4	1.4	33.8	37.4	0.2	0.2	
RGC1-6			0.2					
-		6.2	8.8	53.4	67.6	7.2	0.2	-
		1.55	2.20	13.35	16.90	1.80	0.05	

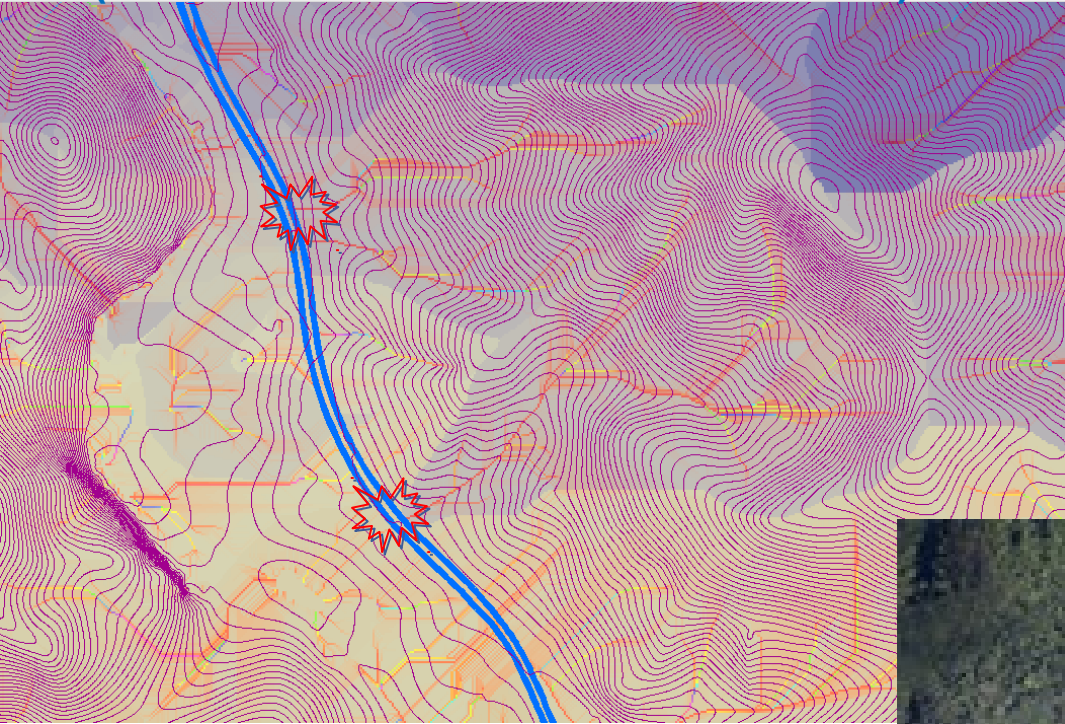
Intensity / volume / duration

CASE STUDY – GUA TEMPURUNG AREA (SURFACE ANALYSIS)



- DTM and mapping
- Surface analysis
- Hydrology Analysis
 - Flow direction
 - Flow accumulation
 - Stream order

CASE STUDY – GUA TEMPURUNG AREA (CATCHMENTS - HYDROGEOLOGY)



Basin:

- Catchment
- Funnel shape
- Small outlet
- Impact point



CASE STUDY – CONCLUSION

Slope failures:

Characteristics observed

- Slopes with inclination between 31° to 40°
- Slope aspects facing either north or south.
- Slopes with concave surfaces
- Slopes located near or at stream flow alignment

Rainfall Threshold

- Based on 2 case study
- Threshold recommended = 50.0 mm
(For early warning)

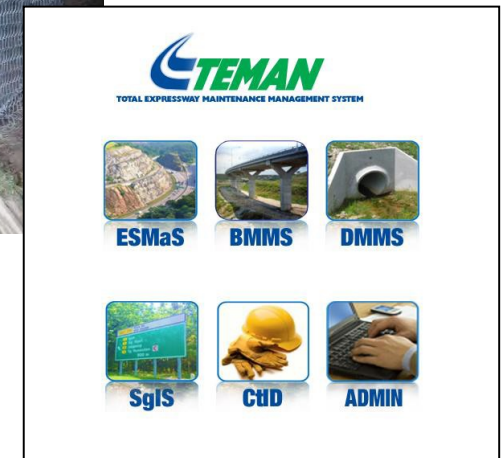
Area	Highest rainfall recorded (mm/hour)
Jelapang area	56.2 mm/hour
Gua Tempurung area (7 nos. of slope failures)	61.6 mm/hour

Potential point of Impact

CASE STUDY – PREVENTIVE MEASURE?

Preventive measures :

- Debris Flow Net
- Controlled channel
- Rainfall monitoring (RTMS & EWS)
- Aerial surveillance



THANK YOU

