R&D Opportunities with iFFRM

A
Technical Talk
by
Abdul Razak Bahrom

in conjunction with
Jabatan Pengairan dan Saliran Malaysia
Malaysian Hydrological Society,
International Hydrological Programme (UNESCO-IHP Malaysia)
and
Jurutera Perunding Zaaba Sdn. Bhd.

June 14, 2012

iFFRM
Integrated Flood Forecasting and River Monitoring
KLANG VALLEY

What is iFFRM?

- iFFRM stands for
  Integrated Flood Forecasting and River Monitoring

- It is a large system that encompasses hardware and software, processes and procedures, telemetric and databases, and operational and maintenance systems to forecast floods and monitor the rivers.

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Integrated Flood Forecasting and River Monitoring
KLANG VALLEY

iFFRM Operational Objectives

- To accurately and effectively monitor rainfall, water level, water flow, water quality, debris and mud flow, and tidal and saltwater intrusions in real-time.
- To accurately and effectively forecast flood events in real-time.
- To monitor and control all remote stations, sensors, instruments, and provide visual displays of information.

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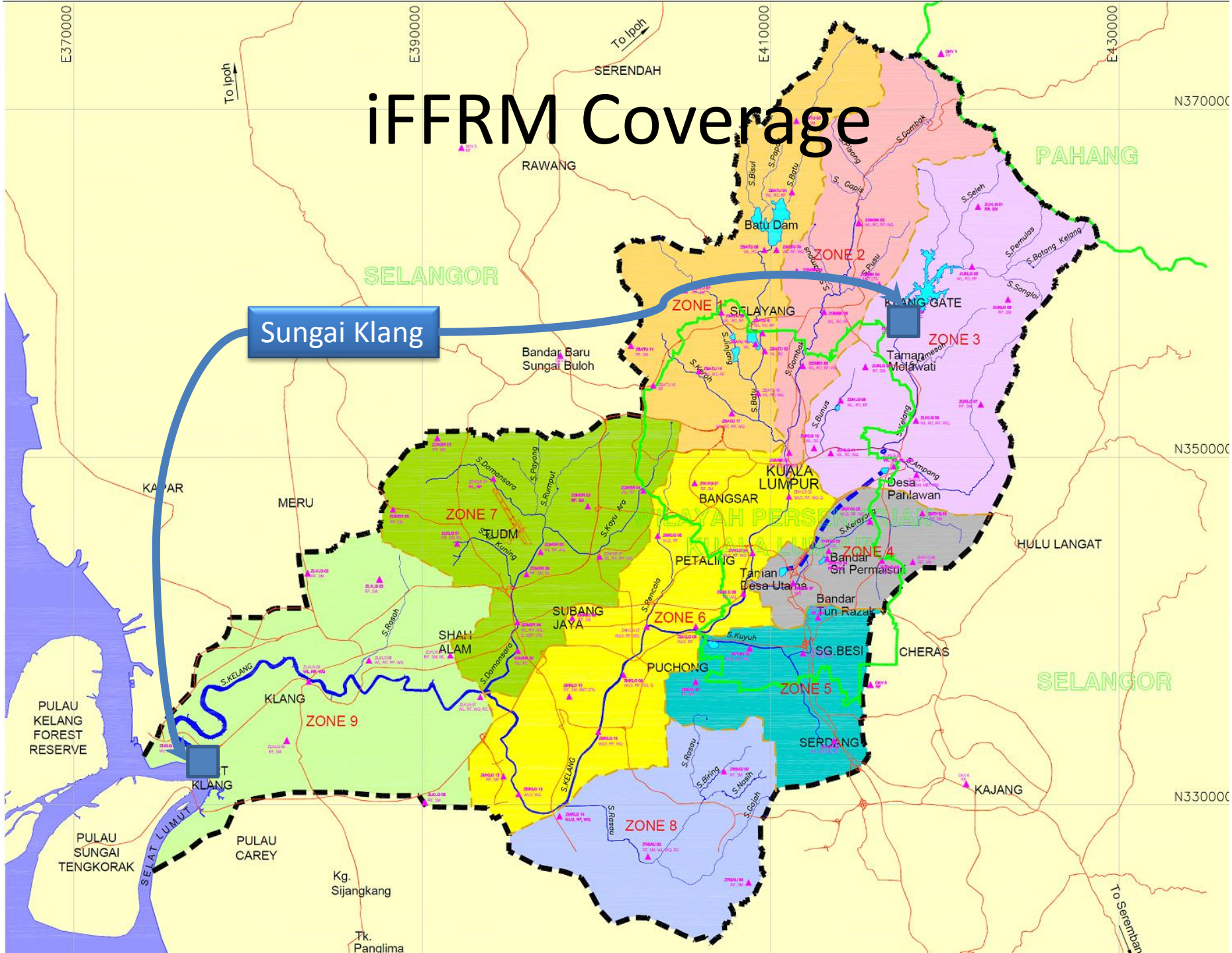
iFFRM Coverage
Sungai Klang
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
ZONE 7
ZONE 8
ZONE 9
SELANGOR
PAHANG
SERENDAH
RAWANG
Batu Dam
SELAYANG
KLANG GATE
Bandar Baru Sungai Buloh
Taman Melawati
KUALA LUMPUR
BANGSAR
Desa Pahlawan
MERU
KAPAR
TUDM
PETALING
Taman Desa Utama
Bandar Sri Permaisuri
Bandar Tun Razak
SUBANG JAYA
SHAH ALAM
PUCHONG
SG.BESI
CHERAS
SERDANG
KAJANG
HULU LANGAT
KLANG
PULAU KELANG FOREST RESERVE
PULAU SUNGAI TENGKORAK
PULAU CAREY
SELAT LUMUT
Kg. Sijangkang
Tk. Panglima
To Ipoh
To Seremban
E370000
E390000
E410000
E430000
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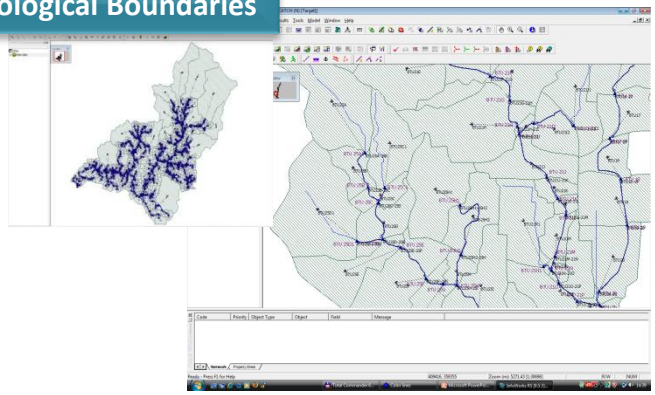
N350000
N330000

iFFRM Flood Forecasting Model

Hydrological Boundaries



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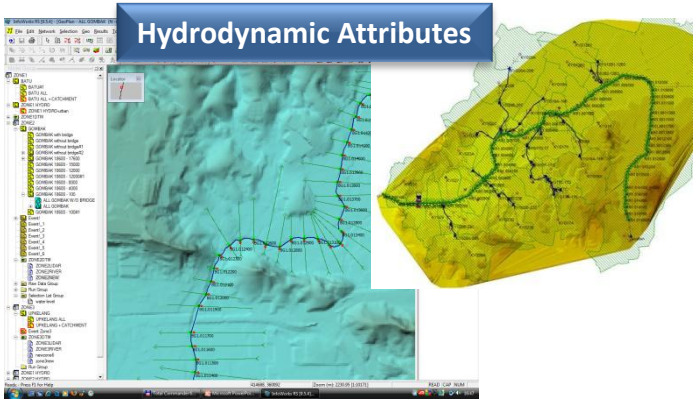
Hydrodynamic Attributes



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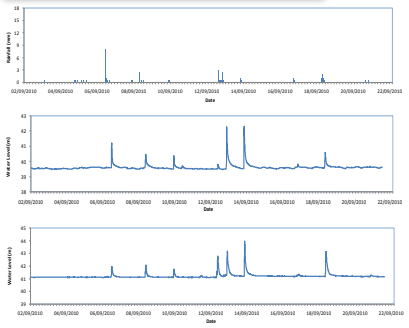
Observed Conditions



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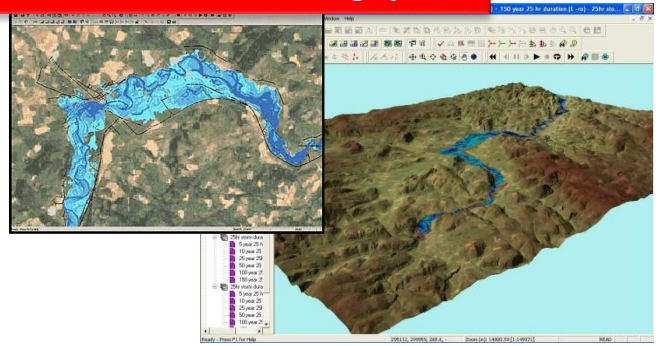
The iFFRM Flood Forecasting System



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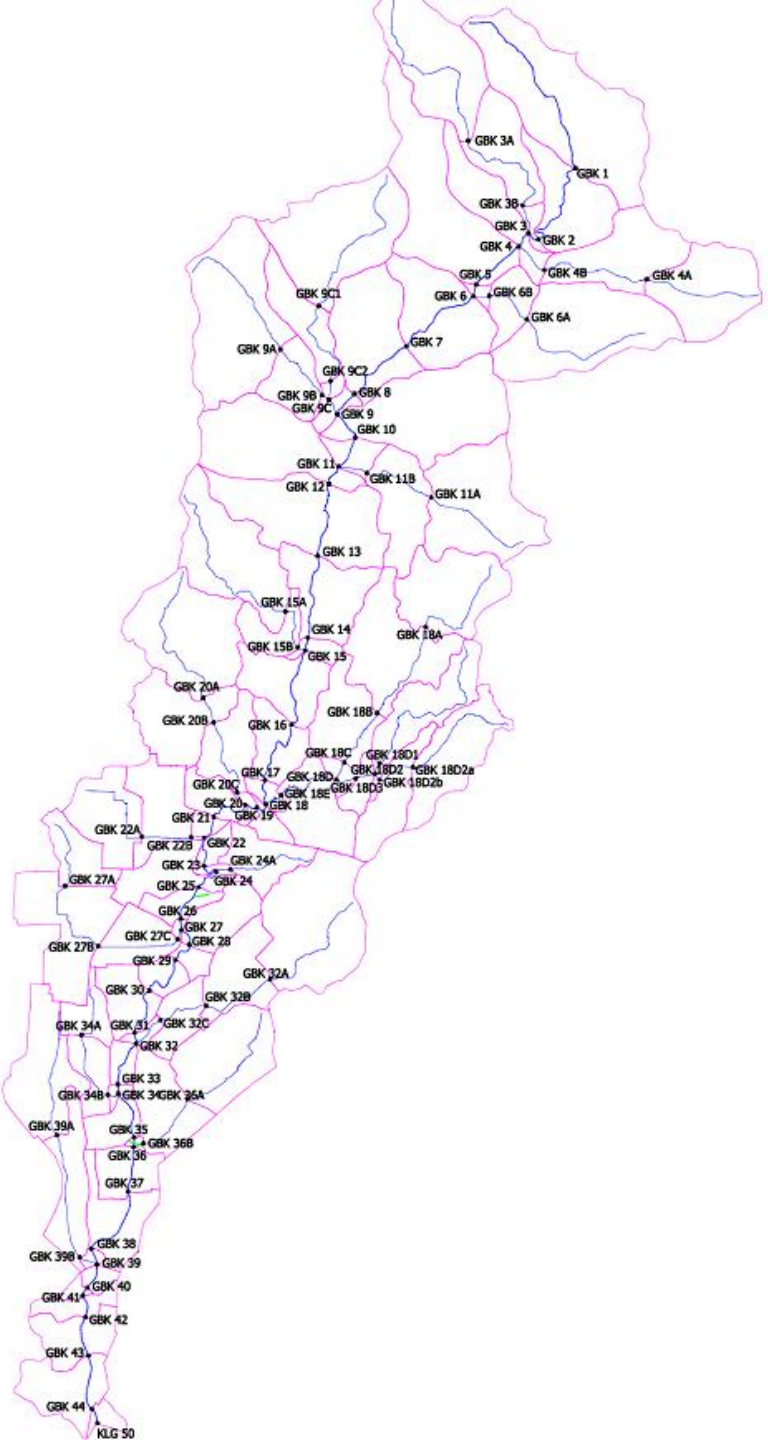
Hydrological Schematic – Zone 1

Parameter	Values
Catchment (km^2)	148
Subcatchments	46
Nodes	299
Links	298
Network Objects	644
Computational Length (m)	38,774
River Sections	240
Boundary Nodes	50
Junction Nodes	9

Hydrological Schematic – Zone 2

Parameter	Values
Catchment (km^2)	122
Subcatchments	64
Nodes	298
Links	297
Network Objects	679
Computational Length (m)	58,020
River Sections	210
Boundary Nodes	67
Junction Nodes	21



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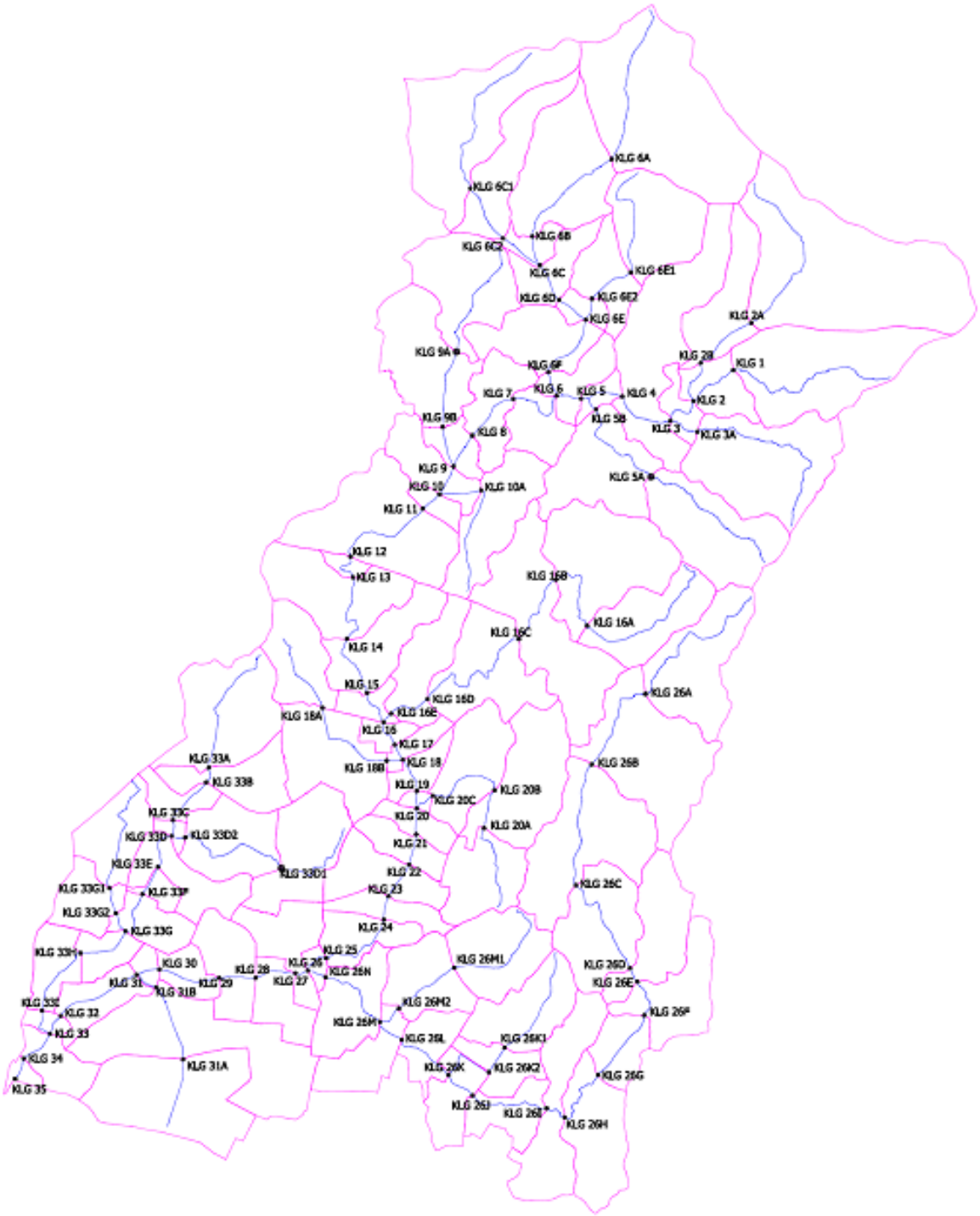
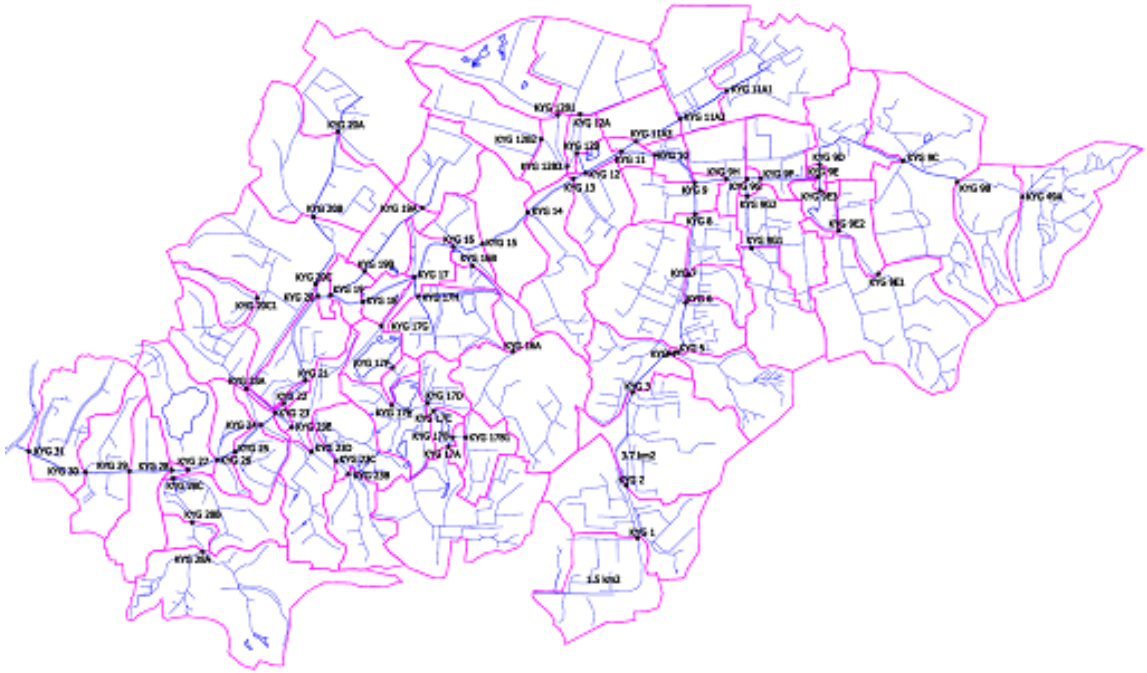
Hydrological Schematic – Zone 3

Parameter	Values
Catchment (km^2)	182
Subcatchments	53
Nodes	386
Links	385
Network Objects	825
Computational Length (m)	67,121
River Sections	289
Boundary Nodes	55
Junction Nodes	24



Hydrological Schematic – Zone 4

Parameter	Values
Catchment (km^2)	61
Subcatchments	47
Nodes	295
Links	294
Network Objects	636
Computational Length (m)	44,114
River Sections	157
Boundary Nodes	49
Junction Nodes	35



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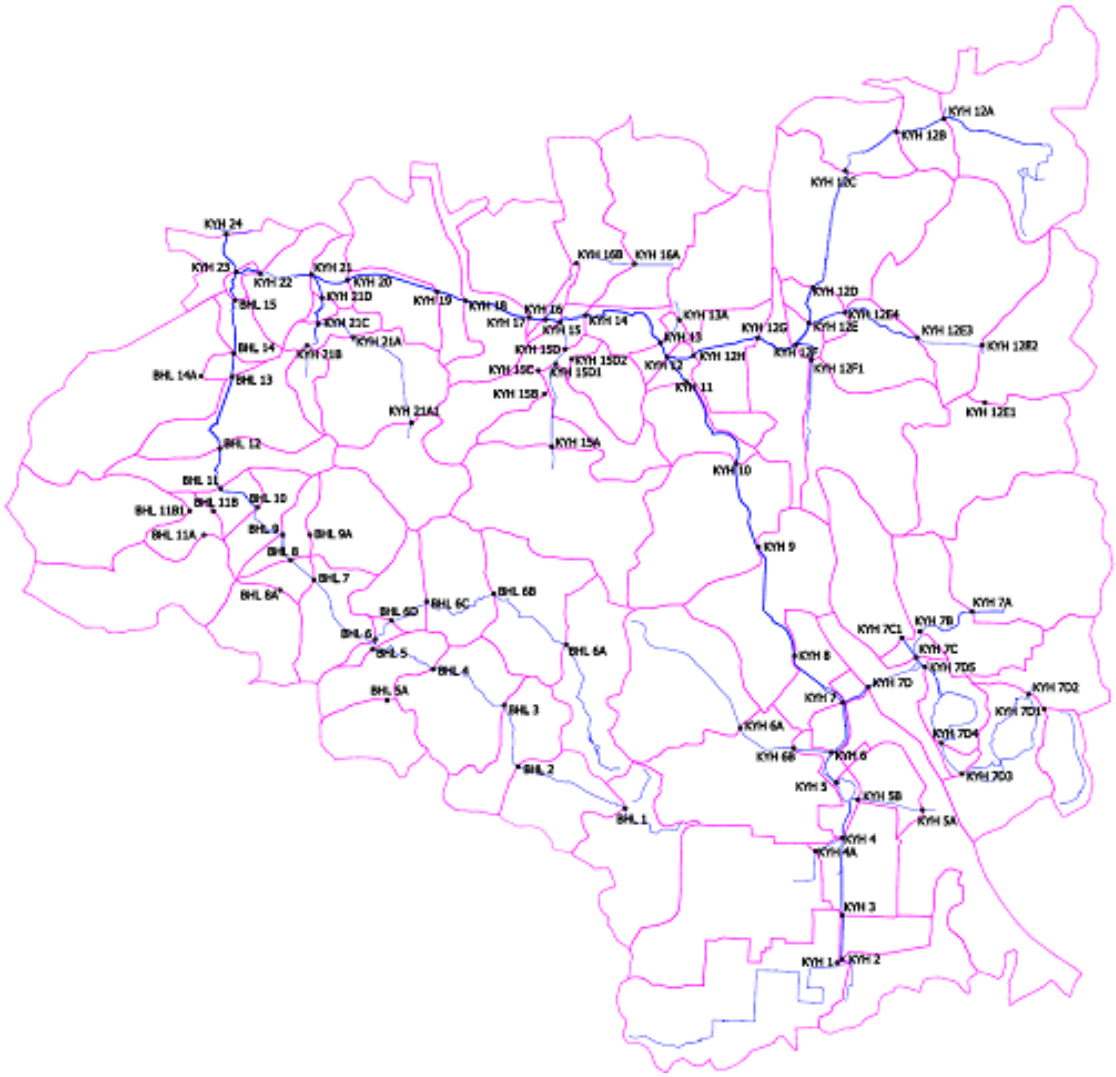
Hydrological Schematic – Zone 5

Parameter	Values
Catchment (km^2)	80
Subcatchments	76
Nodes	371
Links	370
Network Objects	817
Computational Length (m)	68,523
River Sections	134
Boundary Nodes	71
Junction Nodes	62



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Hydrological Schematic – Zone 6

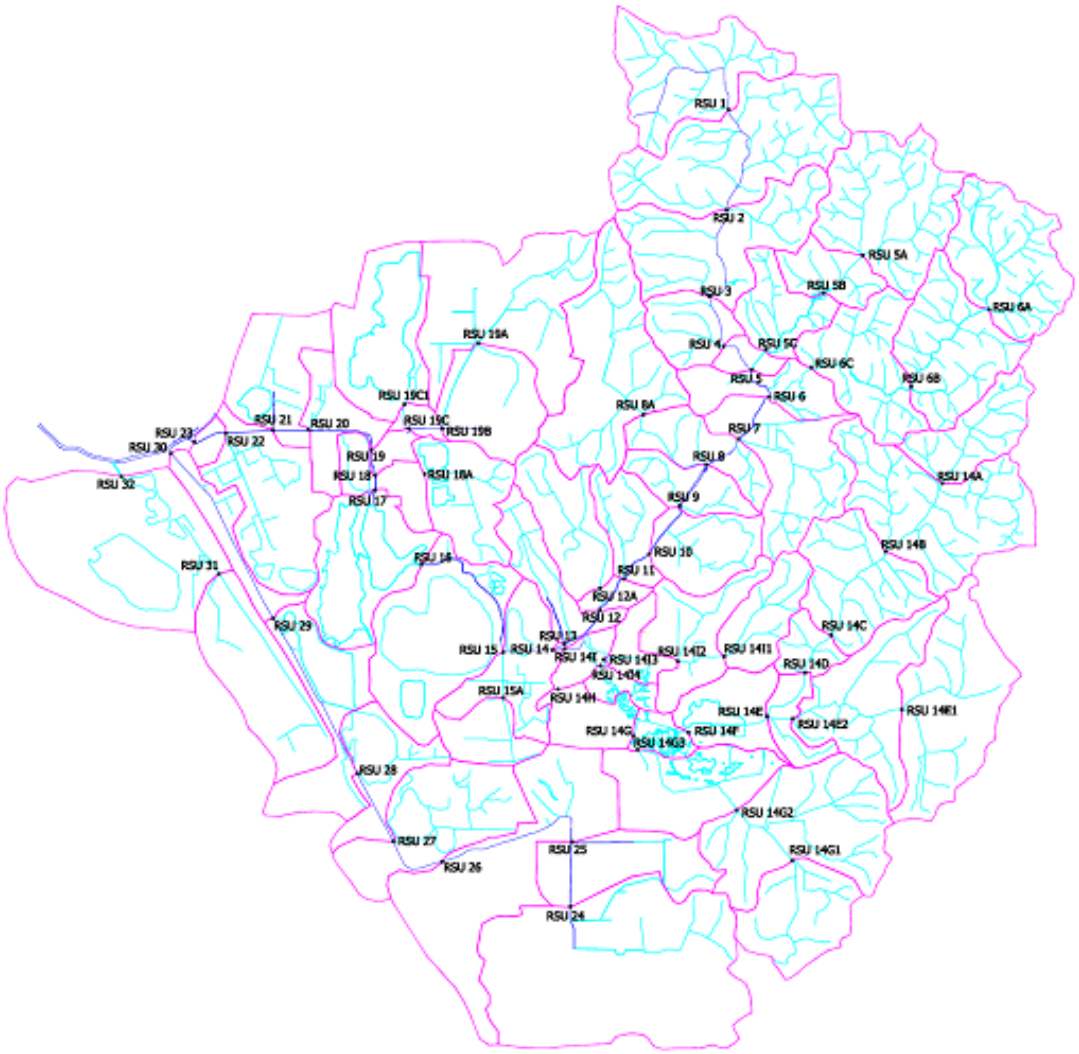
Parameter	Values
Catchment (km^2)	171
Subcatchments	99
Nodes	657
Links	656
Network Objects	1,432
Computational Length (m)	115,451
River Sections	408
Boundary Nodes	100
Junction Nodes	64

Hydrological Schematic – Zone 7

Parameter	Values
Catchment (km^2)	153
Subcatchments	95
Nodes	688
Links	687
Network Objects	1,470
Computational Length (m)	98,969
River Sections	436
Boundary Nodes	105
Junction Nodes	62

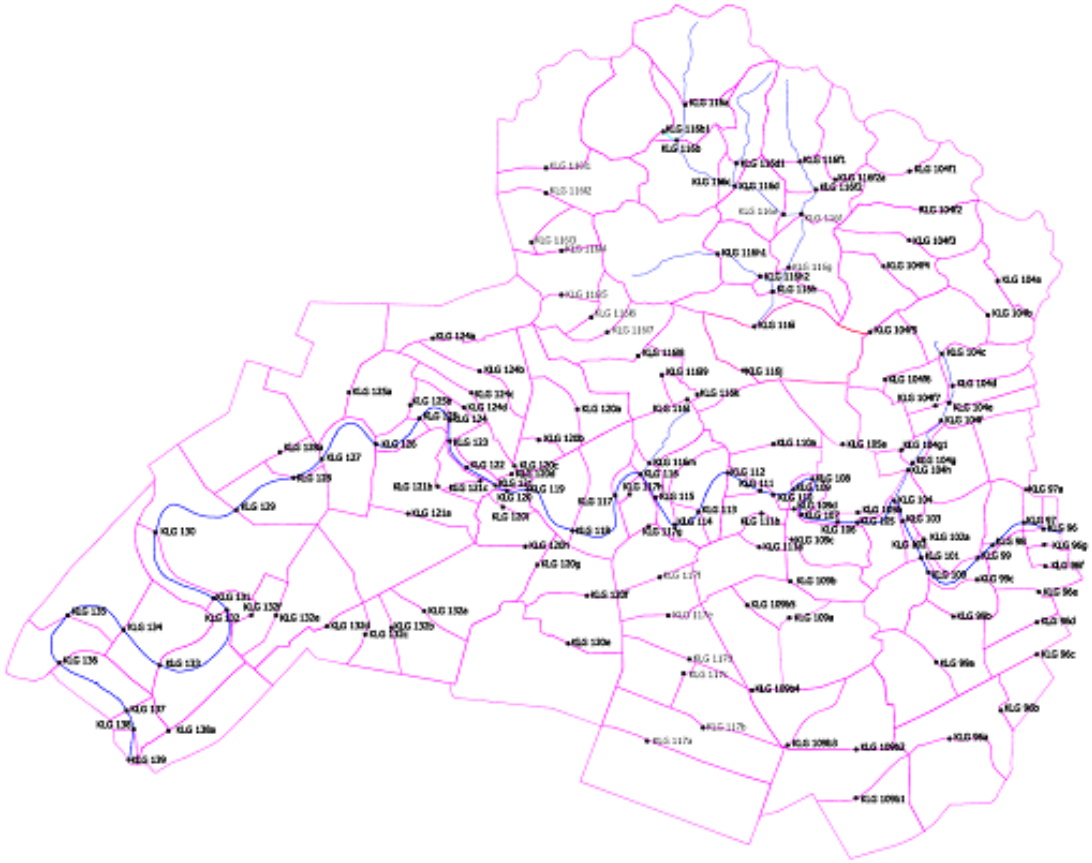
Hydrological Schematic – Zone 8

Parameter	Values
Catchment (km^2)	132
Subcatchments	32
Nodes	208
Links	207
Network Objects	488
Computational Length (m)	54,894
River Sections	118
Boundary Nodes	35
Junction Nodes	23



Hydrological Schematic – Zone 9

Parameter	Values
Catchment (km^2)	163
Subcatchments	94
Nodes	626
Links	625
Network Objects	1,345
Computational Length (m)	124,353
River Sections	347
Boundary Nodes	97
Junction Nodes	74



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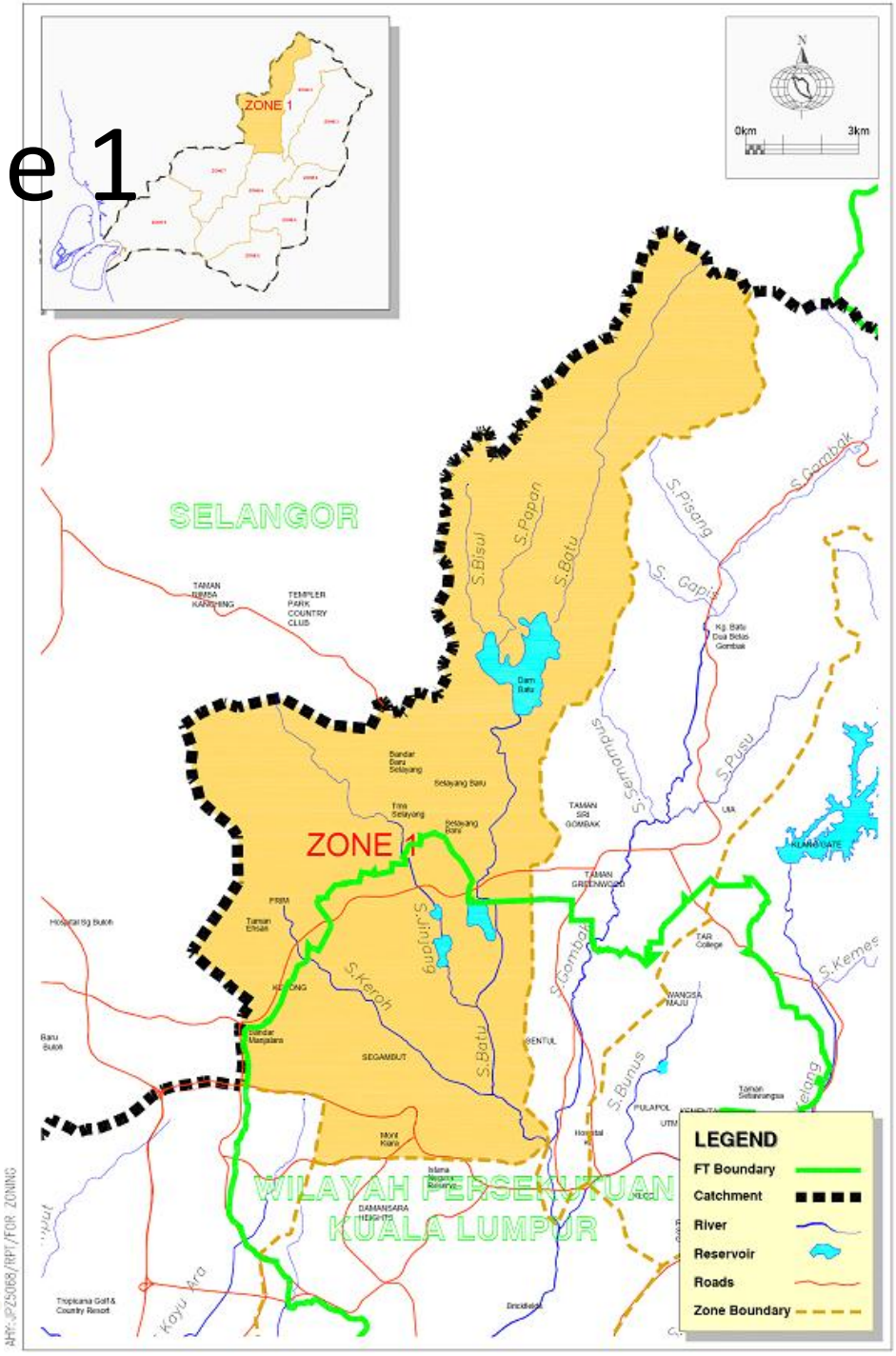
Zone 1

- 14 RTU Stations
- 10 Rainfall Stations
- 4 Soil Moisture Stations
- 9 Water Level Stations
- 3 Water Quality Stations

- 1 Jungle Station



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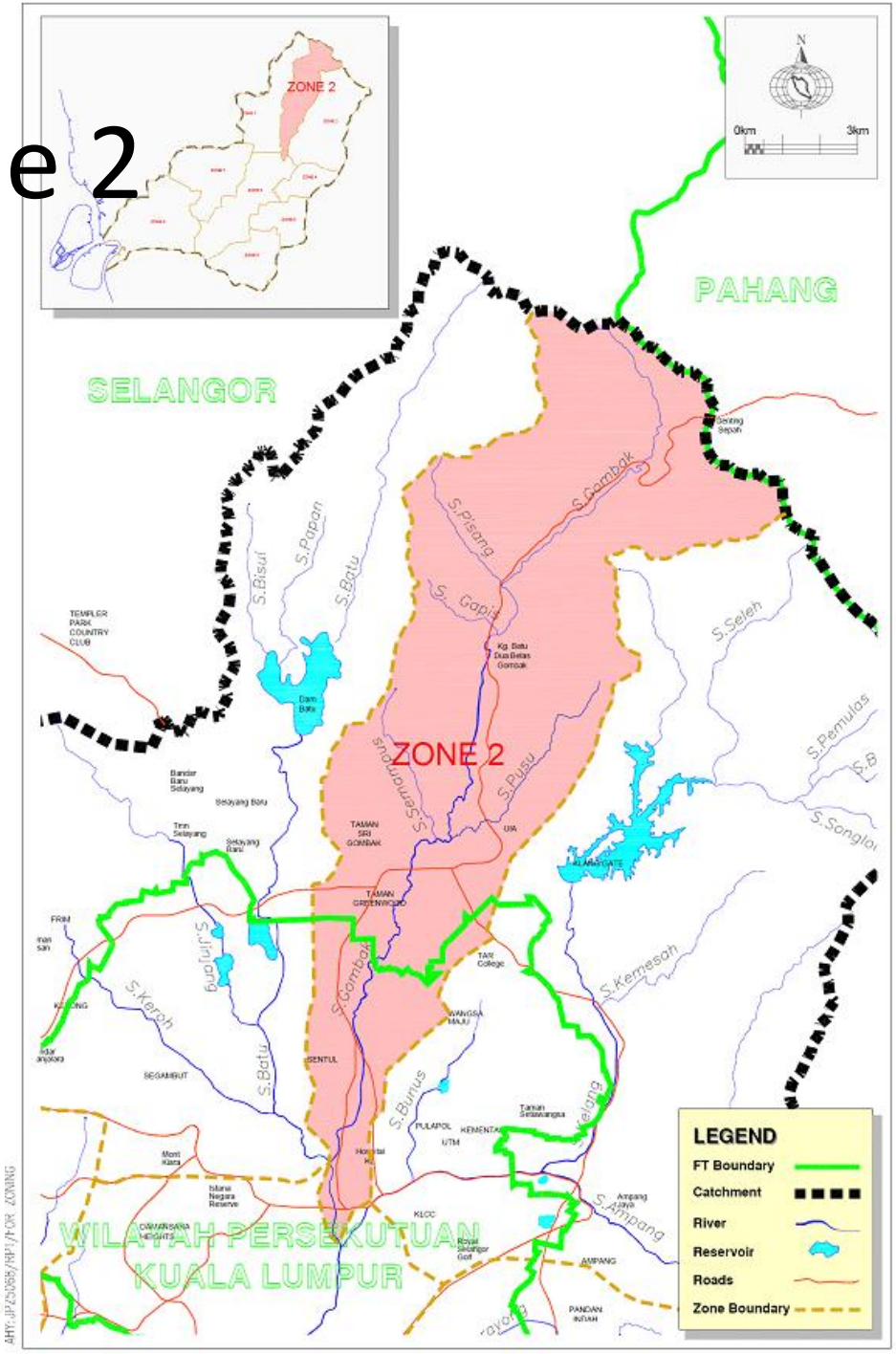
Zone 2

- 6 RTU Stations
- 6 Rainfall Stations
- 3 Soil Moisture Stations
- 3 Water Level Stations
- 1 Water Quality Station
- 1 Water Flow Station
- 1 Meteorological Station



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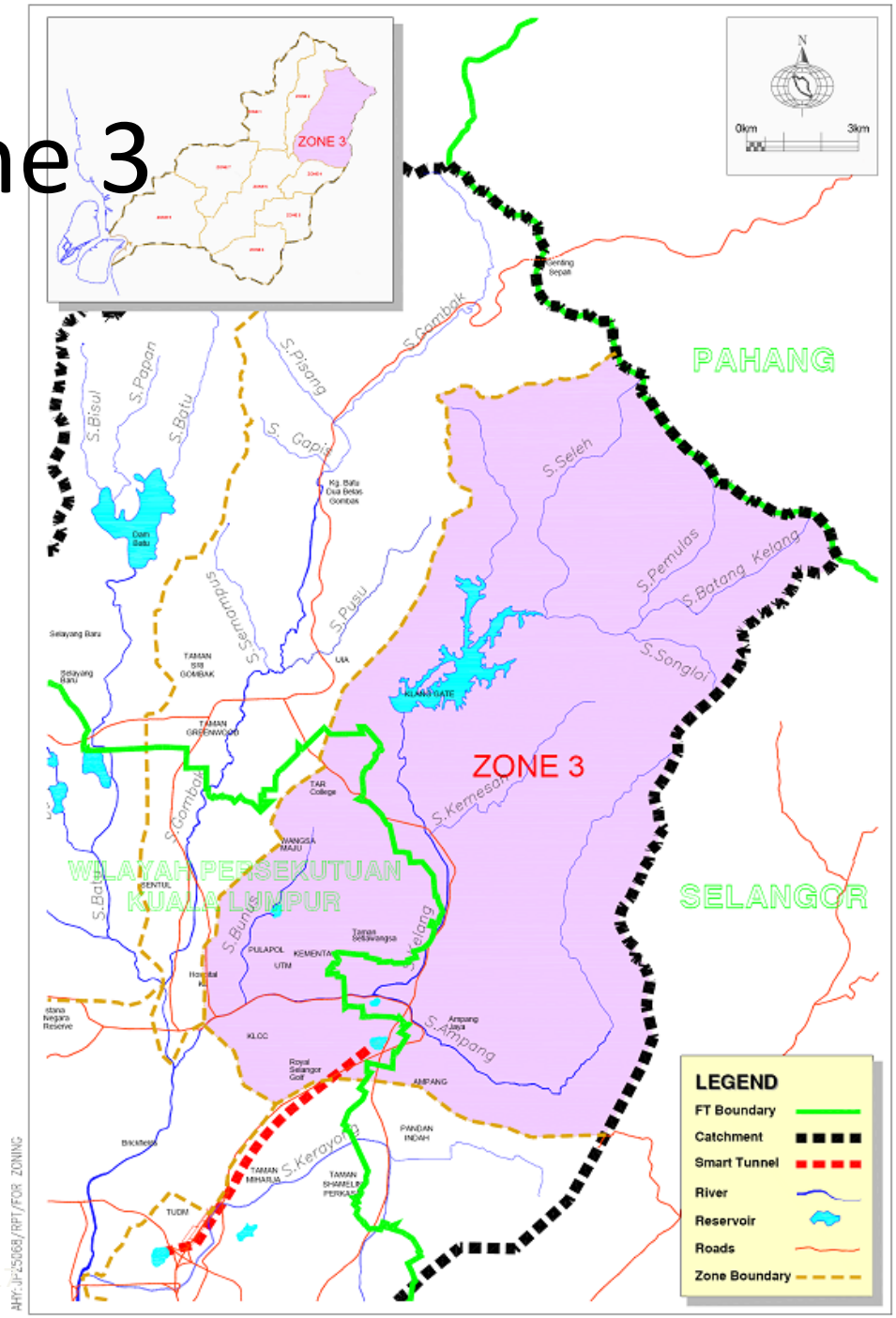
Zone 3

- 13 RTU Stations
- 10 Rainfall Stations
- 5 Soil Moisture Stations
- 8 Water Level Stations
- 4 Water Quality Stations
- 1 Meteorological Station

- 4 Jungle Stations



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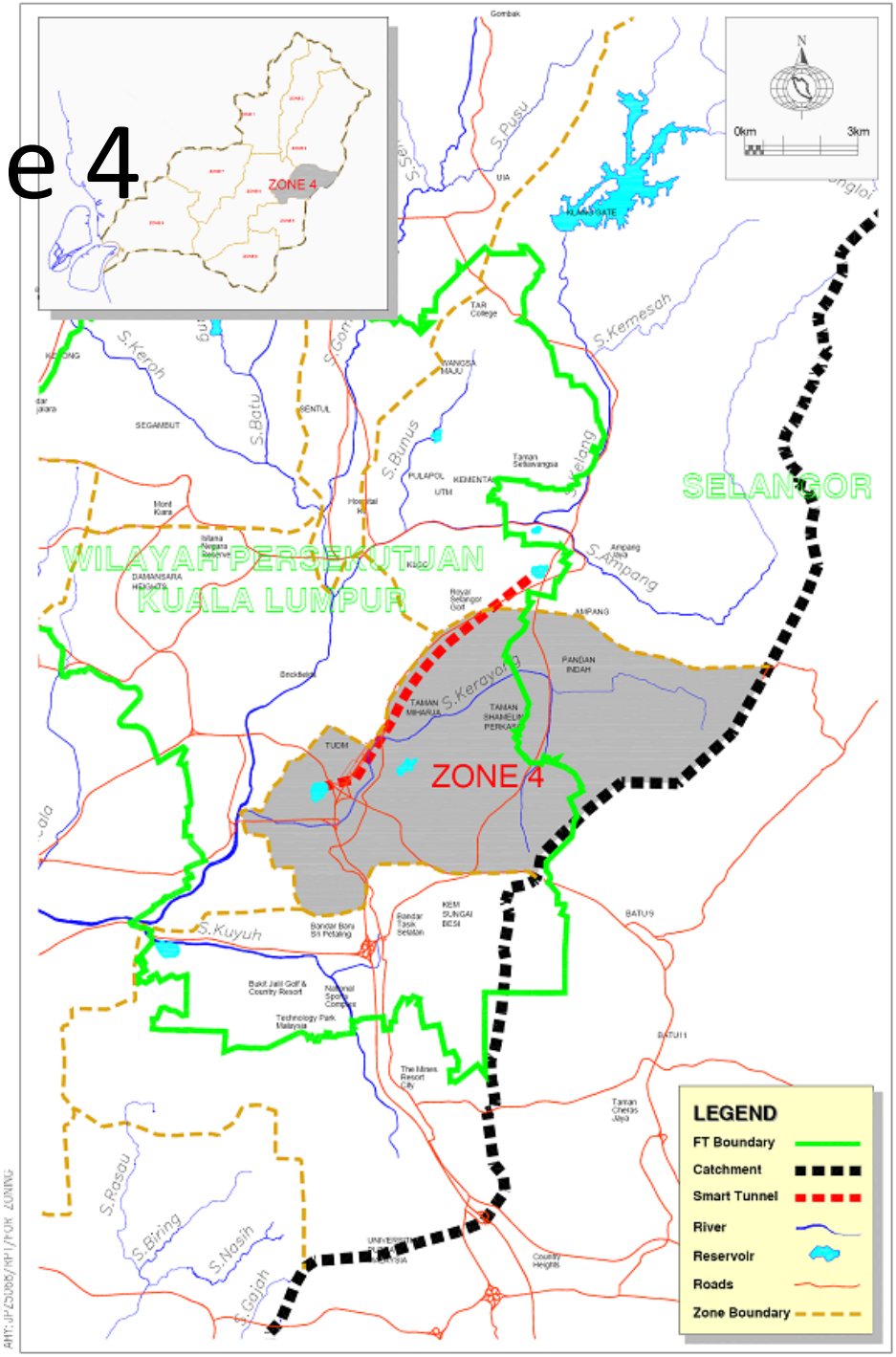
Zone 4

- 7 RTU Stations
- 4 Rainfall Stations
- 3 Soil Moisture Stations
- 5 Water Level Stations
- 2 Water Quality Stations



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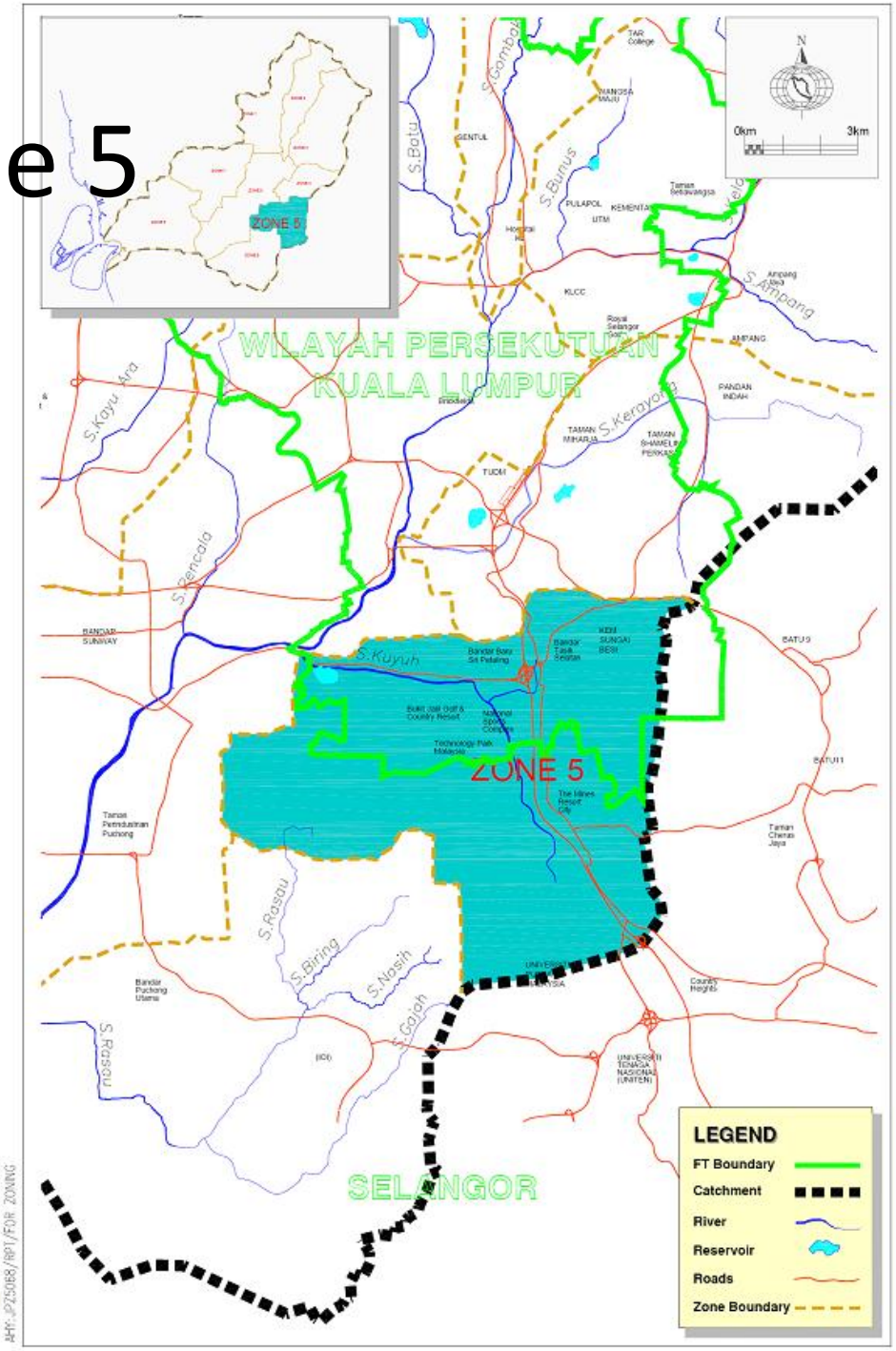
Zone 5

- 4 RTU Stations
- 4 Rainfall Stations
- 3 Soil Moisture Stations
- 3 Water Level Stations
- 1 Water Quality Station



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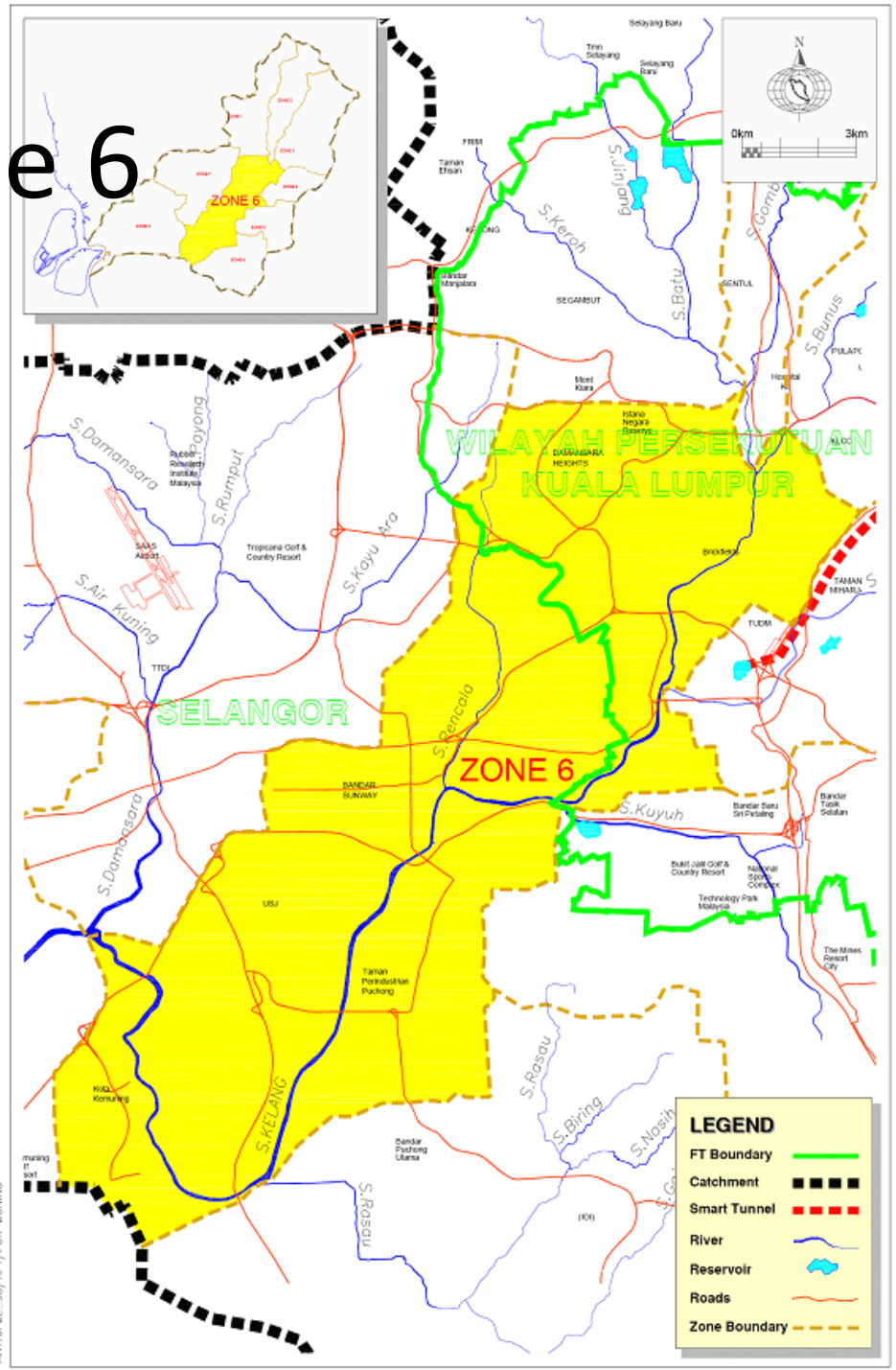
Zone 6

- 14 RTU Stations
- 13 Rainfall Stations
- 4 Soil Moisture Stations
- 9 Water Level Stations
- 8 Water Quality Stations
- 2 Water Flow Stations
- 1 Meteorological Station



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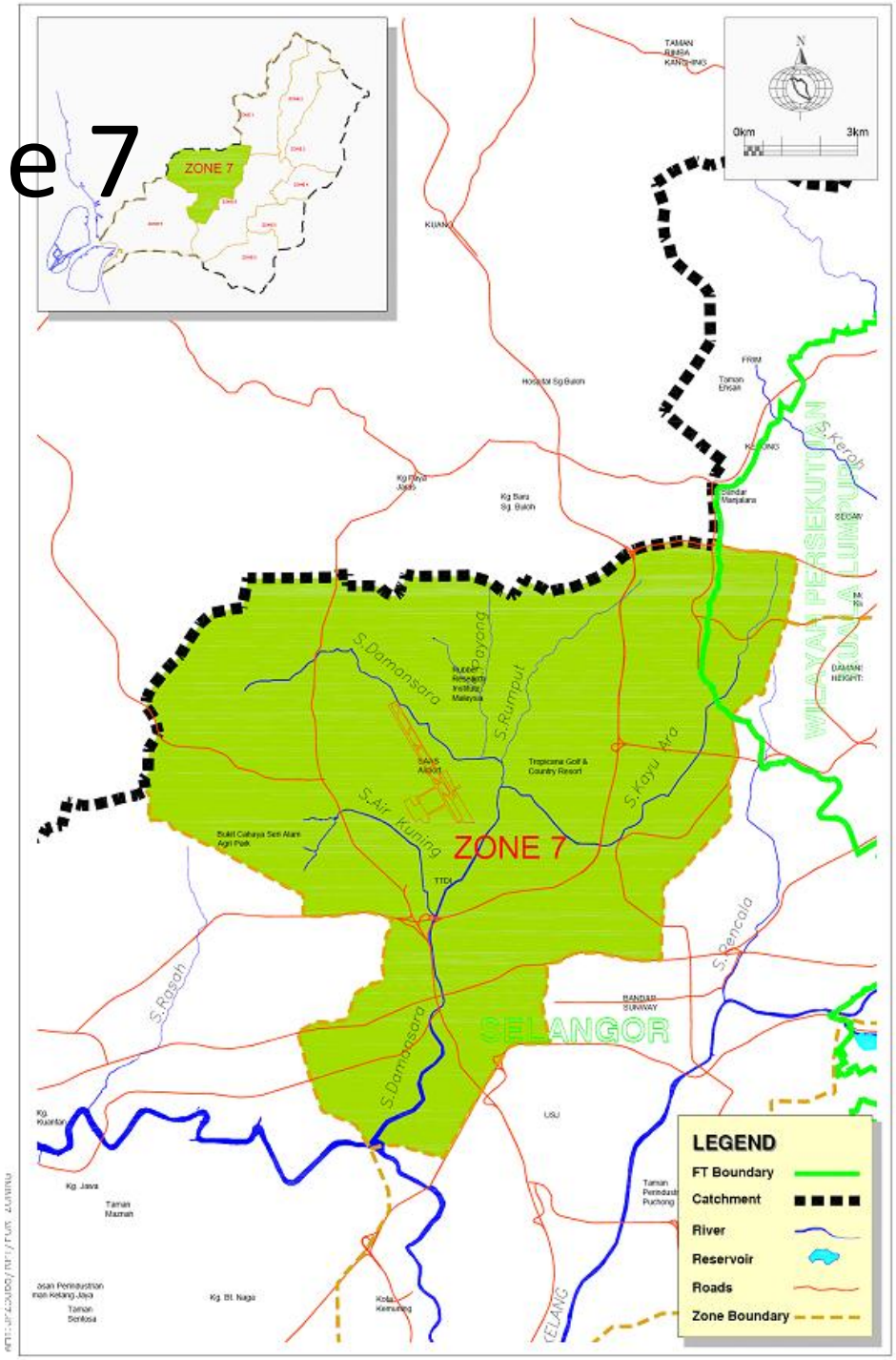
Zone 7

- 10 RTU Stations
- 9 Rainfall Stations
- 4 Soil Moisture Stations
- 7 Water Level Stations
- 3 Water Quality Stations
- 1 Water Flow Station



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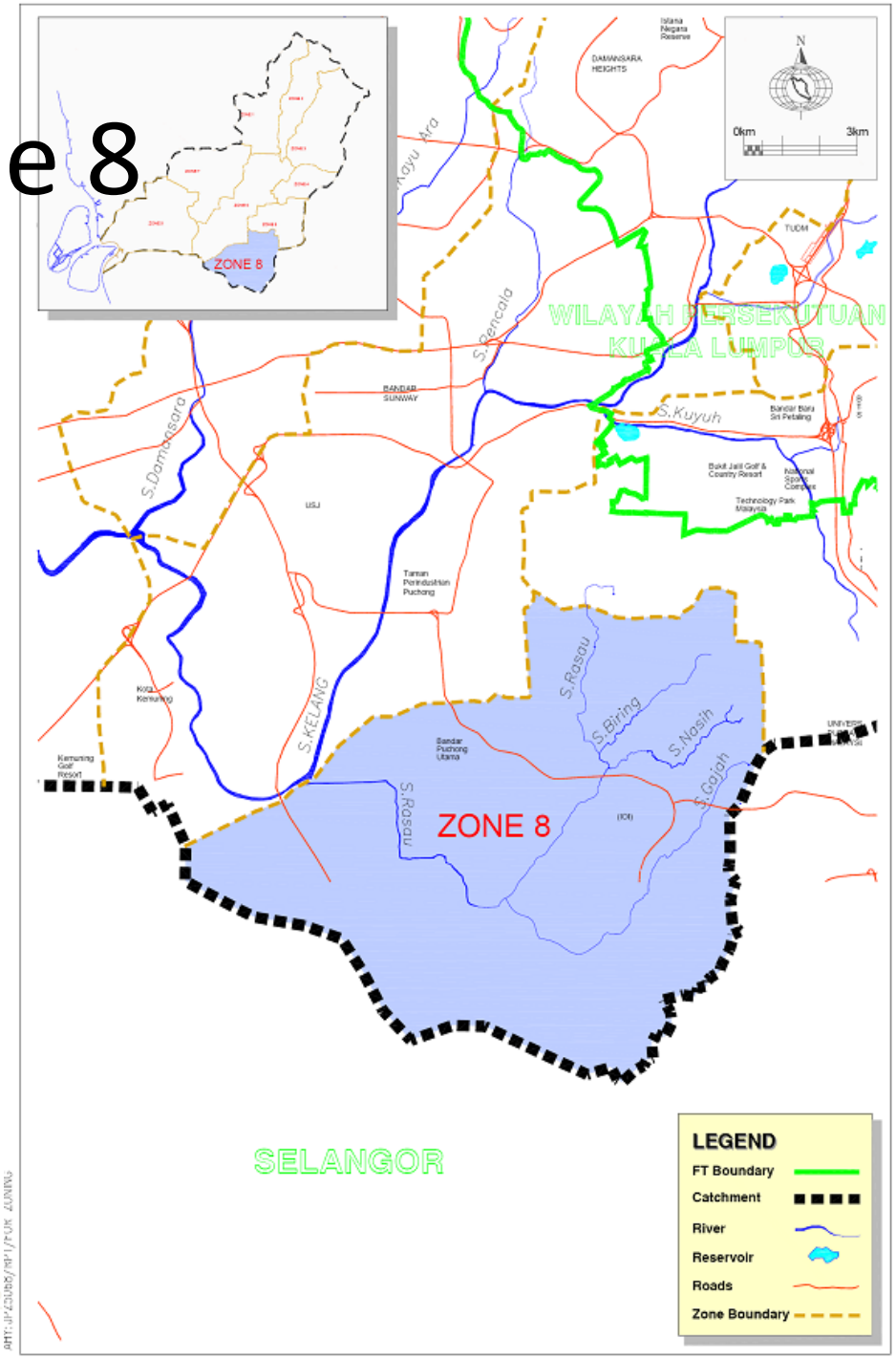
Zone 8

- 4 RTU Stations
- 4 Rainfall Stations
- 4 Soil Moisture Stations
- 4 Water Level Stations
- 1 Water Quality Station



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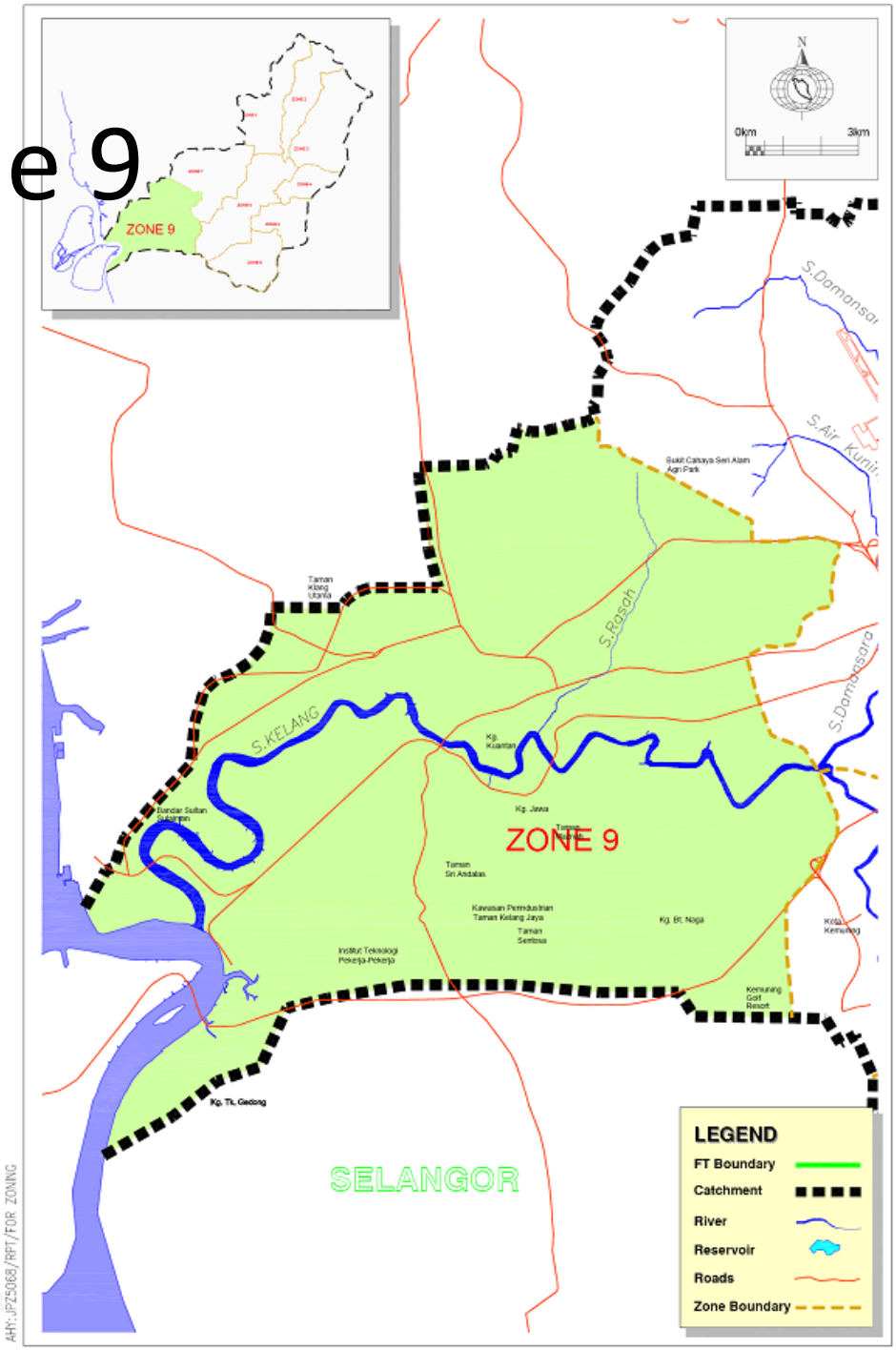
Zone 9

- 10 RTU Stations
- 10 Rainfall Stations
- 6 Soil Moisture Stations
- 6 Water Level Stations
- 4 Water Quality Stations
- 1 Vertical Profiler Station



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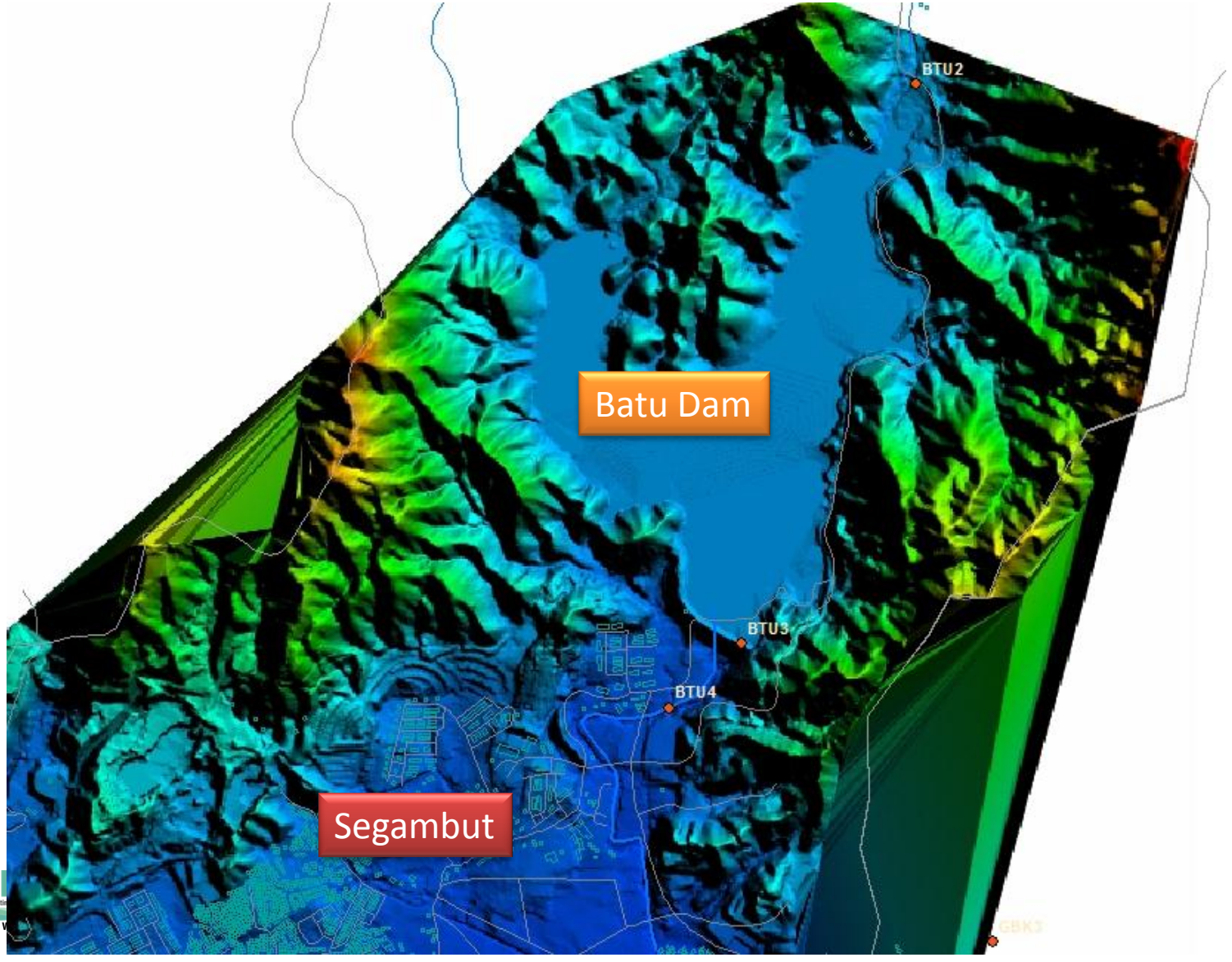
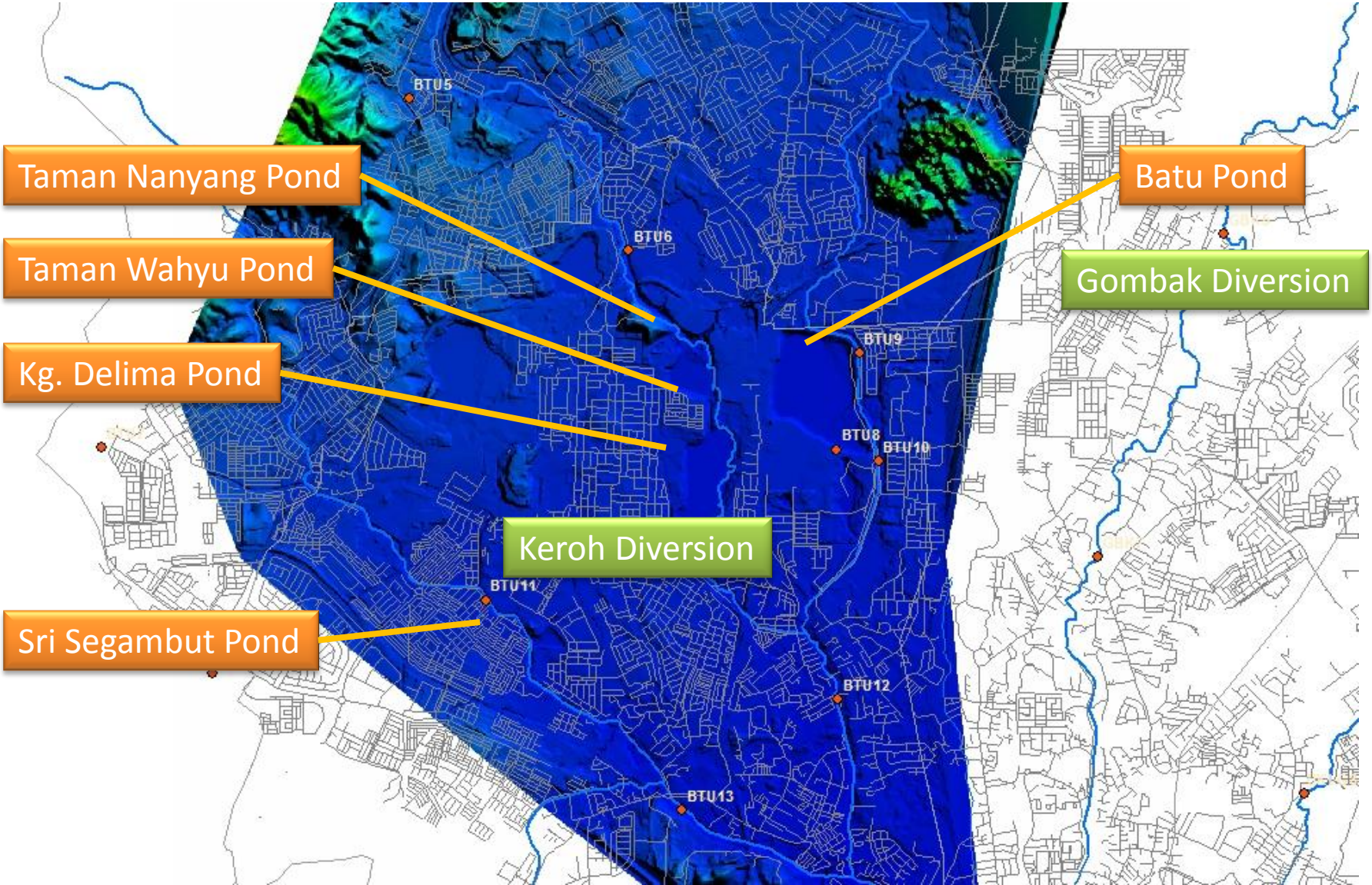
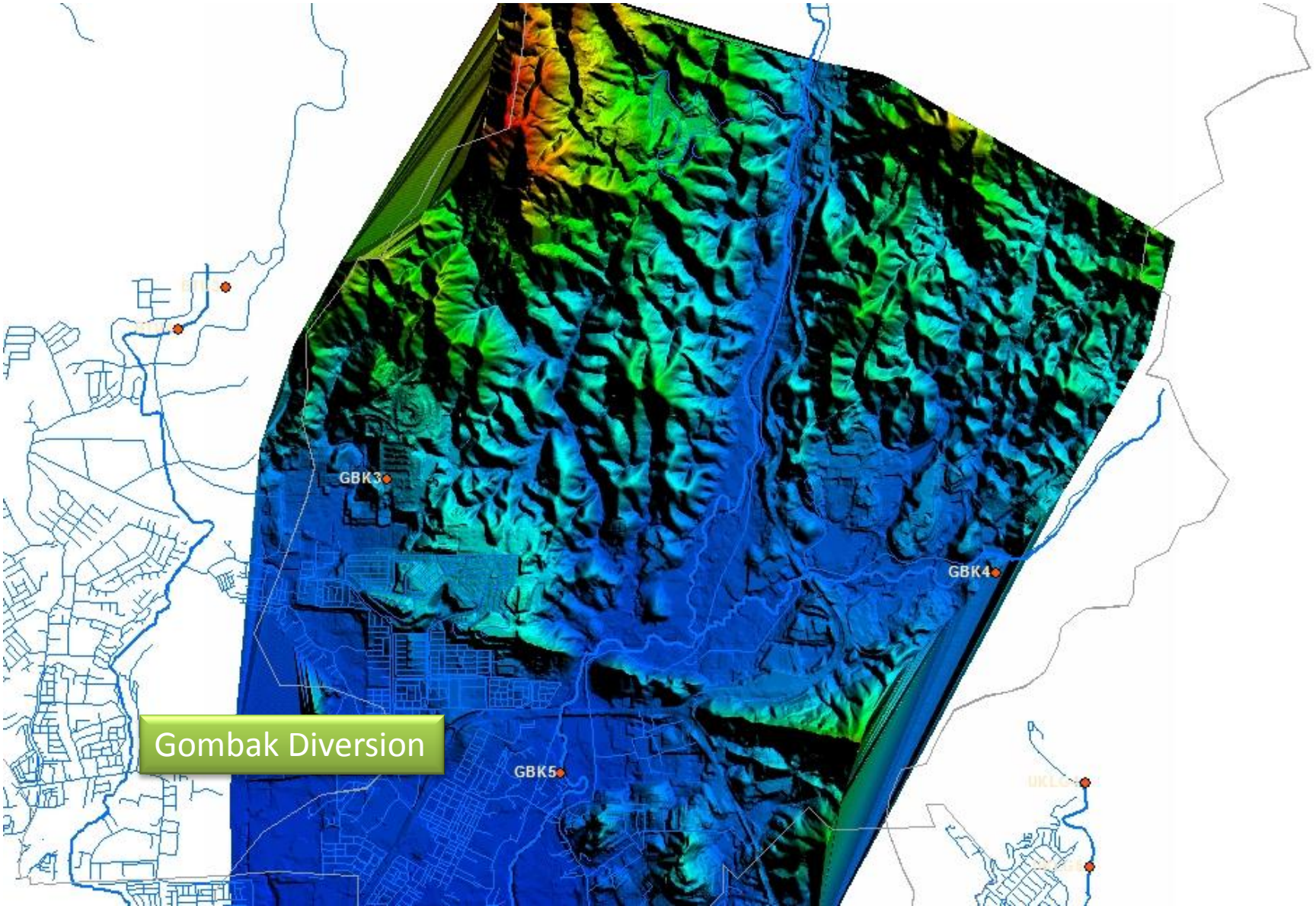
iFFRM Zone 1 (North)



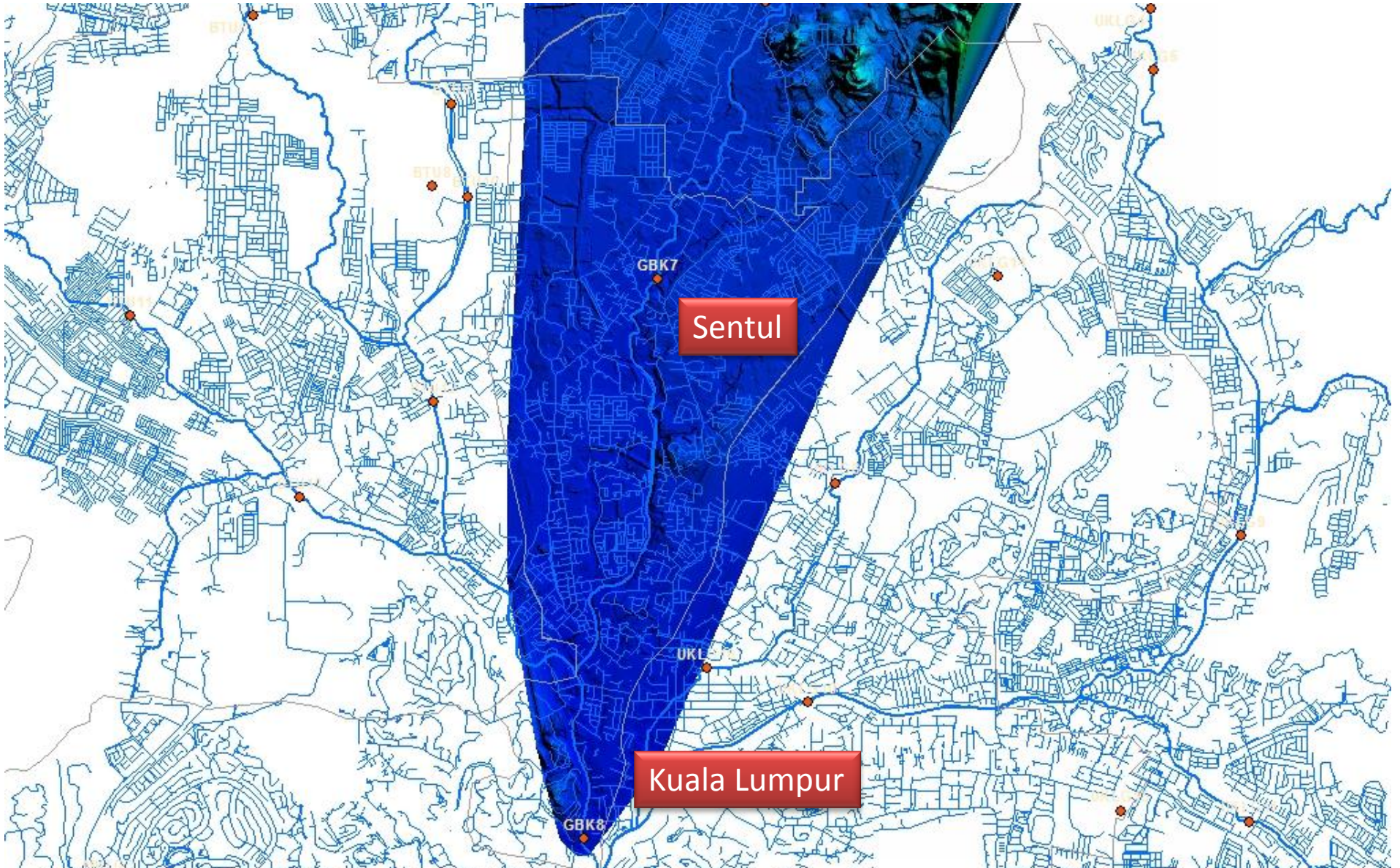
iFFRM Zone 1 (South)



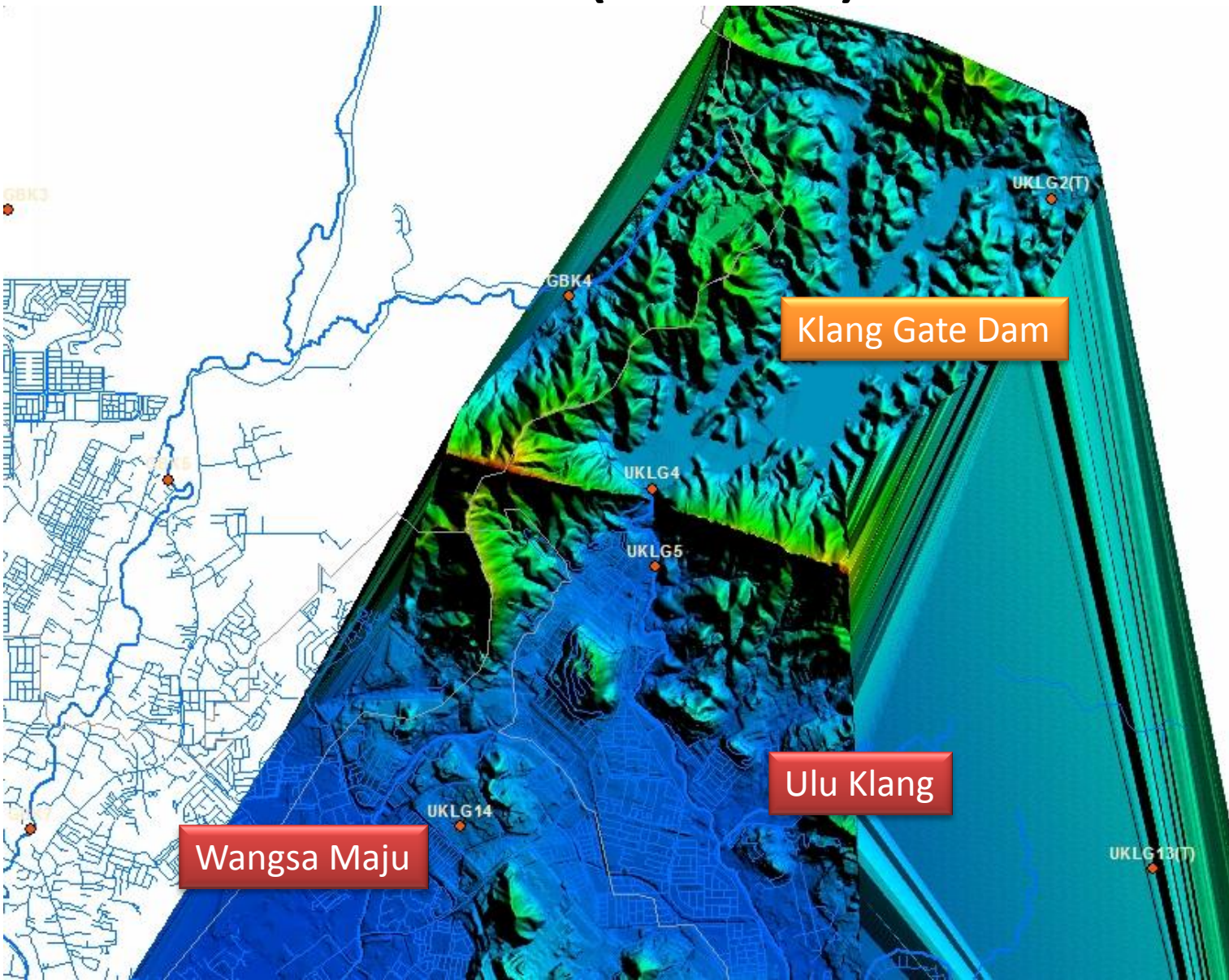
iFFRM Zone 2 (North)



iFFRM Zone 2 (South)



iFFRM Zone 3 (North)



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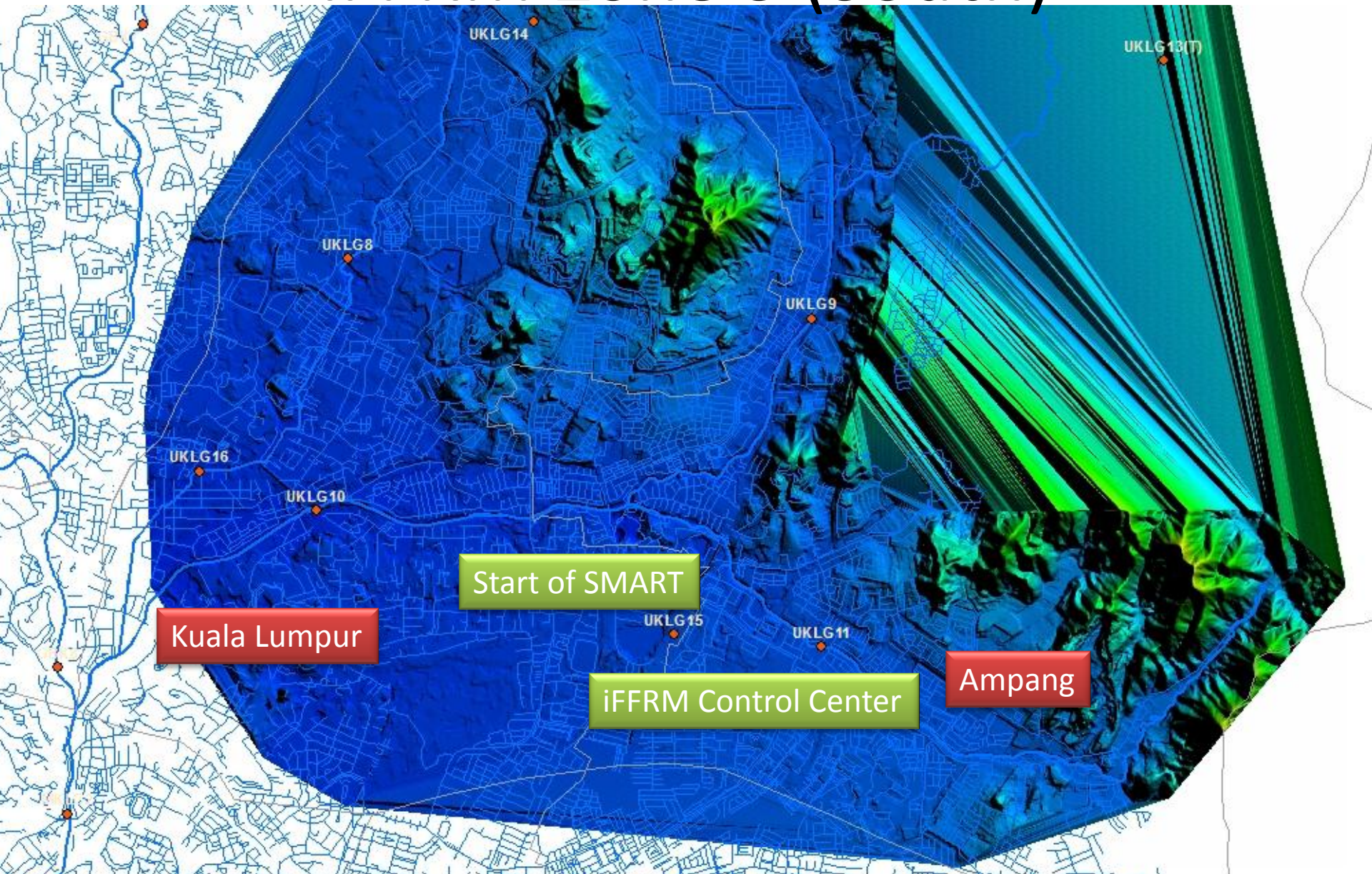
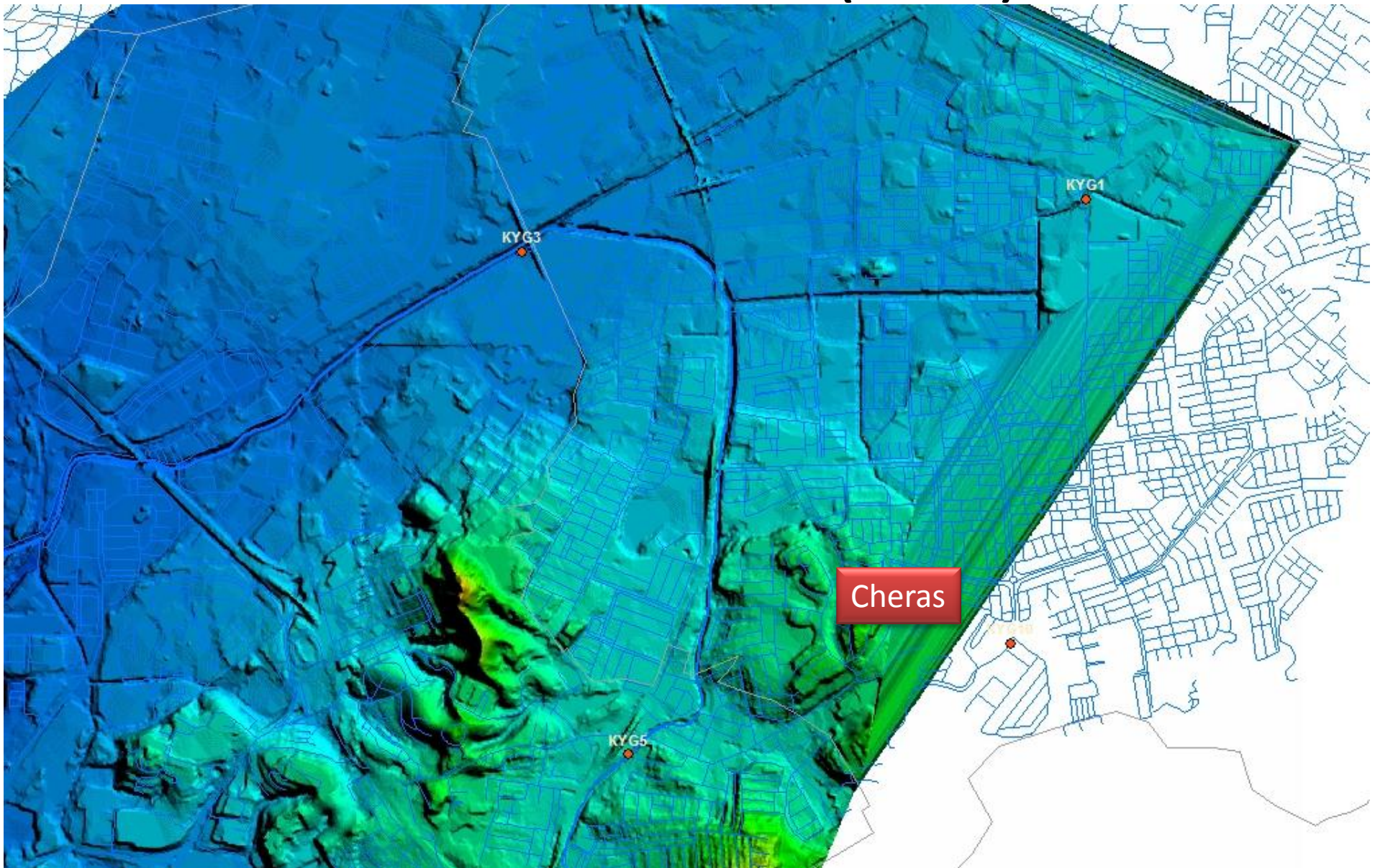
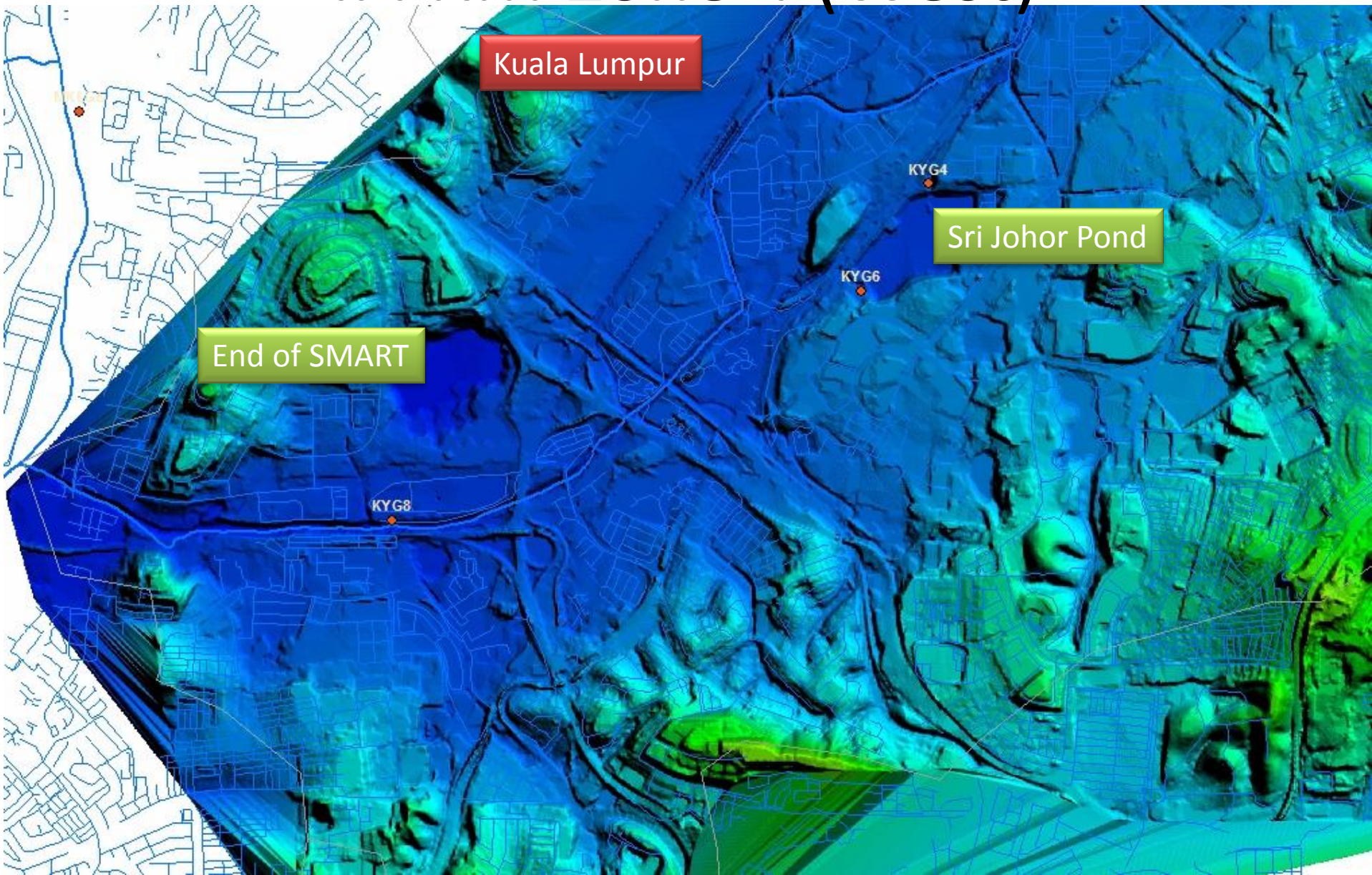
iFFRM Zone 3 (South)



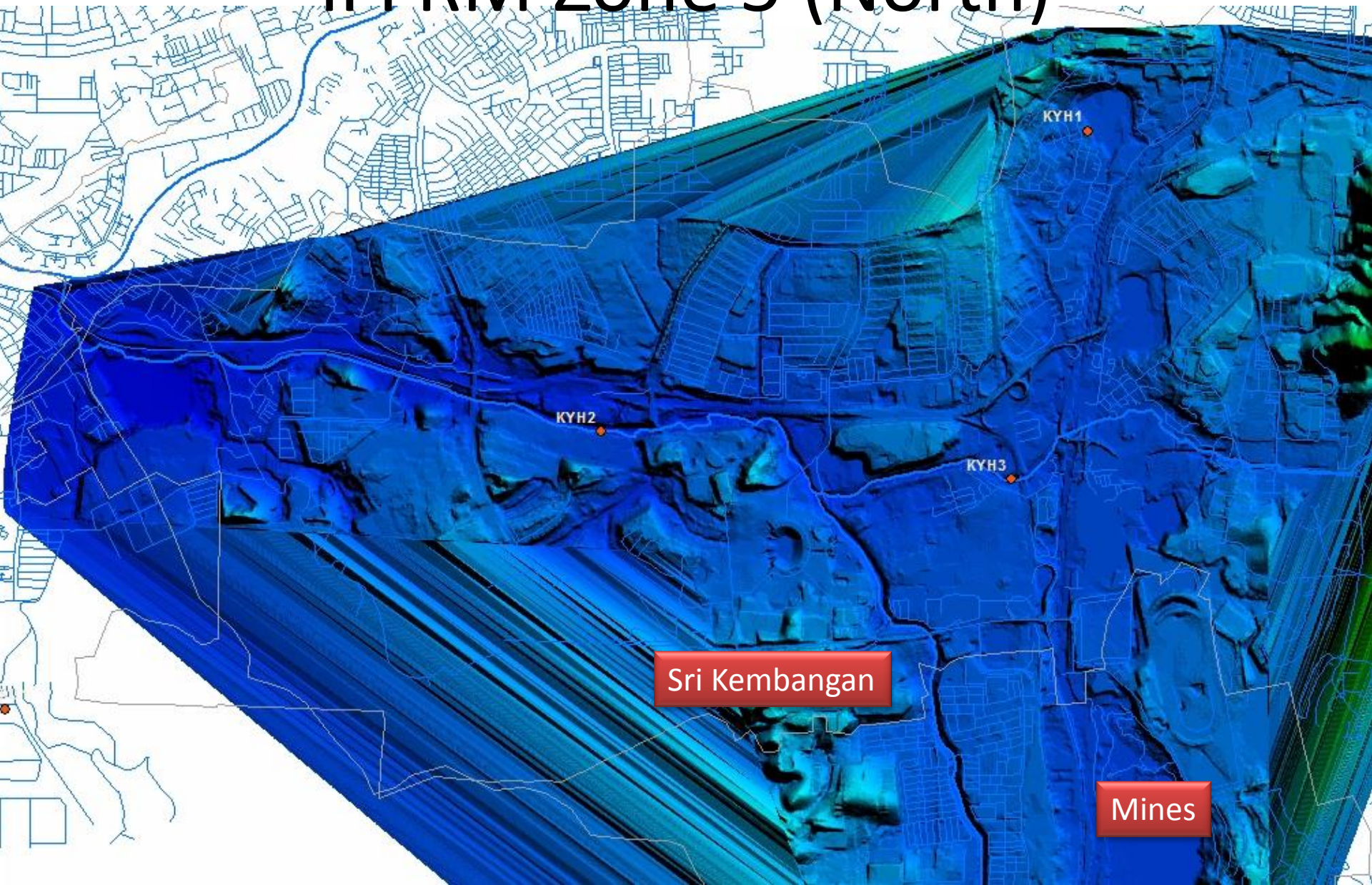
iFFRM Zone 4 (East)



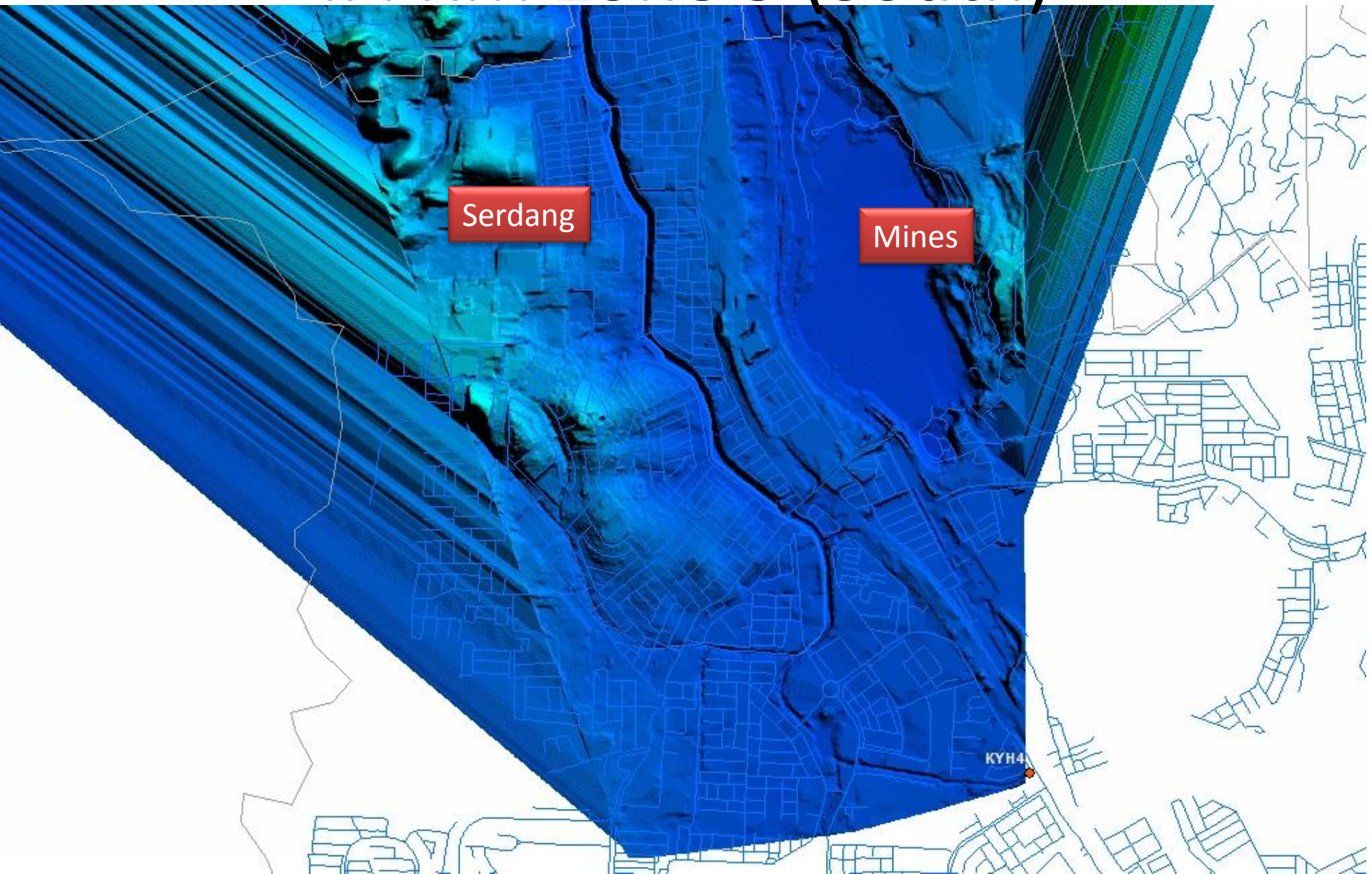
iFFRM Zone 4 (West)



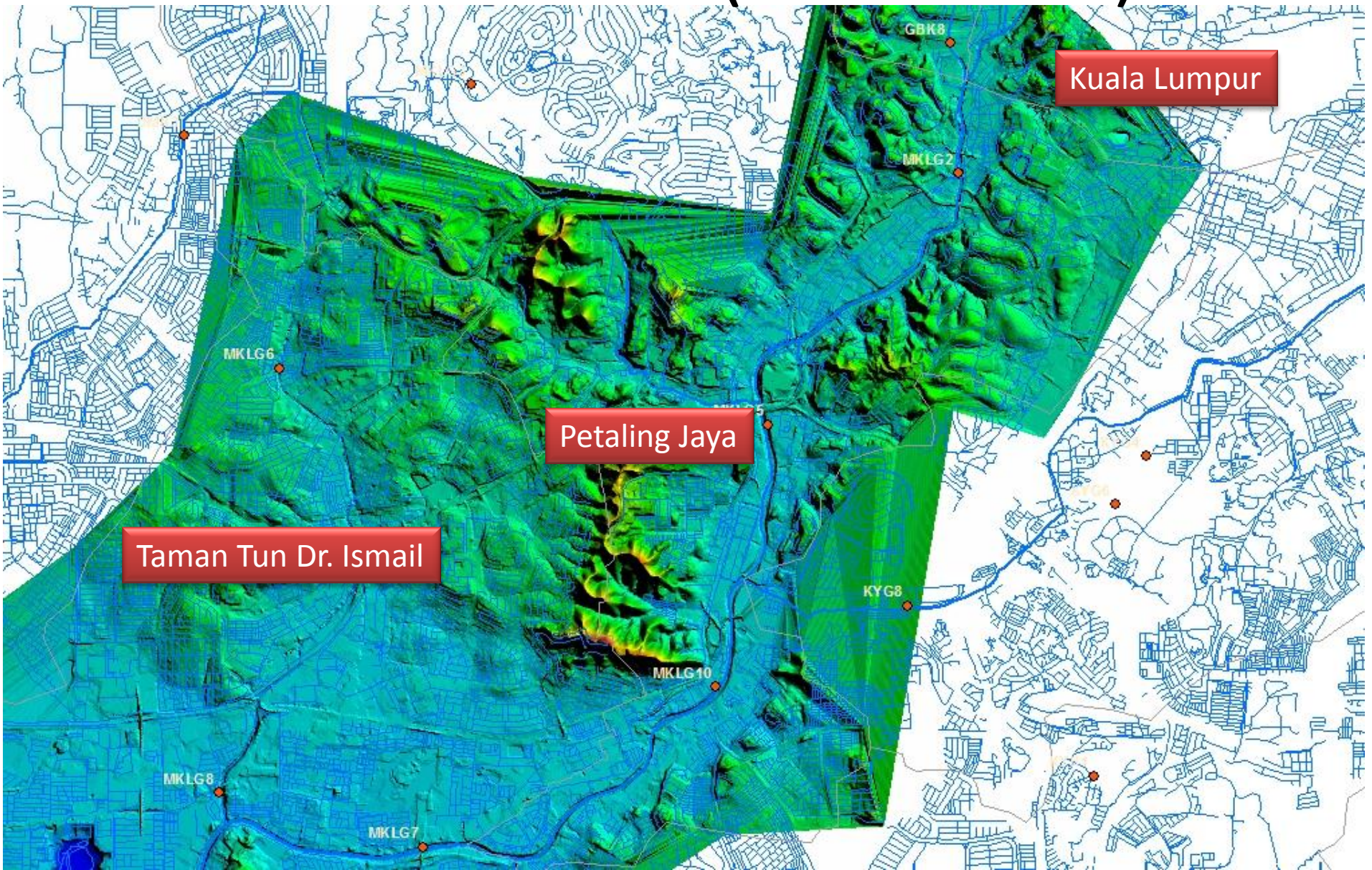
iFFRM Zone 5 (North)



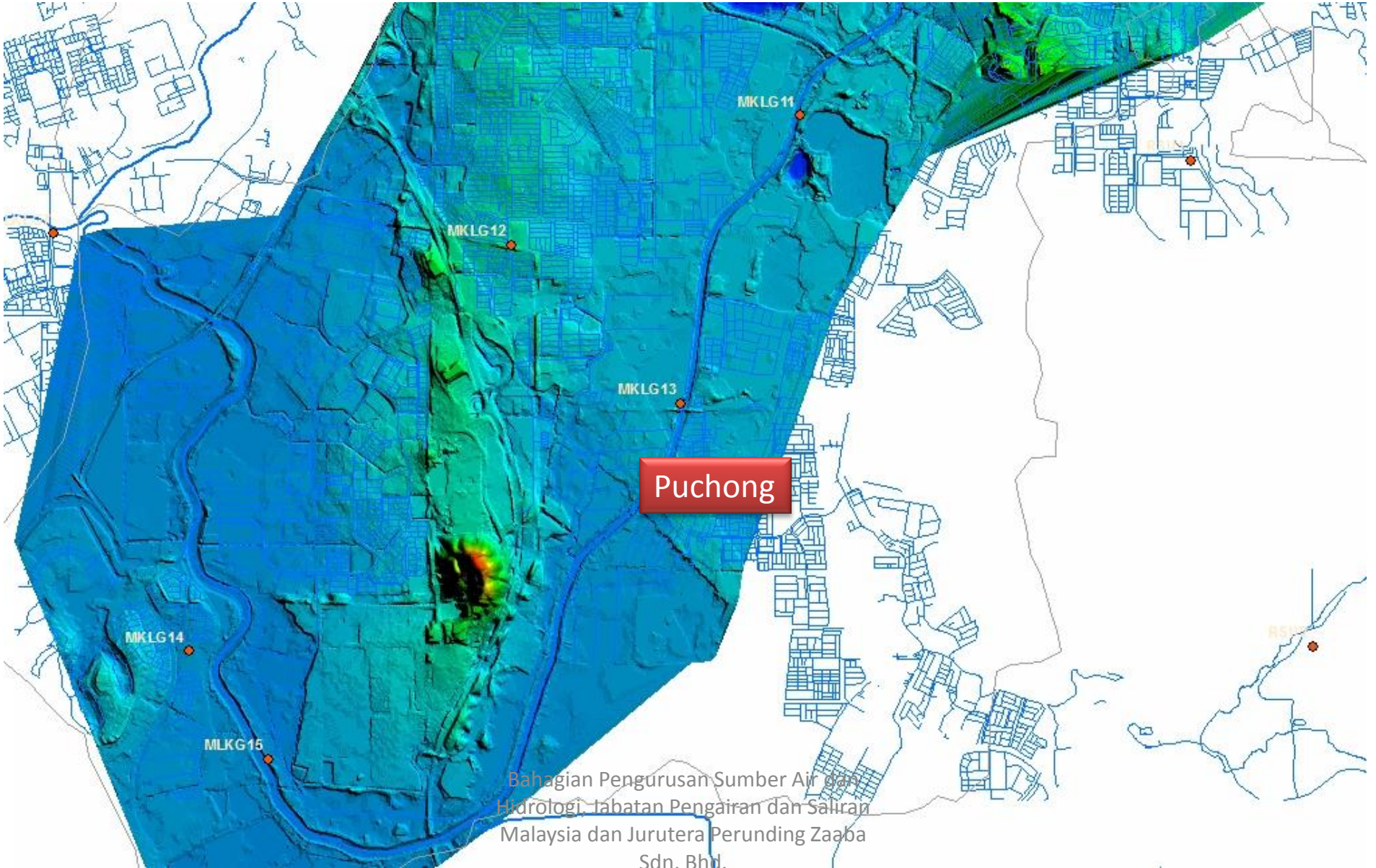
iFFRM Zone 5 (South)



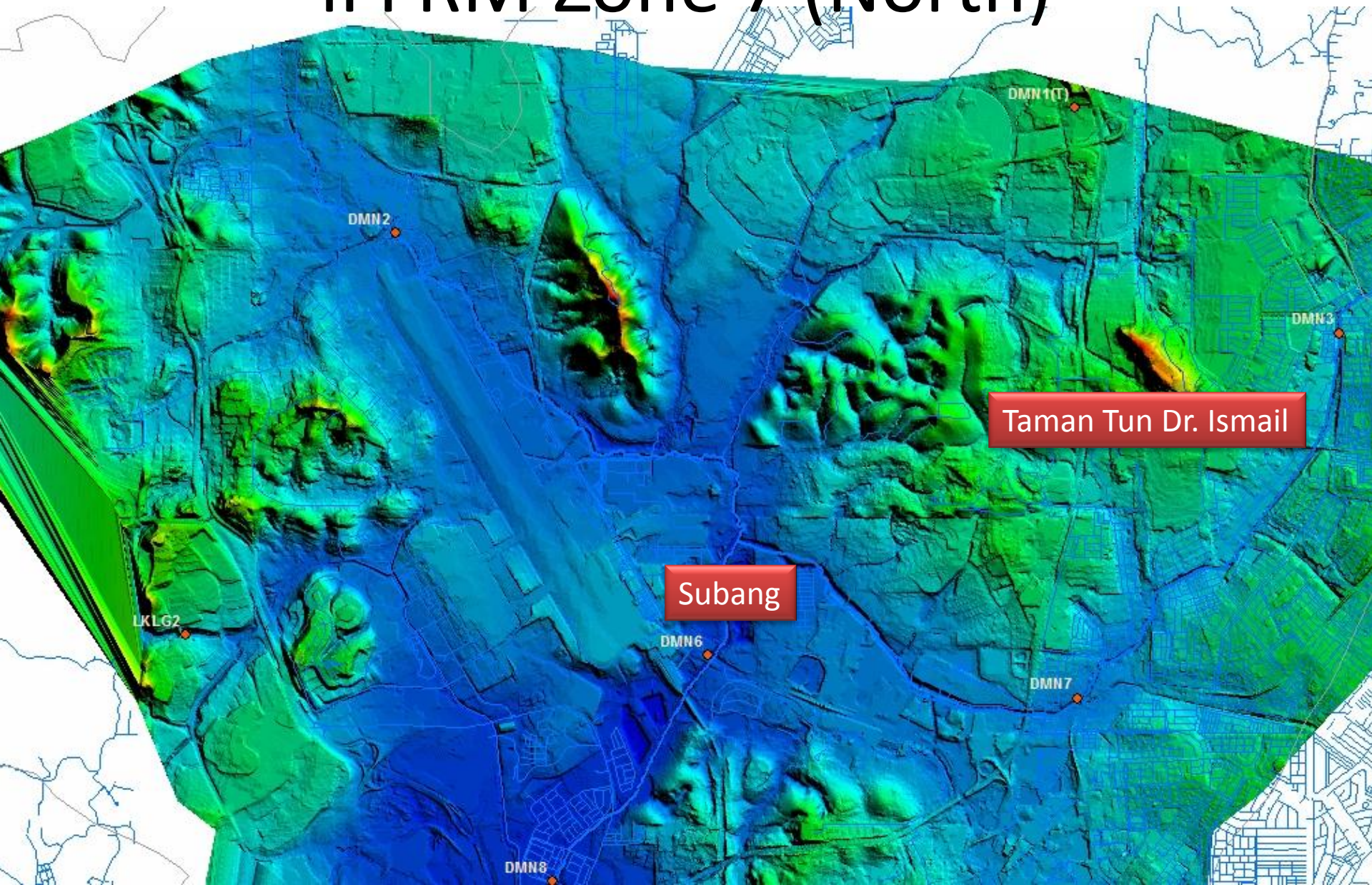
iFFRM Zone 6 (North-east)



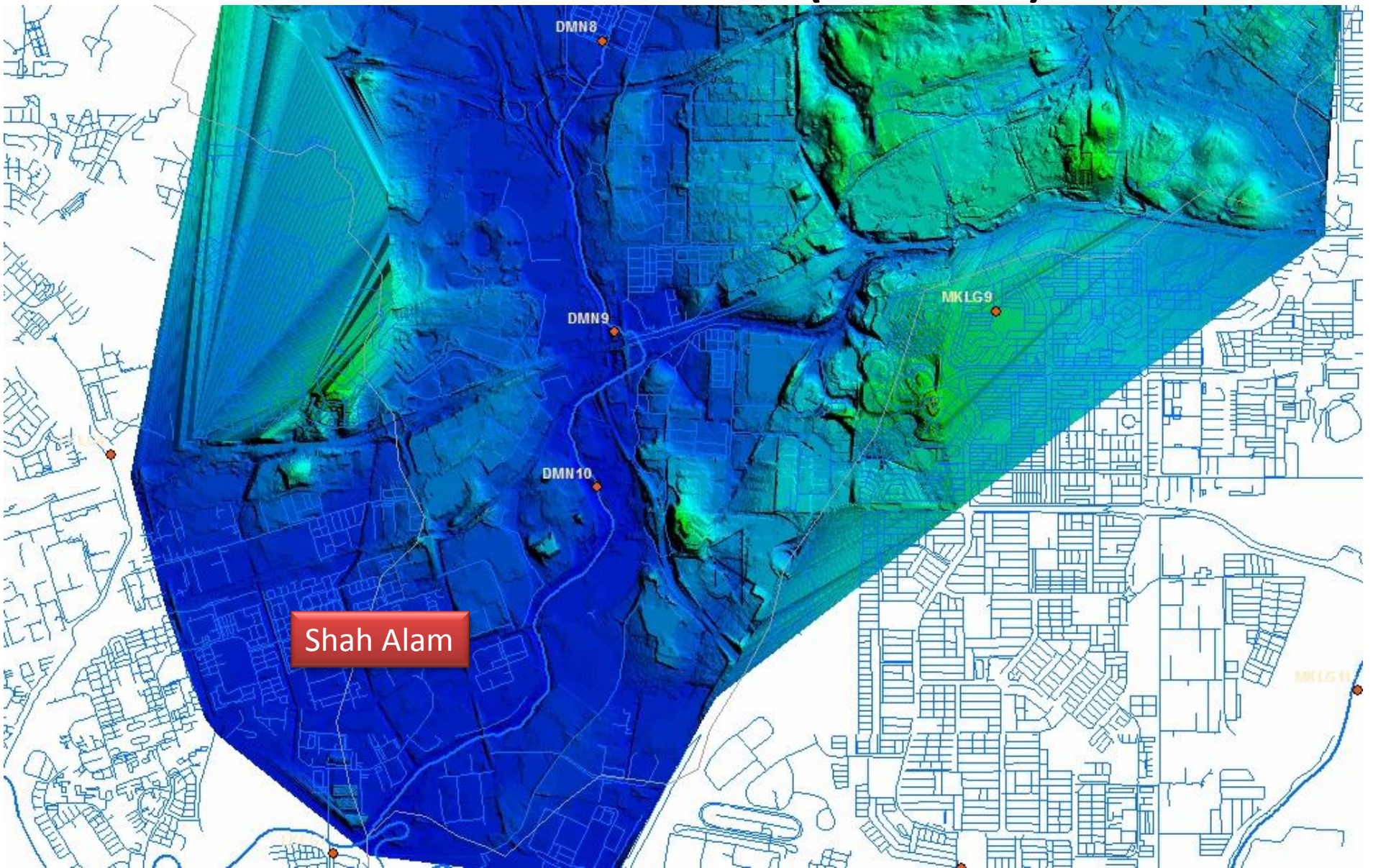
iFFRM Zone 6 (South-west)



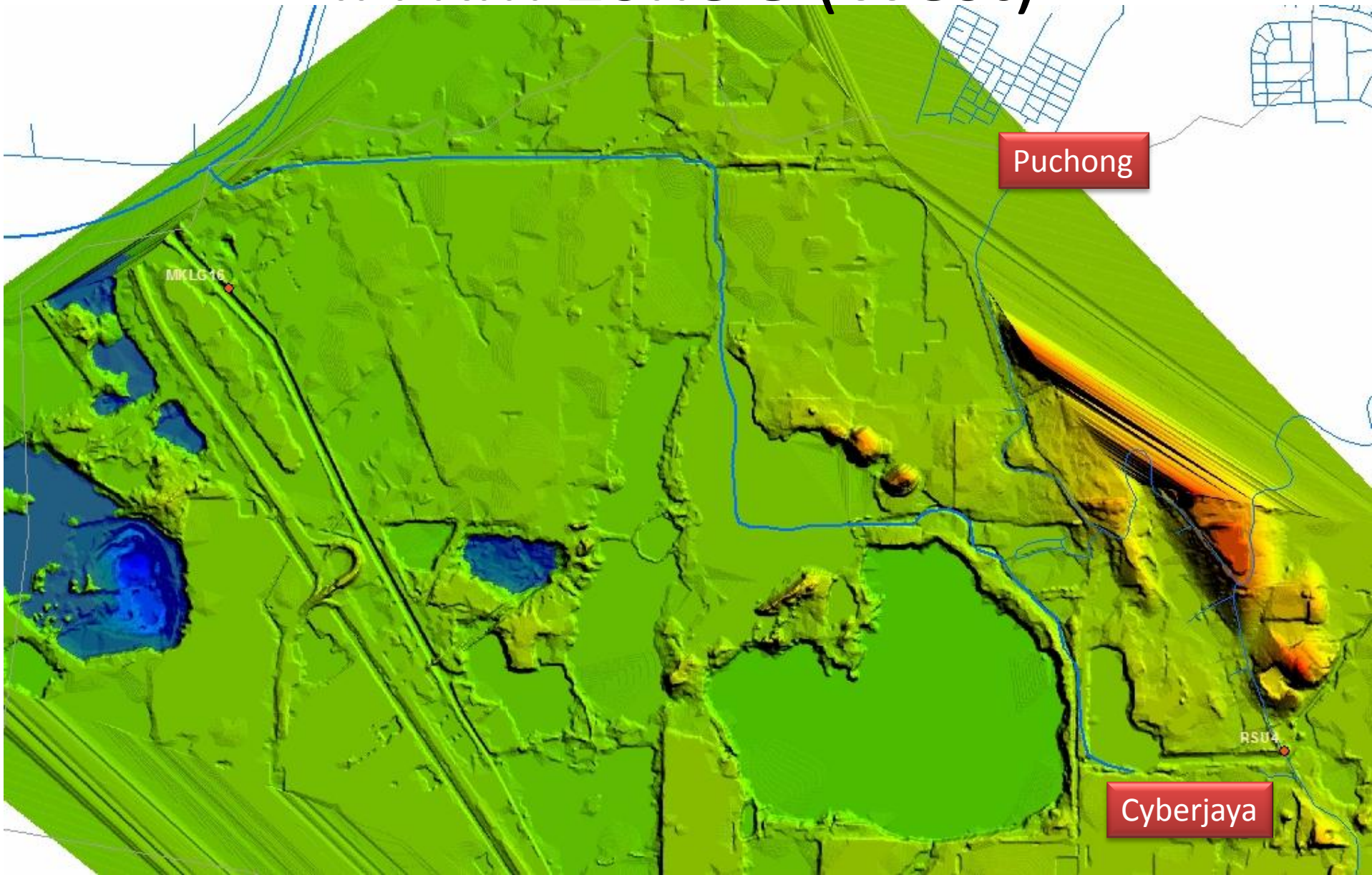
iFFRM Zone 7 (North)



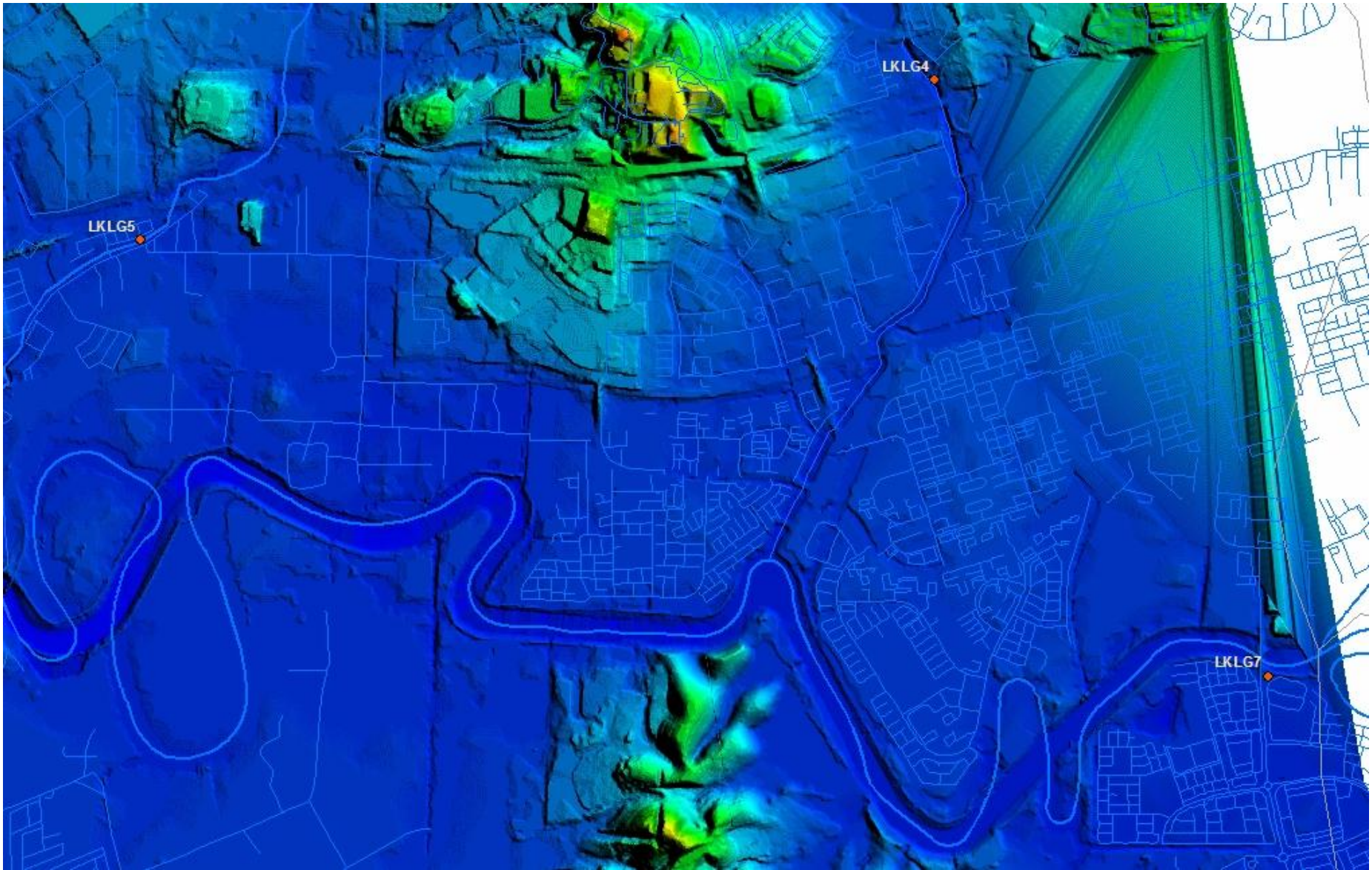
iFFRM Zone 7 (South)



iFFRM Zone 8 (West)

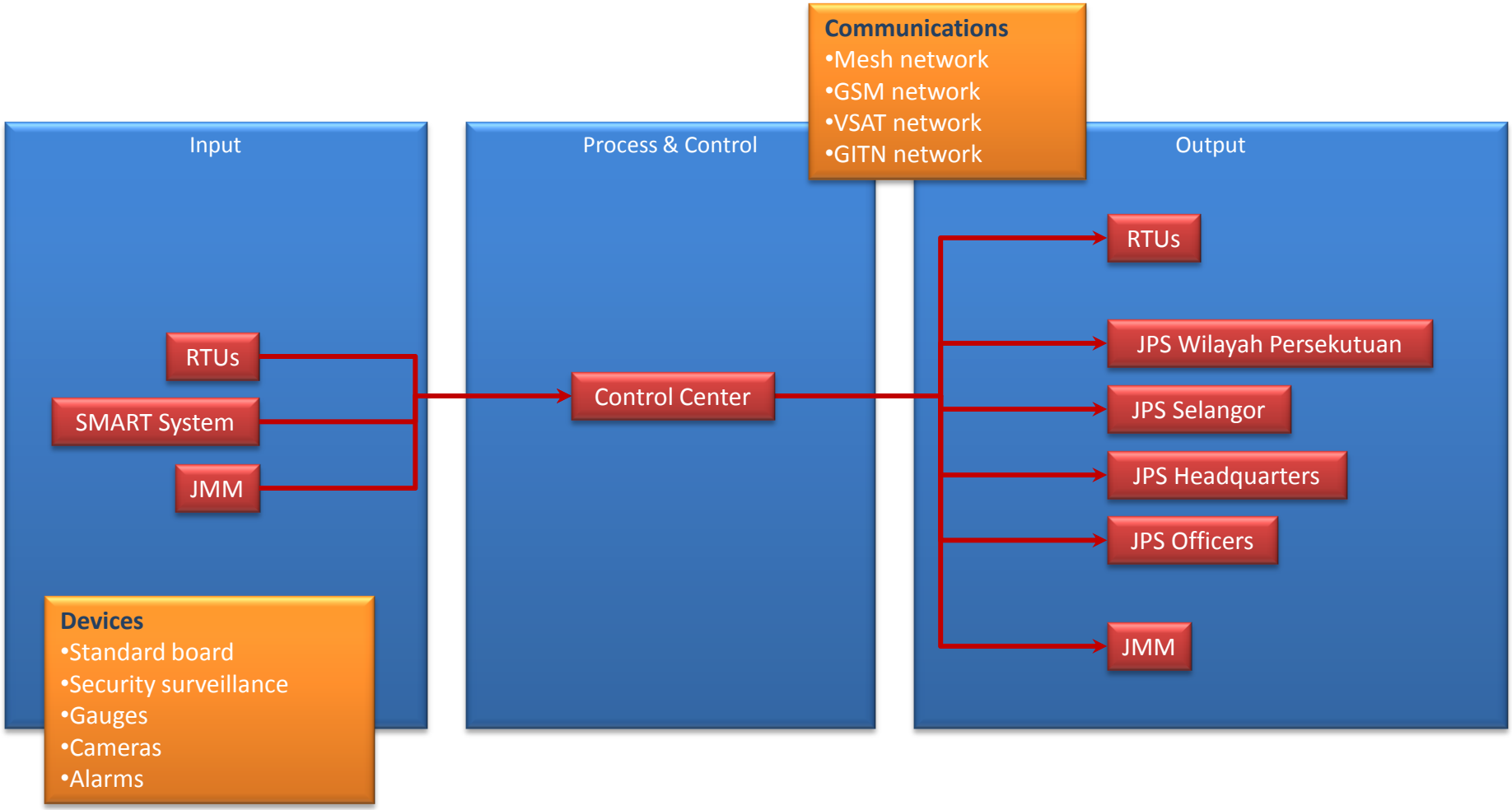


iFFRM Zone 9 (East)



iFFRM Zone 9 (West)

The iFFRM System



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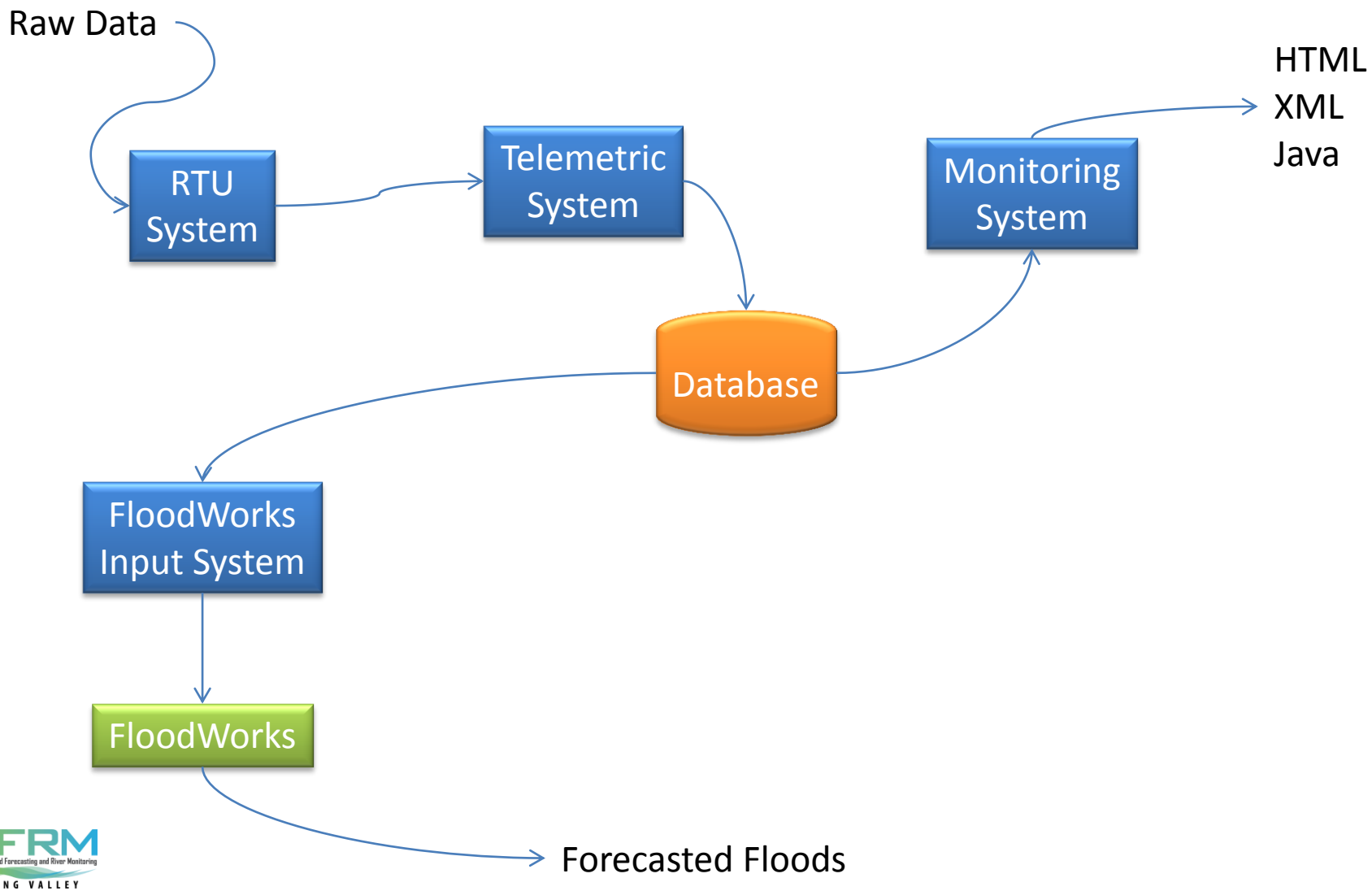
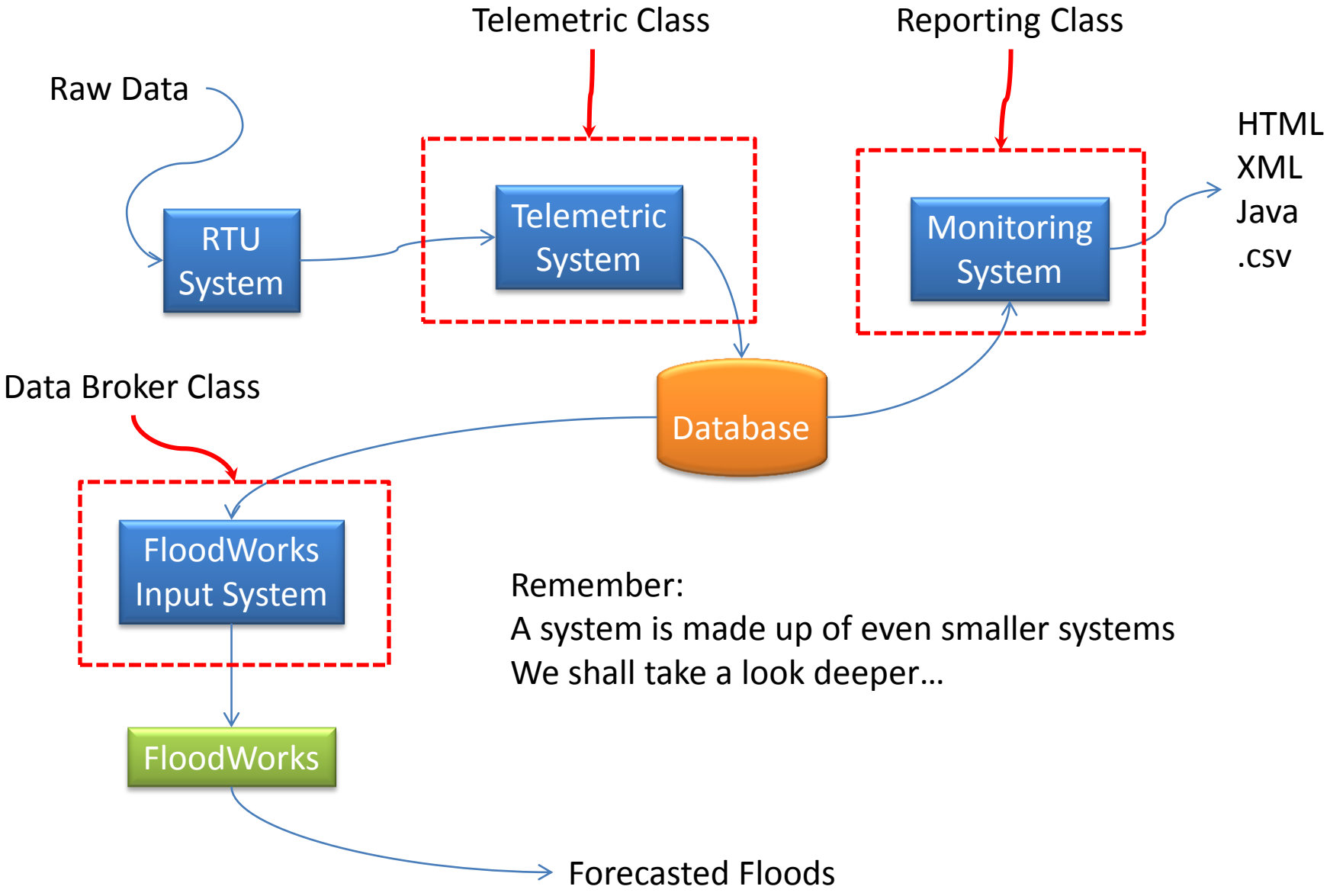
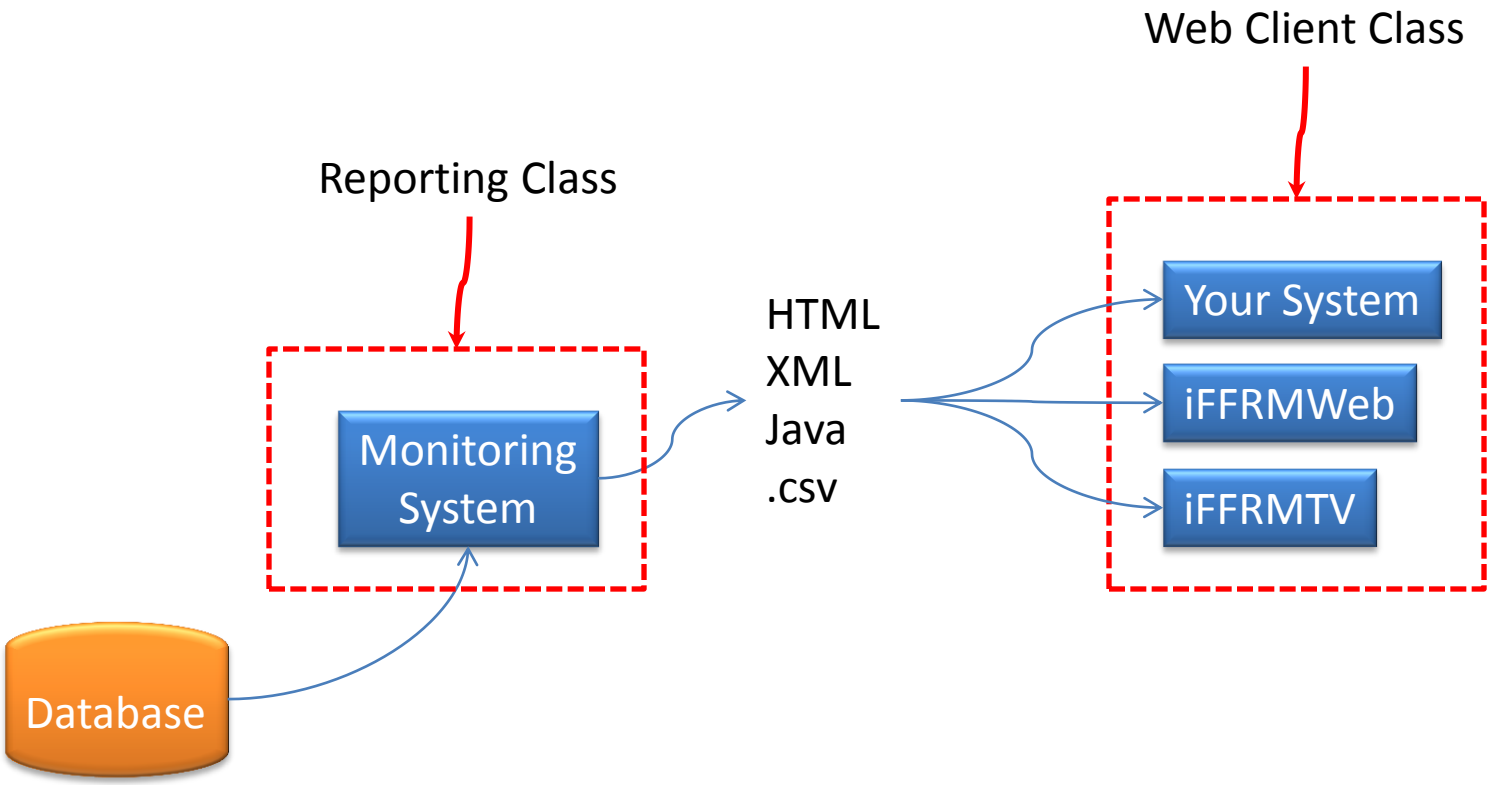
iFFRM Data Flow



iFFRM Application Classes

- The custom applications can be divided into 4 classes:
  - Telemetric
  - Data brokers
  - Report generators
  - Web clients


Telemetric Class
Reporting Class
Raw Data
RTU System
Telemetric System
Monitoring System
HTML
XML
Java
.csv
Data Broker Class
Database
FloodWorks Input System
Remember:
A system is made up of even smaller systems
We shall take a look deeper…
FloodWorks
Forecasted Floods



iFFRM is an OPEN ARCHITECTURE system

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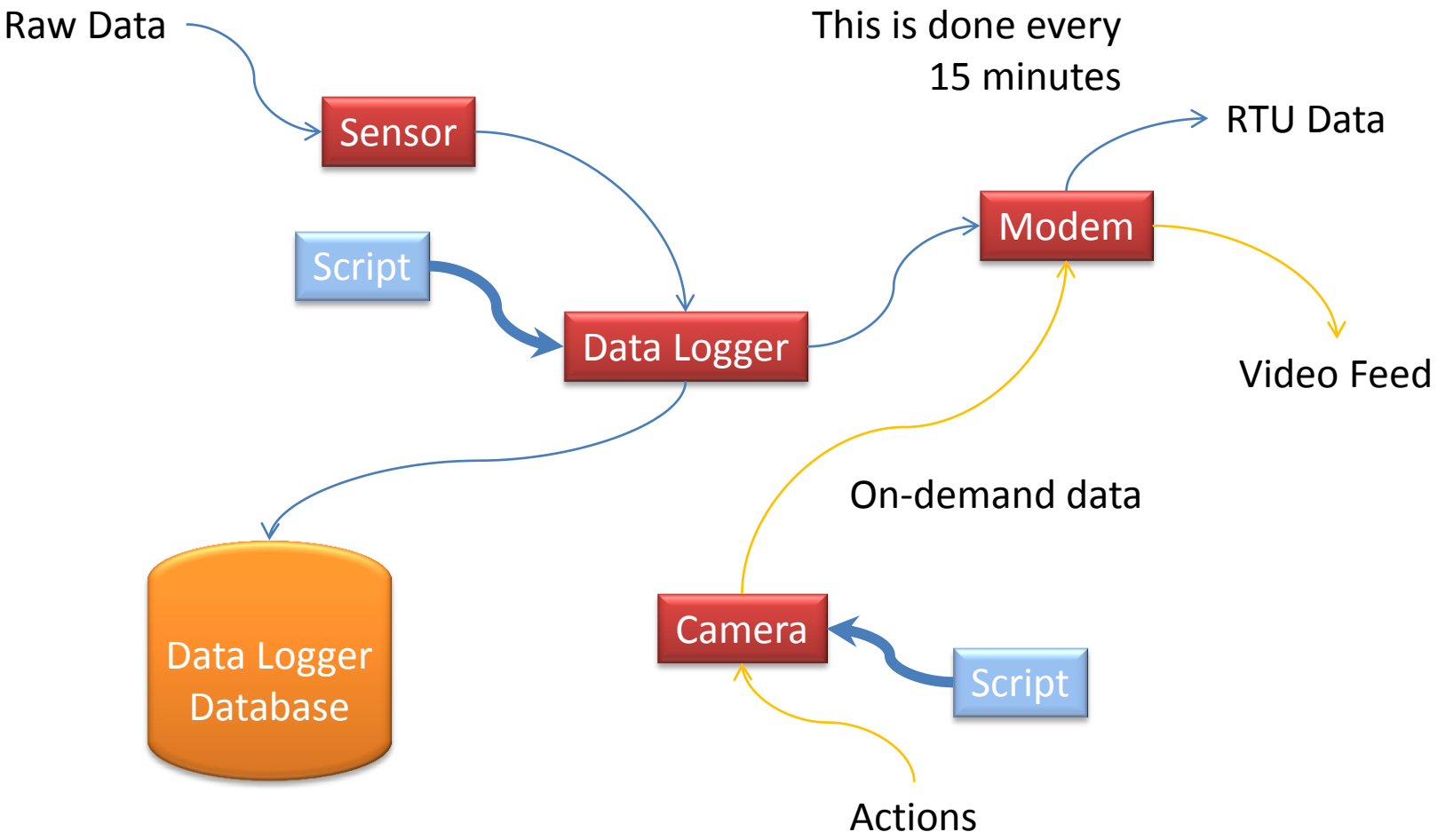
RTU Data Flow



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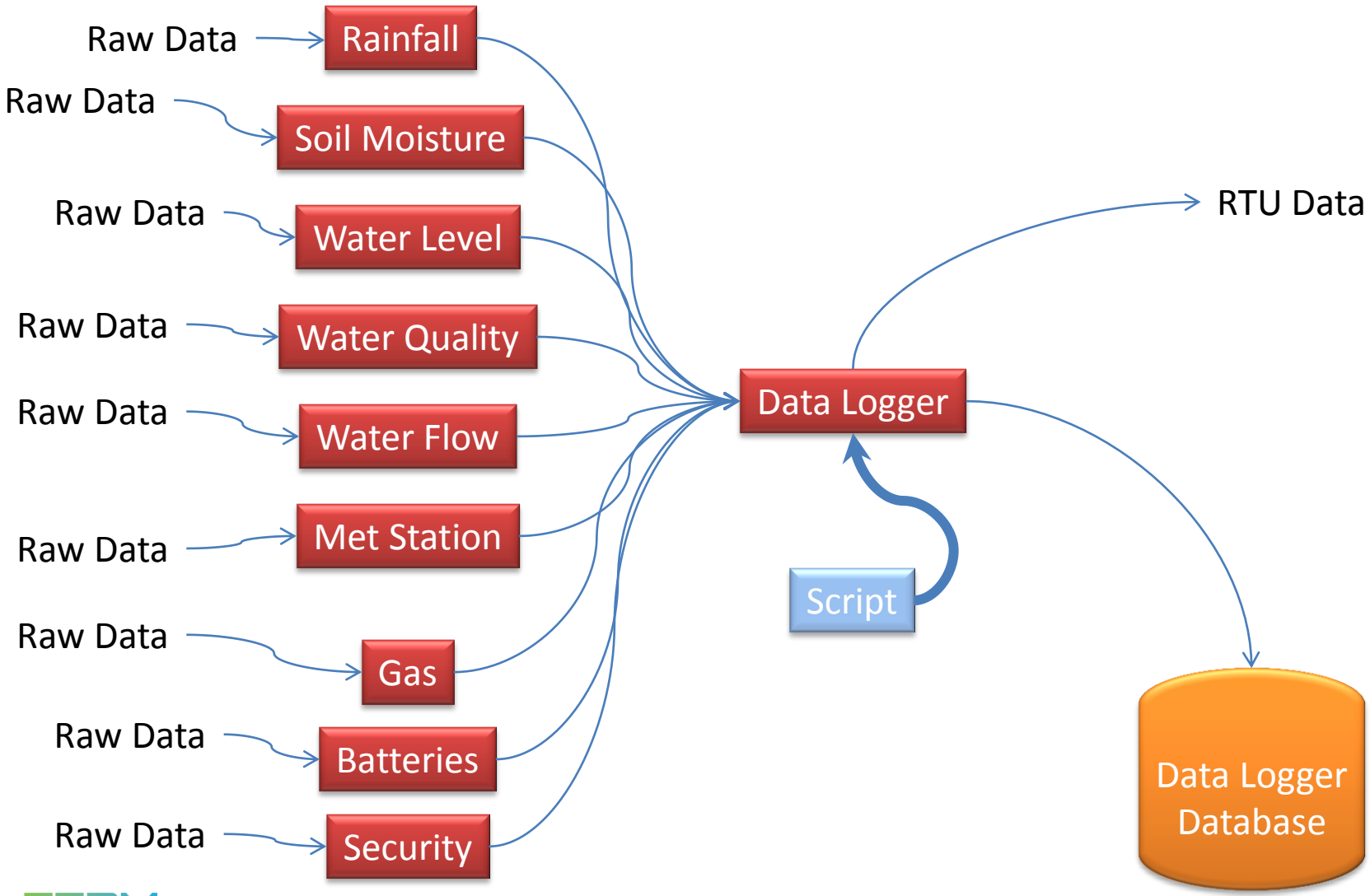
Sensor Data Flow



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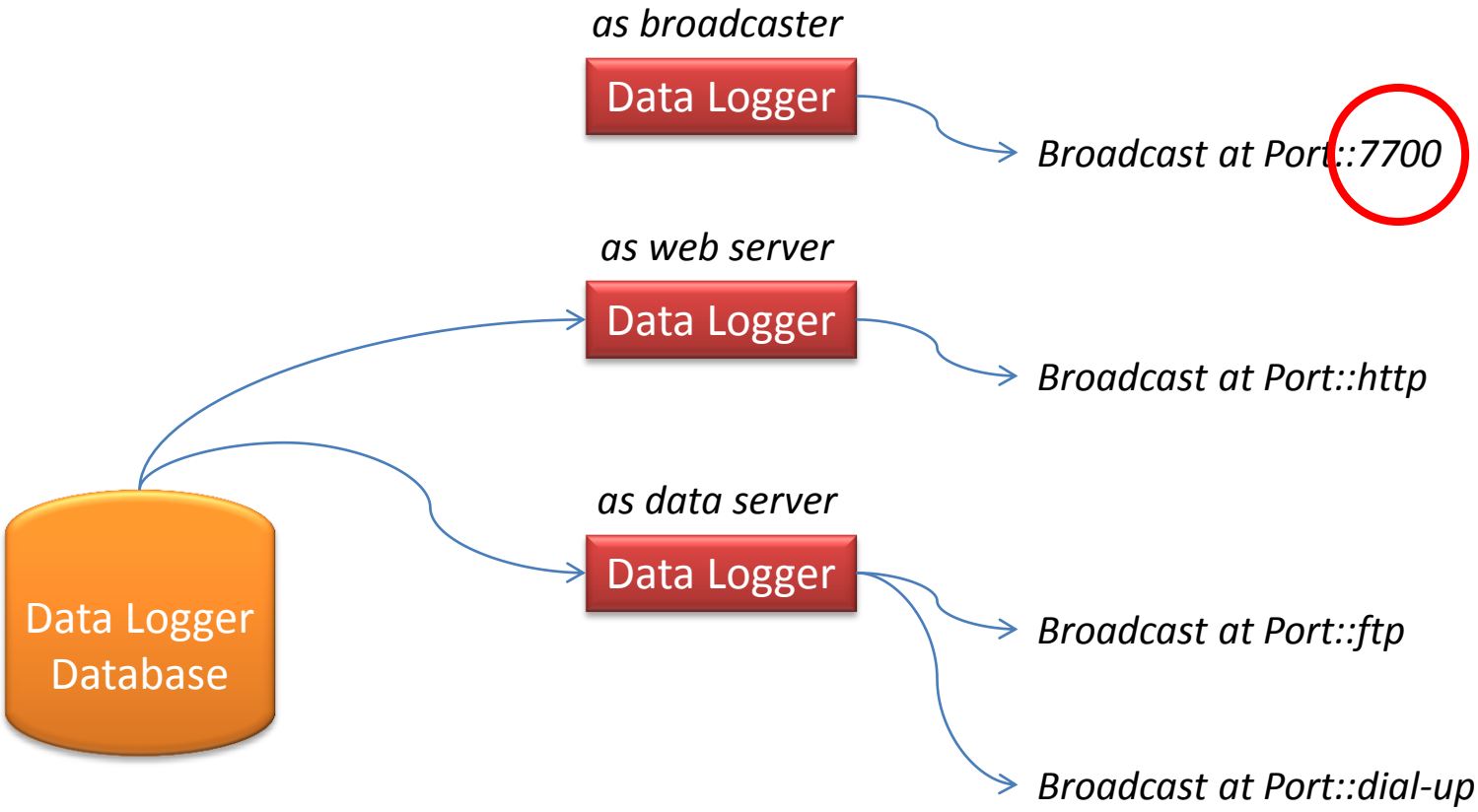
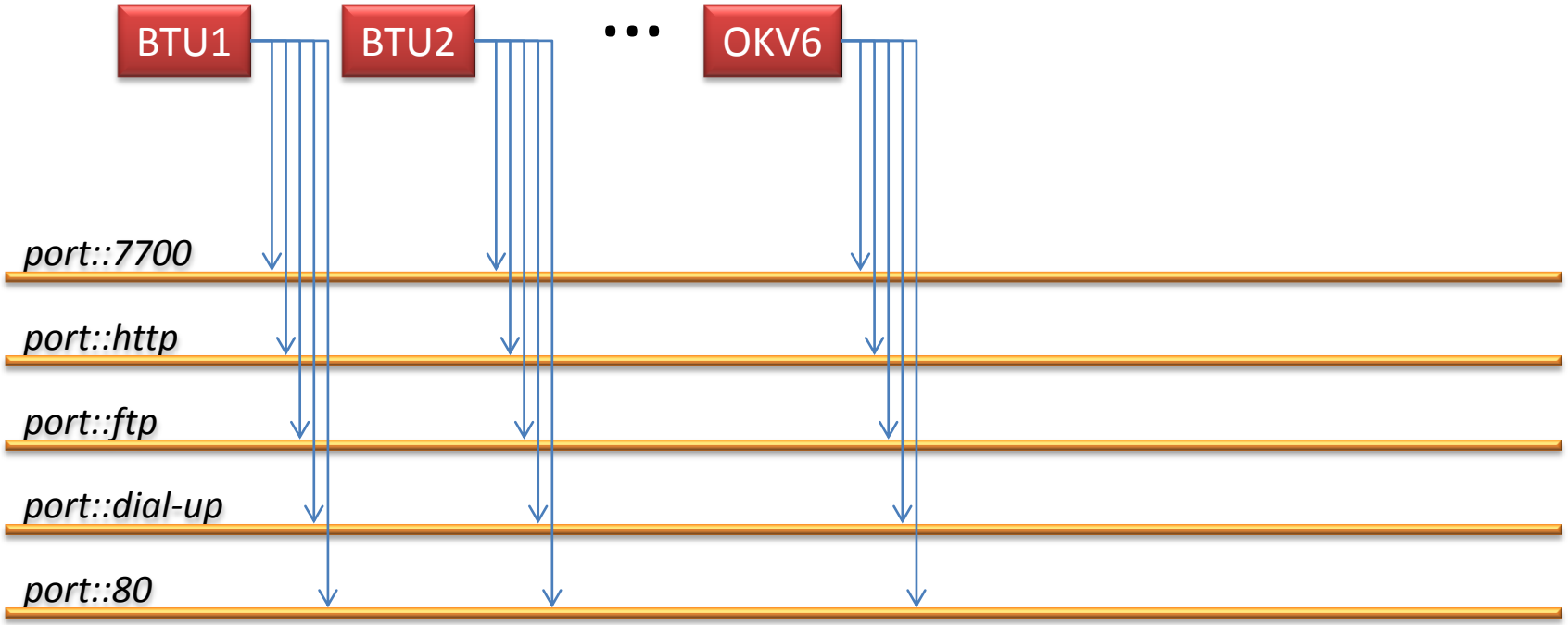
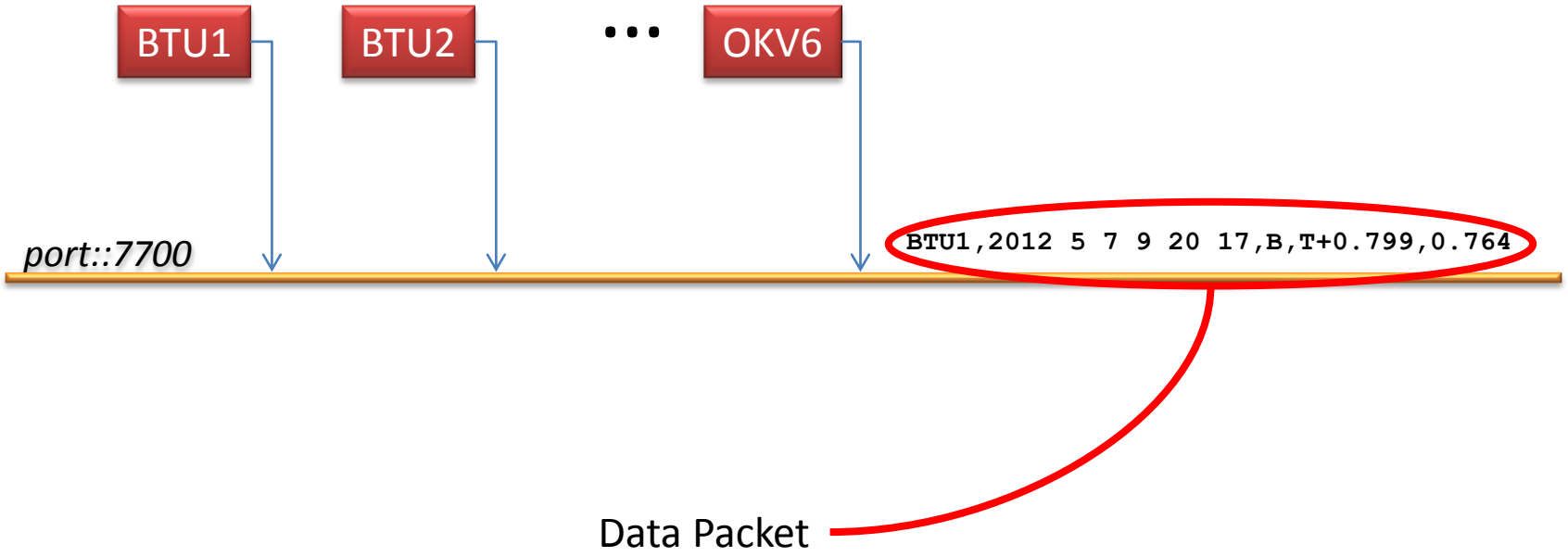
Data Logger Data Outflow



Data Flow (outside Control Center)



Real-time Data Flow



Some facts:
About 400 packets are generated every 5 minutes,
but within 20 seconds

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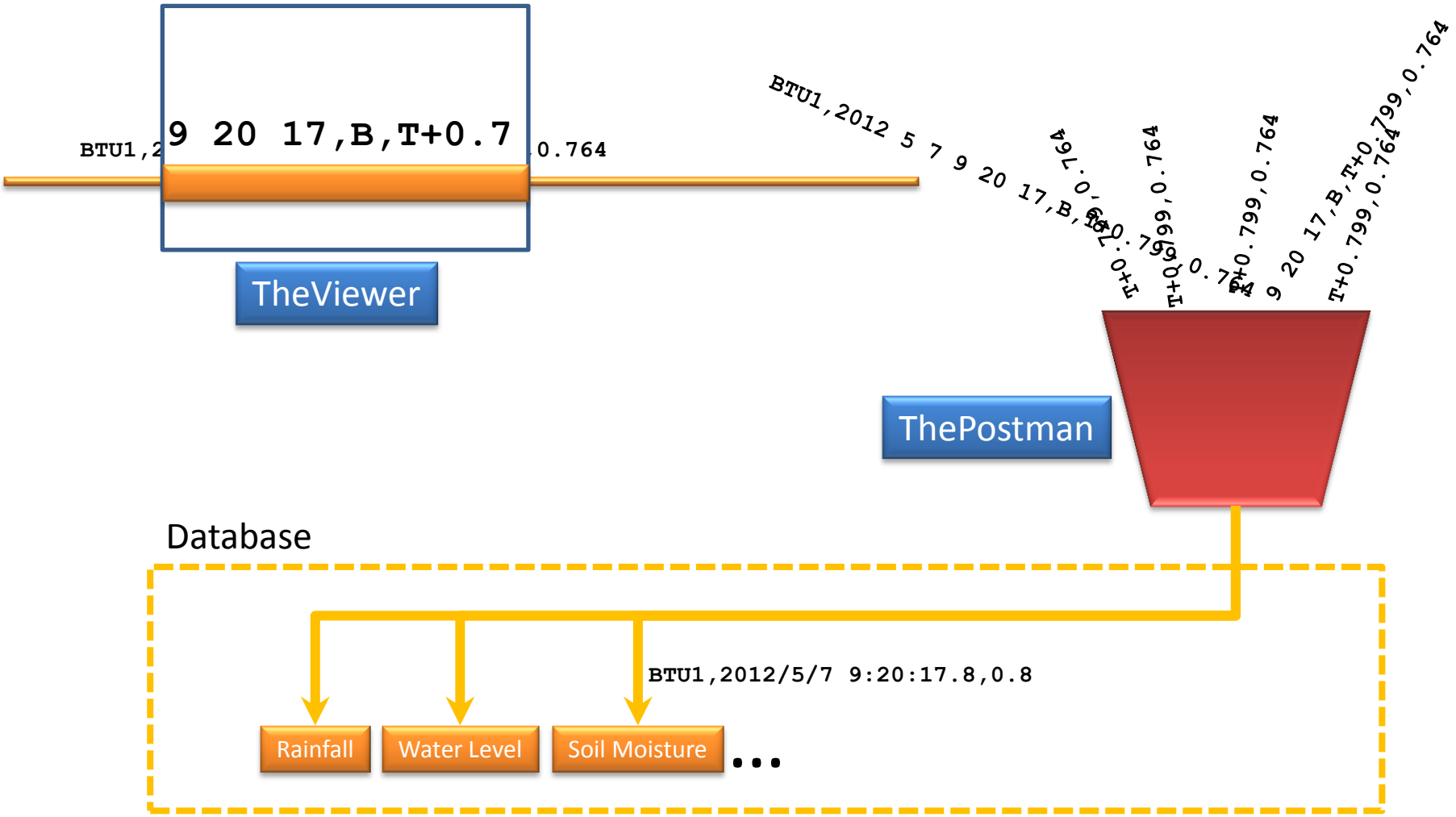
Telemetric Data Flow



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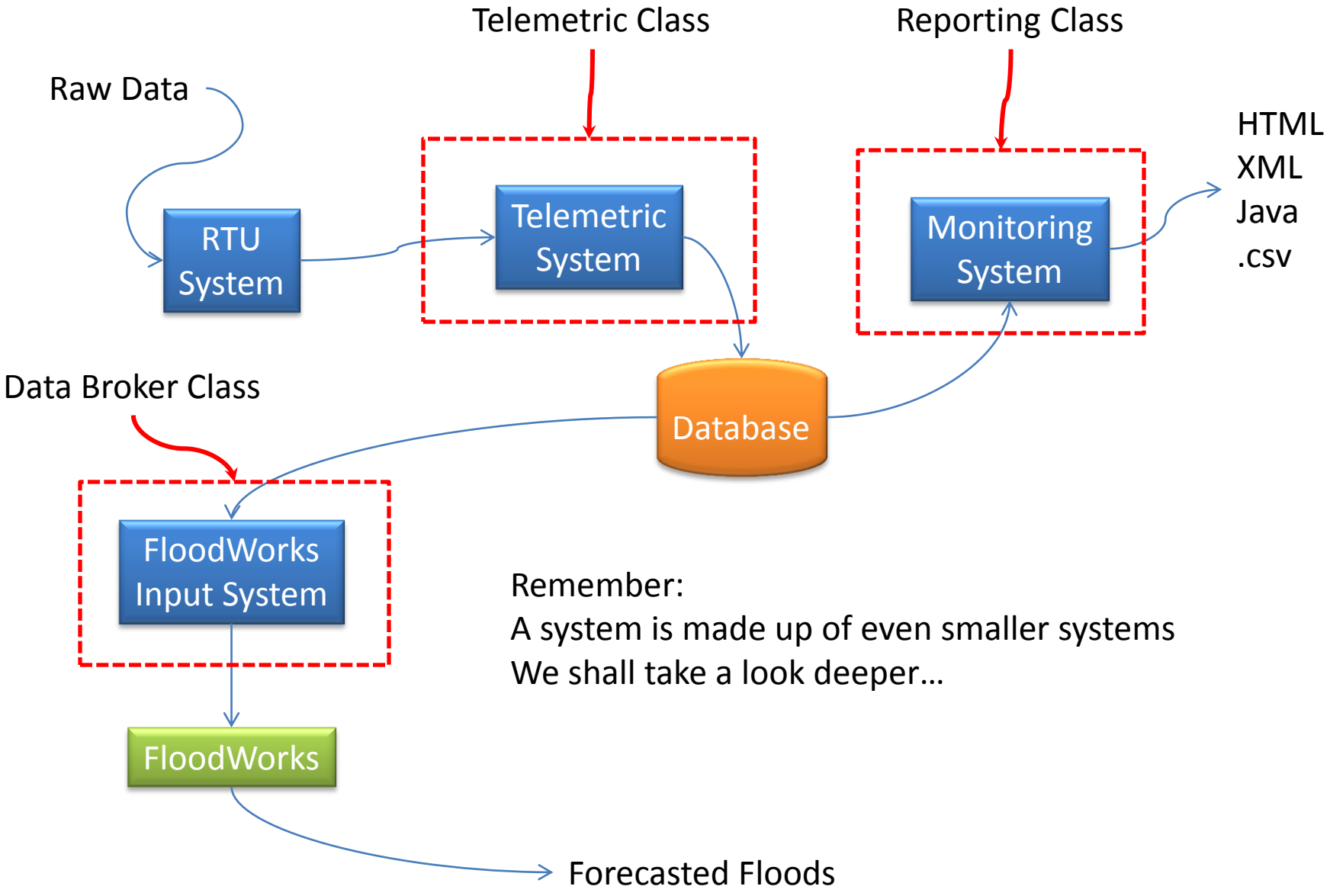
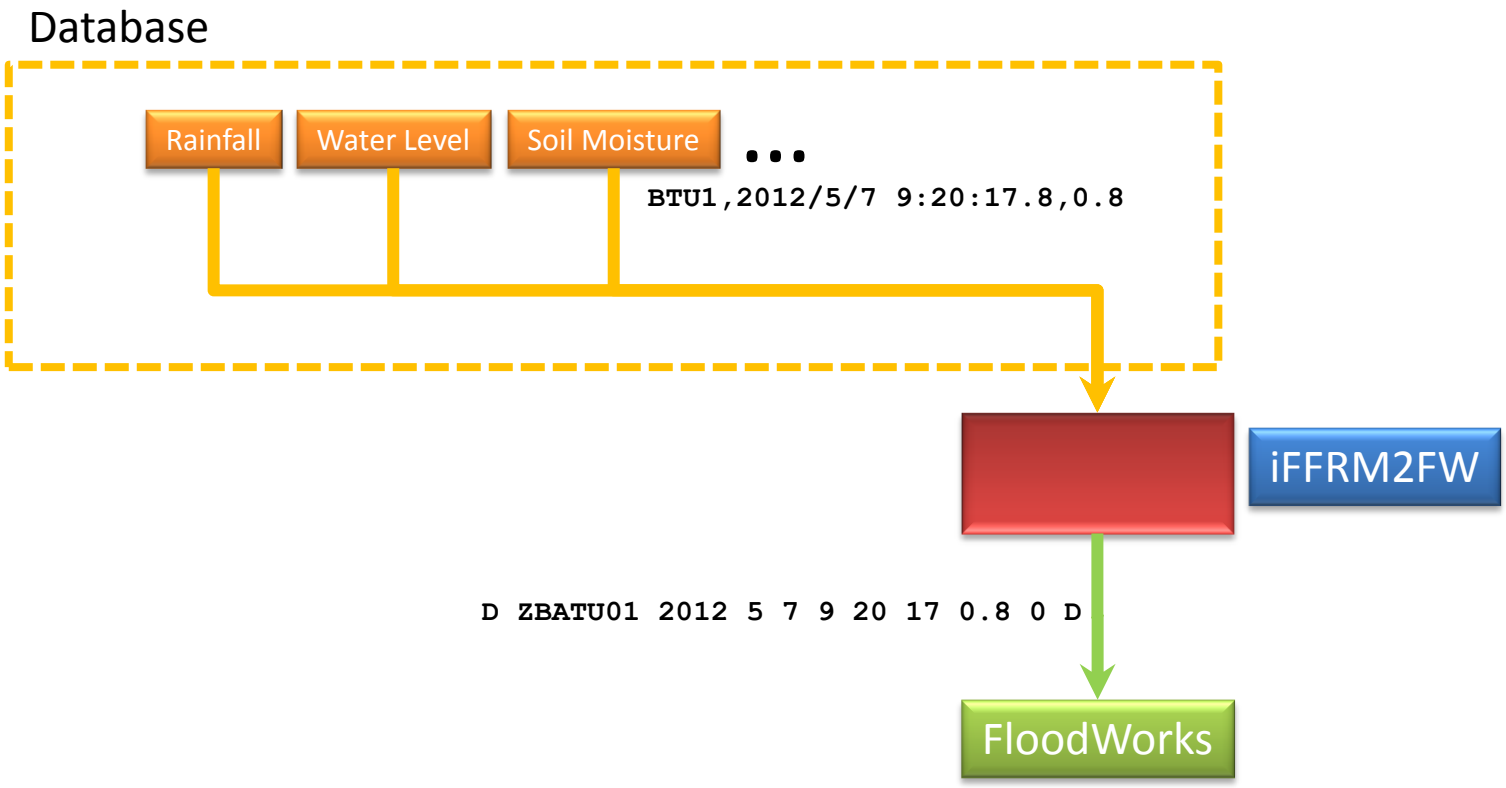
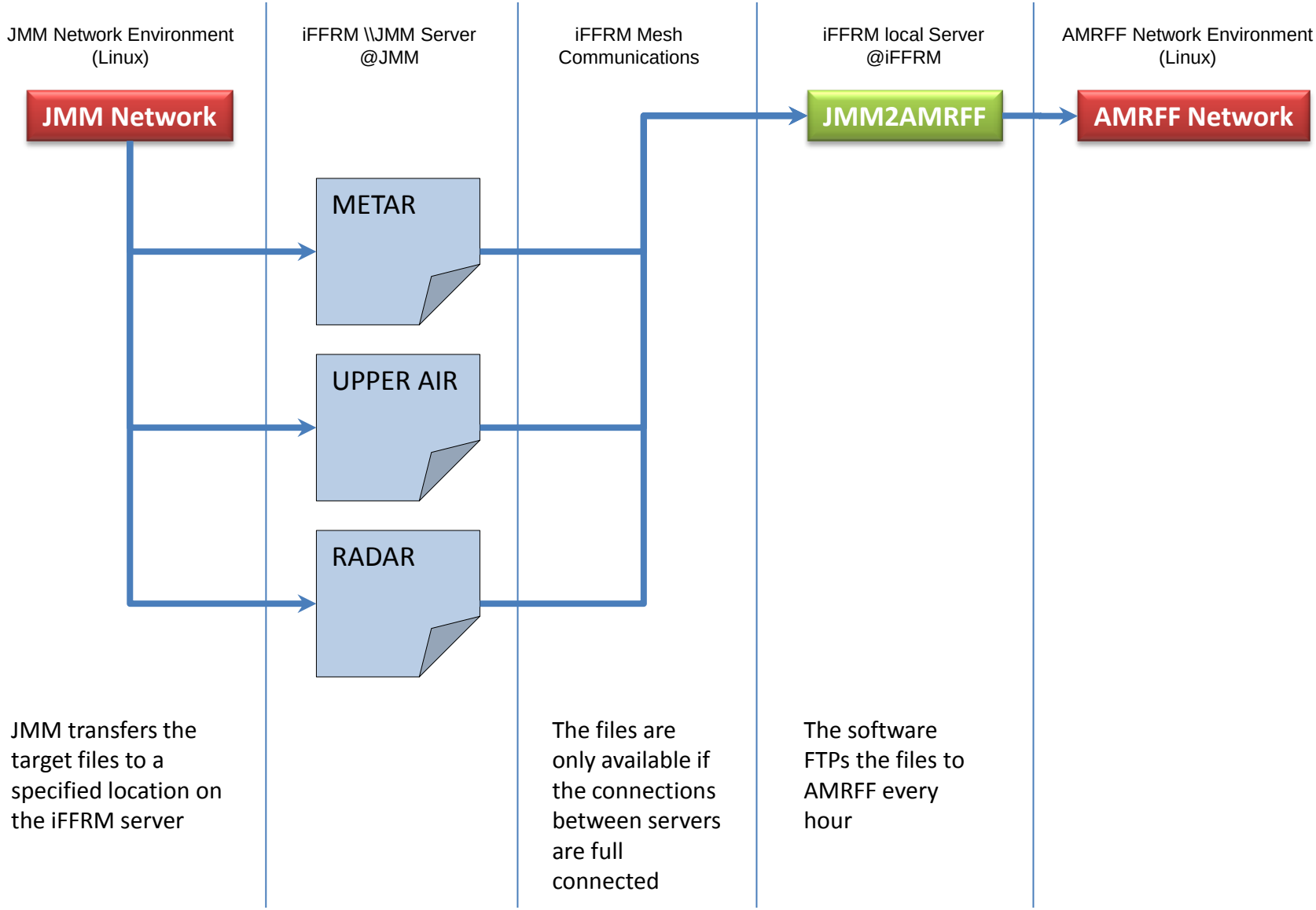

Telemetric Class
Reporting Class
Raw Data
RTU System
Telemetric System
Monitoring System
HTML
XML
Java
.csv
Data Broker Class
Database
FloodWorks Input System
Remember:
A system is made up of even smaller systems
We shall take a look deeper…
FloodWorks
Forecasted Floods

FloodWorks Data Flow





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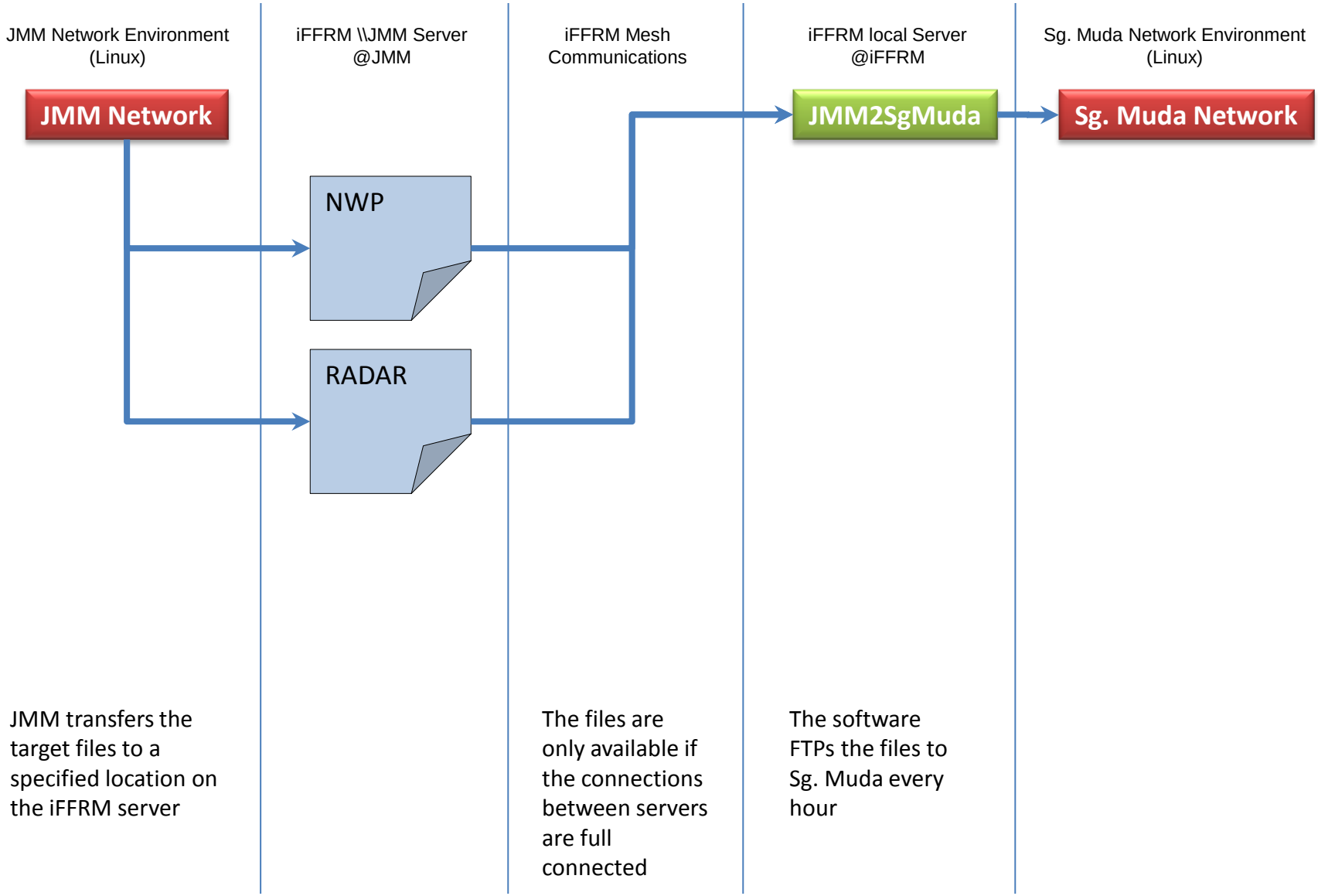
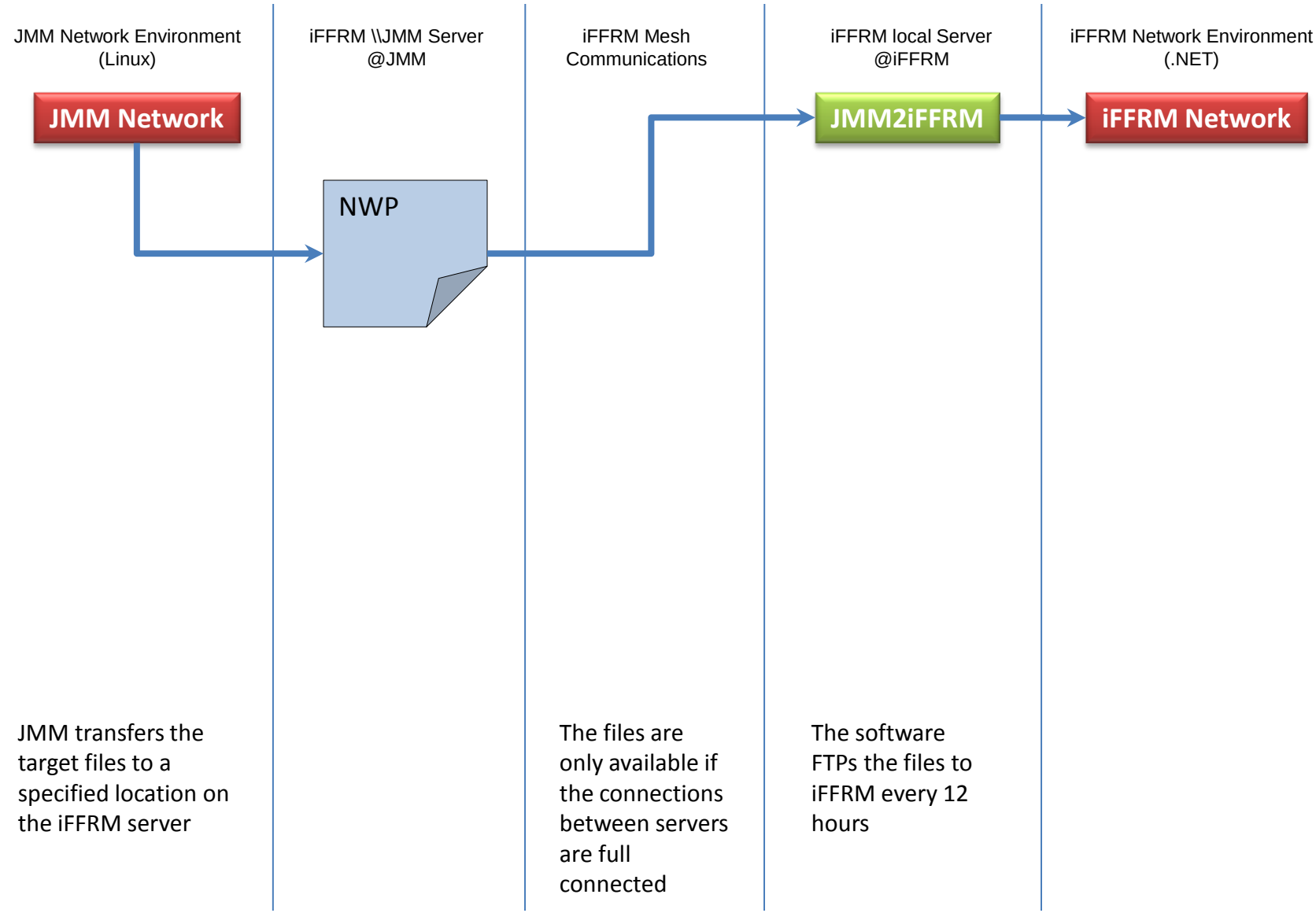

JMM Network Environment (Linux)
iFFRM \\JMM Server @JMM
iFFRM Mesh Communications
iFFRM local Server @iFFRM
Sg. Muda Network Environment (Linux)
JMM Network
NWP
RADAR
JMM2SgMuda
Sg. Muda Network
JMM transfers the target files to a specified location on the iFFRM server
The files are only available if the connections between servers are full connected
The software FTPs the files to Sg. Muda every hour



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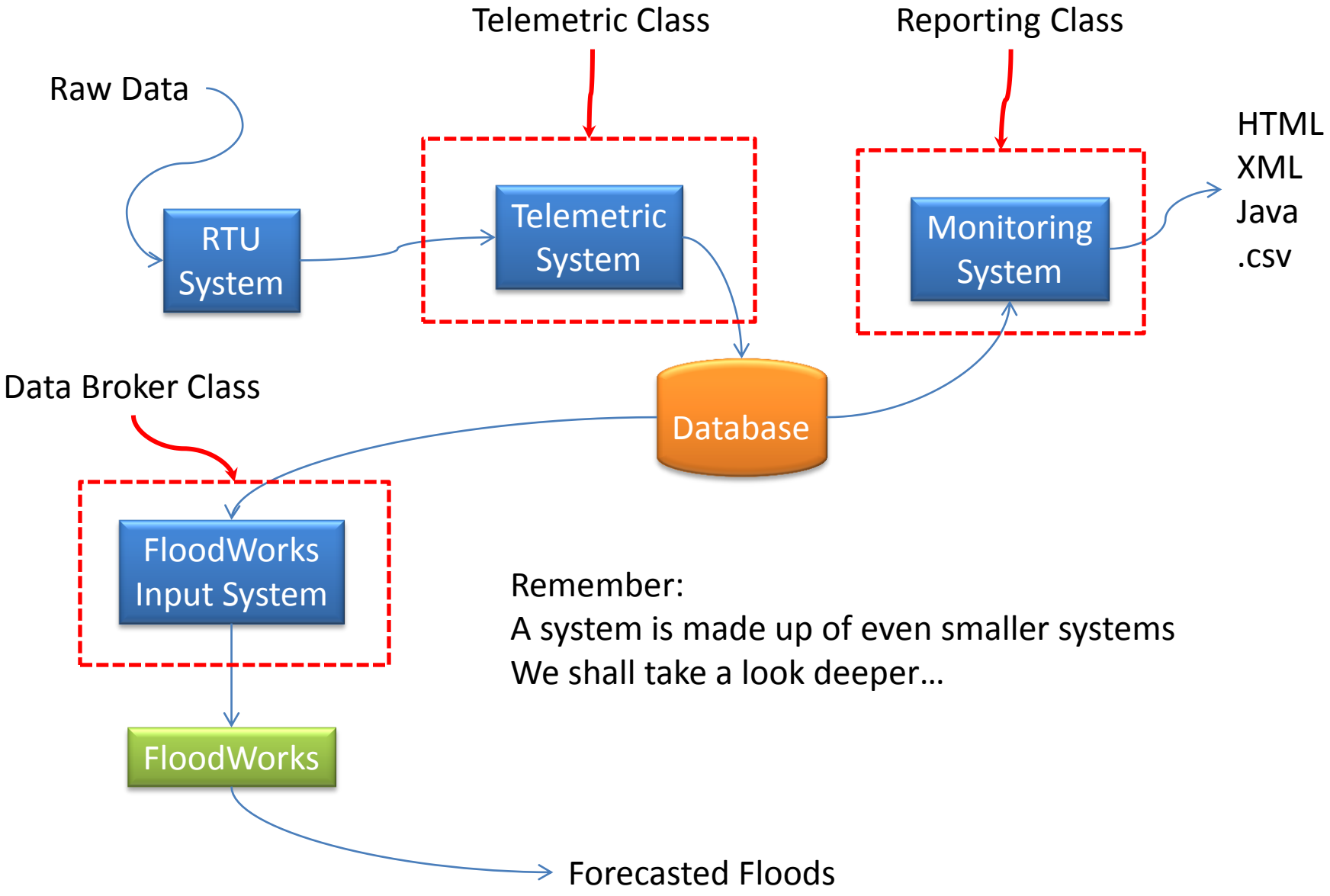
Telemetric Class
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.csv
Data Broker Class
Database
FloodWorks Input System
Remember:
A system is made up of even smaller systems
We shall take a look deeper…
FloodWorks
Forecasted Floods

Report Generator Class

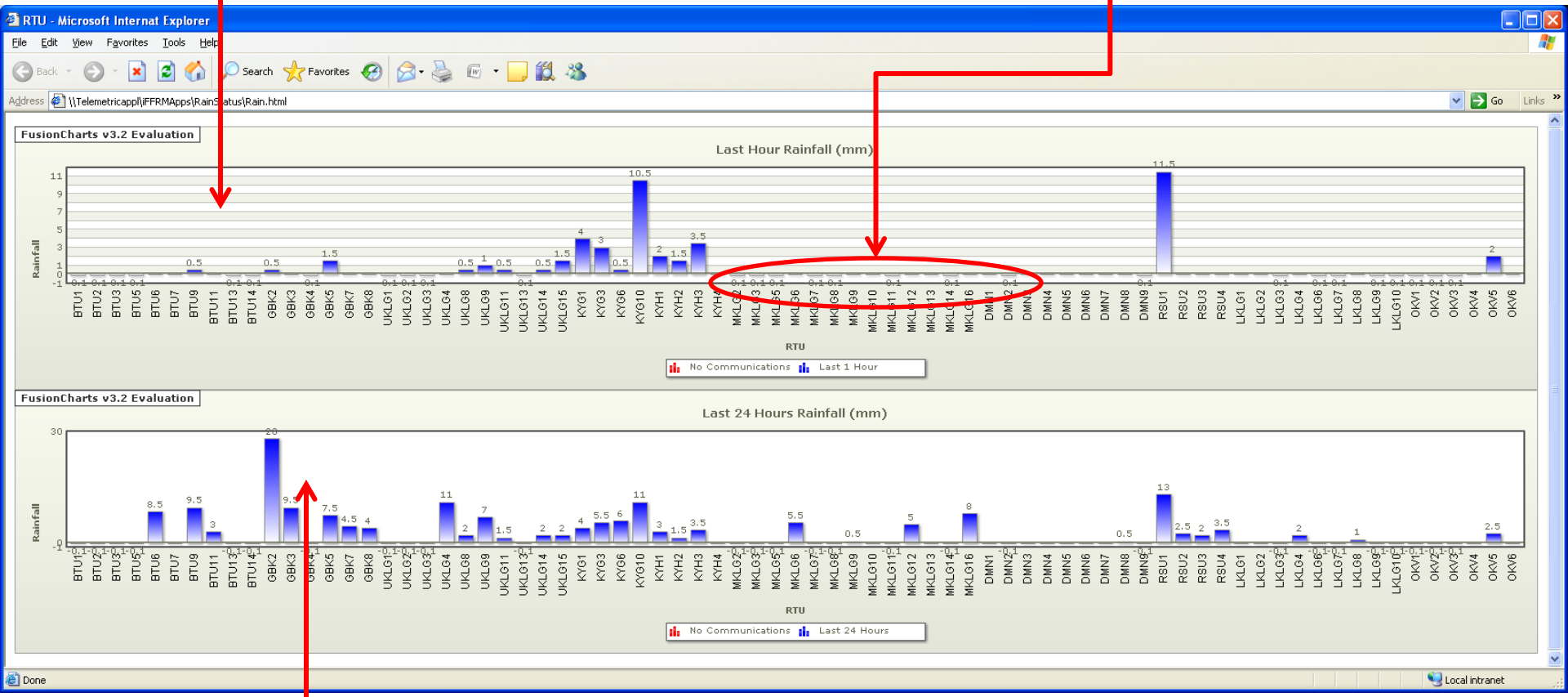
- Automatically generates reports 24 hours a day
  - Hydrological status of the Klang Valley
  - Health status of the RTUs

- The objective is to save user time and effort
- Reports are updated as soon as the data are available

RainStatus

Rain chart – last 1 hour

Stations with NO REAL-TIME communications



Rain chart – last 24 hours

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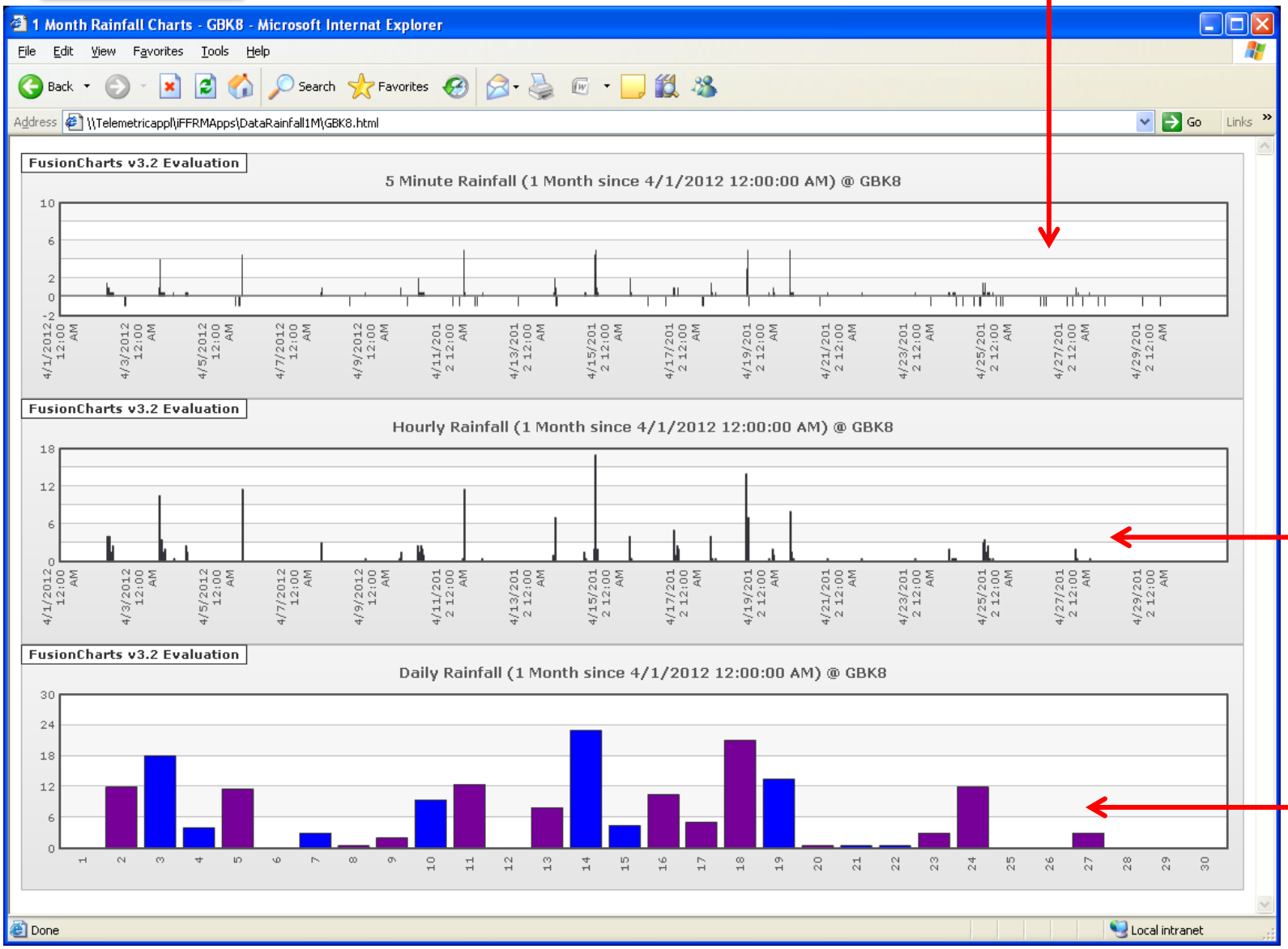
Rainfall1M



Rain chart every 5 minutes

Rain chart every 1 hour

Rain chart every 24 hours

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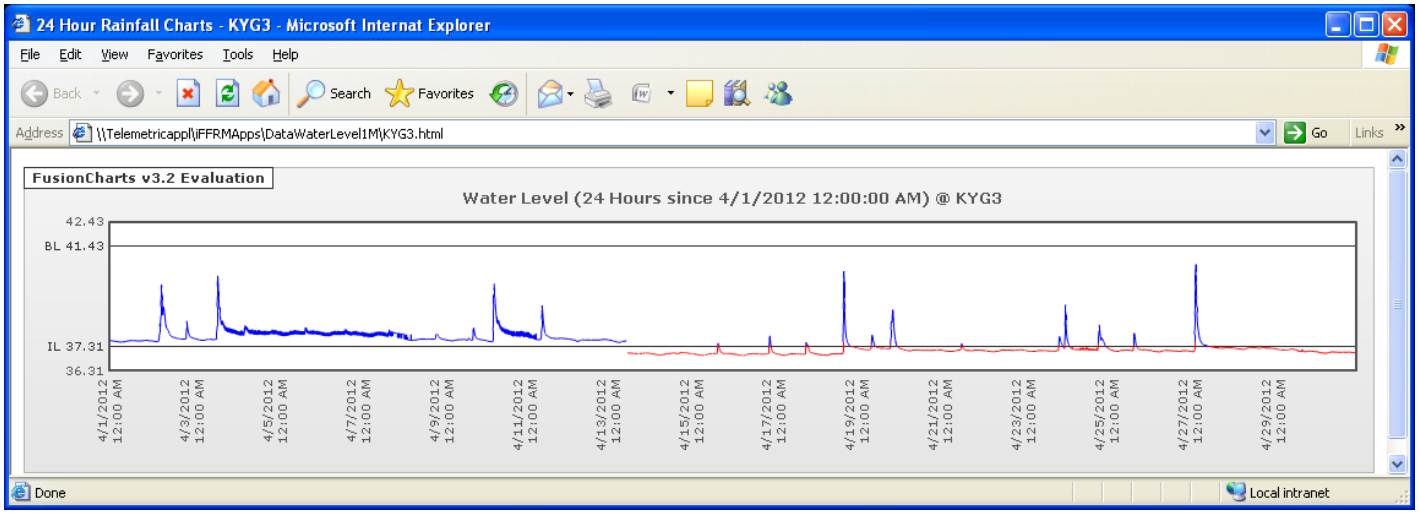
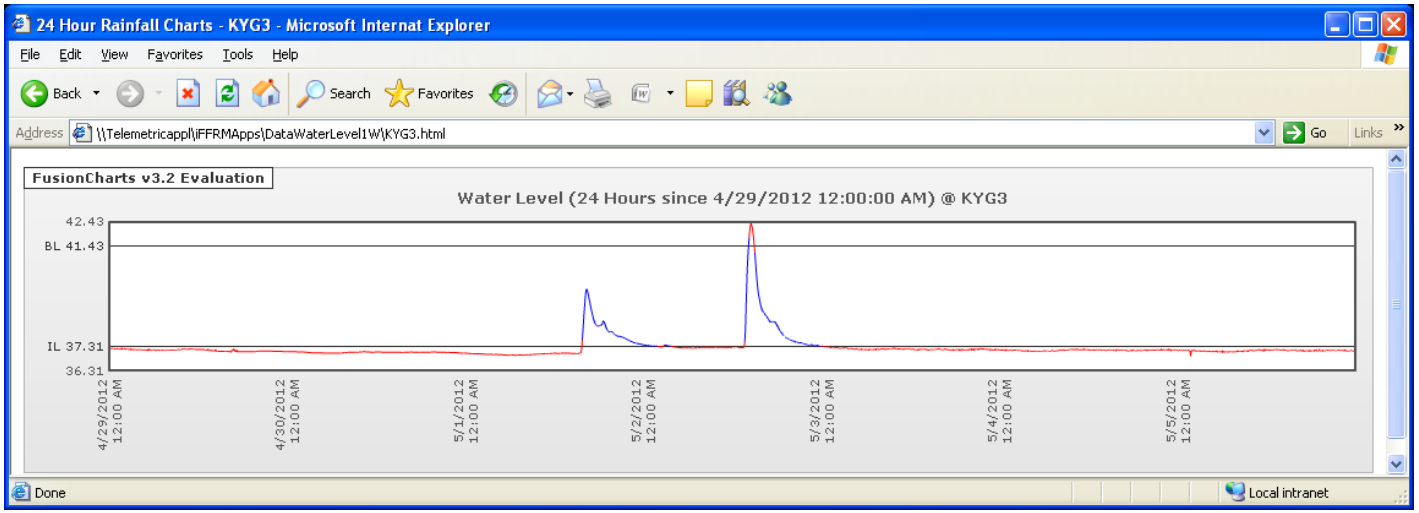


WaterLevel1M



WaterLevel1W

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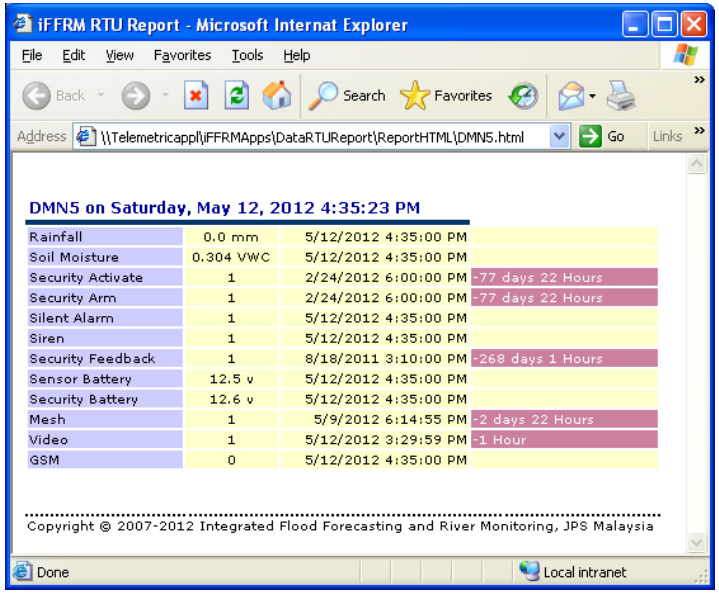
RTUReport .html file



Updated every 5 minutes
For the .html file (the page refreshes)
All stations status are generated

RTUReport .txt file

```
DMN5 Report
Saturday, May 12, 2012 4:35:23 PM
Parameter                 Value     Last Recorded Date Remarks
-----------------------------------------------------------------------
Rainfall                    0.0 mm  5/12/2012     4:35 PM
Soil Moisture             0.304 VWC 5/12/2012     4:35 PM
Security Activate               1   2/24/2012     6:00 PM -77 days 22 Hours
Security Arm                    1   2/24/2012     6:00 PM -77 days 22 Hours
Silent Alarm                    1   5/12/2012     4:35 PM
Siren                           1   5/12/2012     4:35 PM
Security Feedback               1   8/18/2011     3:10 PM -268 days 1 Hours
Sensor Battery             12.5 v   5/12/2012     4:35 PM
Security Battery           12.6 v   5/12/2012     4:35 PM
Mesh                            1    5/9/2012     6:14 PM -2 days 22 Hours
Video                           1   5/12/2012     3:29 PM -1 Hour
GSM                             0   5/12/2012     4:35 PM
```

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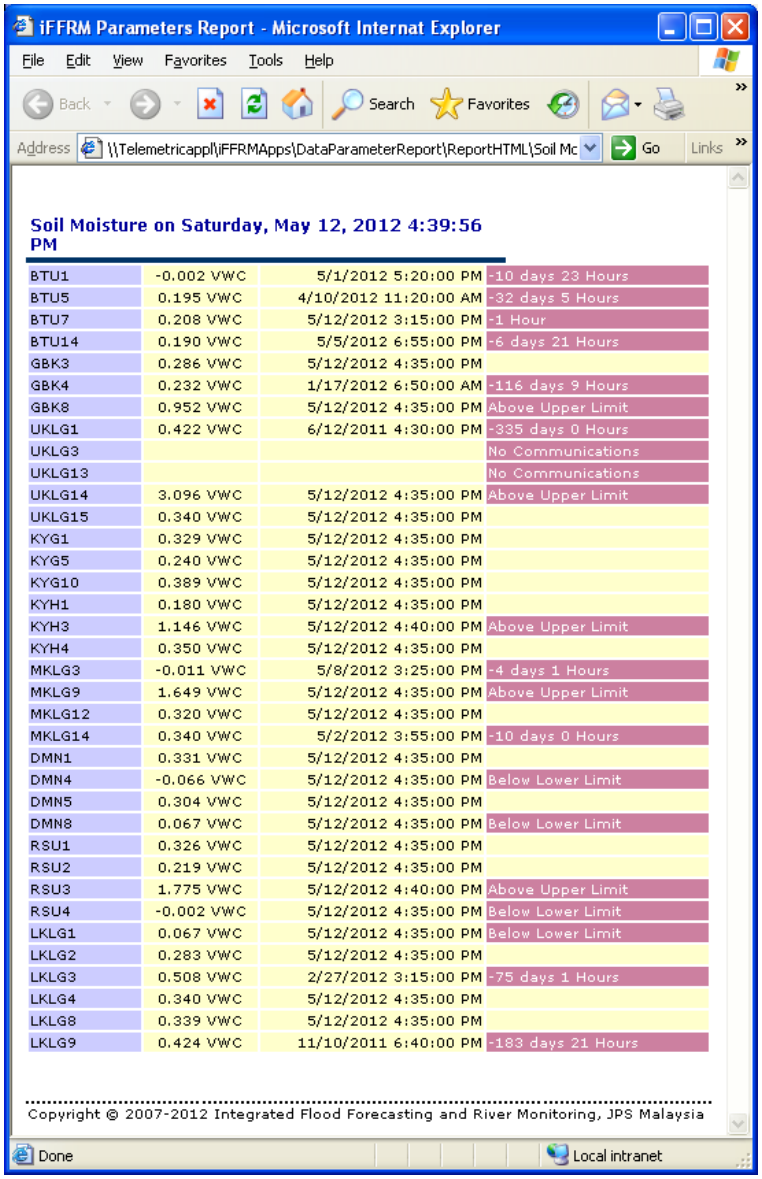
ParameterReport.html file



Updated every 5 minutes
For the .html file (the page refreshes)
All parameter status are generated

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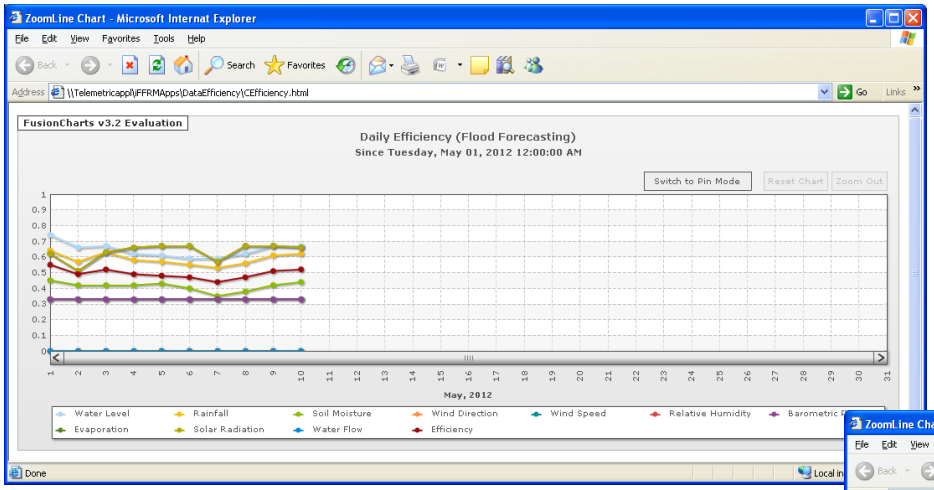
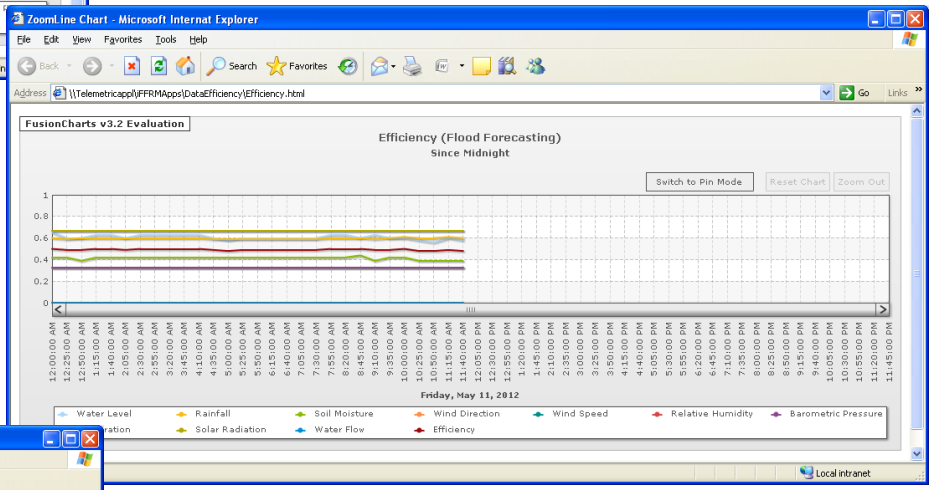
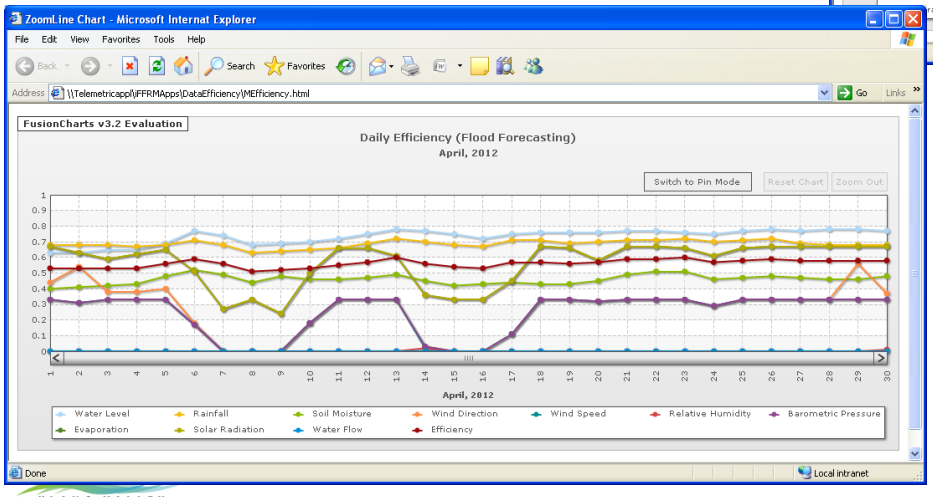
KLANG VALLEY



Running monthly daily efficiency



Running efficiency (Today)



Previously monthly daily efficiency

KLANG VALLEY

Web Client Class

- Web pages to customized the iFFRM data available to users.
- iFFRMWeb
  - Like a web site that can display any of the data available. Point and click
- iFFRMTV
  - Like a television that ONLY display any of the data available.

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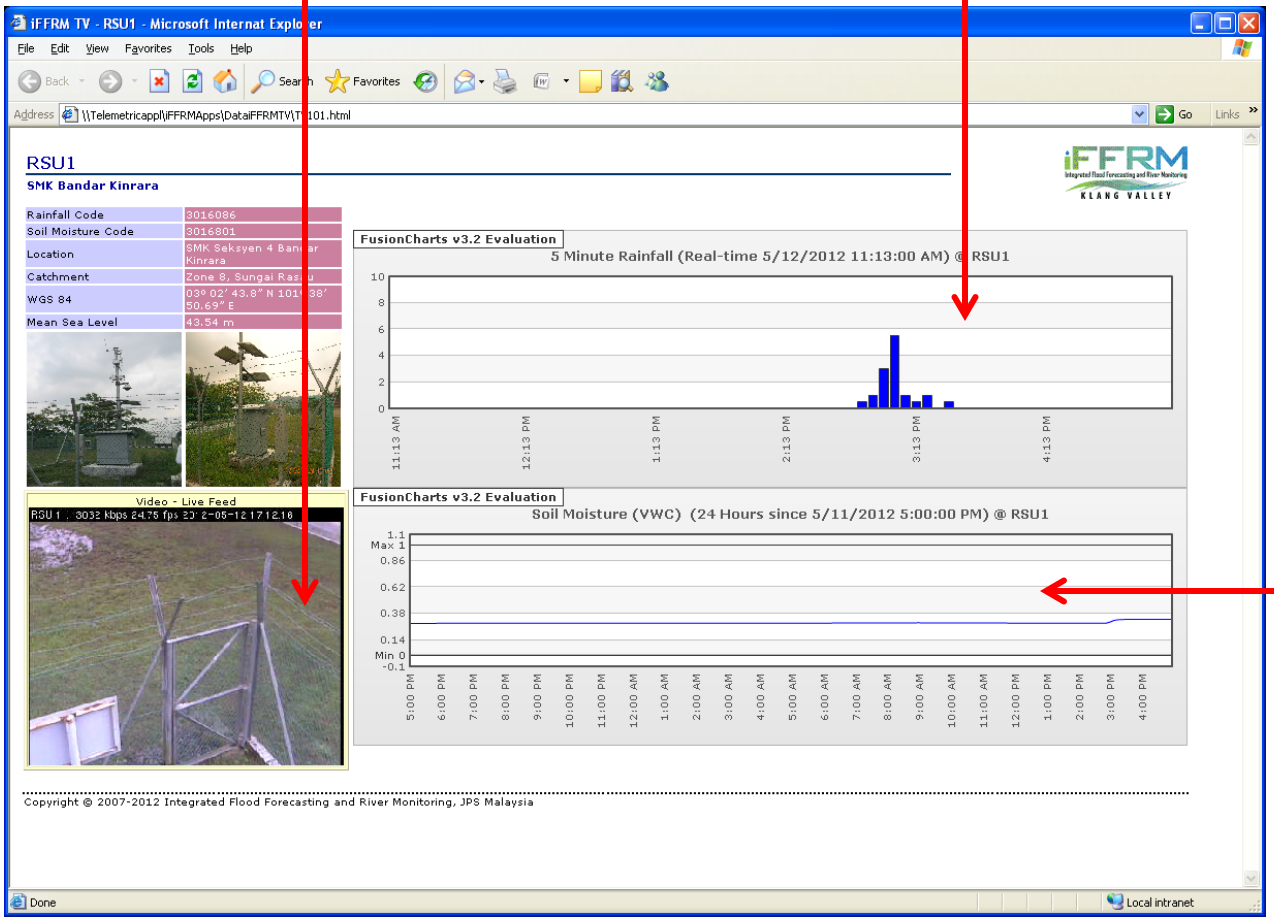
Live video feed

Real-time rain chart



Real-time water level chart

R&D OPPORTUNITIES

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iFFRM Advancement Philosophy

- DO NOT disrupt the operations of the Telemetric Class Applications
- DO NOT create a by-pass system
- DO NOT compete with the Reporting Class Applications
- DO NOT replace the existing iFFRM Applications
- DO NOT modify the Database structures

- QUESTION everything iFFRM
- COMPETE with the existing flood forecasting model
- ANALYZE all data to extrapolate and interpolate virtual data
- EXPAND iFFRM

IS THERE A FUTURE IN RAIN?

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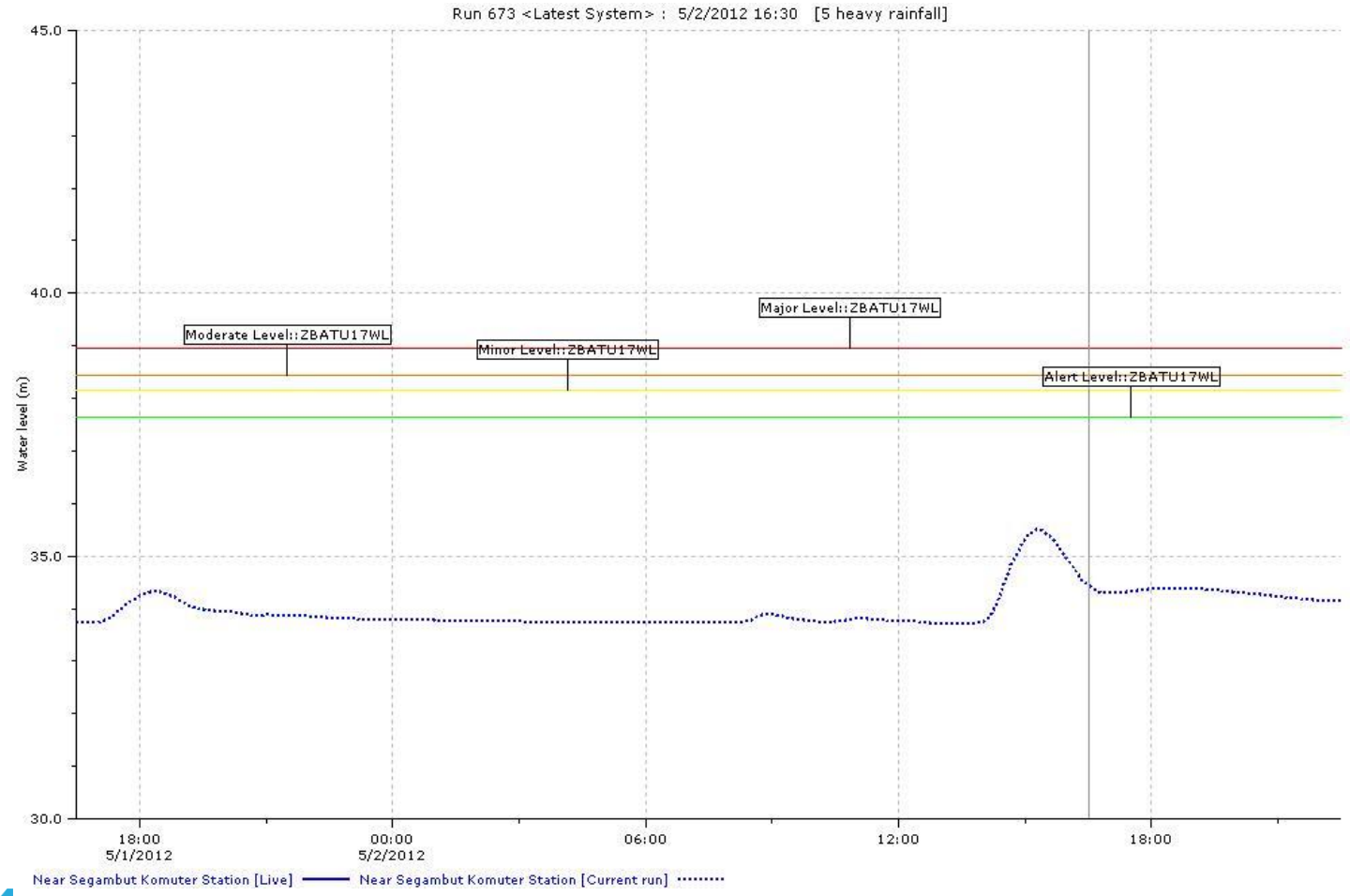
Rainfall Events

- Input
  - Observed rainfall
  - Forecasted rainfall (3 days)
- Problem
  - They are not the same and create problems during flood forecasting.
  - When the forecasted rainfall is off by at least 1 hour, the forecasted flow decreases rapidly.

Flood Forecasting with Future Rain



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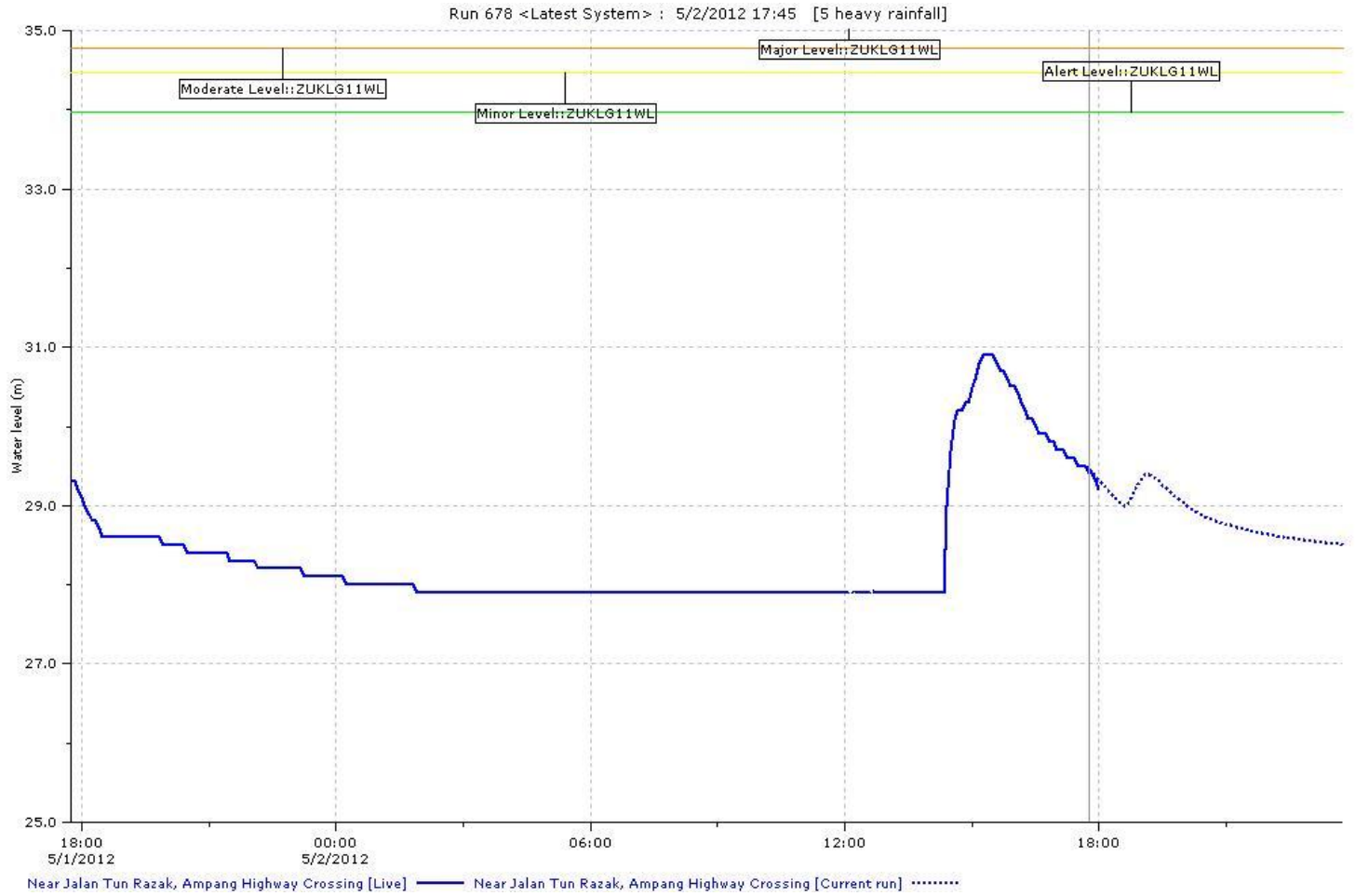
After an Event + Future Rain



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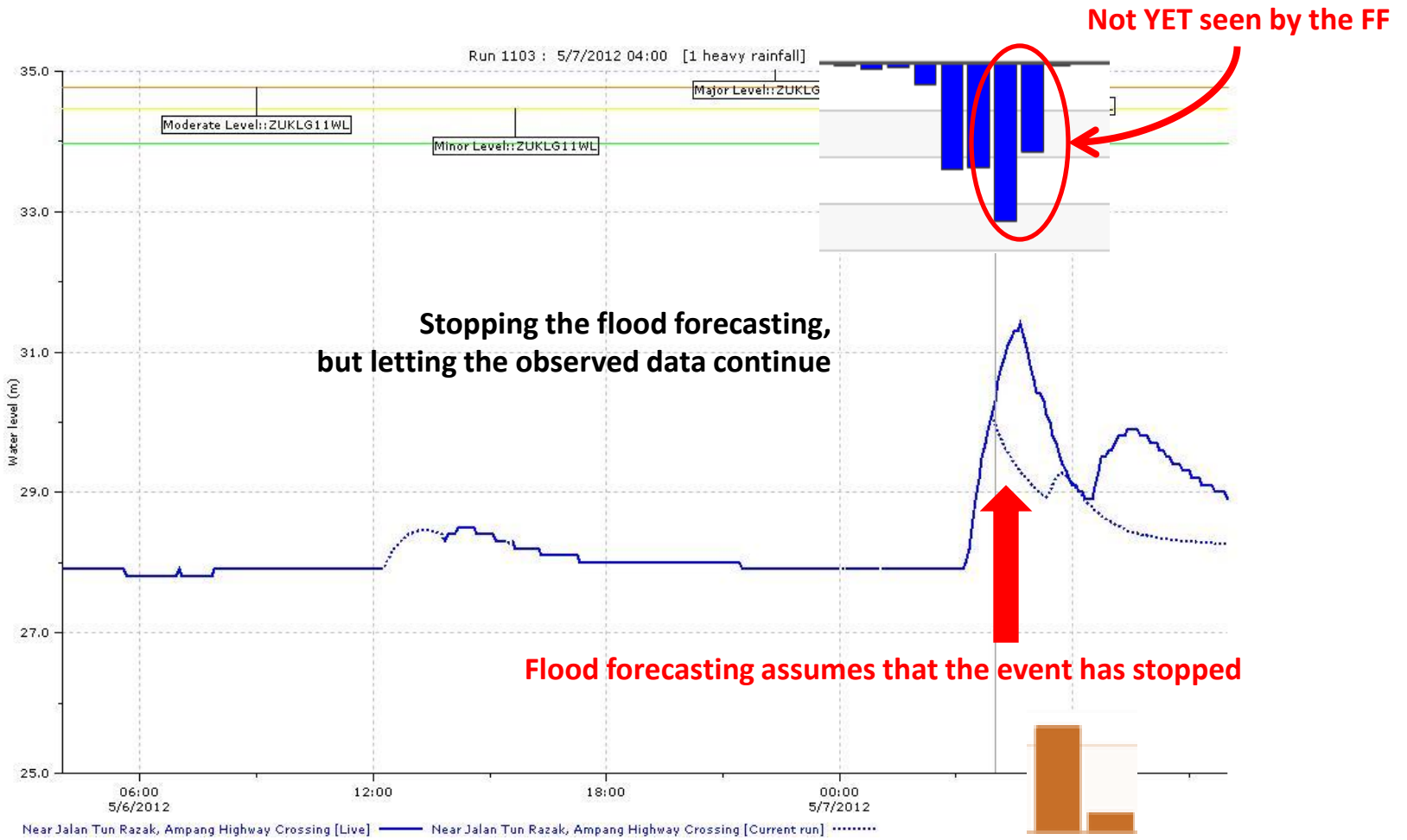
In the Middle of an Event



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Opportunities

- Can forecasted rainfall event be expedited or delayed?
  - What are the losses (gains) over the expedited period?
  - What is the distribution pattern for a 5-minute duration?
  - Is there a distribution pattern correlation with the quantity of rainfall?

Benefits

- The moment an observed rain event of a certain quantity is detected, then the enhanced forecasted rain can be applied.
  - Can be used to accurately (more or less) forecast the immediate future rain
  - Can be used to fill out missing rain information and treat it as observed
  - Can vastly improve the flood forecasting model

AKAN BANJIR DI SANA SINI

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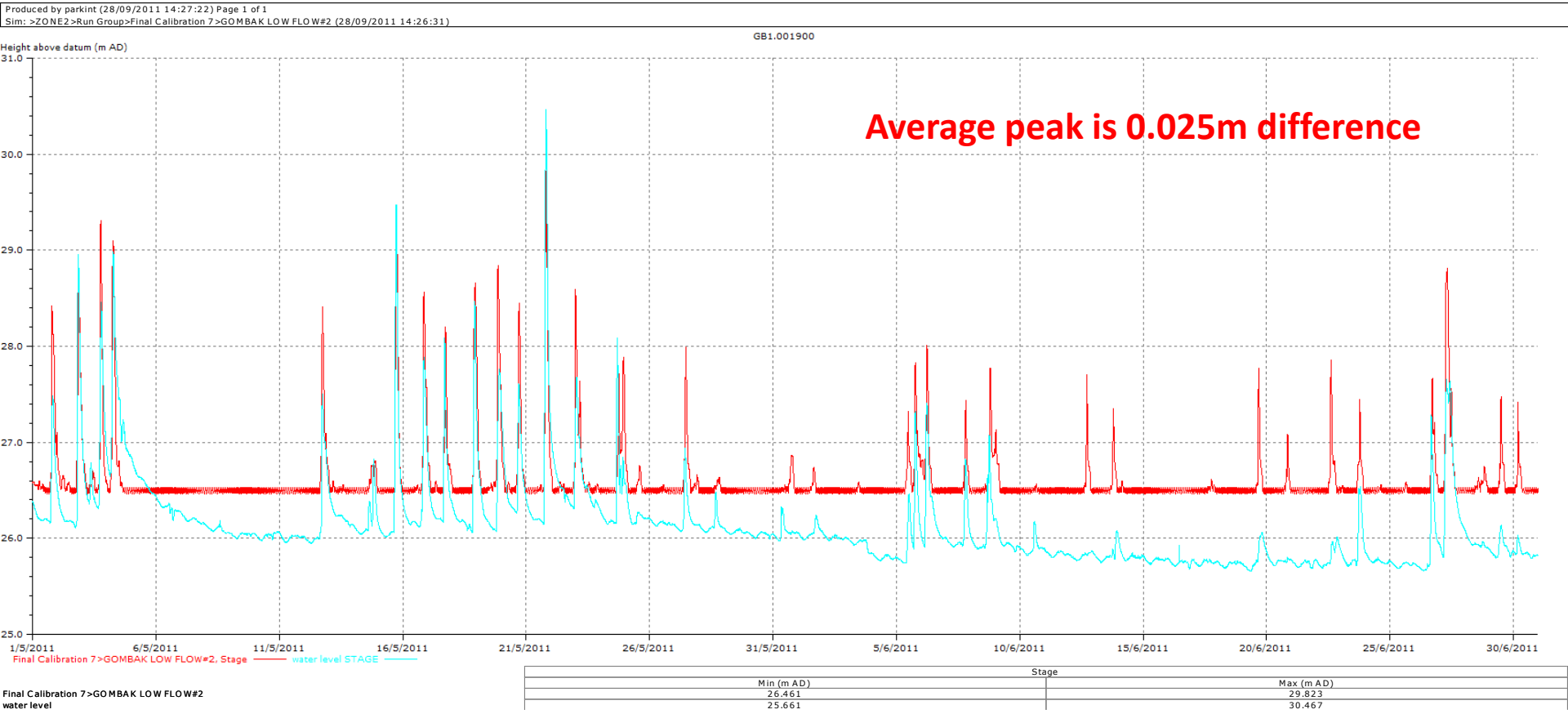
Forecasted Flood Event

- Output
  - Forecasted flow at selected points on the river
  - Forecasted water levels at selected areas of the river
- Problem
  - Can we issue these as warnings to the public?
  - Should we tag the warnings with confidence levels?

Opportunities

- How accurate is the forecast?
  - Can we measure the accuracy?
  - Is there a correlation model between the forecasted and observed events?
  - Should we over-forecast?
  - Or should we under-forecast?
  - If so, by how much?

Calibrating the Model



Final Calibration 7>GOMBAK LOW FLOW#2 water level	Stage	
	Min (m AD)	Max (m AD)
	26.461	29.823
	25.661	30.467

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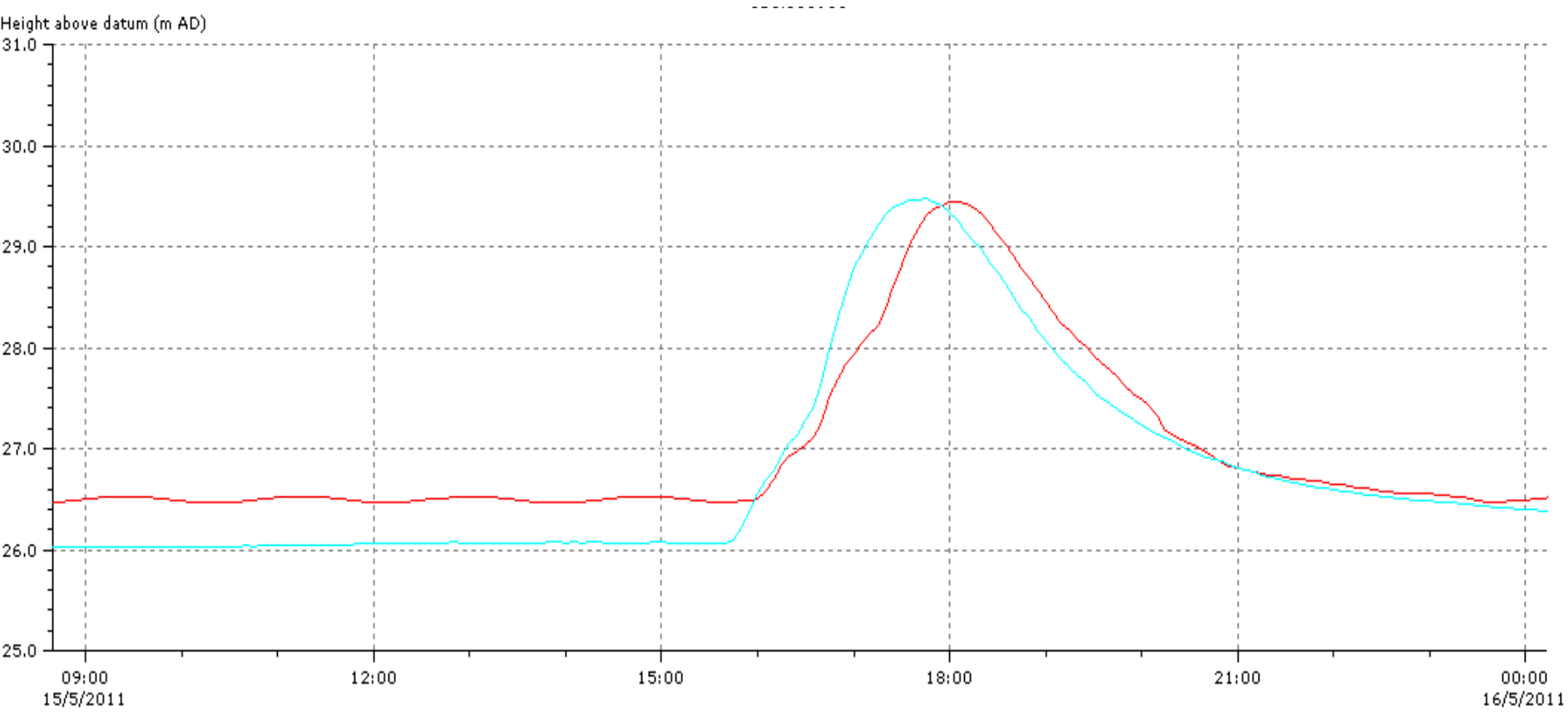
Selecting a Peak



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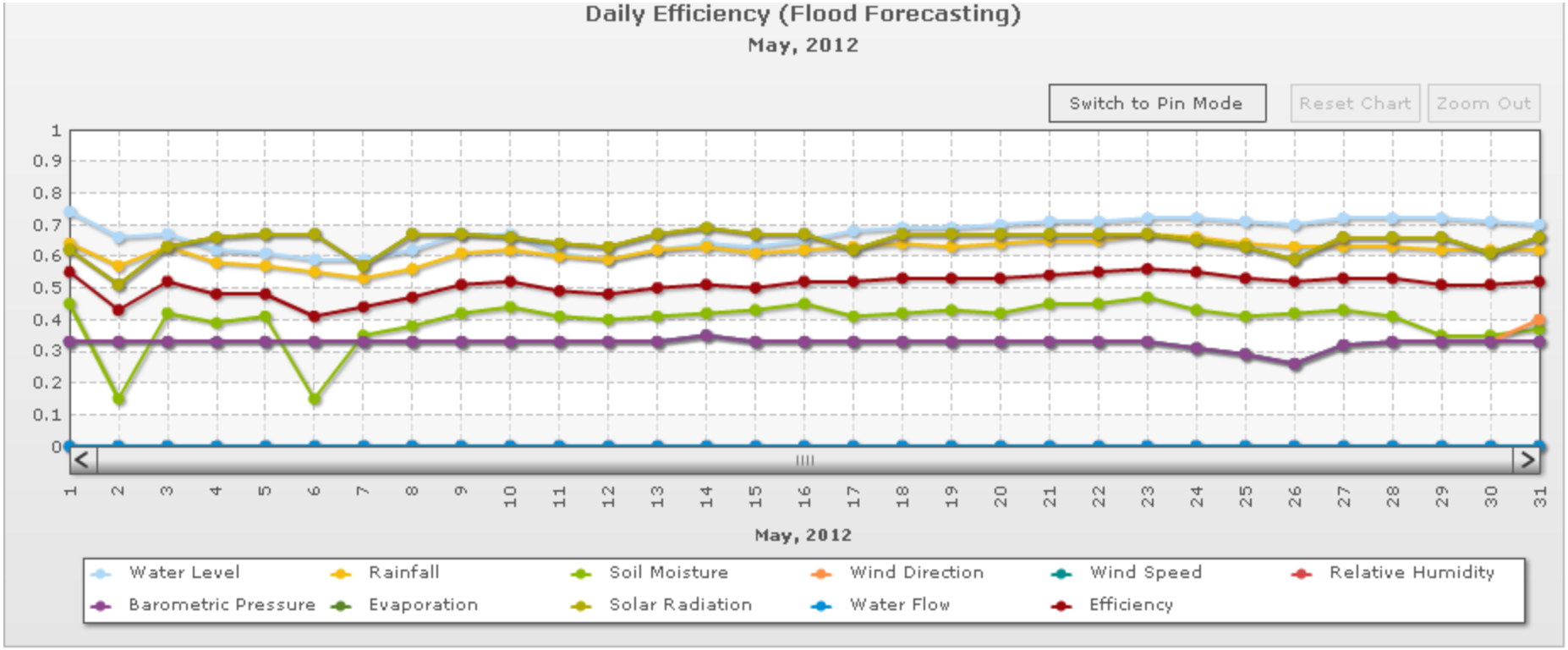
- iFFRM generates in real-time the KPIs of the forecasting related sensors.
- And collectively generates the efficiency
- Efficiency weightages:
  - Rainfall @ 40%
  - Water Level @ 24%
  - Soil Moisture @ 20%
  - Water Flow @ 10%
  - Meteorological Parameters @ 6%

KPI of Data Collection



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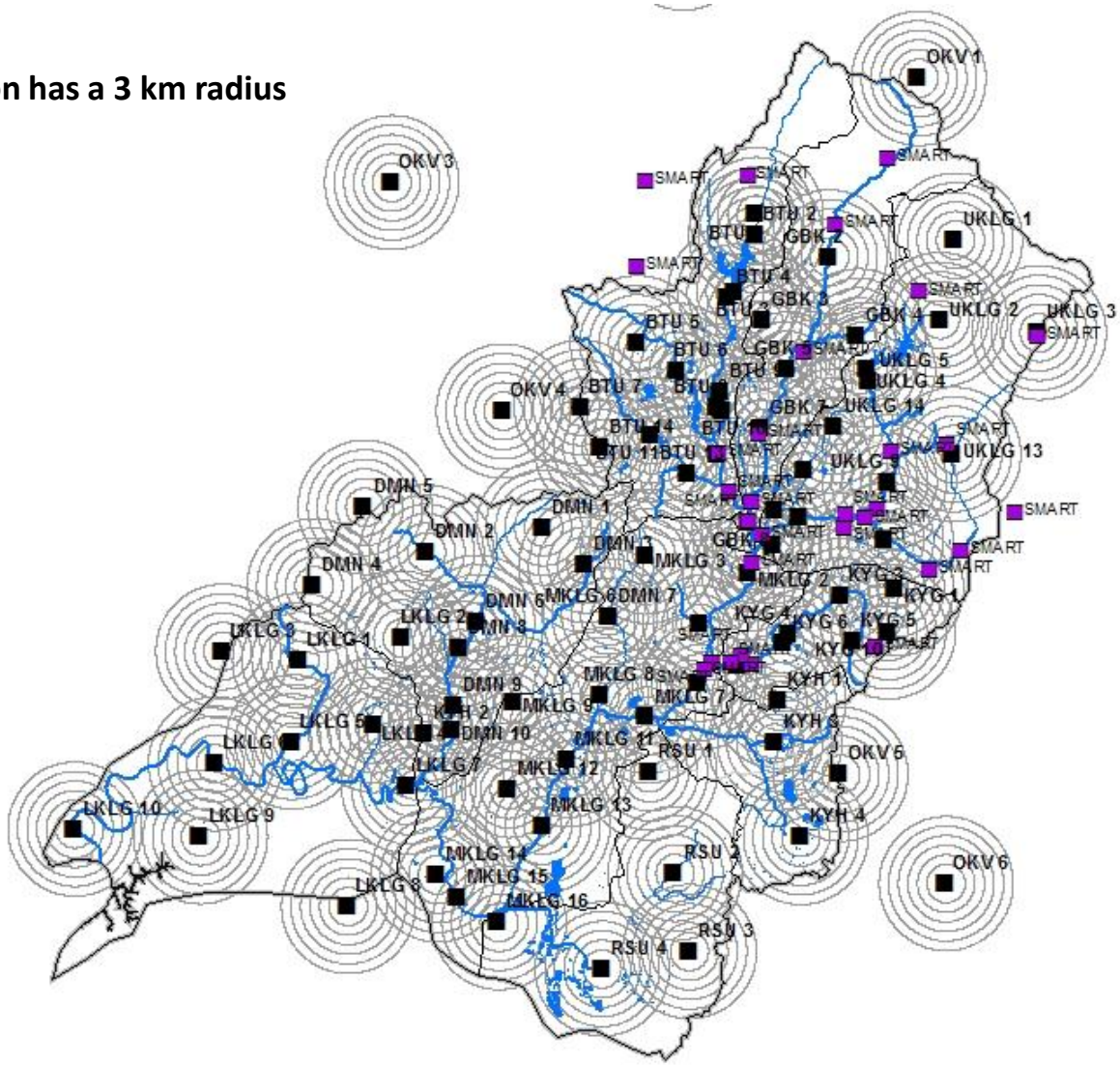
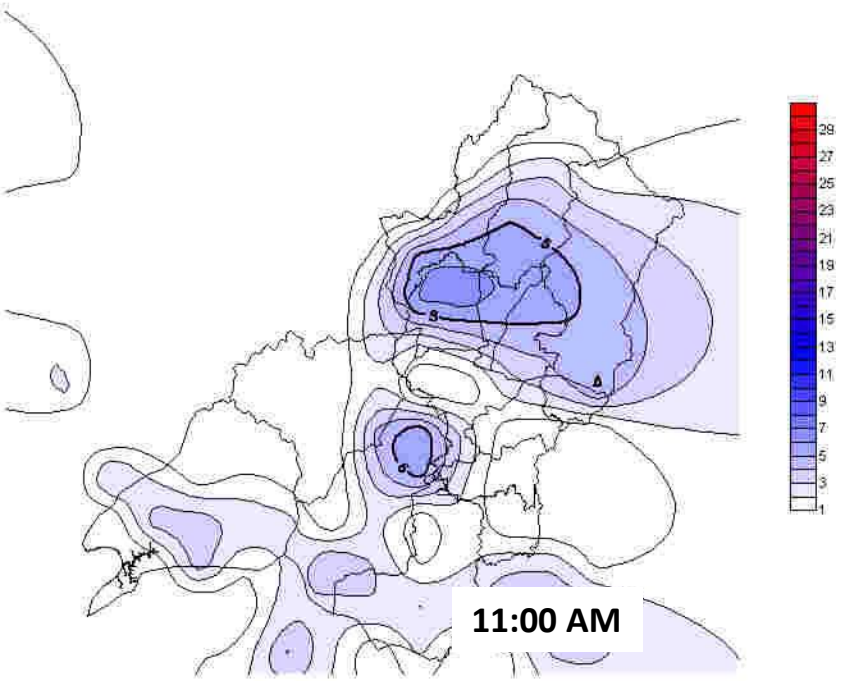
Rainfall Station Coverage

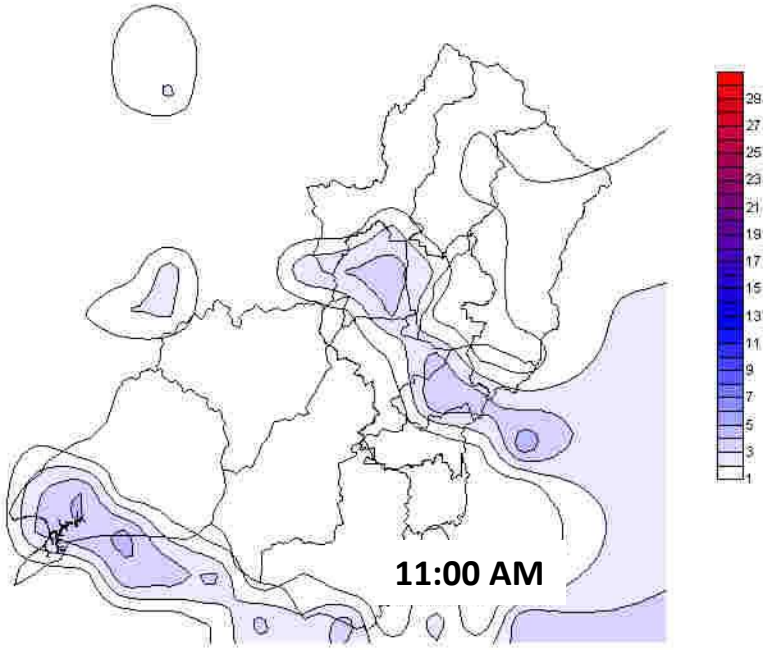
Each station has a 3 km radius



Future Rain Sensitivity



Predicted 15 hours earlier



Predicted 3 hours earlier

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- This generates a simple linear efficiency measuring the quality of the inputs.
- Can this be extended to become a viable correlation model to measure the accuracy?
- Over time can this meta model be used to apply any error corrections to the forecast?

ARE THERE PARALLEL WORLDS?

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Multi Forecasting Models

- Is one enough?
- Can we have two, three, or four models running at the same time?
- No two models will output the exact same forecast.
- iFFRM has an open architecture and was specifically designed and developed to accommodate multiple models. Just plug and play away.

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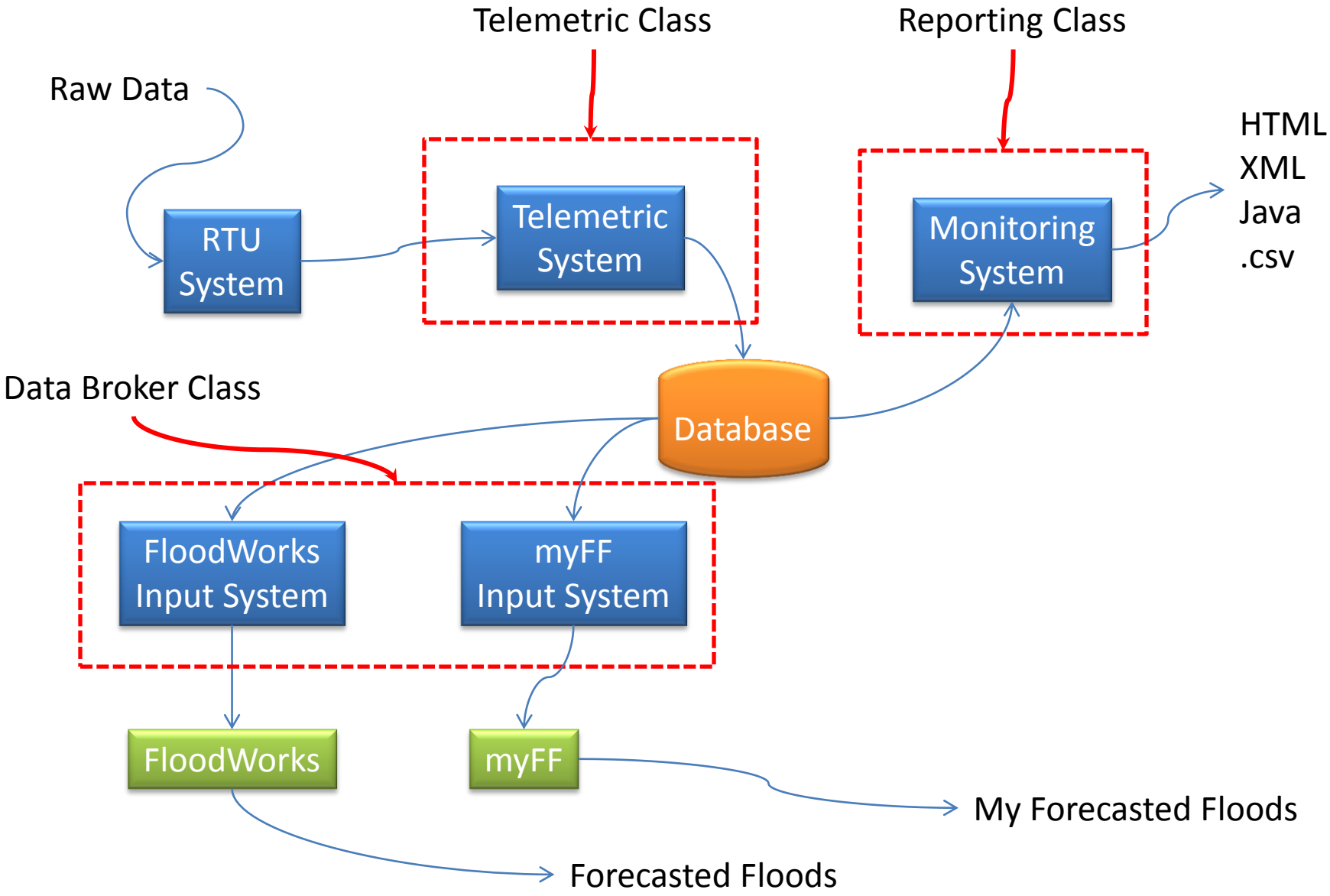
- iFFRM via its Data Broker Class Applications can feed data to any models (but for Klang Valley only – for now)
- Can input:
  - Observed hydrological parameters
  - Observed selected meteorological parameters
  - Forecasted rain
  - Performance indicators
  - Video feeds
  - Historical data for calibration
  - Hydrodynamic features



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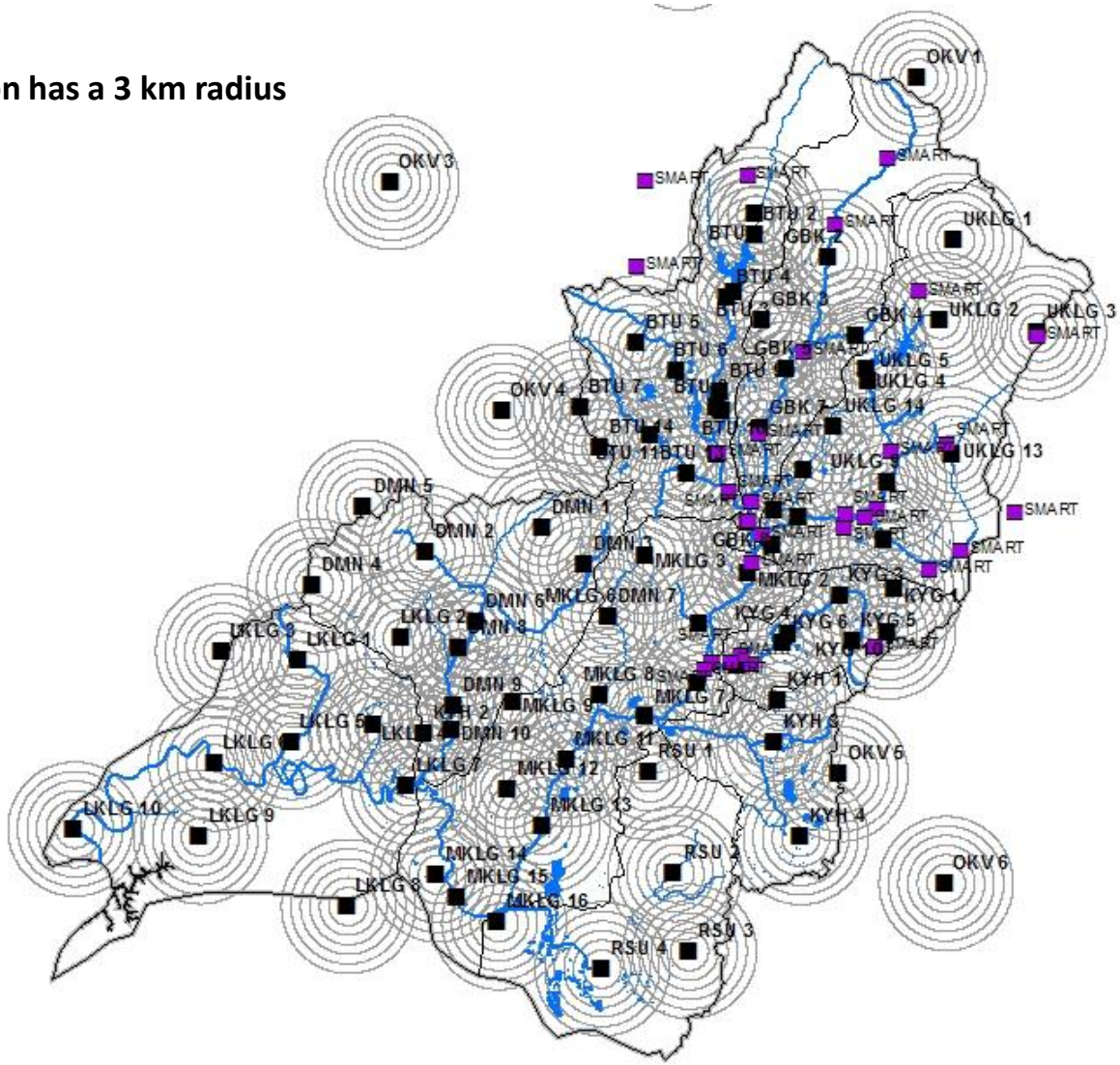
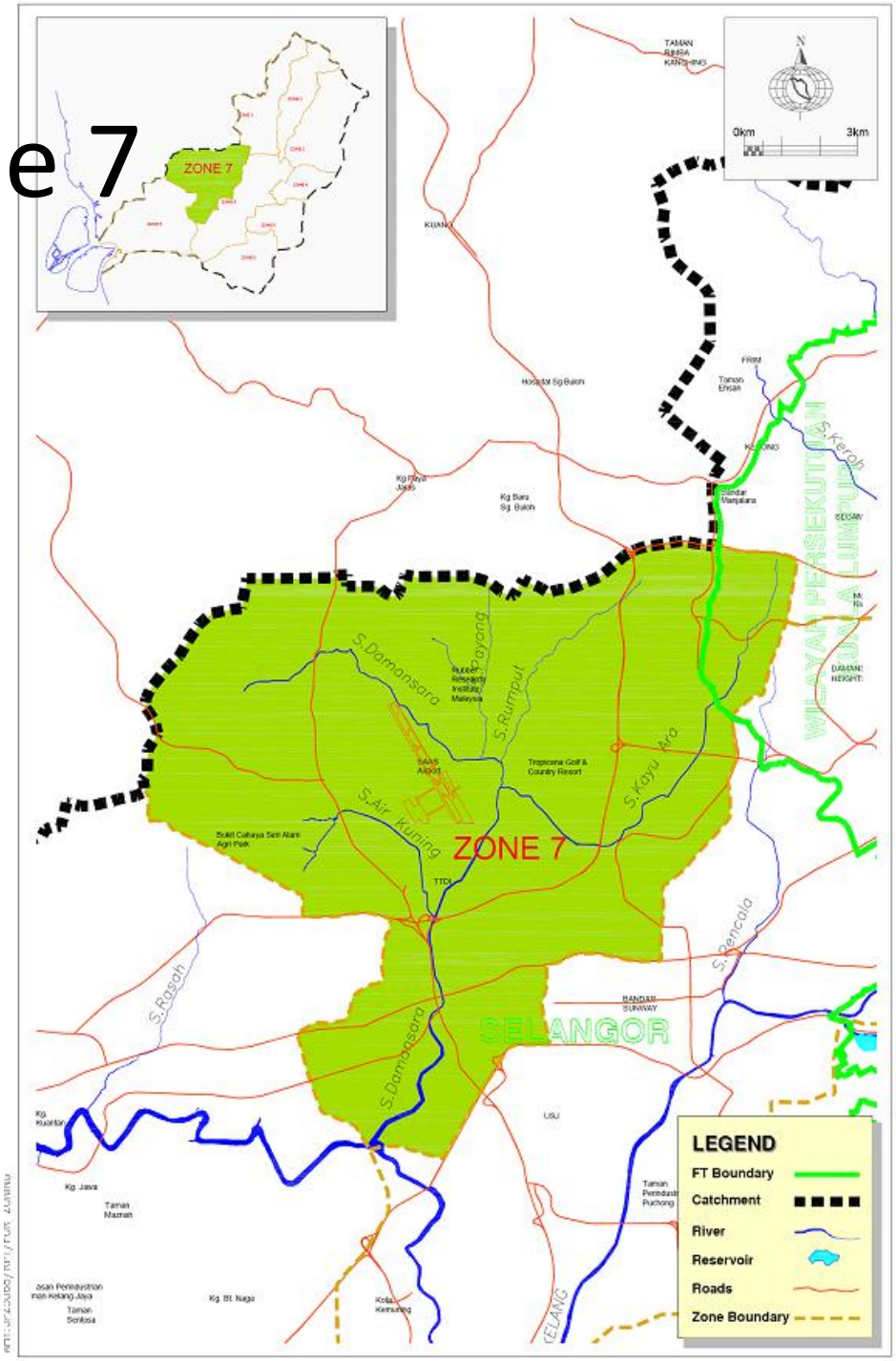


Zone 7

- 10 RTU Stations
- 9 Rainfall Stations
- 4 Soil Moisture Stations
- 7 Water Level Stations
- 3 Water Quality Stations
- 1 Water Flow Station



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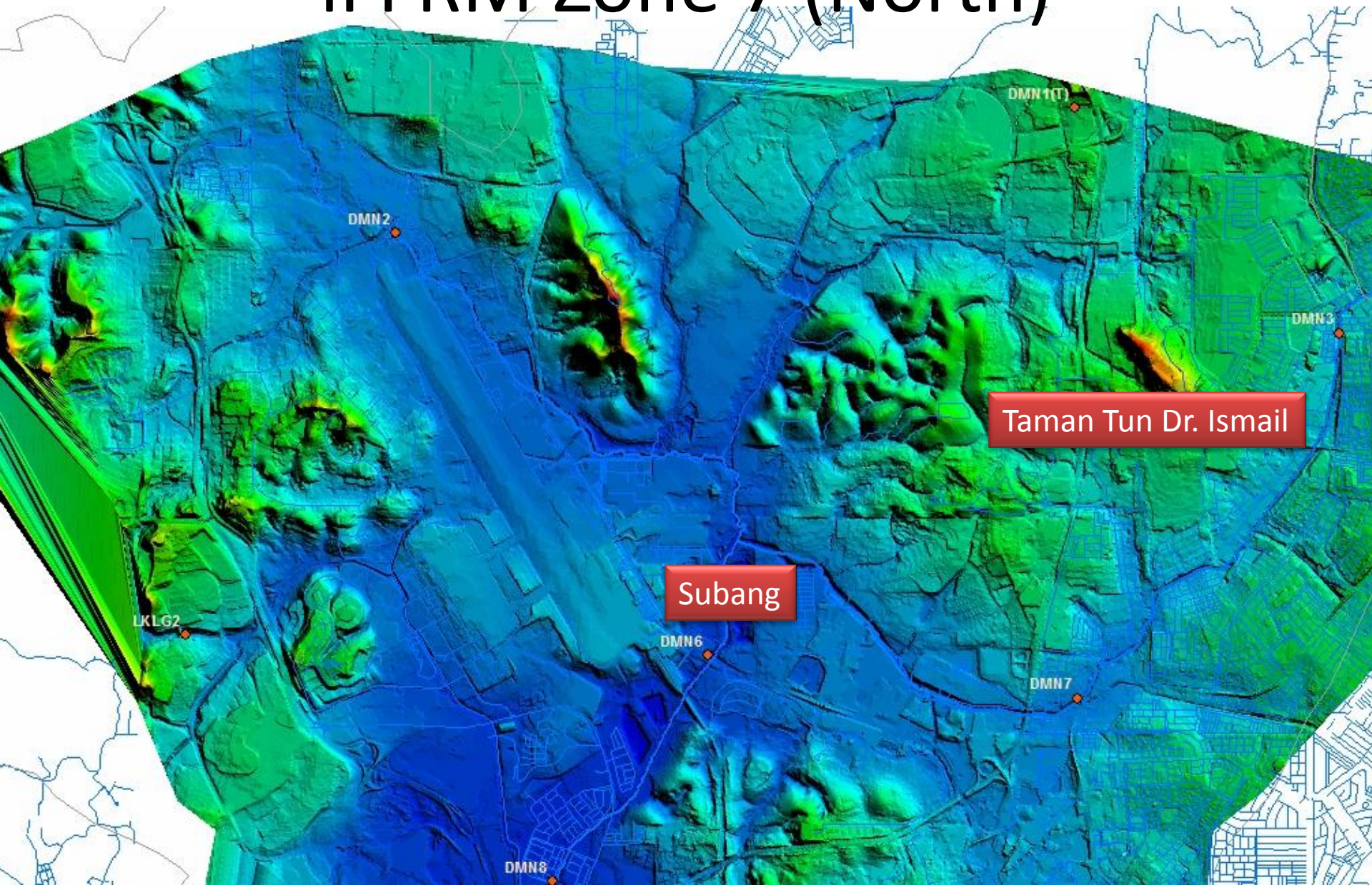
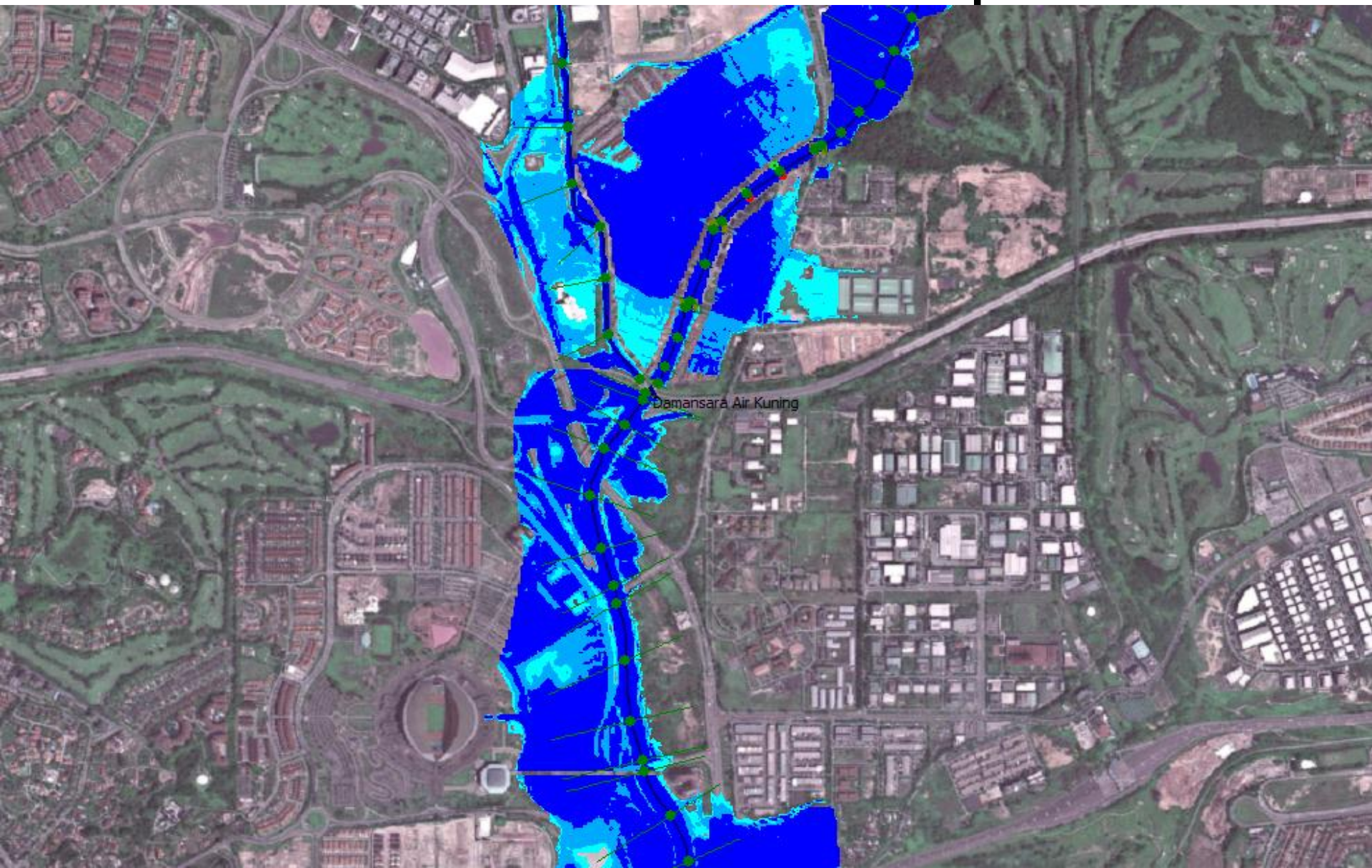
iFFRM Zone 7 (North)



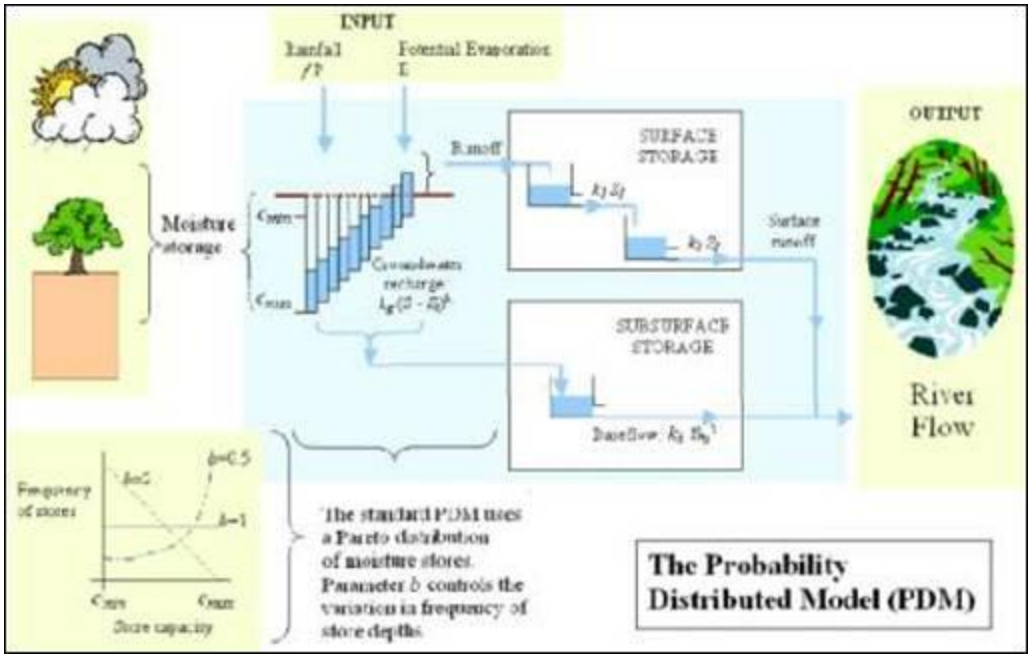
Hydrological Schematic – Zone 7

Parameter	Values
Catchment (km^2)	153
Subcatchments	95
Nodes	688
Links	687
Network Objects	1,470
Computational Length (m)	98,969
River Sections	436
Boundary Nodes	105
Junction Nodes	62

Zone 7 – Floodmap



Have your own model to connect to iFFRM



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Multiple Model Opportunities

- Multiple models can support each other
- Average results can be used
- A mixed model for a single catchment can be researched
- Distributed computing for speed can be tried
- What-if scenarios can built to approve new man-made hydrological features

In Summary

- iFFRM has an open architecture
- There are about 1,700 data points available at any one time
- There is a mixture of urban and rural areas
- Historical, real-time, and future rains are available
- Communications is at a very high speed
- Video history for events are available

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- Nearly 1,000 sub-catchments
- 1 minute rain is available (to study intensities)
- More catchment can be attached to iFFRM
- Many man-made hydrological features are available

THANK YOU

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