Climate Change and Land use Impacts on Flood in Malaysia: Preliminary Results for Terengganu River Basin

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Outline

- Flood in Malaysia, major land use
- Major Land use practices
- Flood responses to land use
- Climate change influence
- Case Study: Terengganu River Basin

Introduction

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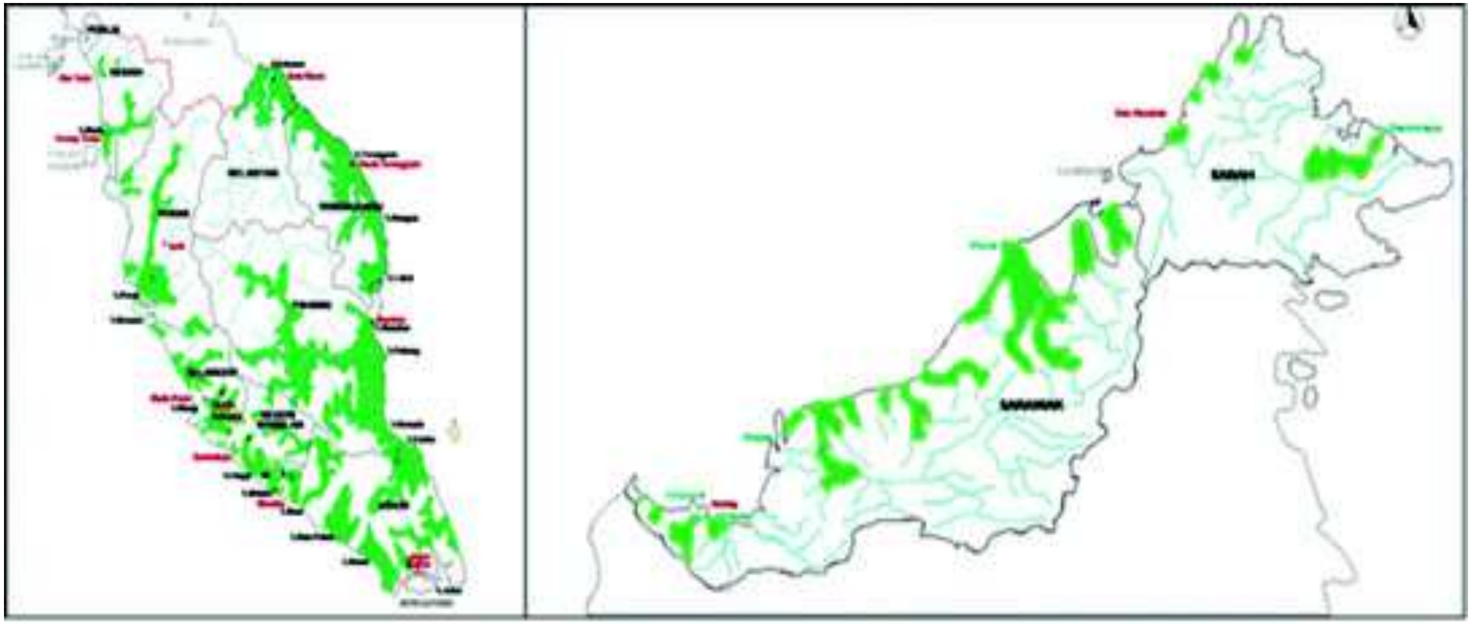
Flood Prone Areas in Malaysia



- Affecting 10.1% of the total land mass and 5.67 million population
- Average annual loss is about **USD 250 mil.**

Source: Zulkifli Yusop (UTM)

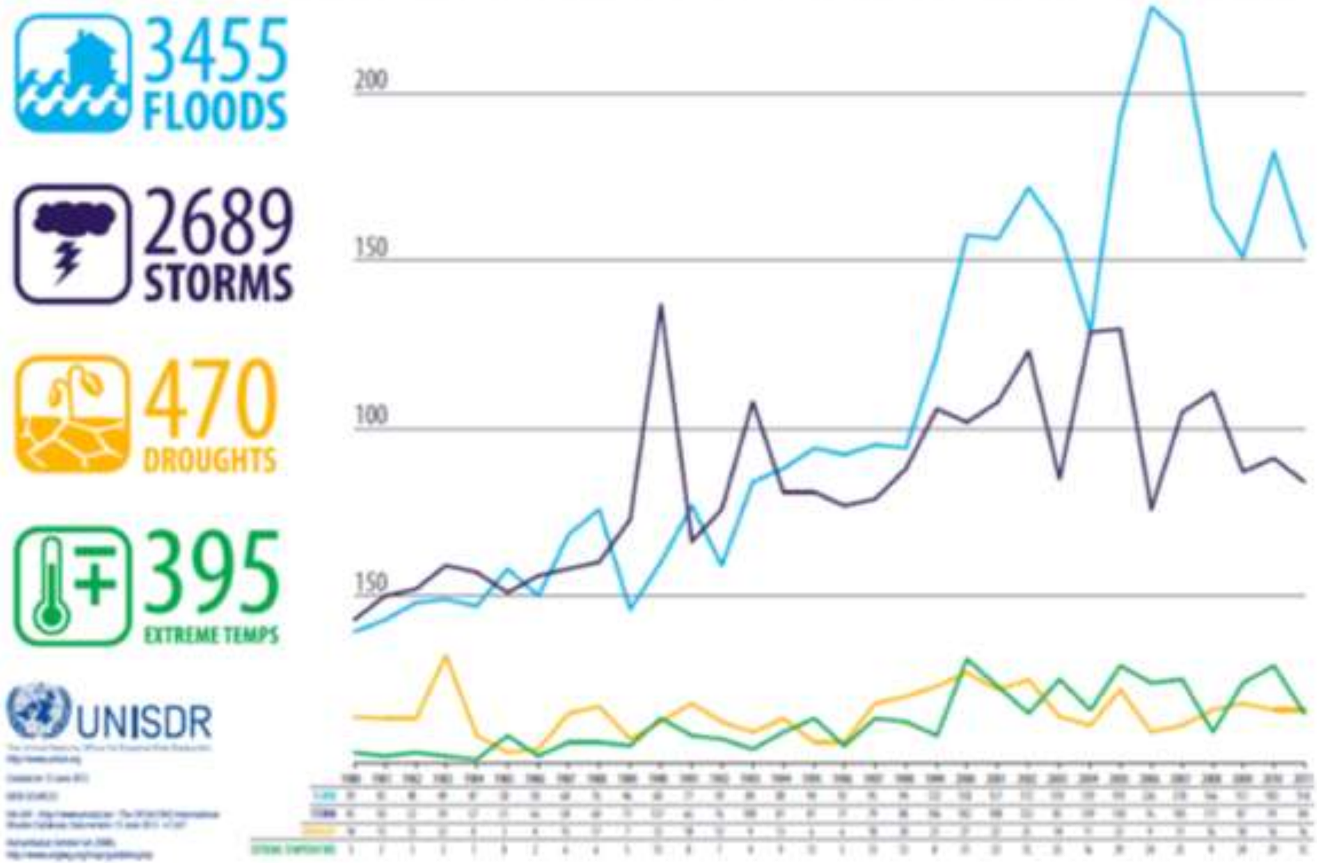
Water Related Disaster in Malaysia

No	Type of Disaster	No of Death	No of victim	Remarks
1	Flood 1965	6	300,000	Kelantan and Terengganu River Basins
2	Flood 1967	50	125,000	
3	Flood 1970	61	243,000	
4	Highland Towers landslide 1993	48	1000	
5	Flood 1993	30	20,000	
6	Debris flow at Genting Sempah 1995	20	5,000	
7	Storm Greg, Sabah, 1996	270	1,150	
8	Debris flow, Post Dipang 1996	44	500	
9	Landslide Kg Gelam, Sabah, 1999	17	300	Heavy storm cause landslide
10	Flood 2006	52	244,051	Kelantan, Terengganu, Perak, Kelang, Johor, Muar and Batu Pahat River Basins
11	Landslide, Hulu Langat 2011	16	200	Heavy storm caused landslide
12	Flood Dec 2014	25	300,000	Kelantan, Terengganu, Pahang and Perak River basins, 1600 lost homes

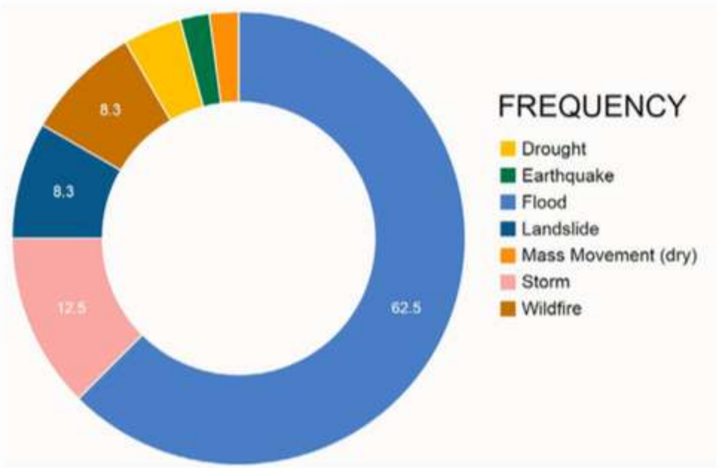
High	Medium	Low
Flood	Forest Fire Landslide	Earthquake Tsunami Drought Storm Haze

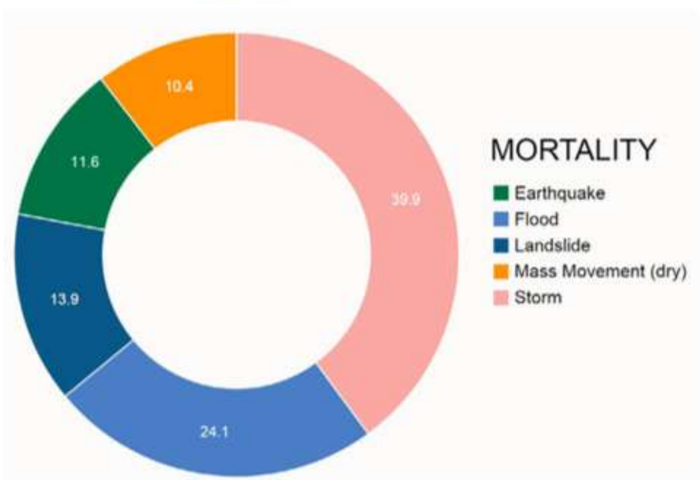
Source: Zulkifli Yusop (UTM)

Number of Climate-Related Disasters Around the World 1980-2011

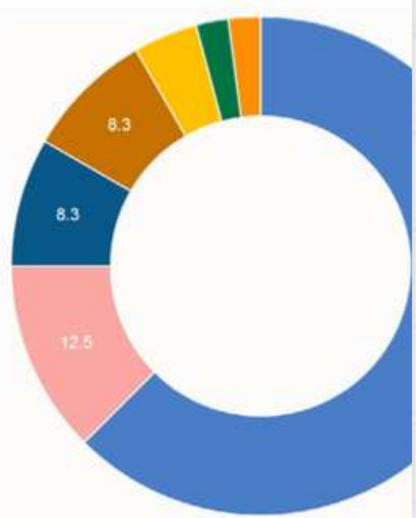


Source: Internationally Reported Losses 1990 – 2014, The International Disaster Database





Malaysia's Reported Losses Between 1990-2 (CEDM&HA, 2015)



Hazard	Absolute [Million US$]
Earthquake	10.49
Storm Surge	0.52
Tsunami	5.52
Flood	1,271.09
Multi-Hazard	1,287.62

Source: Zulkifli Yusop (UTM)

Major floods were reported since the early 20th century

British Officers during large flood in Kota Bharu, Kelantan in **1926**.

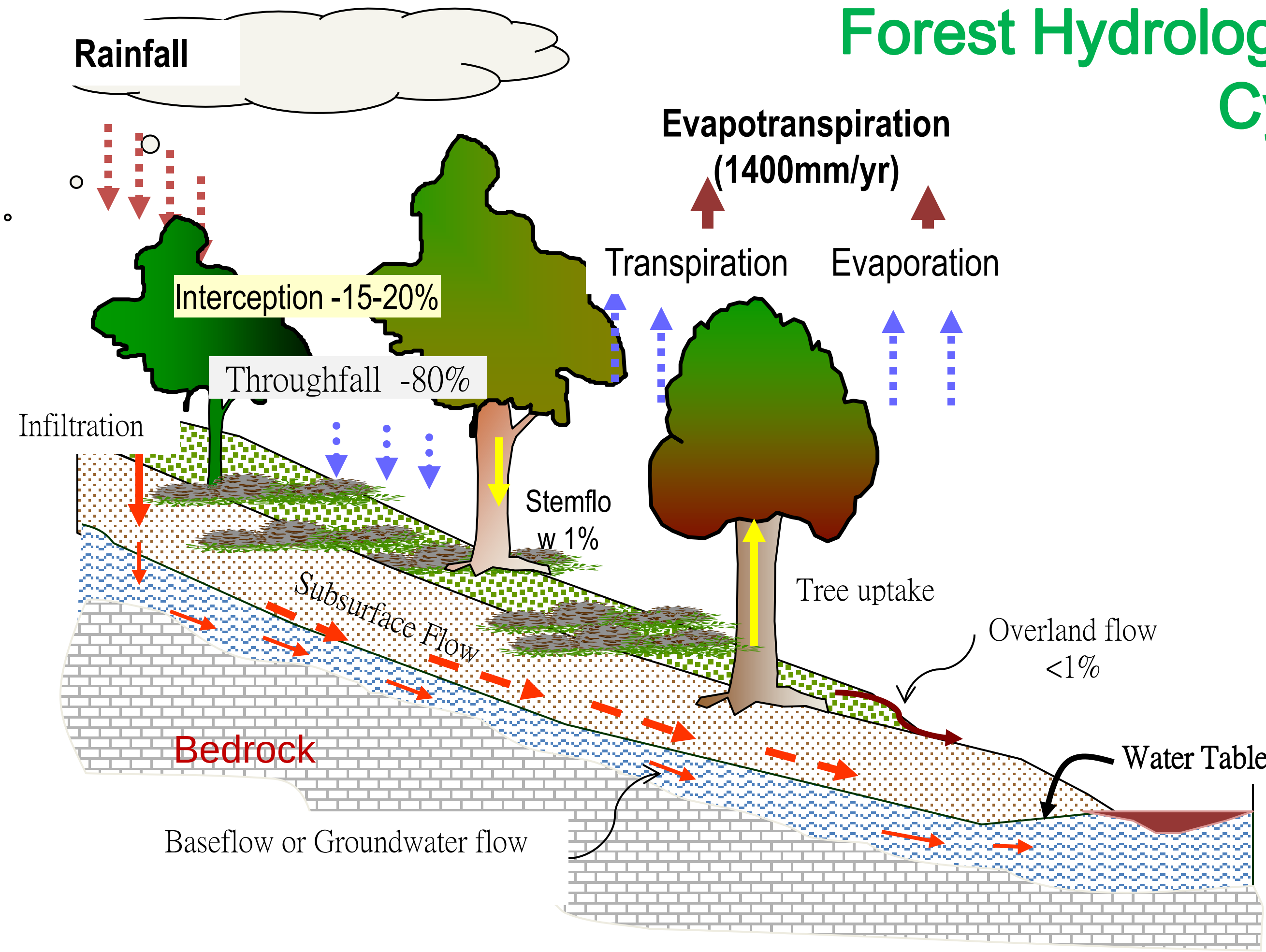
10 days rainfall in Dec 1926, has caused large flood, known as "Bah Merah" or red flood by the local people in the state of Kelantan. The flood had caused losses of life and damages to houses and agricultural crops. About 40 years latter, in 1967, another big flood occurred which had taken 38 life and about 537,000 people were evacuated (84% of the population).

Landuse

Forest - an Ultimate Protection

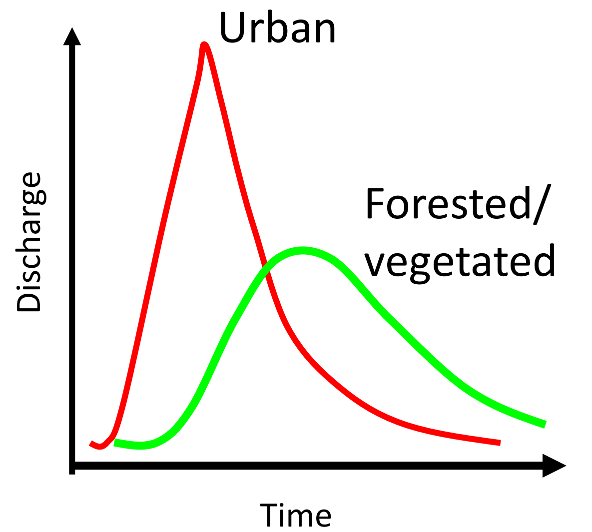
- Forest: multi-layered canopy, undergrowth, litter layer, thick hair root → high infiltration
- Low erosion < 1 ton/ha/yr

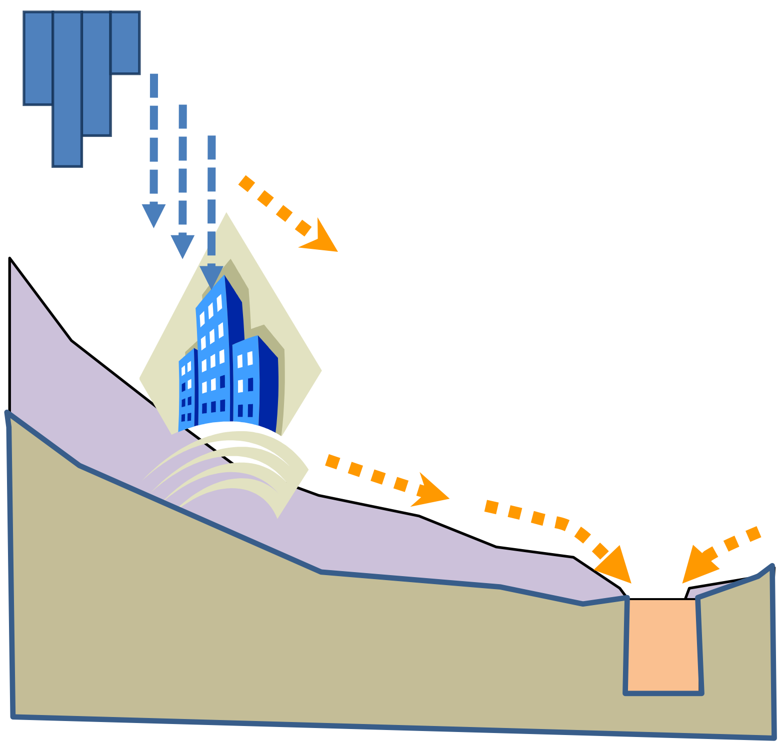
Forest Hydrological Cycle

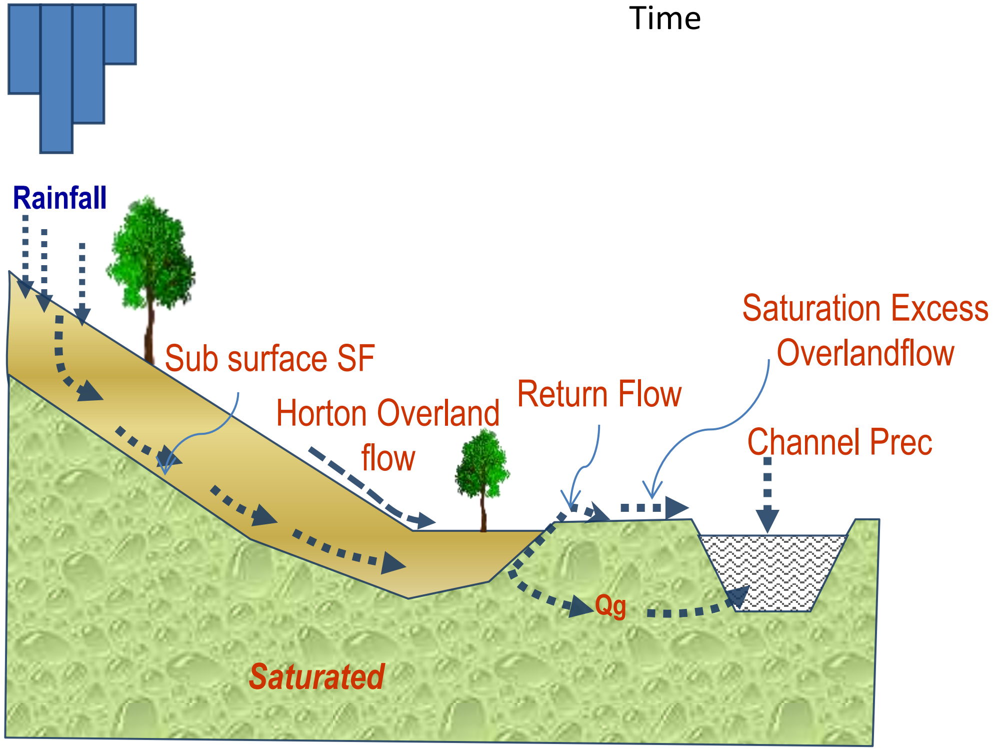


Urban catchment –
Simple runoff processes

Vegetated/forested Catchment – more complicated runoff processes

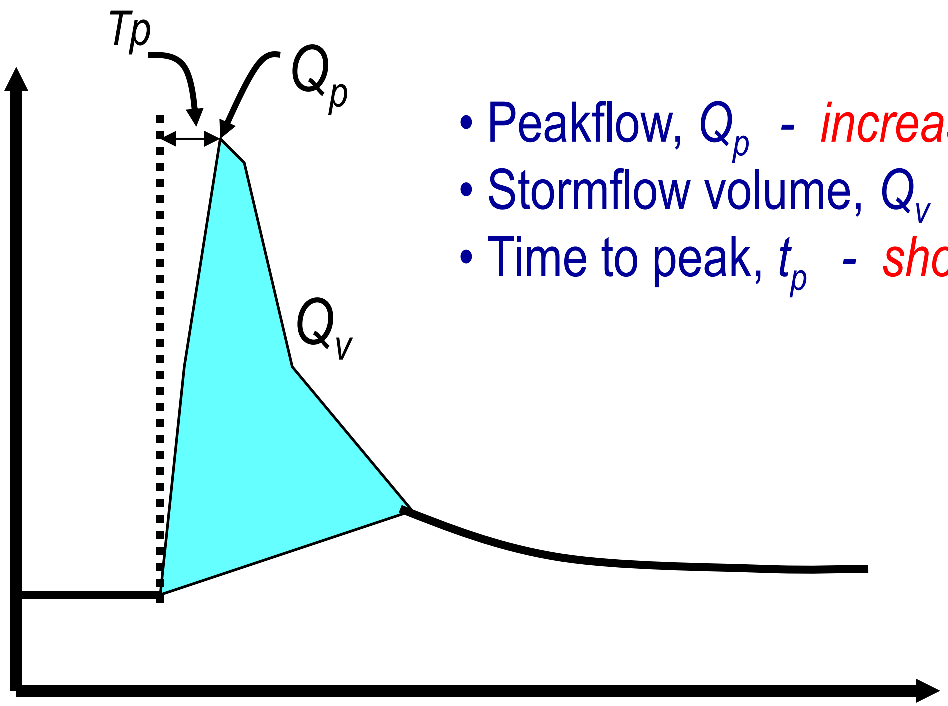






Upstream Land use

Stormflow Response



- Peakflow, Q_p - *increase*
- Stormflow volume, Q_v - *increase*
- Time to peak, t_p - *shorter*

Stormflow Response to Rainfall in Forested Catchment

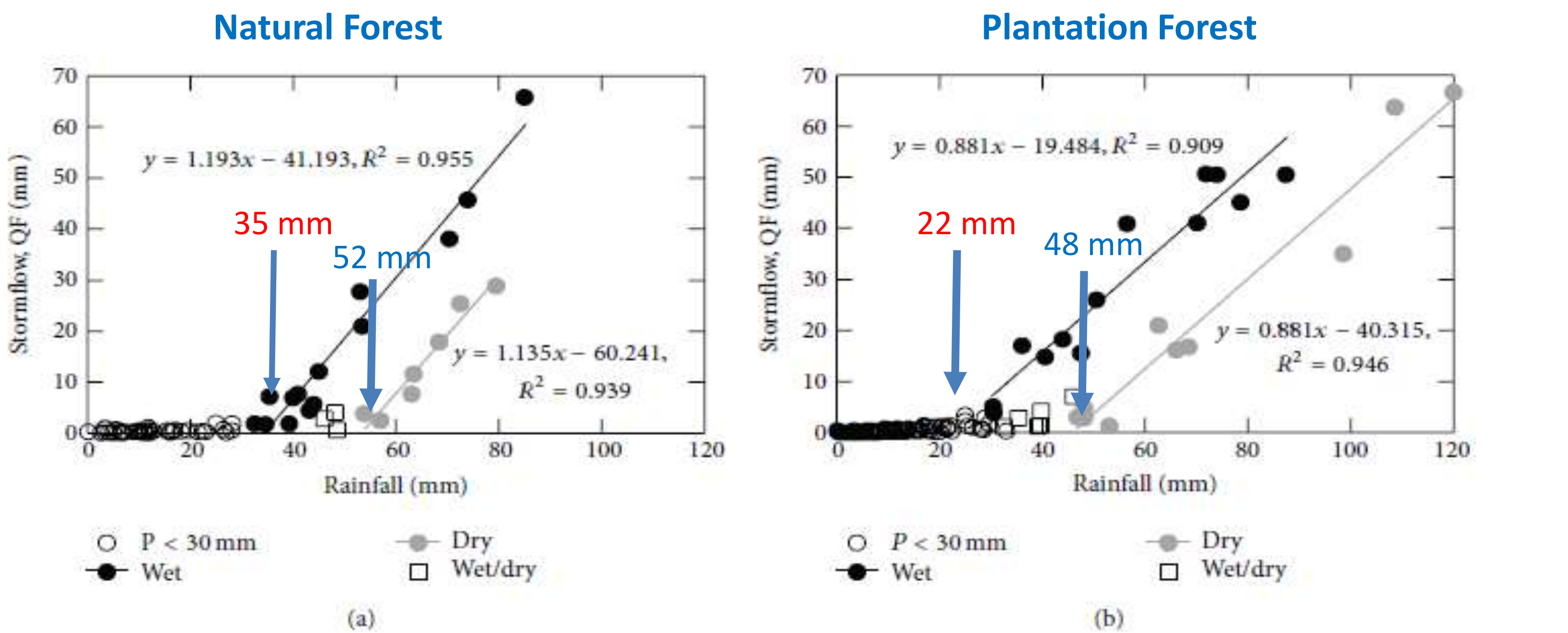
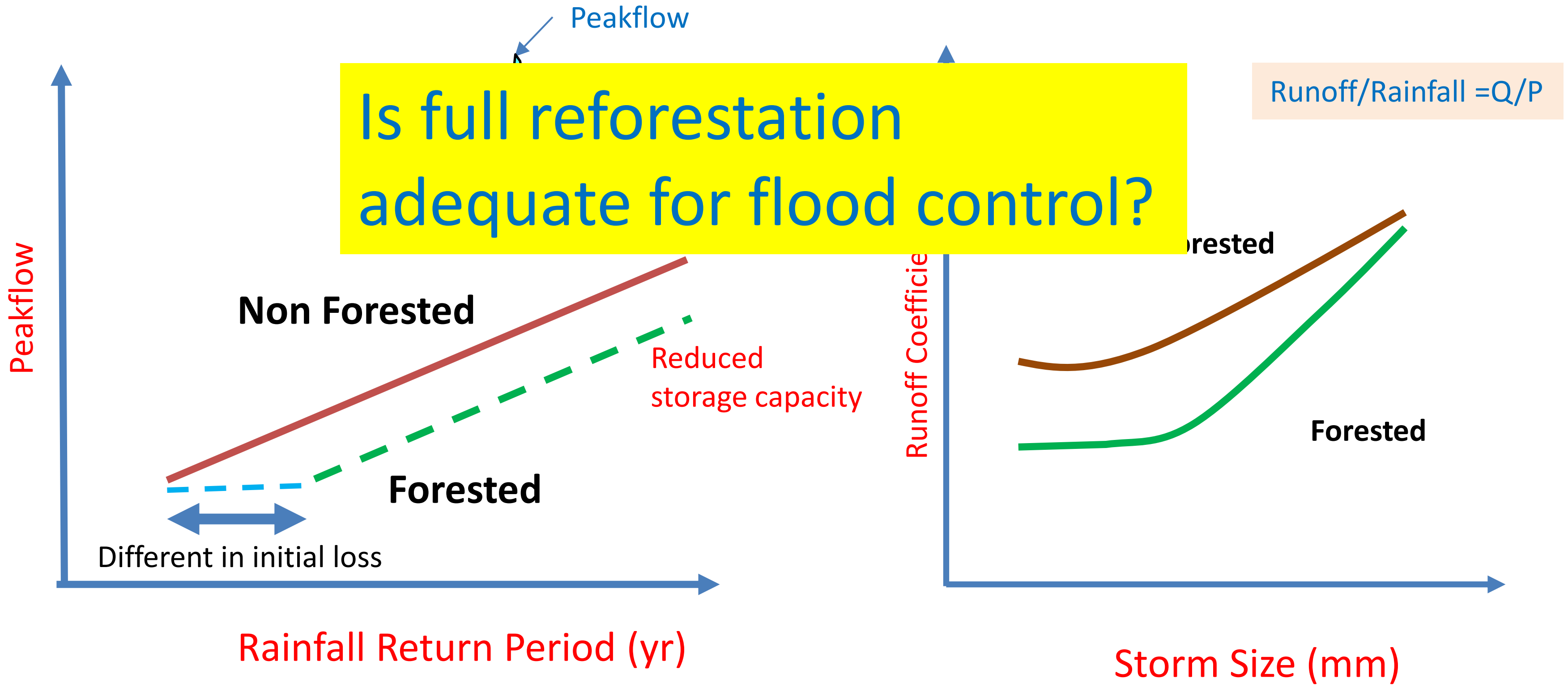


FIGURE 3: Relationships between stormflow (QF) and rainfall events during wet and dry conditions in control catchment C1 (a) and plantation catchment C3 (b) for observation from January 2006 to June 2007.

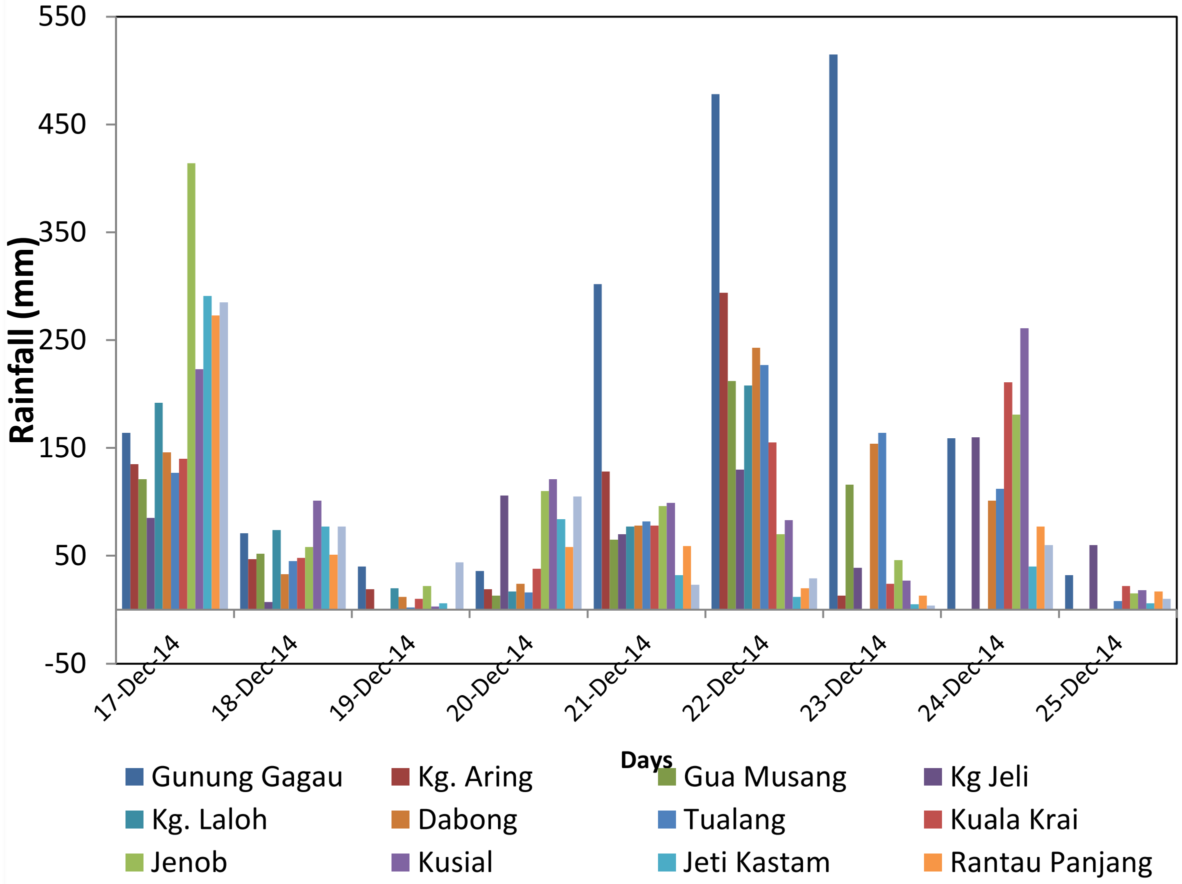
Peakflow Response to Storm Size



Is full reforestation adequate for flood control?

Zulkifli Yusop (UTM)

Rainfall that caused Kelantan 2014 Flood



- Max Rainfall at Gunung Gagau 1765 mm (17 to 24 Dec)
- Other stations; Jenob 997 mm, Kusial 918 mm, Kuala Kerai 704 mm, Dabong, 791 mm, Tualang 783 mm, Kg Aring 655 mm
- Water level peak at Kuala Krai on 25 Dec
- Annual Rainfall 2300mm

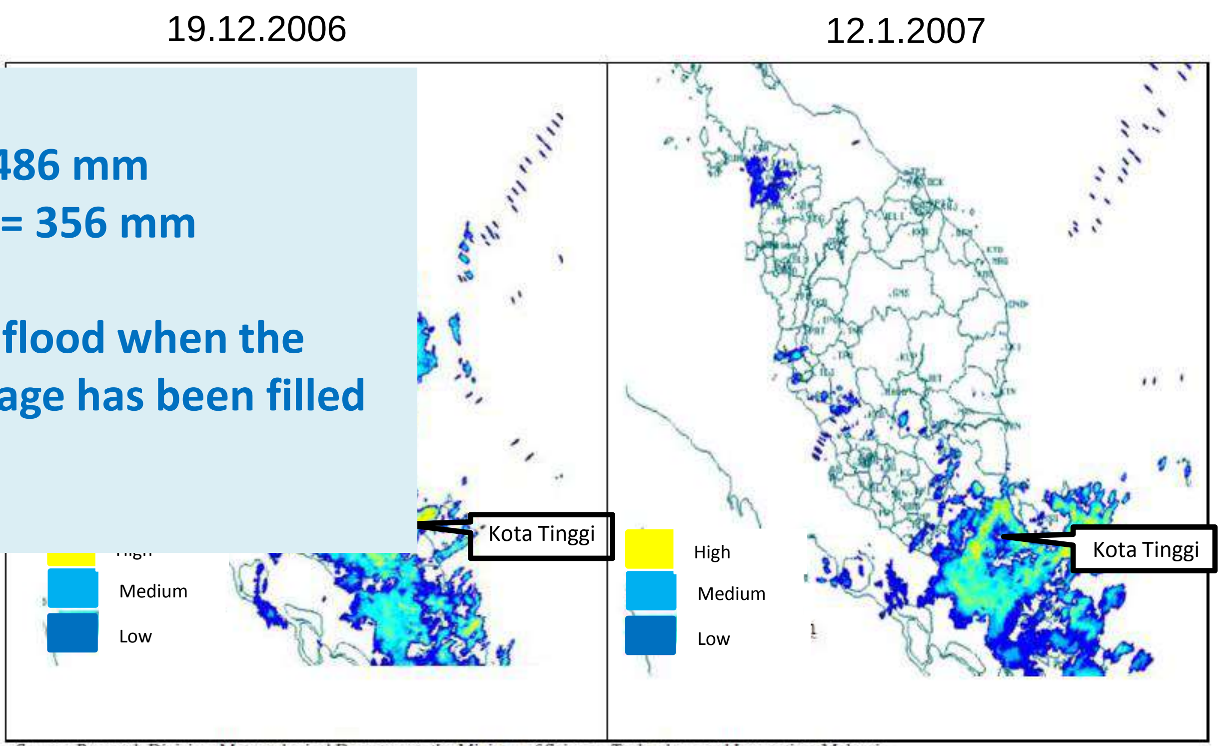
Kota Tinggi flood 2006/07

Total rainfall

First wave = 486 mm

Second wave = 356 mm

More prone to flood when the hydrologic storage has been filled up



Source: Research Division, Meteorological Department, the Ministry of Science, Technology and Innovation, Malaysia.

2014 Flood in Kelantan

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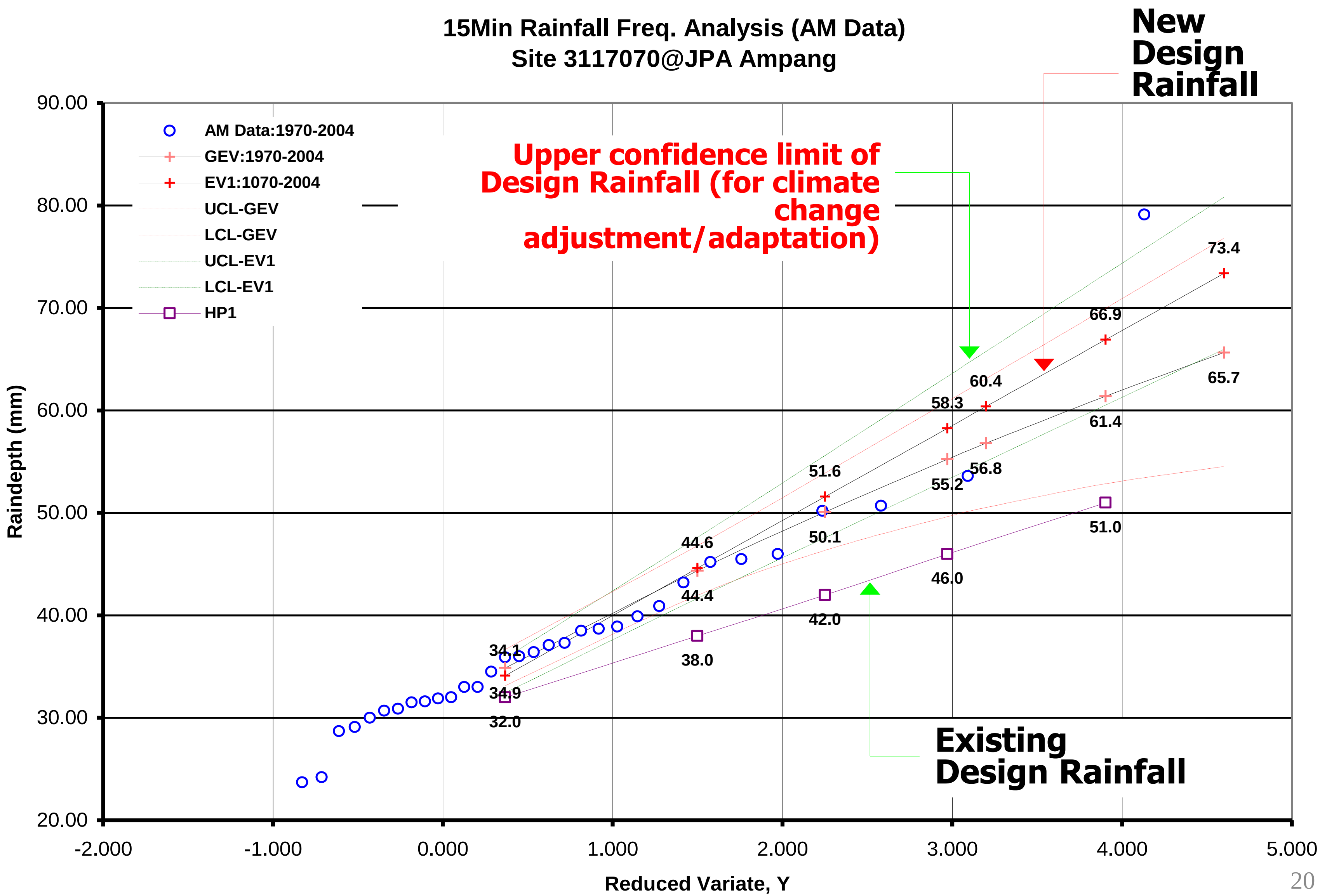
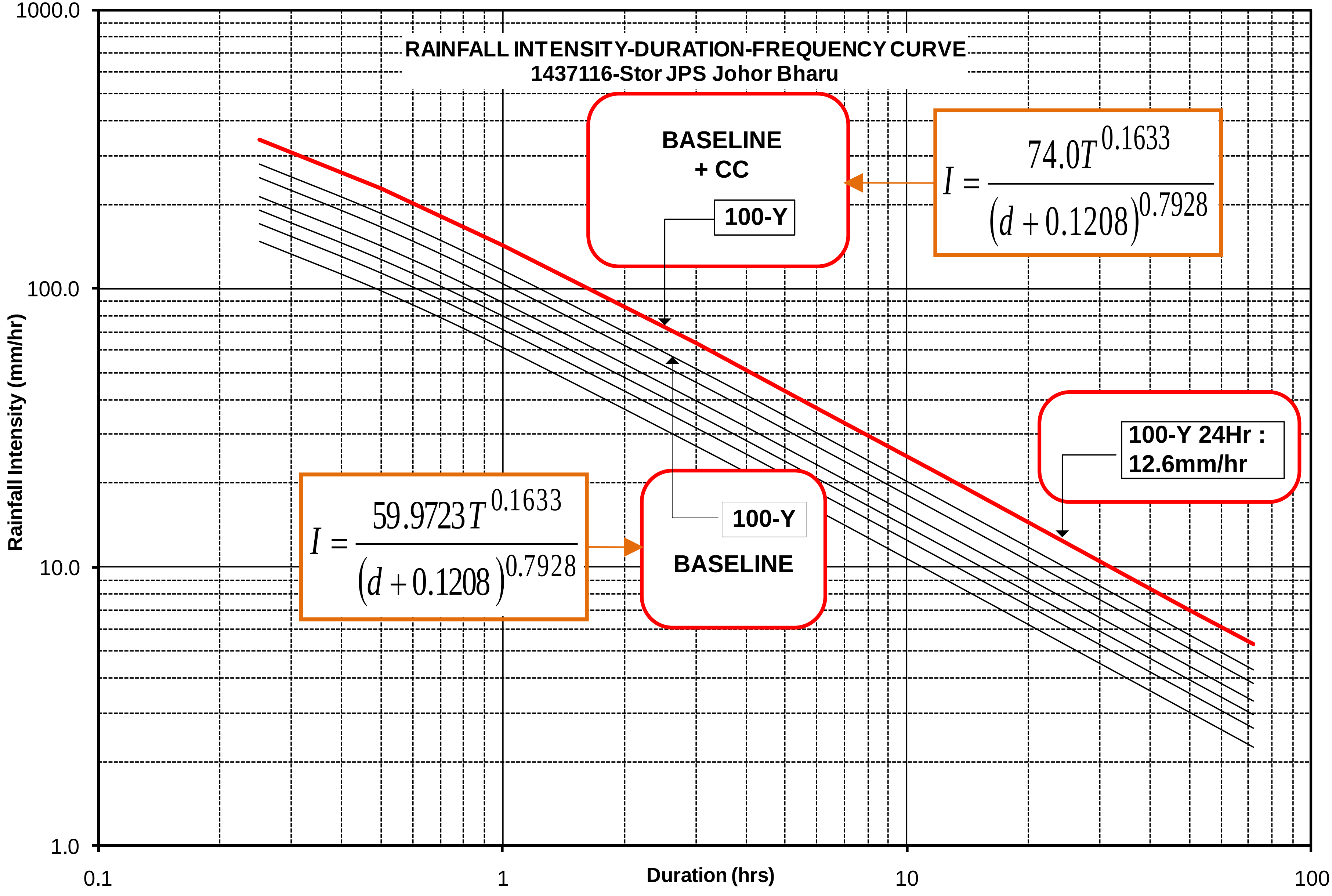
Flash Flood in Kuala Lumpur

Framework for V&A Guidelines for FLOOD MITIGATION

Updated Intensity-Duration-Frequency Curve (IDF) –Design Rainstorm

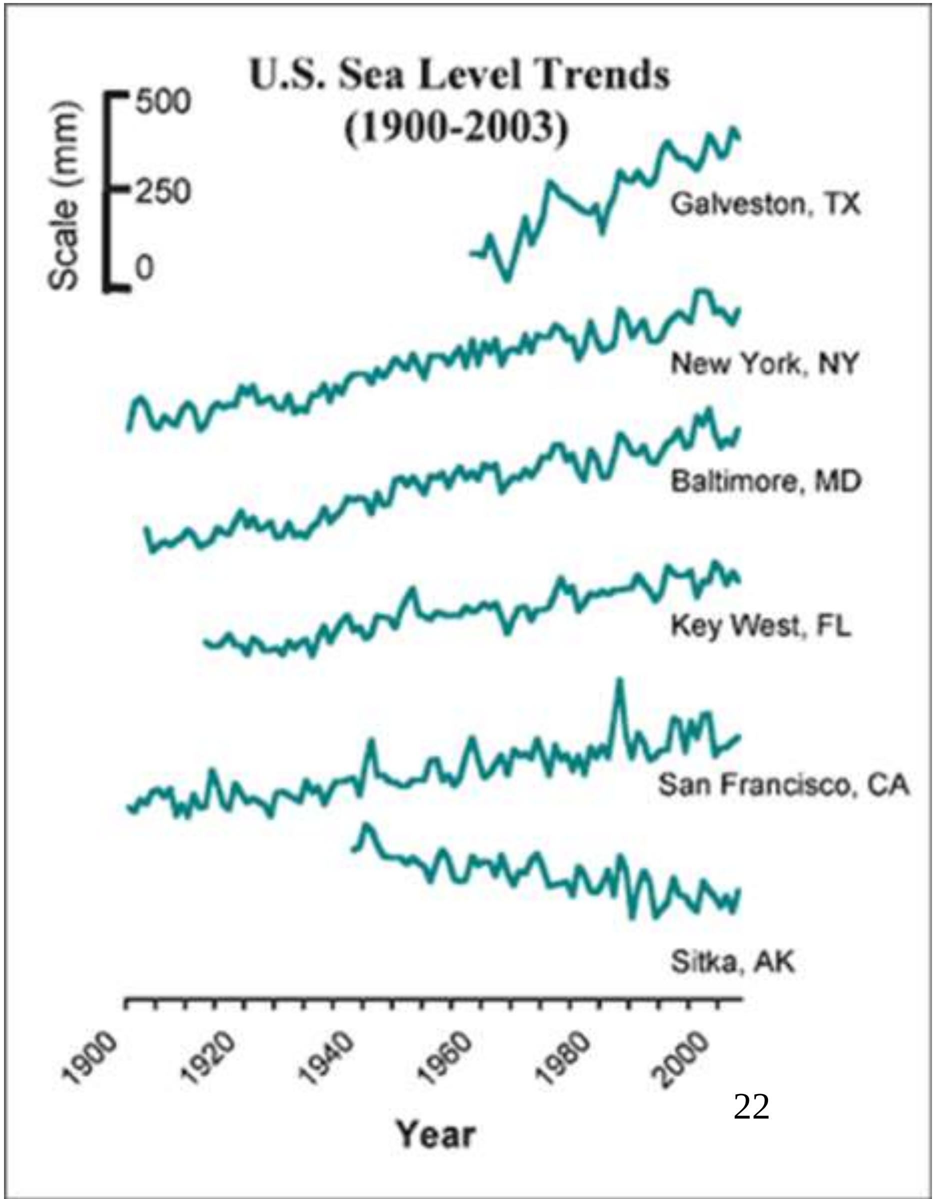




RAINFALL INTENSITY-DURATION-FREQUENCY CURVE
1437116-Stor JPS Johor Bharu
BASELINE
+ CC
100-Y
$I = \frac{74.0T^{0.1633}}{(d+0.1208)^{0.7928}}$
100-Y 24Hr :
12.6mm/hr
$I = \frac{59.9723T^{0.1633}}{(d+0.1208)^{0.7928}}$
100-Y
BASELINE
Rainfall Intensity (mm/hr)
1000.0
100.0
10.0
1.0
0.1
1
10
100
Duration (hrs)

Sea Level Rise

- Data on sea level rise collected over 20 years (1986-2006) at the southern tip of Peninsular Malaysia recorded an increase of 1.3 mm/year or 13 cm per decade.
- Global mean 10 to 20 cm over the past century. In the future, the rise is expected to take place at a much faster rate
- Salt water intrusion: already detected in some rivers, Sg Johor, Sg Muar
- More intense coastal erosion
- Damage to agricultural crops

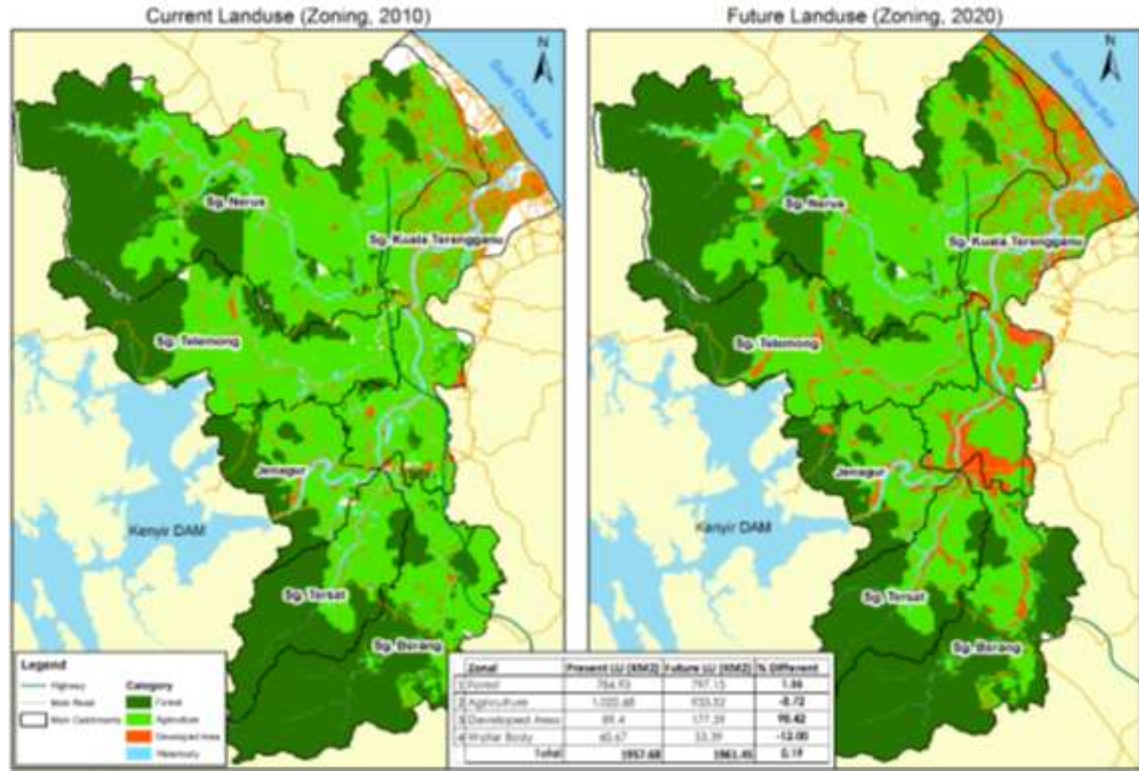


Flood Mapping – Terengganu River Basin

- Basin area =1,978 km^2, total river length ~ 120km
- A large man made reservoir (Kenyir Dam) in the upstream; catchment area 2,600 km^2 and water body 370 km^2.
- Capacity 13.6 bil m^3.
- The reservoir has been effective in attenuating large floods
- But during the 2014 Flood, the dam water level has reached maximum and the highest over the last 30 years
- Strong need to simulate future flood affected by changing landuse and climate change

Sg Terengganu Basin – The Catchments

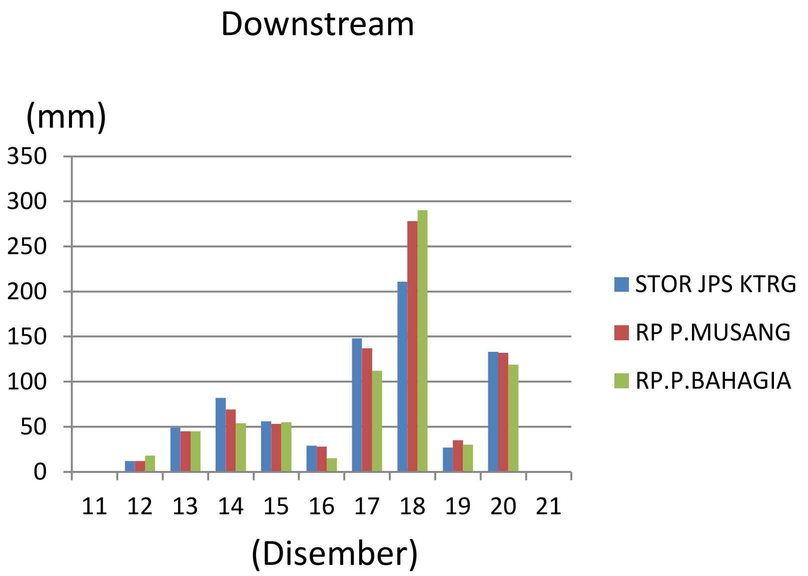
Terengganu river basin
and its sub catchment

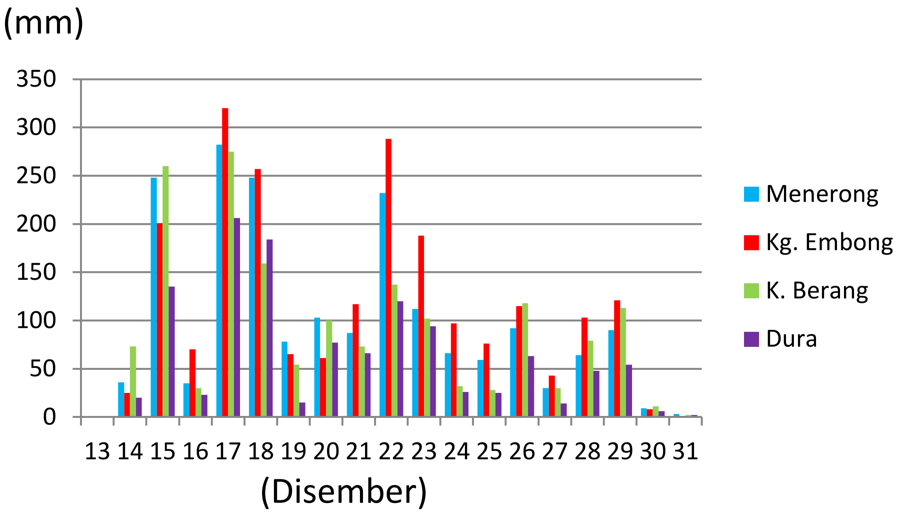


Landuse in 2010 and projected in 2020

Forest area +1.56%
Agricultural area - 8.72%
Develped aea +98.4%

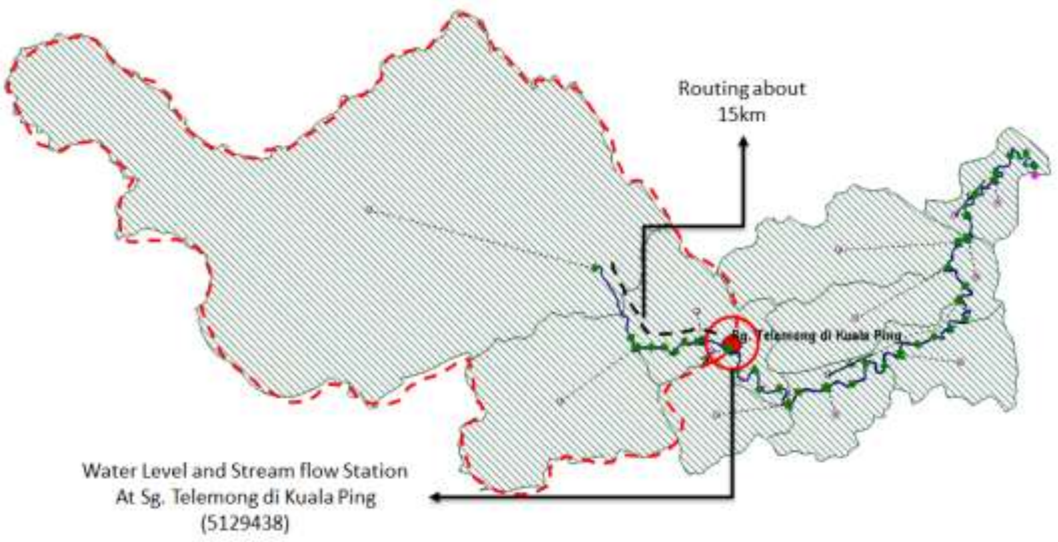
Historical Observed, Flood Event 2014





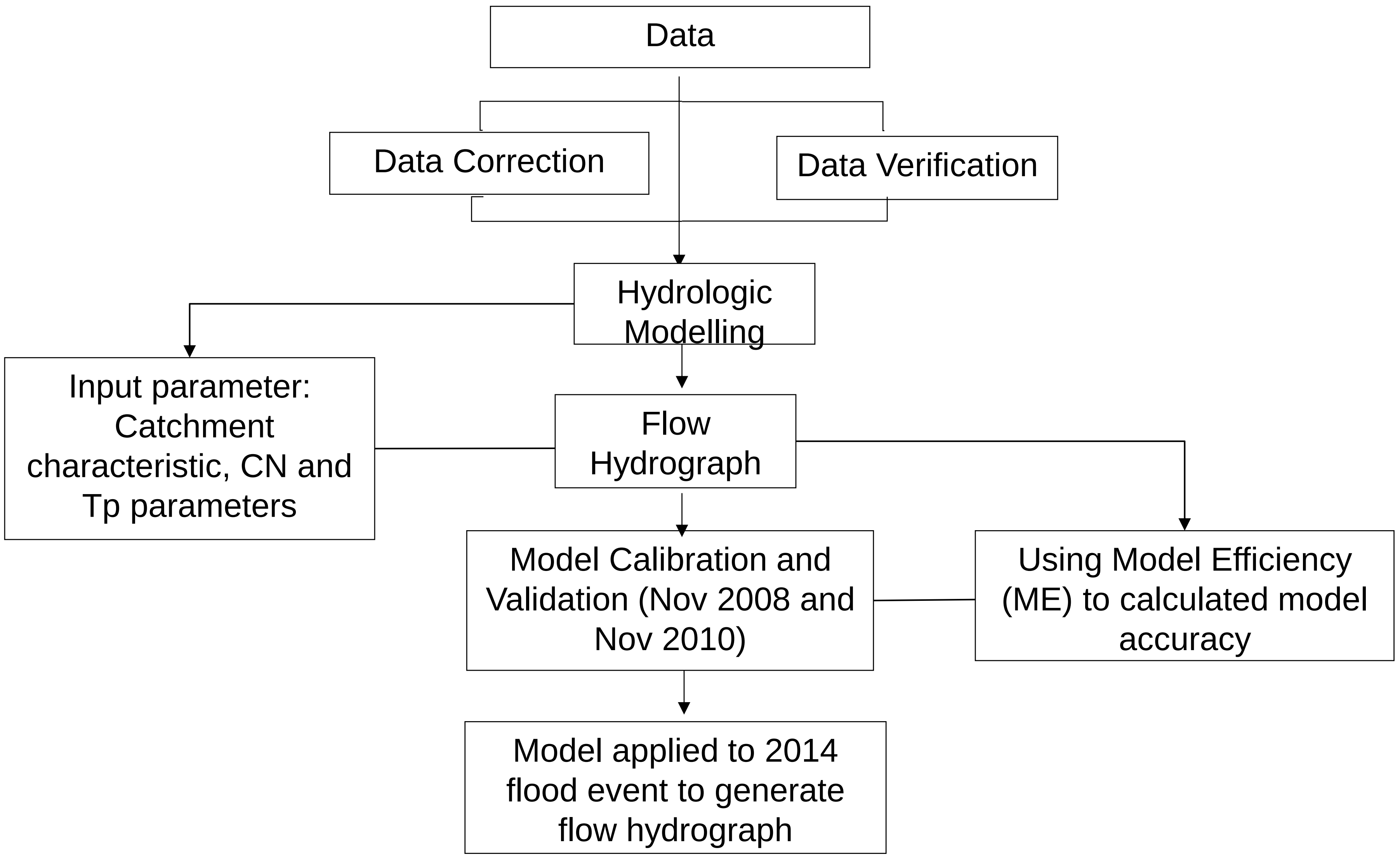
- Total rainfall in the upstream over 10 days was 1677 mm, 2.8 times higher then the average December rainfall

Hydrological Modeling



- The model was calibrated and validated using streamflow data at Sg. Telemong at Kuala Ping (St no: 5129438)
- Areal rainfall was estimated using data from 19 stations
- Calibration data: 23 to 26 Nov. 2008, and for the validation from 23 to 27 Nov on 2010.
- The events represent highflow but not causing flood.
- Calibration using flood event data is not possible because of overbank flow that make rating the curve invalid.

General Methodology on Hydrological Analysis



Hydrological Modelling Process

- Hydrological transformation method - US SCS Unit Hydrograph to
- Runoff was determined from rainfall for each sub-catchment
- The time to peak (Tp) from the SCS Computed unit hydrograph

$$T_p = \frac{D}{2} + 0.6\, t_c$$

where

D = time duration (hrs) of excess rainfall

t_c = Time of concentration

ID	River name	Time of Concentration, Tc (hrs)	Time of Peak, Tp (hrs)
N1	S. Tepuh	6.3	4.18
N2	S. Tepuh	5.0	3.35
N3	S. Mas	3.4	2.25
N4	S. Lingai	6.8	4.53
N5	S. Lingai	0.5	0.37
[illegible]	[illegible]	[illegible]	[illegible]

Hydrological Losses

- Hydrologic losses were determined based on the CN and soil group

Soil Group

The curve number (CN) is based on hydrological soils type

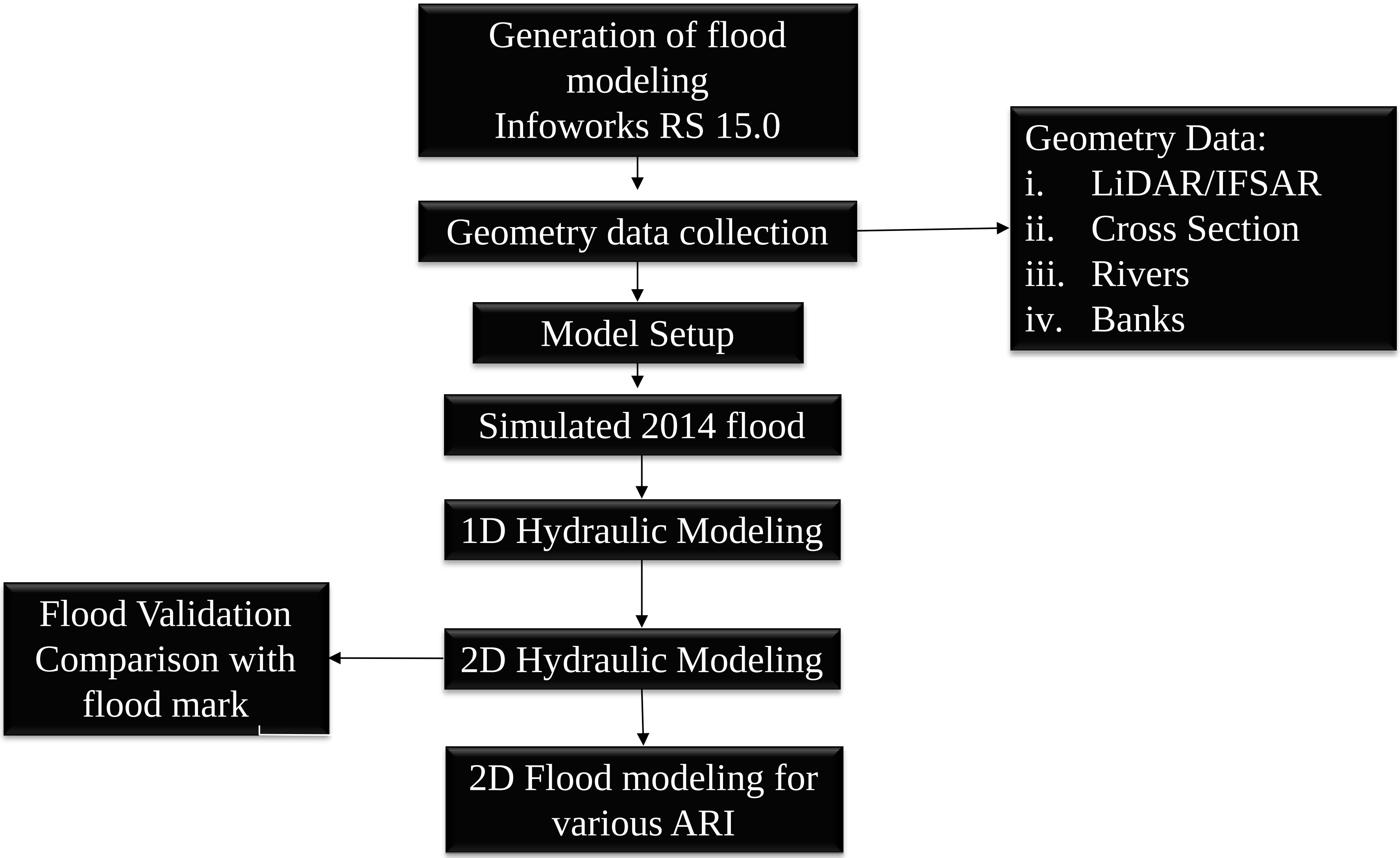
$$CCN = \frac{\sum CiNiAi}{\sum Ai}$$

Where
CCN = is the composite CN,
CN_i = curve number for sub catchment i
A_i = the area for sub catchment i.

The Curve Number (CN) for these sub-catchments can be calculated by using a composite CN which is defined as an aerial weighted average of the CNs for the each sub catchments

ID	River name	Area (km2)	Present CN	Future CN
N1	S. Tepuh	25.2	71	72
N2	S. Tepuh	43.1	67	67
N3	S. Mas	5.1	68	71
N4	S. Lingai	73.1	63	61
N5	S. Lingai	2.2	53	67
N6	S. Lekar	1.2	55	67
N7	S. Lekar	34.7	66	67
N8	S. Pacat	1.4	66	67

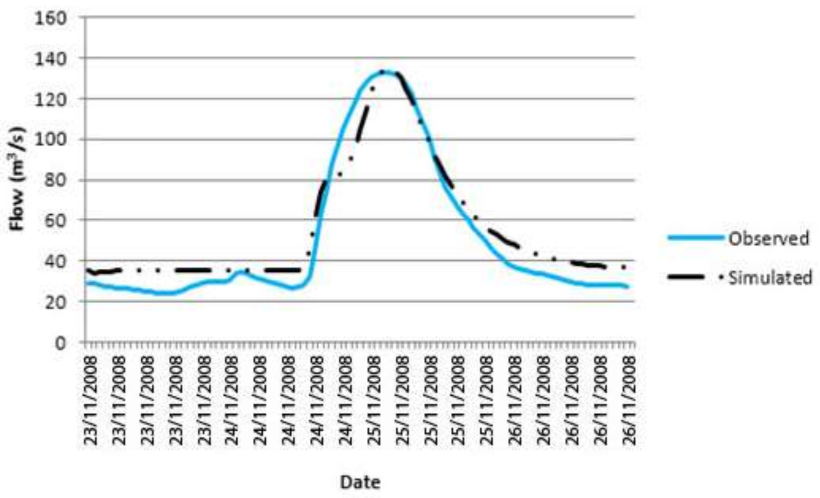
Methodology – flood modelling



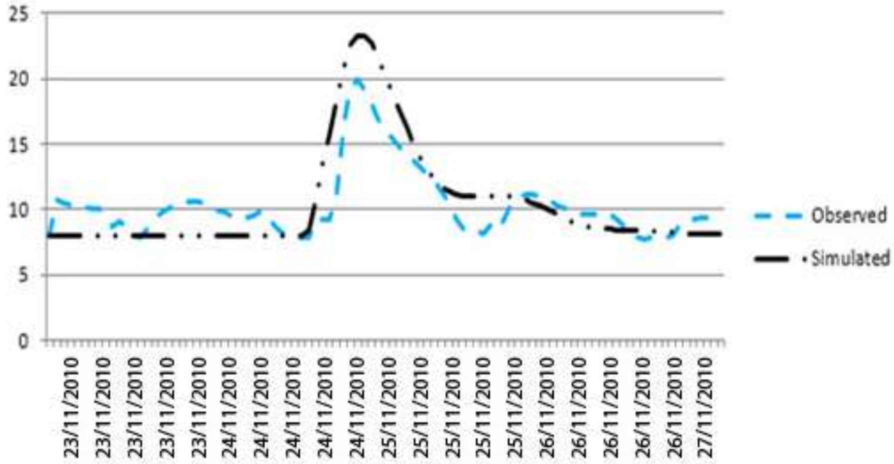
Hydrological Model Calibration and Validation

Model Efficiency, ME

$$ME = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \sim P_o)^2}$$

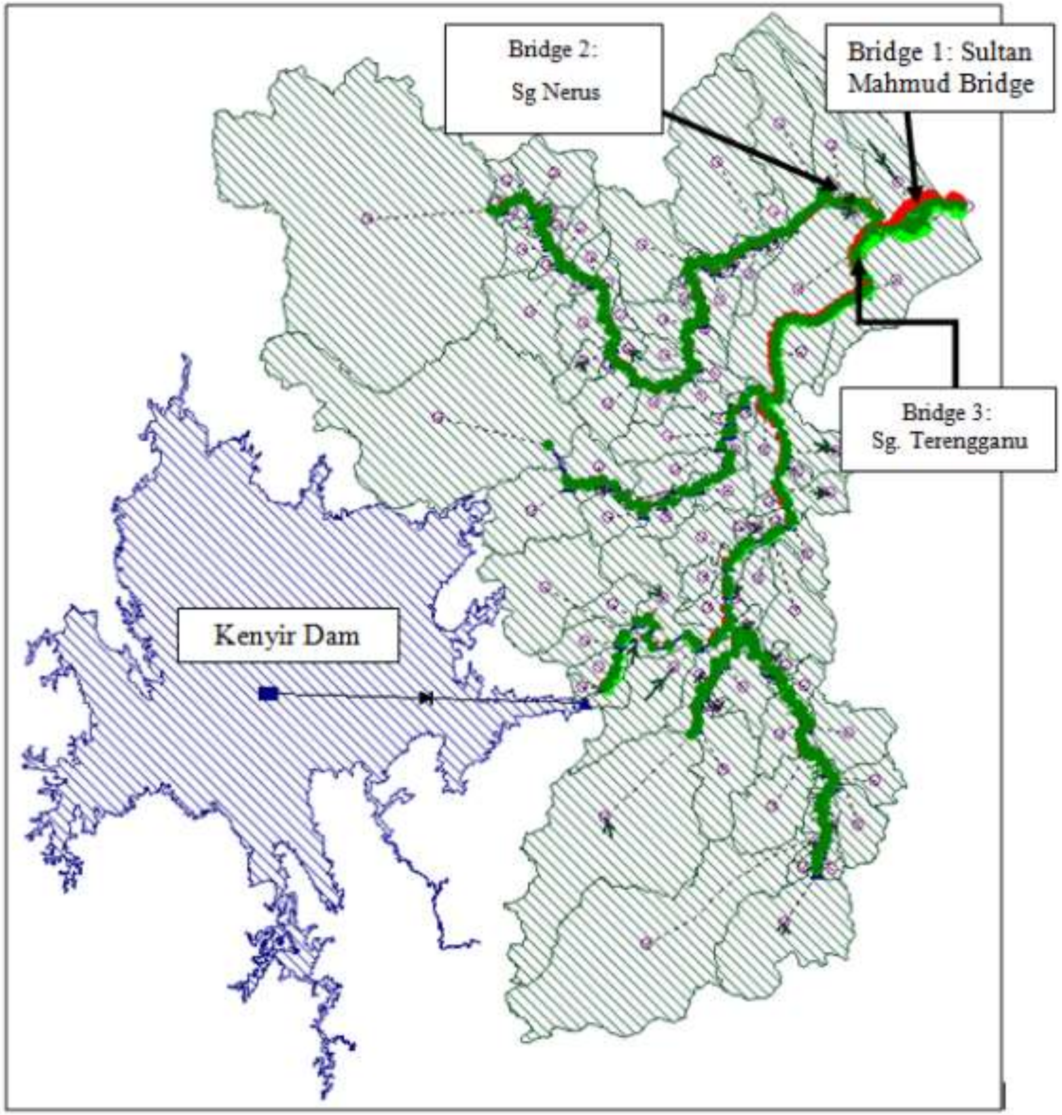


- Model calibration using rainfall-runoff data from 23 to 26 November 2008
- Model accuracy 93%

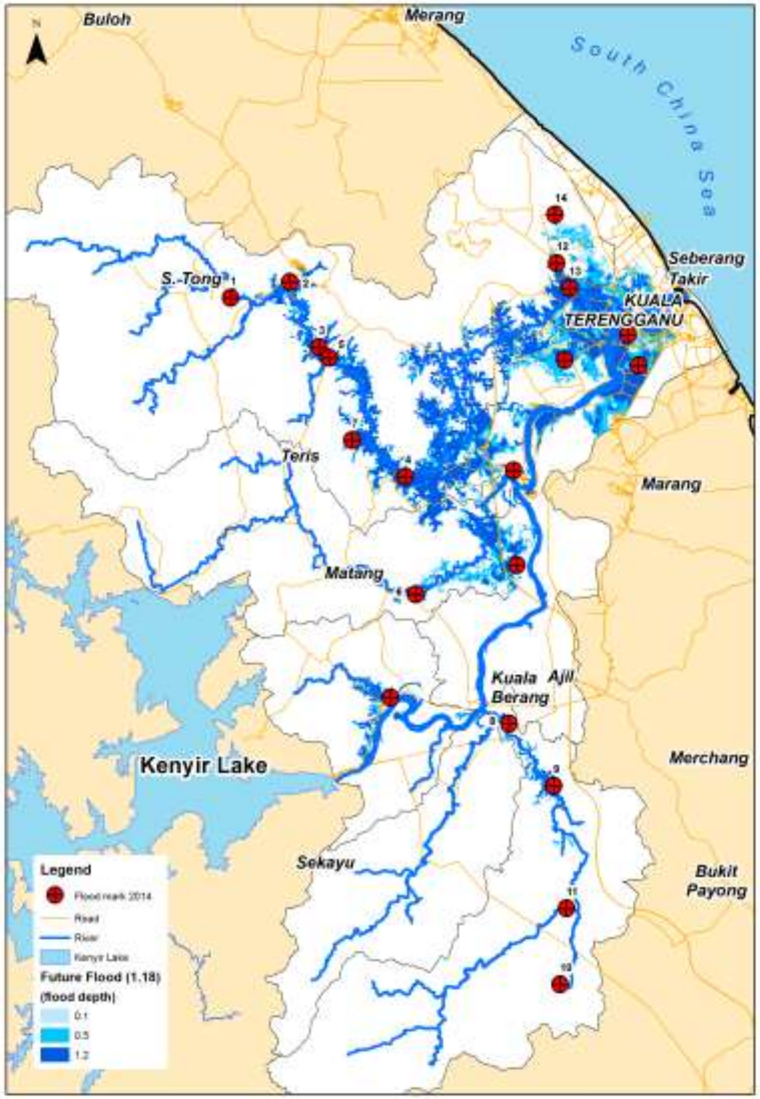


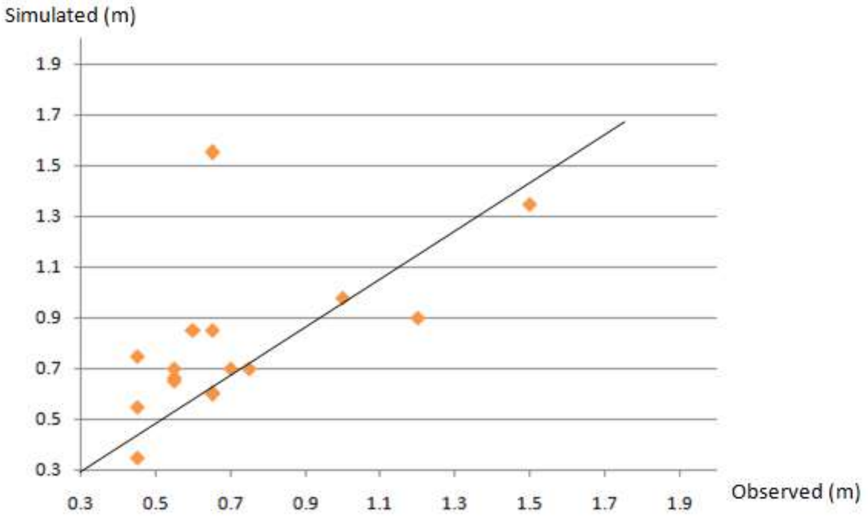
- Model validation using rainfall-runoff data from 23 to 27 November 2010
- Model accuracy 80% model accuracy

2D Model Setup in Infoworks RS



2014 Flood Map at TRB

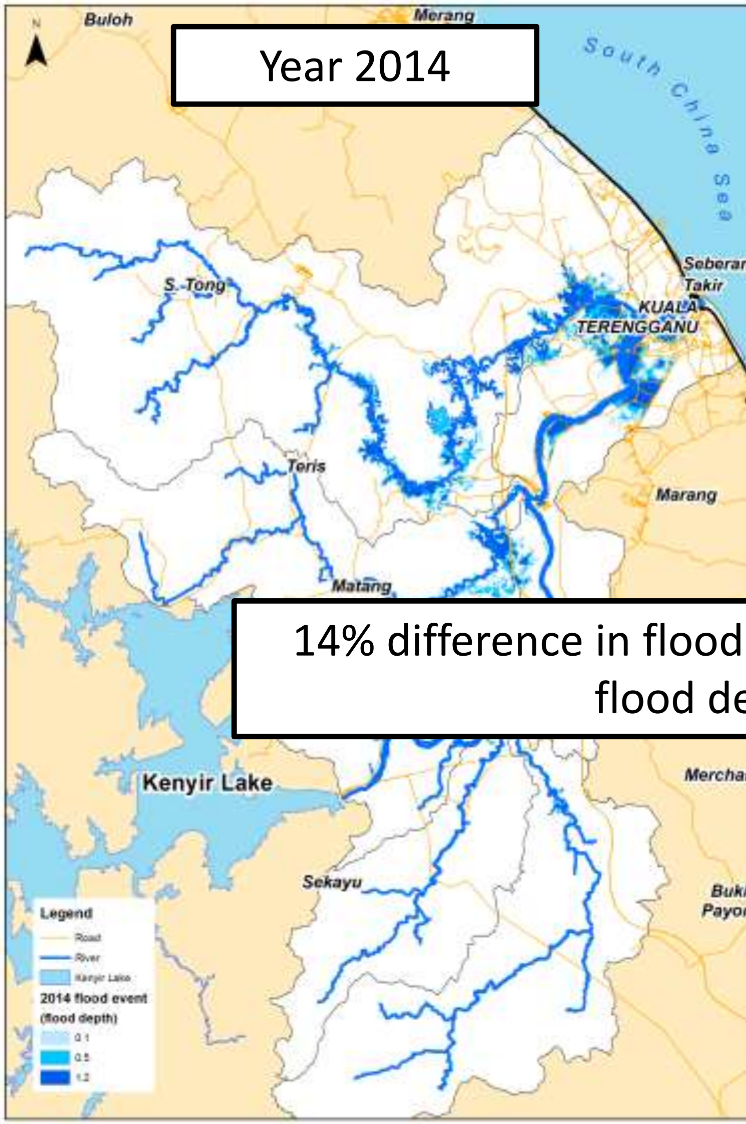


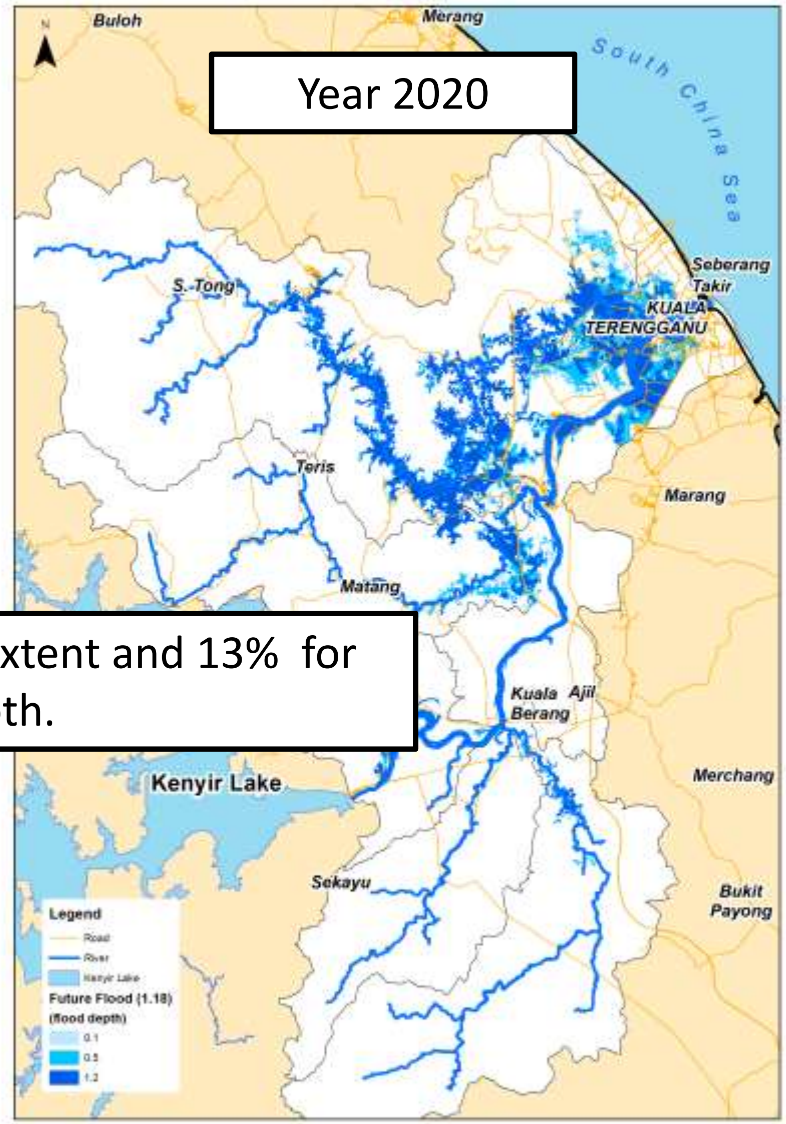


$$\left|\frac{Observed - Simulated}{(Observed + Simulated)/2}\right| * 100\%$$

- The 2D model is validated by comparing the simulated flood against the flood marks at 20 locations.
- About 80% accuracy

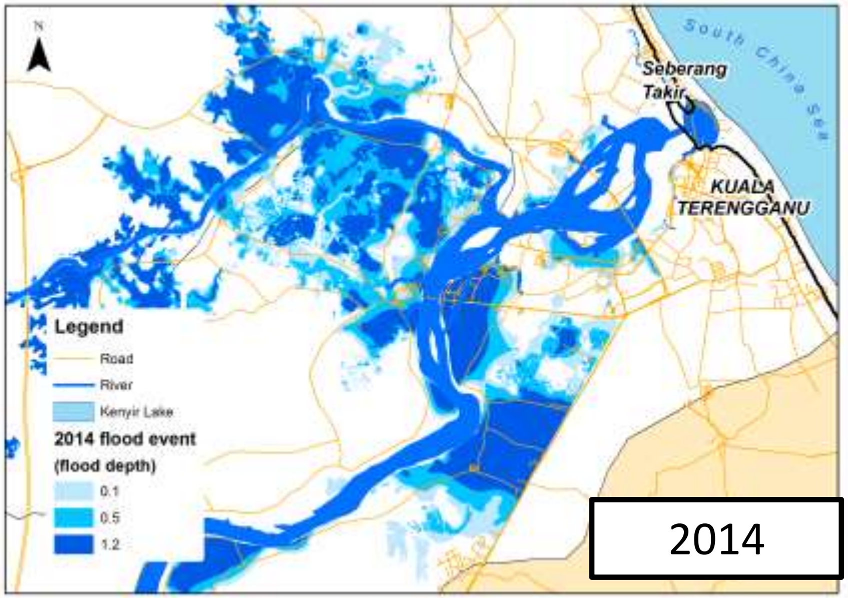
Simulated Flood Maps

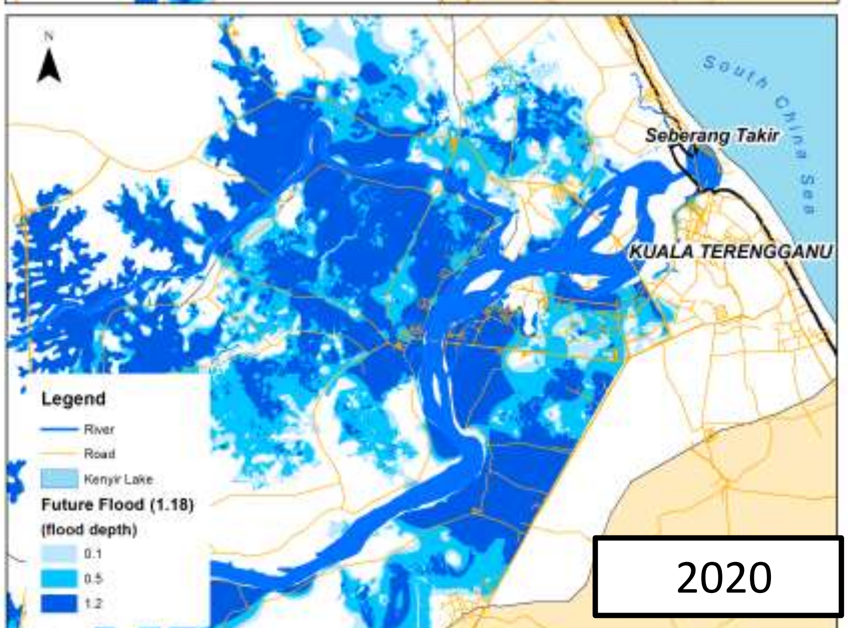




14% difference in flood extent and 13% for flood depth.

Simulated Flood in 2014 and 2020





The differences in flood extent and depth in 2014 Vs 2020 at the downstream of Terengganu River Basin.

Conclusion

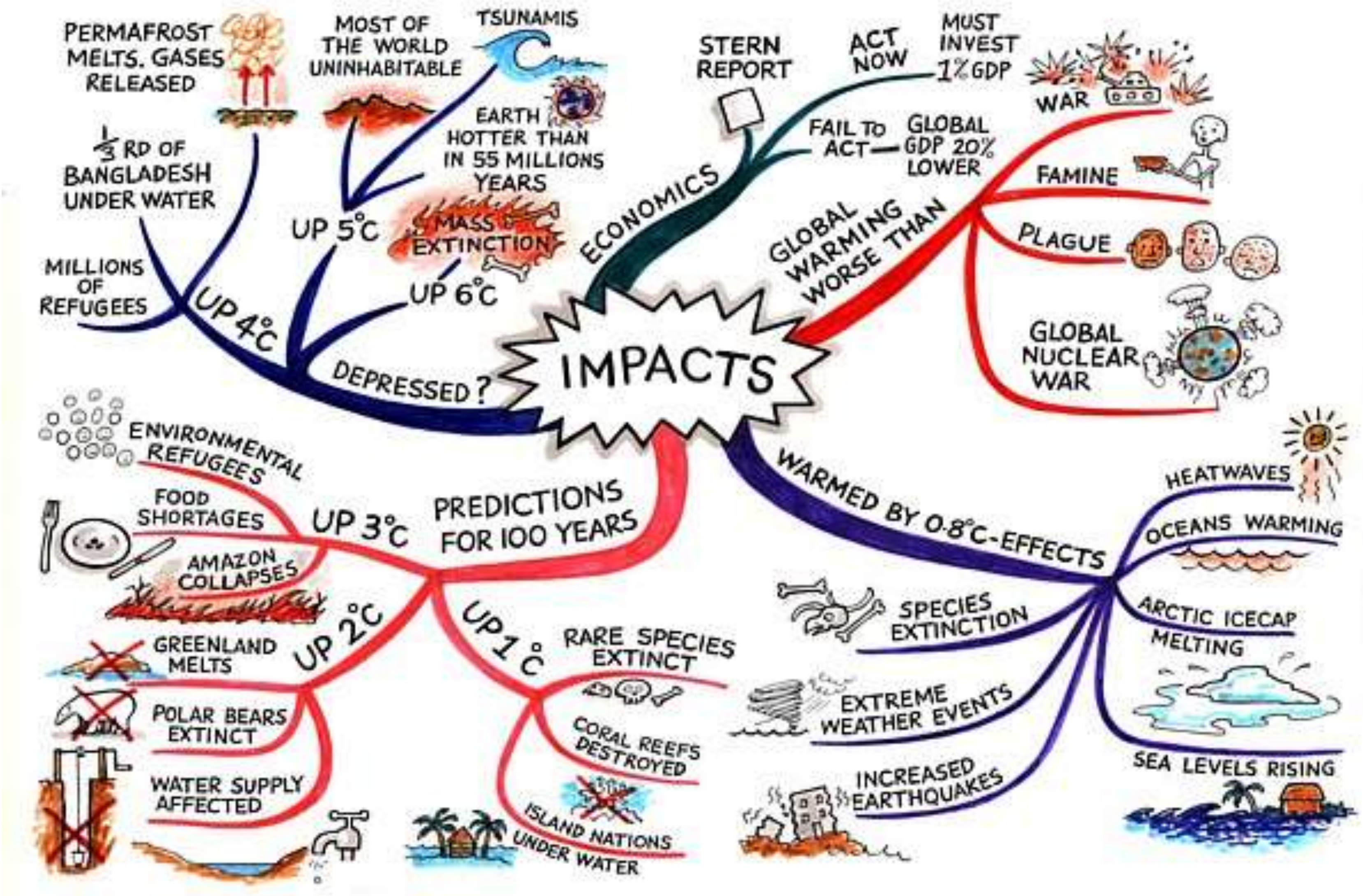
- Prolonged and heavy rainfall is always the main factor contributing to major floods
- Forested land could attenuate normal floods but not for big floods.
- Future flood is expected to be more severe due to more intense rainfall, more impervious land and sea level rise.


THANK YOU

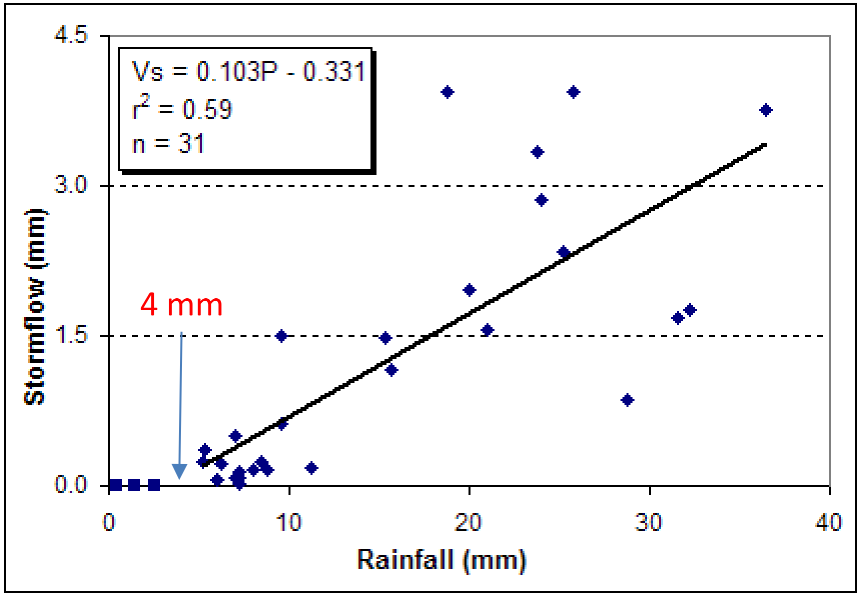
Model Setup - **2D Hydrodynamic**

- The integration of 1D and 2D, give a new dimension on flood visualization
- IFSAR data was used for DEM model input
- The upstream boundary condition used present and future precipitation as the main input
- The modeling of downstream boundary condition used the Highest Astronomical Tide (HAT) of 3.02m was adopted in flood as the boundary condition

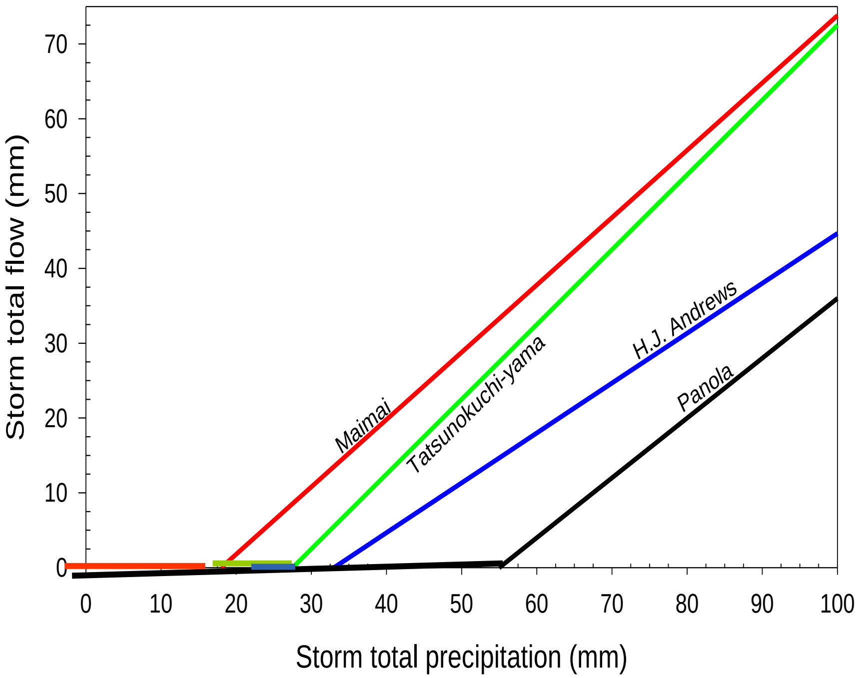
Climate Change Impact



Stormflow vs Rainfall in oil palm catchment



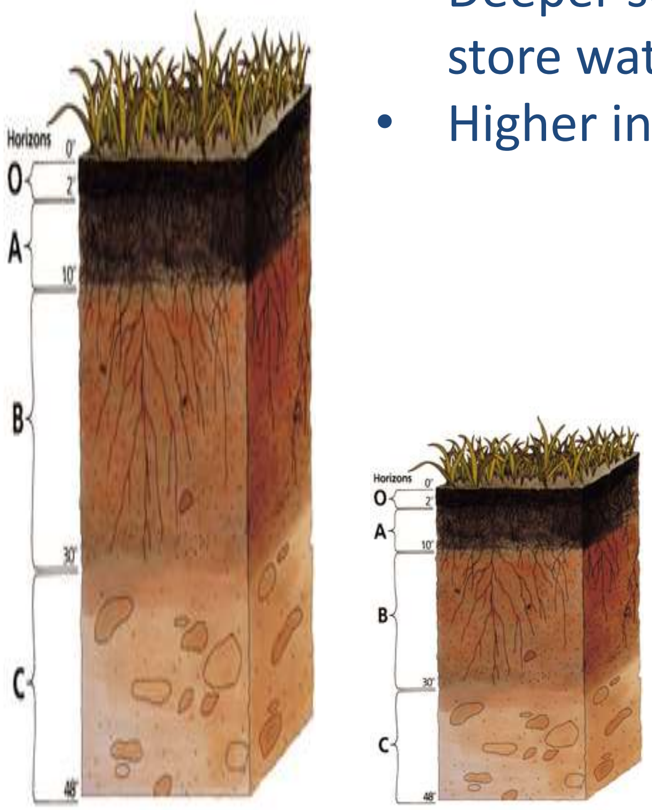
Elsewhere – Forested Catchment



Panola, Georgia, USA (Tromp-van Meerveld and McDonnell, Chapter 1)
Maimai, New Zealand (Mosley, 1979)
Tatsunokuchi-yama exp. forest, Honsyu Island, Japan (Tani, 1997)
H.J. Andrews exp. forest, Oregon, USA (McGuire, unpublished data)

Soil Moisture Storage

- Deeper soil has bigger capacity to store water
- Higher initial loss



Source: Zulkifli Yusop (UTM)