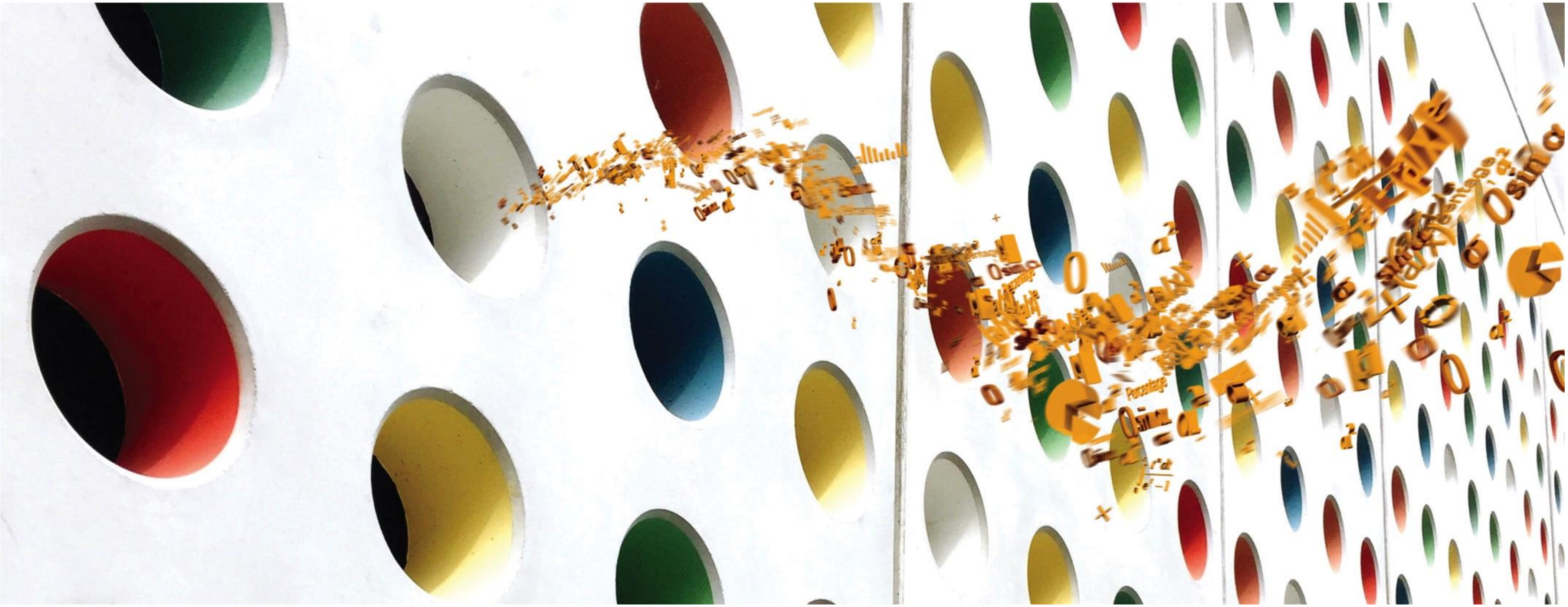

Model Showcase: Next Generation Thai Flood model

Unveil what's inside the new model. A brief overview of Impact Forecasting's model development and solutions

Prepared by Santhosh Dronamraju and Himavant Mulugu of Impact Forecasting

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Presentation for Catastrophe Insight 2018 , TGIA , Bangkok

Agenda

- **Section 1** Impact Forecasting – An Overview
- **Section 2** Impact Forecasting Thailand Flood Model
- **Section 3** Use cases
- **Section 4** Conclusions and Benefits

Impact Forecasting

Over 100 Catastrophe Models

Customisable Models

Transparent ELEMENTS loss calculation platform

Universal Platform running Third Party Models

Data on 12K+ Events for catastrophe analysis and reporting

60 countries

85+ modelling experts over 5 time zones

100+ Models

12 perils

12,000+ events in the catastrophe insights database

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Section 2: Impact Forecasting Thai Flood model

- Anatomy of a catastrophe model
- Hazard Component
- Exposure Component
- Vulnerability Component
- Loss Component

Motivation

Q3/Q4 2011 – Unprecedented flooding hits Thailand

Q3 2012 – First flood model for Thailand released by Impact Forecasting

Q4 2016 - Update of the Impact Forecasting flood model for Thailand initiated

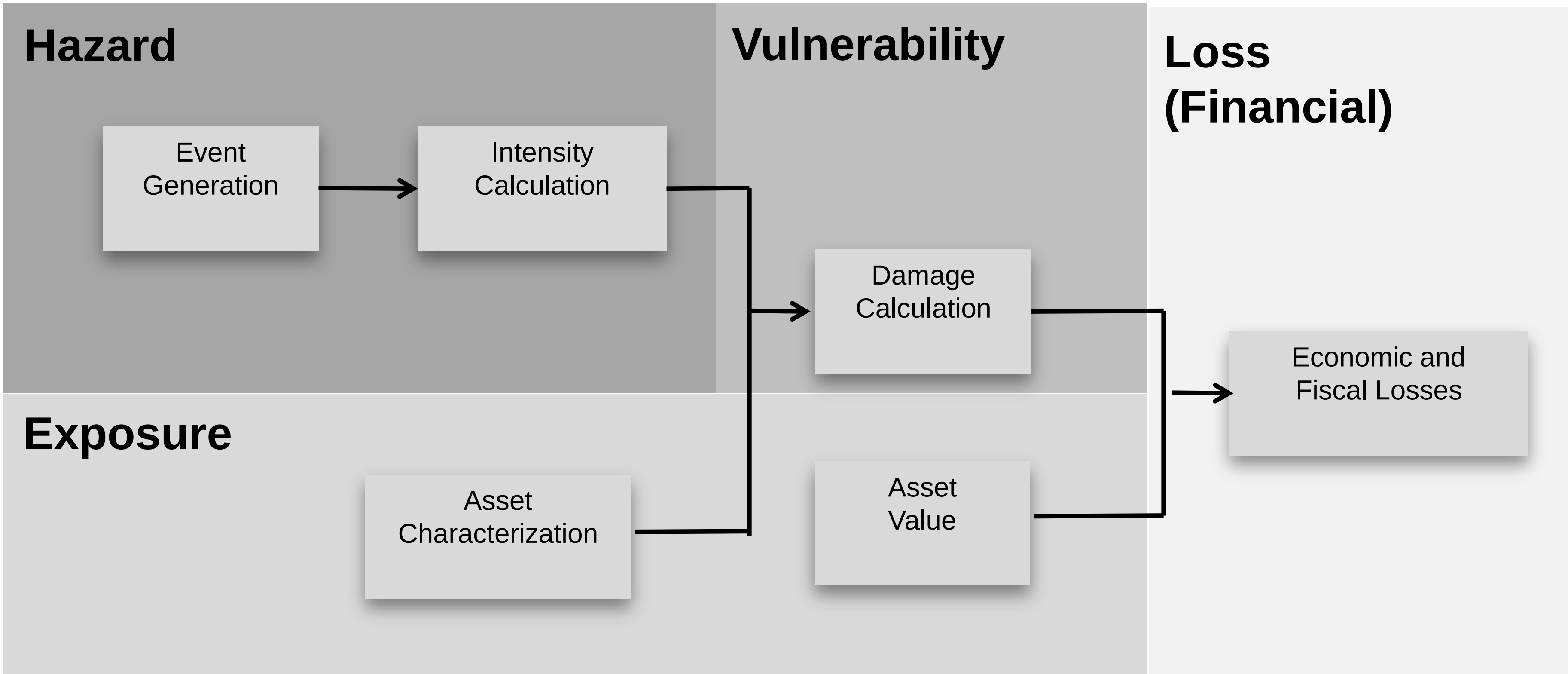
Q4 2017 – Technical model development completed, calibration initiated

Q2 2018 – New model released for production, including underwriting datasets

Section 2: Impact Forecasting Thai Flood model

- Anatomy of a catastrophe model
- Hazard Component
- Exposure Component
- Vulnerability Component
- Loss Component

Anatomy of a Catastrophe model



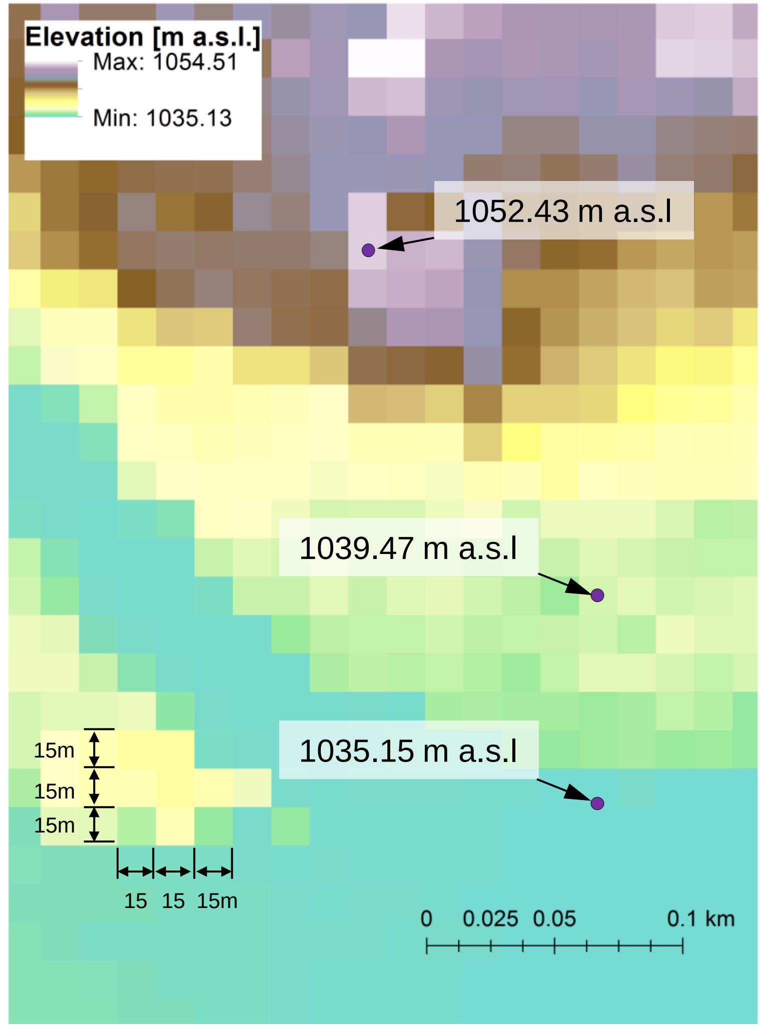
Section 2: Impact Forecasting Thai Flood model

- Anatomy of a catastrophe model
- Hazard Component
- Exposure Component
- Vulnerability Component
- Loss Component

Hazard component- Digital Terrain Model (DTM)

- Basic dataset describing topography
  - 3D representation of Earth surface
  - Gridded set - each cell holds local altitude

- DTM – Parameters
  - Vertical resolution
    - Elevation step/accuracy
  - Horizontal resolution
    - Cell size dimension (proportional to dataset size)
  - Large datasets (100s of GB)
    - Right balance between level of details and processing requirements
  - Resolution should be proportional to accuracy!



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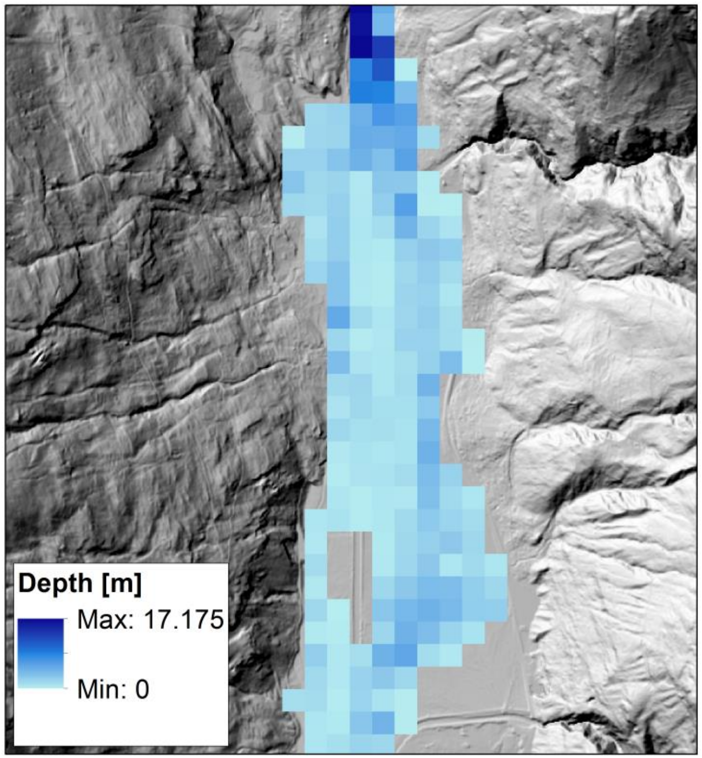
Model considerations - Digital Terrain Model (DTM)

- The effect of digital terrain model's resolution

Resolution [m]	No. Cells	Size
5 x 5	$6{,}23.10^6$	48,49 MB
10 x 10	$1{,}59.10^6$	12,27 MB
15 x 15	$0{,}71.10^6$	5,39 MB
20 x 20	$0{,}40.10^6$	3,03 MB
25 x 25	$0{,}26.10^6$	1,94 MB
50 x 50	$0{,}06.10^6$	0,48 MB
100 x 100	$0{,}016.10^6$	0,12 MB

Model considerations - Digital Terrain Model (DTM)

- The effect of digital terrain model's resolution



Resolution [m]	Comp. Time	Max Depth
5 x 5	665.4 min	4.2 m
10 x 10	79.02 min	4.9 m
15 x 15	26.30 min	4.5 m
20 x 20	13.10 min	5.0 m
25 x 25	3.99 min	6.0 m
50 x 50	0.48 min	9.1m
100 x 100	0.06 min	17.2 m

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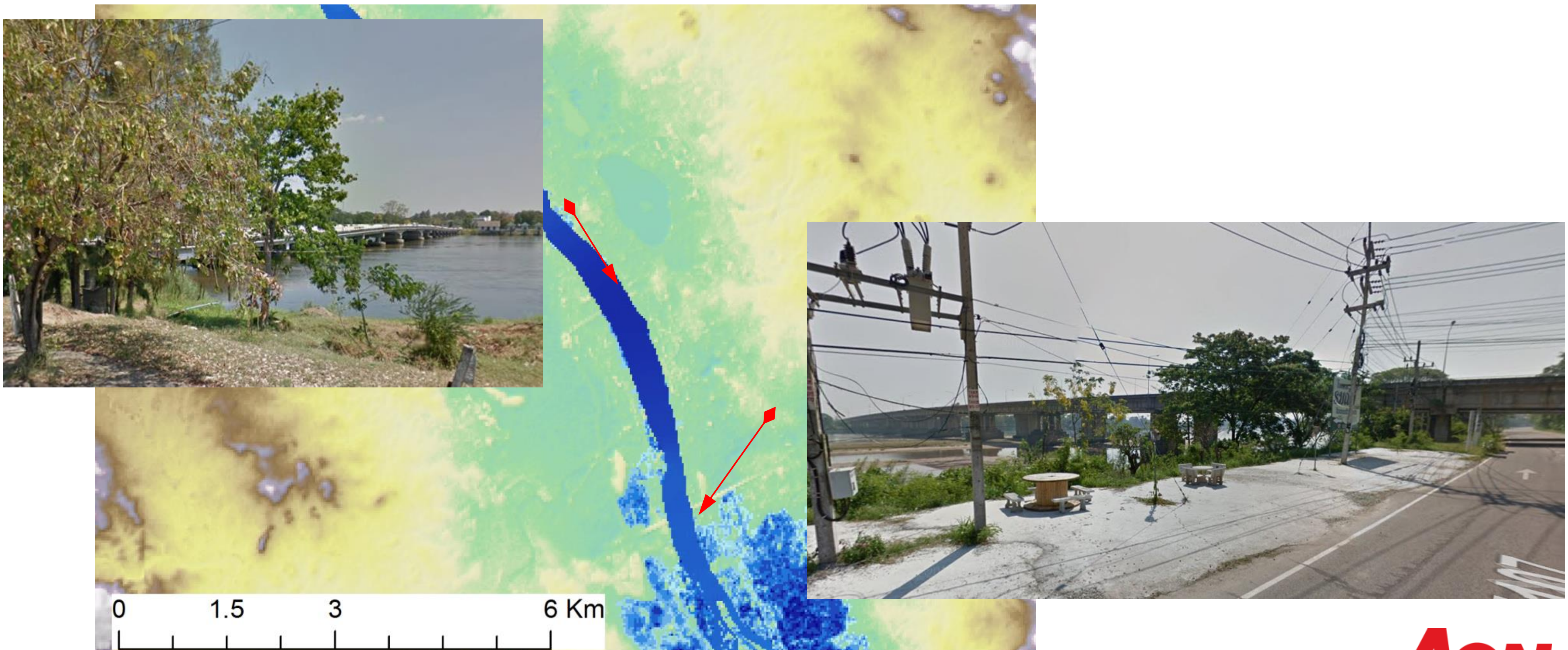
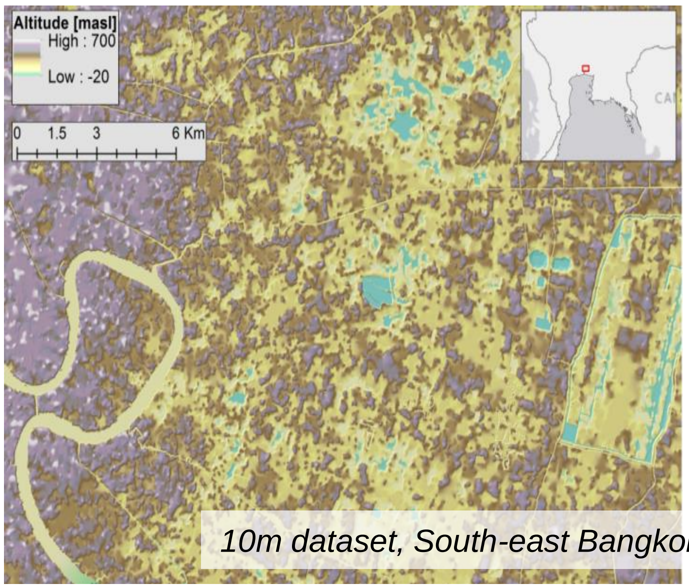
Digital Terrain Model: Corrections

- Majority of DTMs are not derived for inundation modelling, contains obstacles affecting simulation
- Their corrections is difficult and time consuming, must be done semi-manually
- A crucial need of consistency with real river network

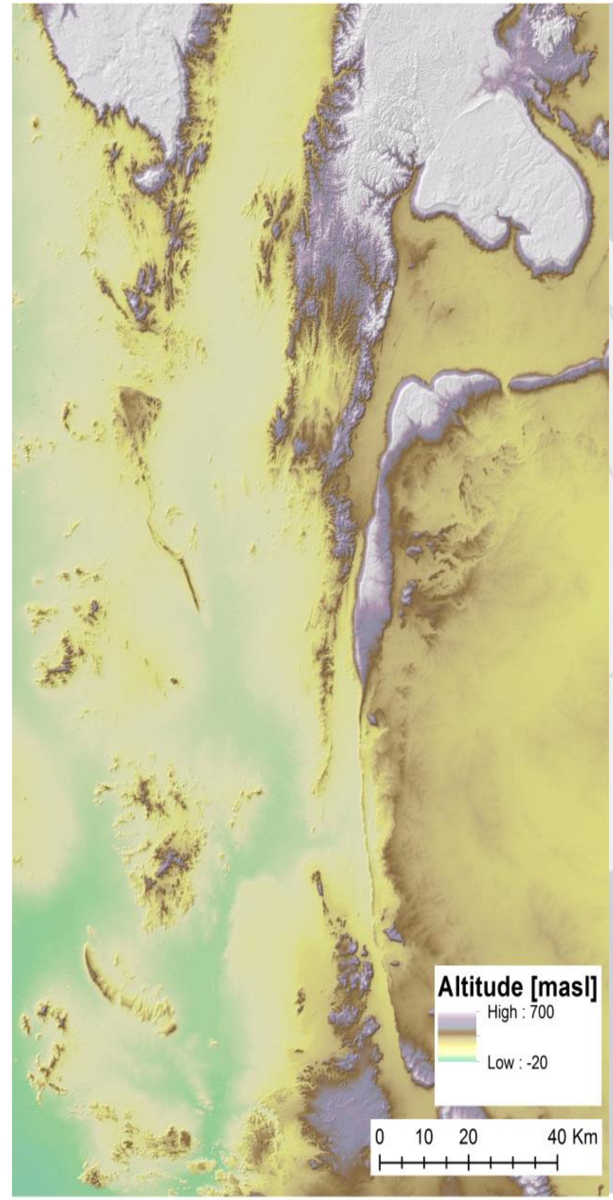


Digital Terrain Model – IF Thailand flood model

- Combination of two dataset used:
  - 10m Digital terrain model for Greater Bangkok (ORD2281 AW3D)
  - 30m Digital elevation model for the rest of Thailand (JAXA)



10m dataset, South-east Bangkok

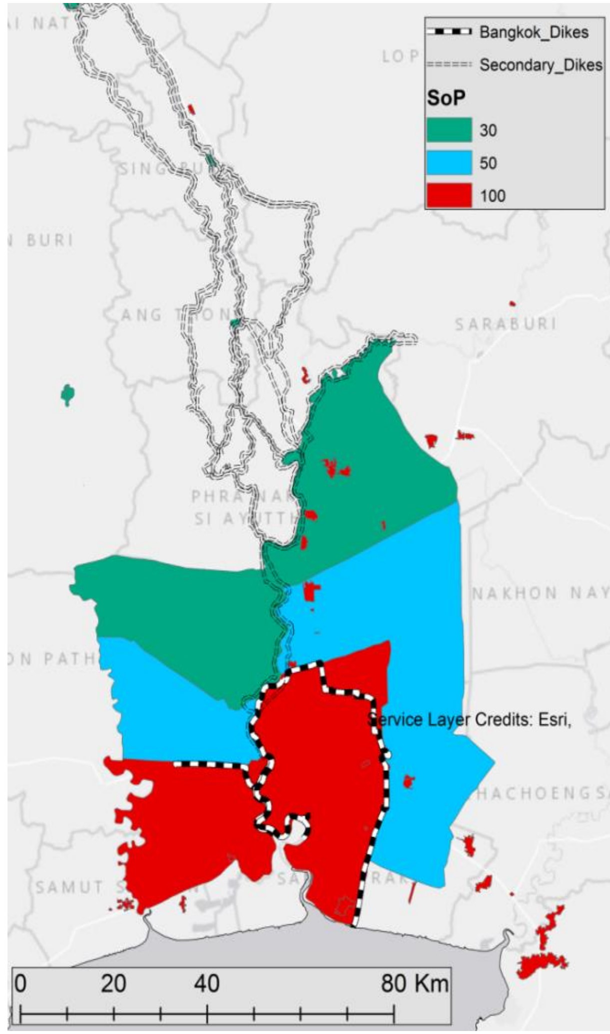


Hazard Component – Flood defence data

- Usually most difficult dataset to acquire, many flood defence types exists
- Complex systems consisting of many individual FD types (retention, diversion and technical measures,…)
- Ongoing development as well as obsolescence, high uncertainty and failure susceptibility
- Given by law, nation-wide or local standards
- Local protection of individual risks (industrial estates), property evacuation ratio

Hazard Component – Flood Defence Data

- In model implemented as:
  - Dike crest level – implemented in hydrodynamic calculation
  - Road structure with considering of bridges and culverts
  - Standard of protection polygons with known locations
  - Assumptions based on land cover and population
- In total:
  - 2,000 km of identified dikes
  - 87 polygons with known SoP
- Retention measures (reservoirs, dry polders,…) applied in hydrological data processing
- JICA report provides key summary
- 4 field visits (2 x in 2012, 2x in 2017)



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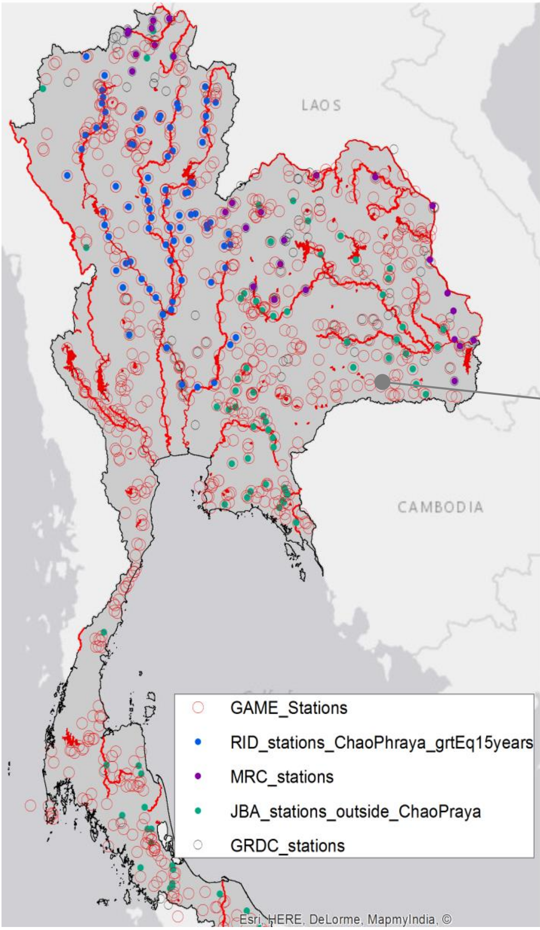
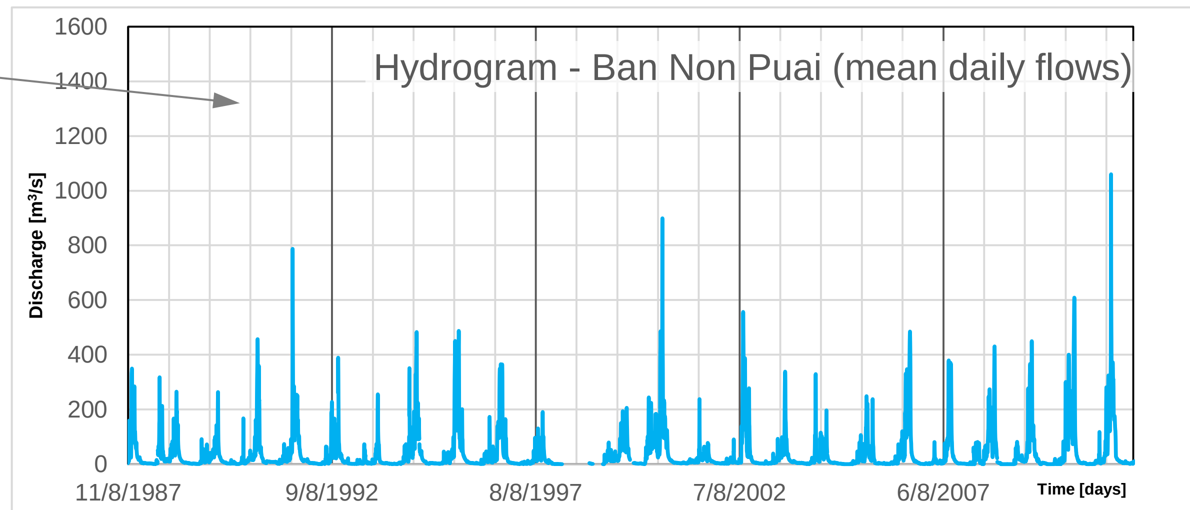
Hazard component – modelled river network

- Extracted from corrected digital terrain model
- Many additional corrections to cover:
  - Irrigation channels
  - River bifurcation
  - Chao Praya River delta
  - Mekong River
- Compared and validated according to public sources (RID, SRTM)
- Split into individual computational segments for hydrodynamic modelling
  - 1,179 computational domains
  - **29,700+ km of modelled rivers** (slightly subjective)
- For each domains a set of hazard maps was calculated
  - From 1 in 5 to 1 in 1,000 years return period of discharge
- Final event maps created by a composition of these segments

Hazard component – Hydrological Data



- 200 gauge stations with time series of observed daily flow (discharge)
- Daily mean or maximum flows, monthly max flows
- Observation length at least 15 years (due to EV distribution fitting)
- Key sources:
  - Royal Irrigation Department
  - Mekong River Commission



- **Design flow estimate (how much water flows)**
- **Event set generation (how often and where the water flows)**

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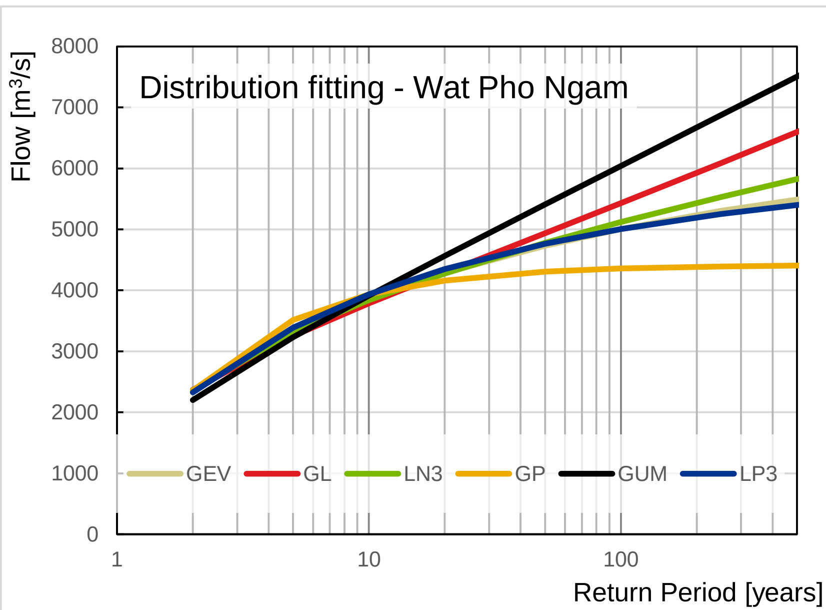
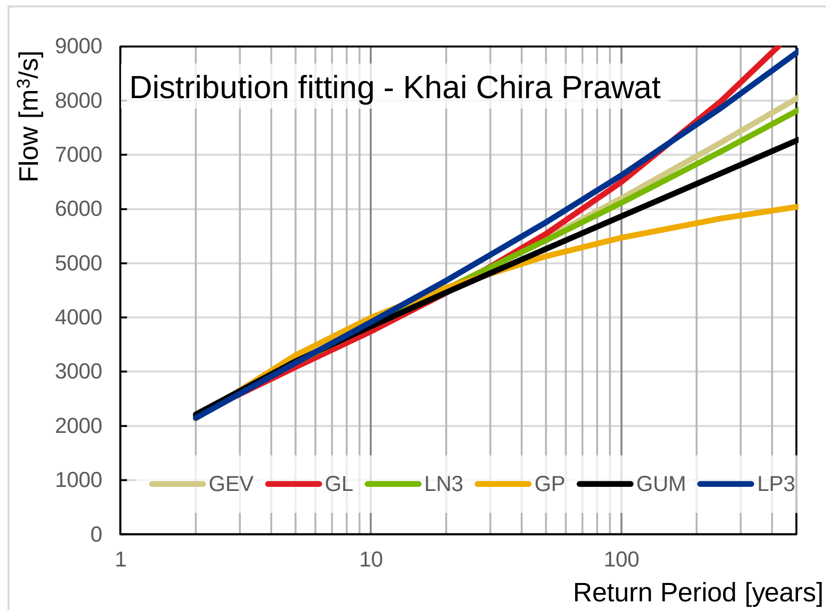
Hazard component – Hydrological Data Processing

- Basic data cleaning, tests for homogeneity, break-points and trends
- Frequency analyses:
  – Fitting extreme value statistical distribution
  – Estimating parameter via *L*-moments.
  – Estimating design flows for specific frequencies (return periods) for 1 in 5 to 1 in 1,000 years
- Most suitable distribution is selected based on the goodness of fits and manual screening





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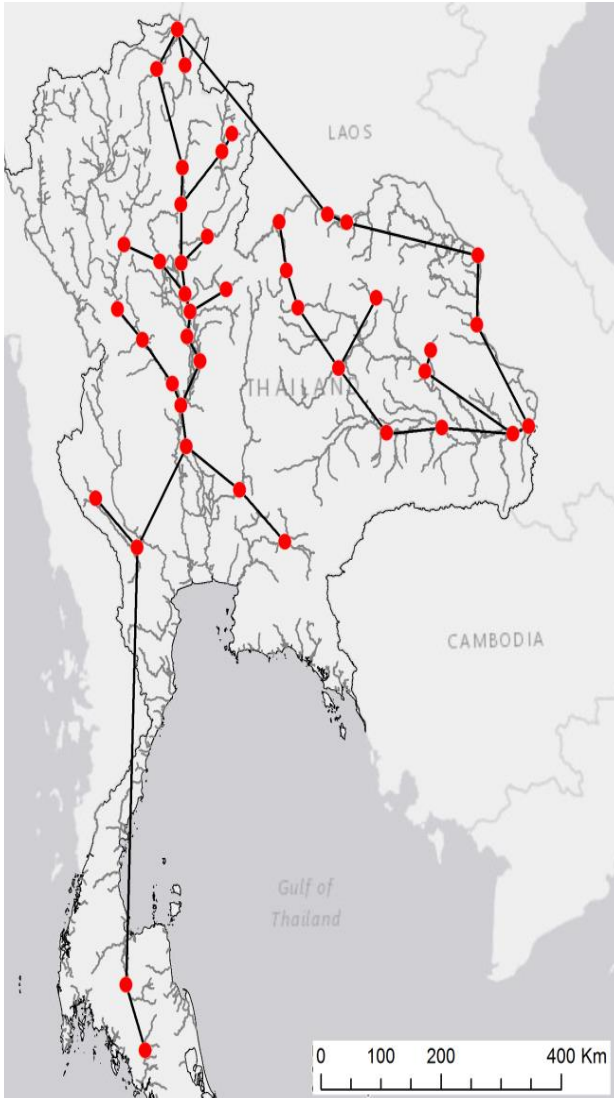
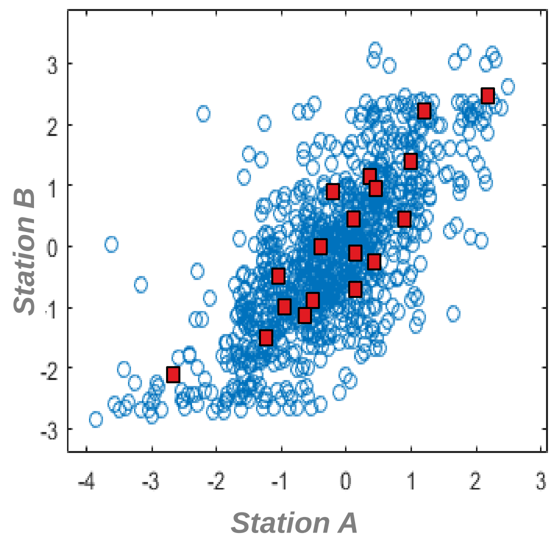
Hazard component – event set



- Designing sufficient number of synthetic however realistic(!) events
- Vine copula (dependency) structure is designed and fitted into hydrological station network (see left)
- Best fitting copula is being selected for each pair of stations
- By combining, the dependency structure and best fitting copula, eventset of sufficient size is generated



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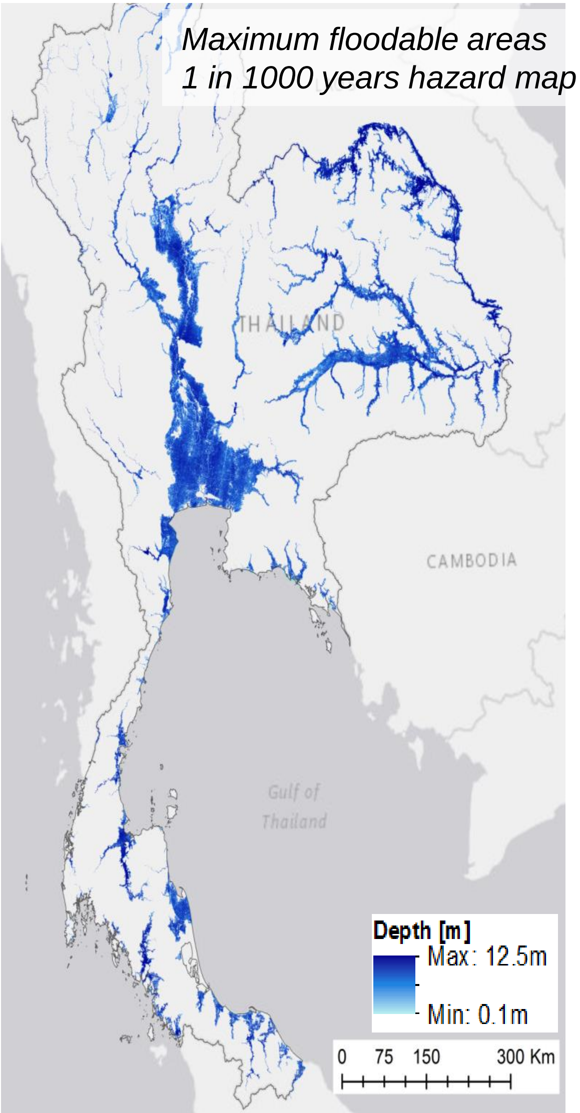
Hazard Component – hydrodynamic simulation



- TUFLOW - 2D hydrodynamic software (BMT WBM Pty Ltd, Australia)
  - Depth averaged shallow water equations with momentum and continuity equations for free flow

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} - c_f v + g\frac{\partial \zeta}{\partial x} + g\,u\left(\frac{n^2}{H^{4/3}} + \frac{f_l}{2g\Delta x}\right)\sqrt{u^2+v^2} - \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) + \frac{1}{\rho}\frac{\partial p}{\partial x} = F_x$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + c_f u + g\frac{\partial \zeta}{\partial y} + g\,v\left(\frac{n^2}{H^{4/3}} + \frac{f_l}{2g\Delta y}\right)\sqrt{u^2+v^2} - \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) + \frac{1}{\rho}\frac{\partial p}{\partial y} = F_y$$

$$\frac{\partial \zeta}{\partial t} + \frac{\partial (Hu)}{\partial x} + \frac{\partial (Hv)}{\partial y} = 0$$

  - Available on CPU and GPU solvers;
    - Impact Forecasting GPU cluster used for majority
  - Grid based software: mesh on the top of DTM
  - Heavily optimized for large scale simulations
  - Enhanced numerical stability

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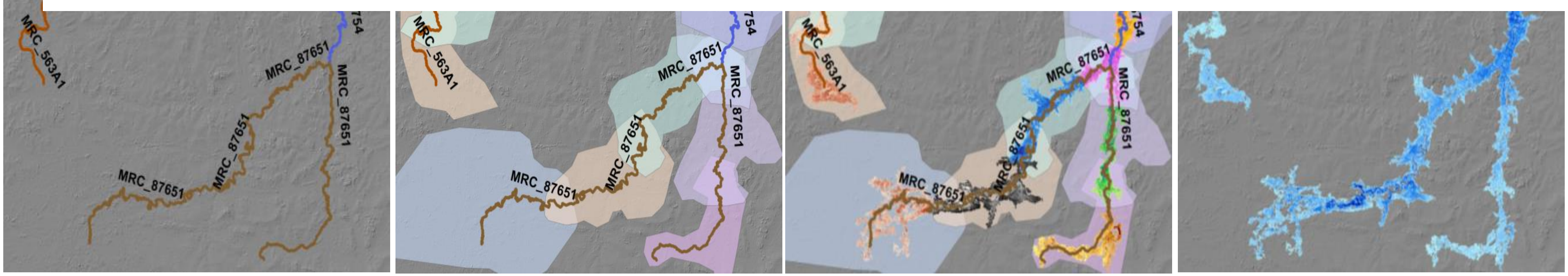
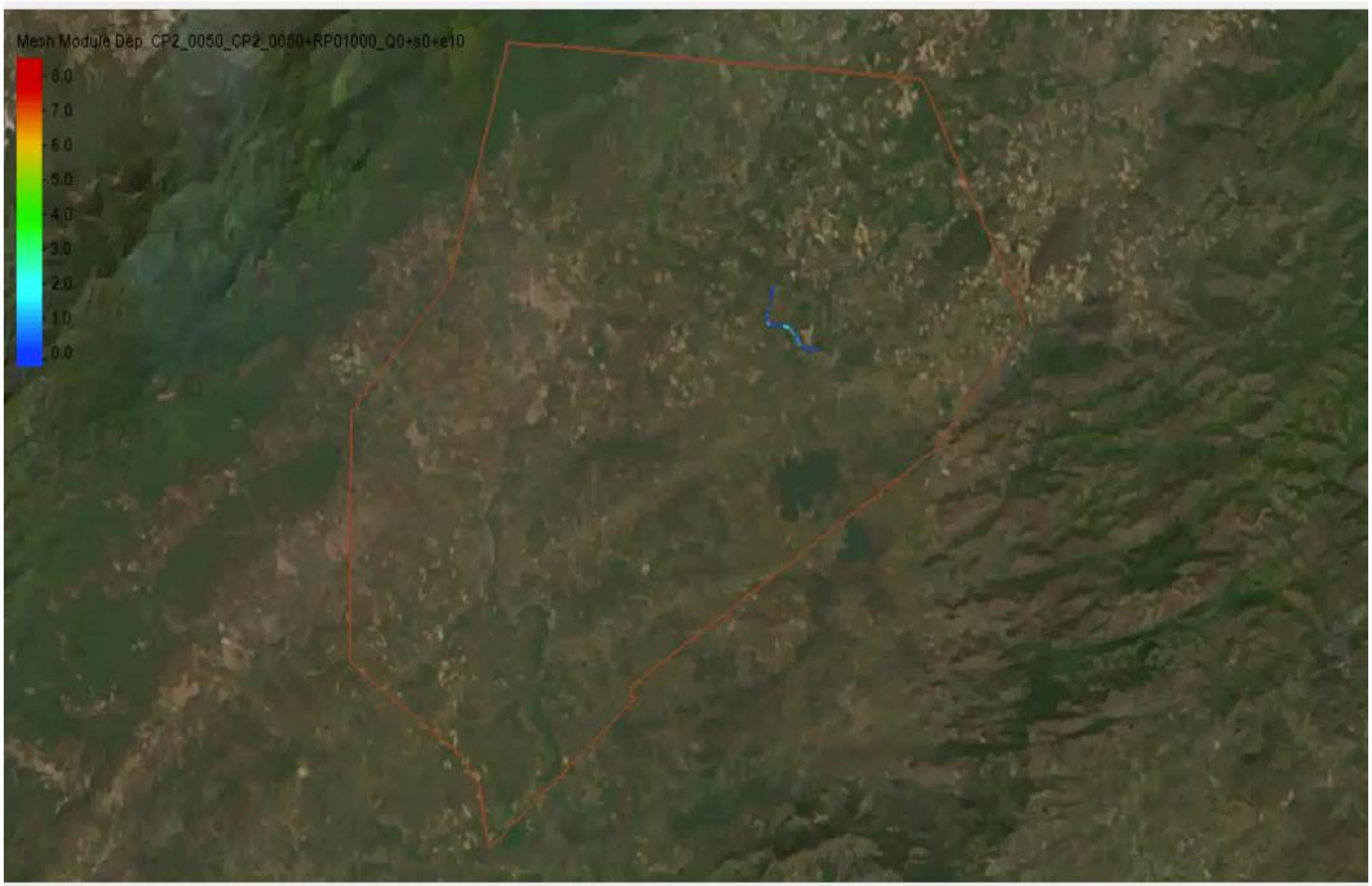
Hazard Component – event map generation

- Event maps are being constructed for individual events by:
  - A segment based composition of interpolated flood hazard maps
  - The interpolation is done on segment/event return period and linear interpolation between nearest higher and lower pre-modelled return period
  - Results on individual segments are finally mosaicked via maximum depths
- Such approach allows construction of “unlimited” number of very accurate event footprints!



GIS Demo

Flood Simulation – an example

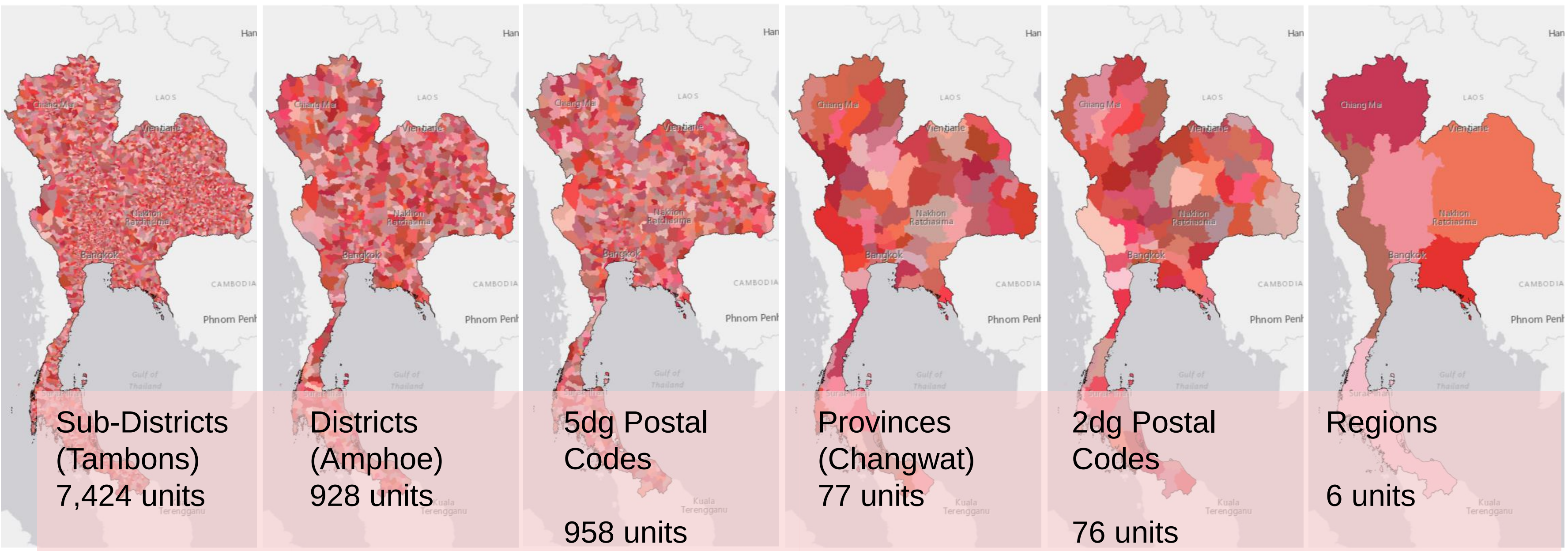


Section 2: Impact Forecasting Thai Flood model

- Anatomy of a catastrophe model
- Hazard Component
- Exposure Component
- Vulnerability Component
- Loss Component

Exposure component –exposure geo-levels

- Many geocoding input level data exists in Thailand – good model must address all or vast majority!
- Units also allow results break-out any of these units, among many others levels
- For flood modelling – please consider the most detailed level possible (ideally with exact coordinates!)



Sub-Districts (Tambons) 7,424 units

Districts (Amphoe) 928 units

5dg Postal Codes 958 units

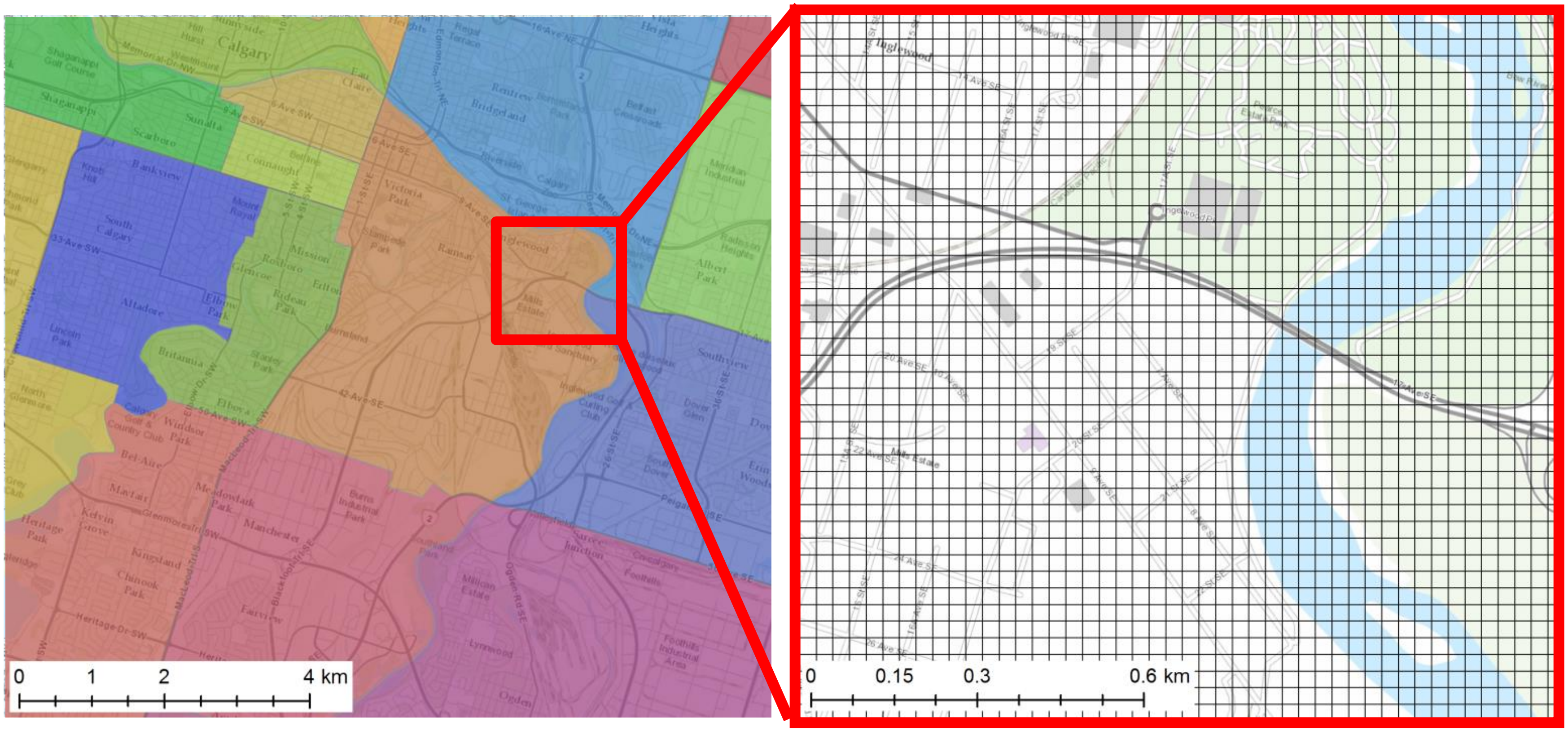
Provinces (Changwat) 77 units

2dg Postal Codes 76 units

Regions 6 units

Geocoding Precisions

- Latitude & Longitude (grid with 30m resolution)
- Higher administrative units (Province, District, Sub District, Region etc)



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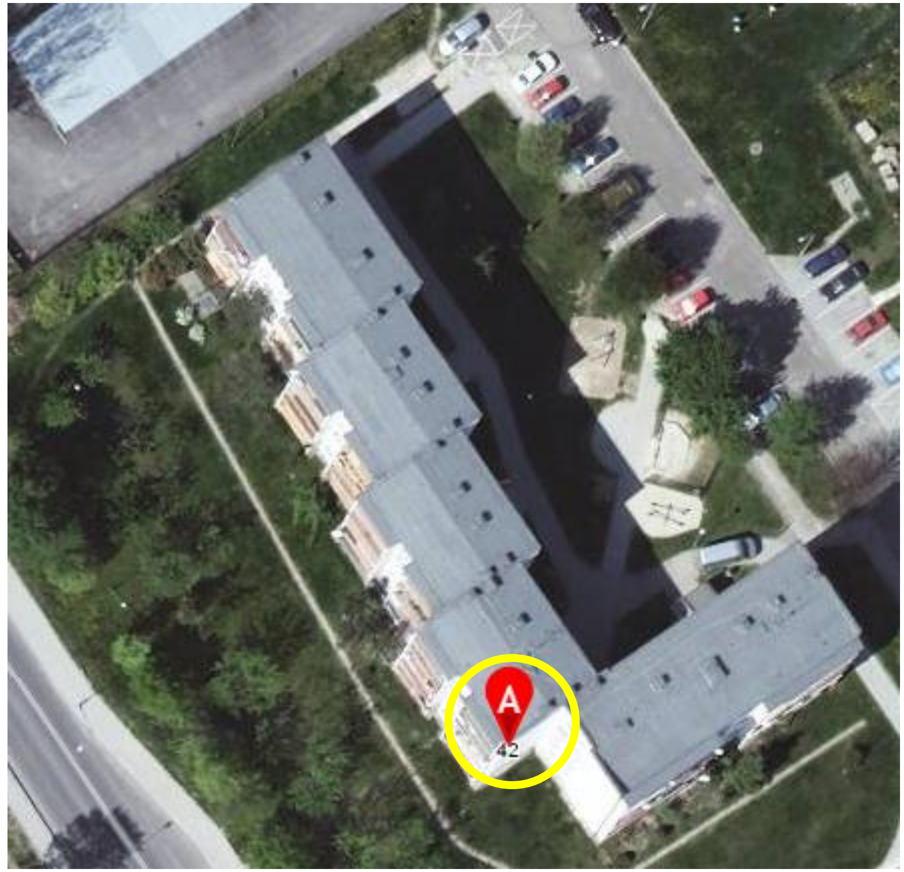
Rooftop geocoding



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AAL – Rooftop vs street precisions

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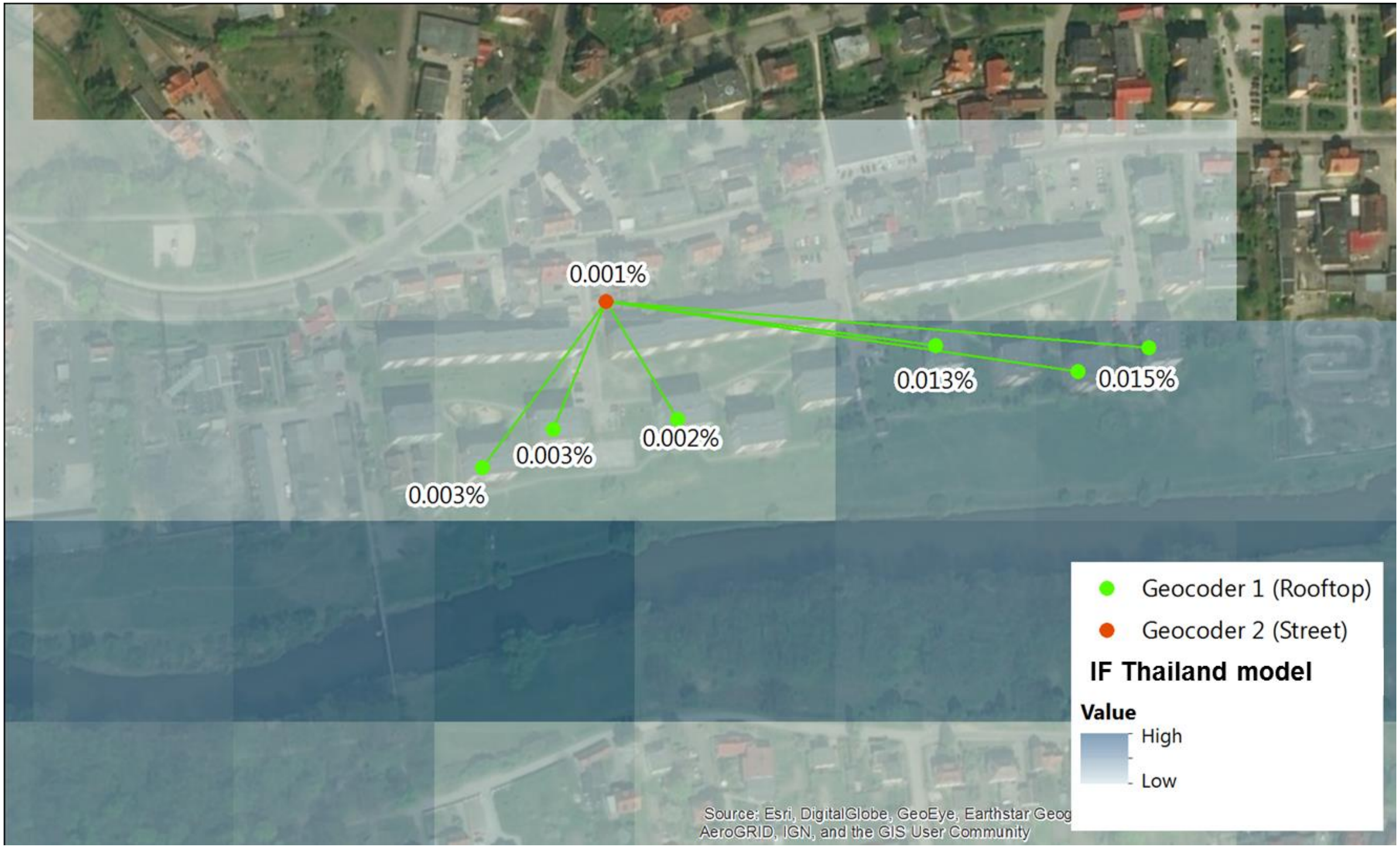
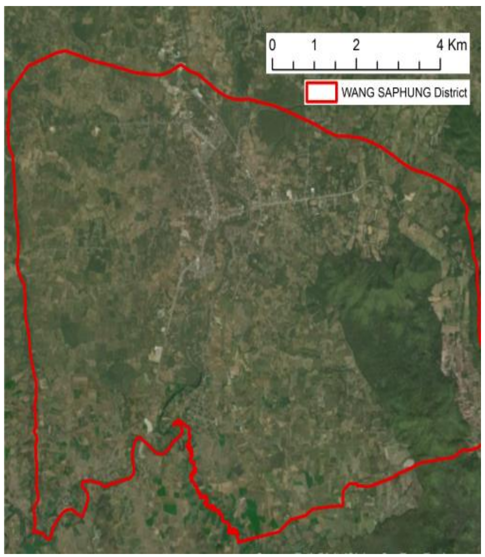
AAL – Rooftop vs street precisions

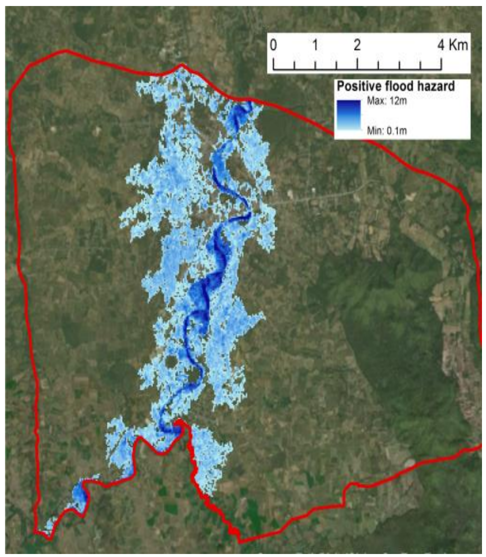


Exposure Component – Aggregated data

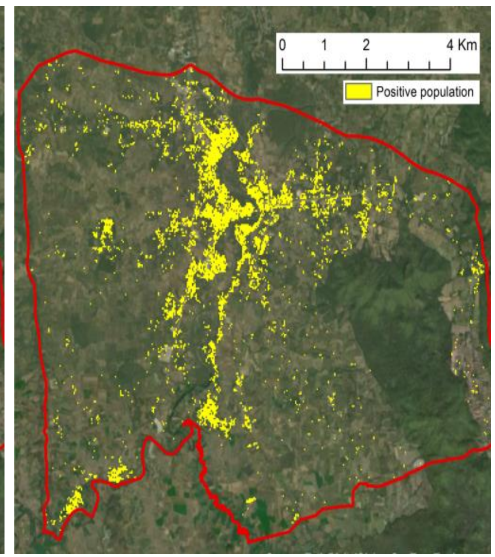
- Exposure distribution on larger units – How to limit the positional uncertainty
- Possible exposure indicators:
  - Population (residential), Luminescence (Commercial), Land cover (Industrial)
  - Not needed for latitude & longitude simulation, Industrial estates



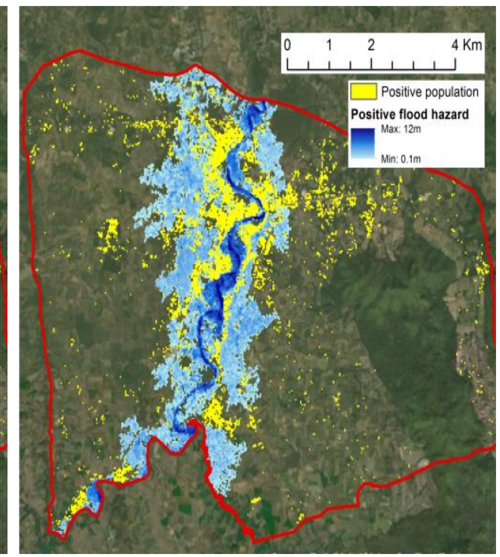
Area = 80.35 km^2



Inundation = 13.50 km^2
(**16.8**% of total **Area**)



Population = 22,272 inh.



12,036 inh. inundated
(**54.0%** of total **Population**)

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Exposure Component – Modelling Industrial Estates

- Modelling spatially-large (mostly industrial) risks
- Single policy location may not likely be representative enough
- Equal exposure distribution within exactly pre-defined and digitized industrial estate polygon
- Policy is modelled on a real share of area affected by particular event

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Section 2: Impact Forecasting Thai Flood model

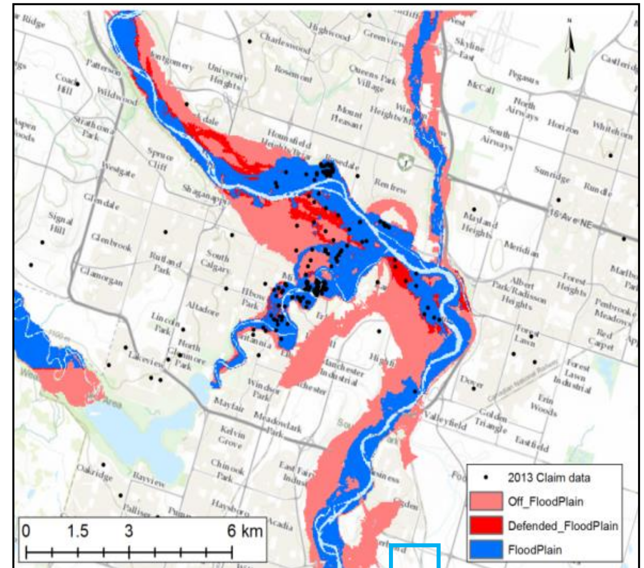
- Anatomy of a catastrophe model
- Hazard Component
- Exposure Component
- Vulnerability Component
- Loss Component

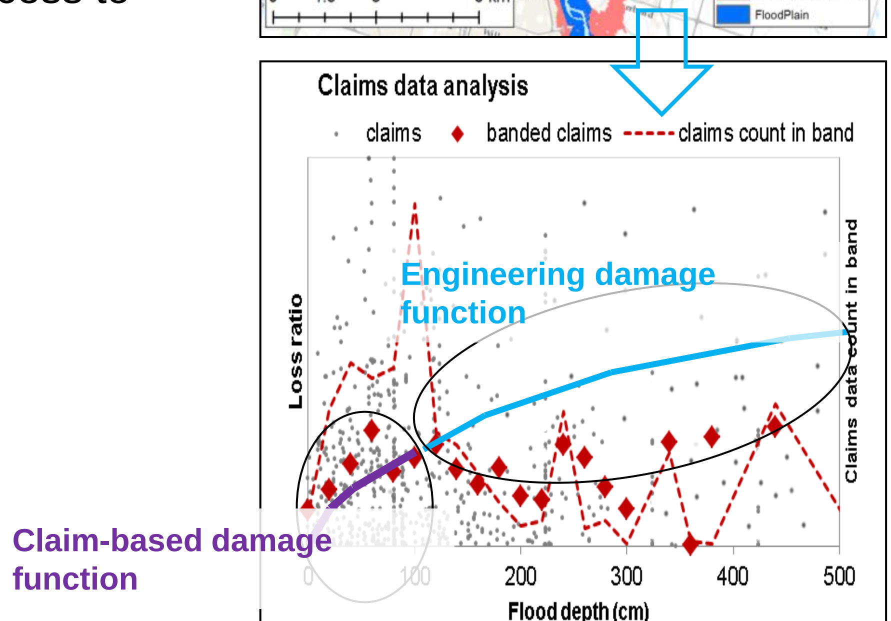
Vulnerability Component

- Essential component to transfer hazard intensity into loss (loss-ratio)
  - Evaluate number of affected number of policies
    - **Chance of loss**
  - Evaluate for each affected policy relevant relative loss
    - **Damage function**

- As part of Aon Benfield, Impact Forecasting has access to large amount of flood claim information

- Unique combination of observed claim data and engineering approaches



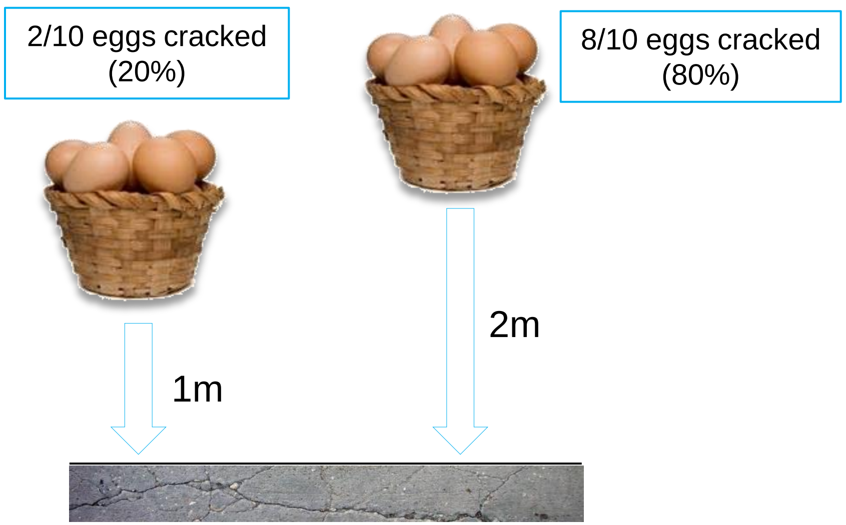


Vulnerability – How it Functions?

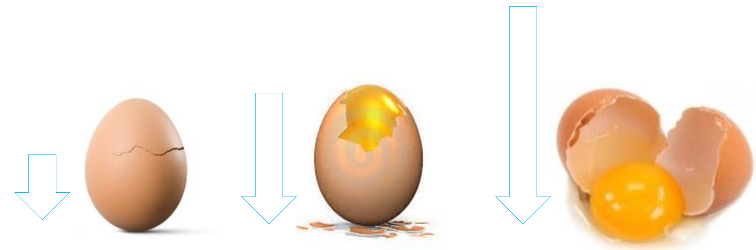
Damage calculation applied in 2-steps:

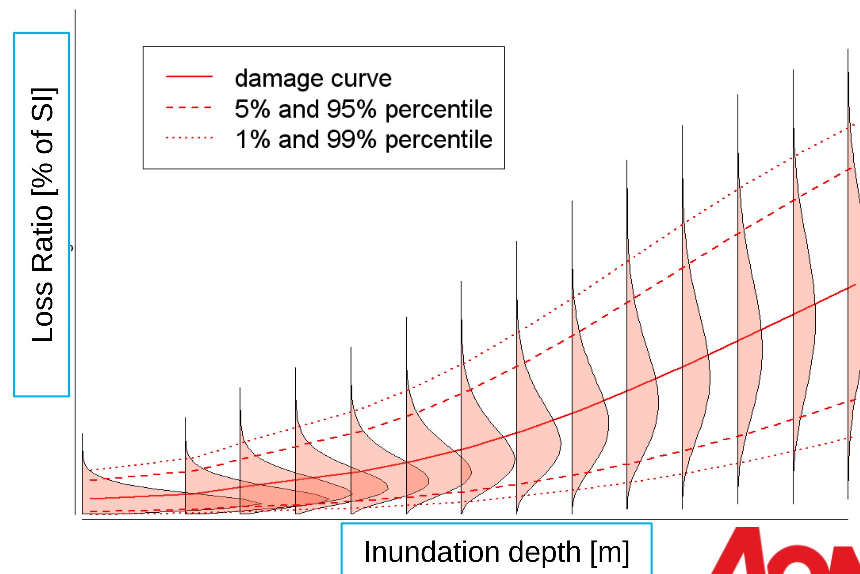
Step 1: Given the intensity of hazard what is the chance to have a loss?

- For eggs → HEIGHT
- For flooding → INUNDATION DEPTH



Step 2: Given that the loss happens - how big is the loss?





- Why is it important?
  - To affect the right number of properties!

Vulnerability Components – Classes Available

- List of supported vulnerability classes for all individual modifiers

Occupancy	Coverage	Construction Name	Basement	Building height
RESIDENTIAL	BUILDING	MASONRY	WITH	1
COMMERCIAL	CONTENT	CONCRETE	WITHOUT	2 – 3
INDUSTRIAL	BUSINESS INTERRUPTION	METAL	*UNKNOWN*	4 – 7
INDUSTRIAL MACHINERY		WOOD		8 – 17
INDUSTRIAL STOCK		*UNKNOWN*		17+
INDUSTRIAL FUNITURE				*UNKNOWN*
INDUSTRIAL ESTATE				
INDUSTRIAL ESTATE MACHINERY				
INDUSTRIAL ESTATE STOCK				
INDUSTRIAL ESTATE FURNITURE				
AGRICULTURAL GENERAL				
HOUSING BUILDINGS				

Motor damage functions categories	
Cars	Large
Light Commercial	Mid-Size
Heavy Commercial	Pick-Up & Trucks and SUV
Compact	Sub-Compact

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Agenda

- **Section 1** Impact Forecasting – An Overview
- **Section 2** Impact Forecasting Thailand Flood Model
- **Section 3** **Use cases**
- **Section 4** Conclusions and Benefits

Tools for catastrophe management

- 01 | Catastrophe models
- 02 | Geocoding solutions
- 03 | Hazard and risk maps
- 04 | Modelling platforms
- 05 | Underwriting platforms
- 06 | Model components
- 07 | Consultancies

'Traditional'

↓

'New'

Targets / uses for cat modelling

- 01 Portfolio modelling for reinsurance
- 02 Accumulation management for reinsurers
- 03 Accumulation management for insurers
- 04 Regulatory needs and ERM
- 05 Underwriting and pricing
- 06 Model evaluation
- 07 Research and education

Targets / uses for cat modelling

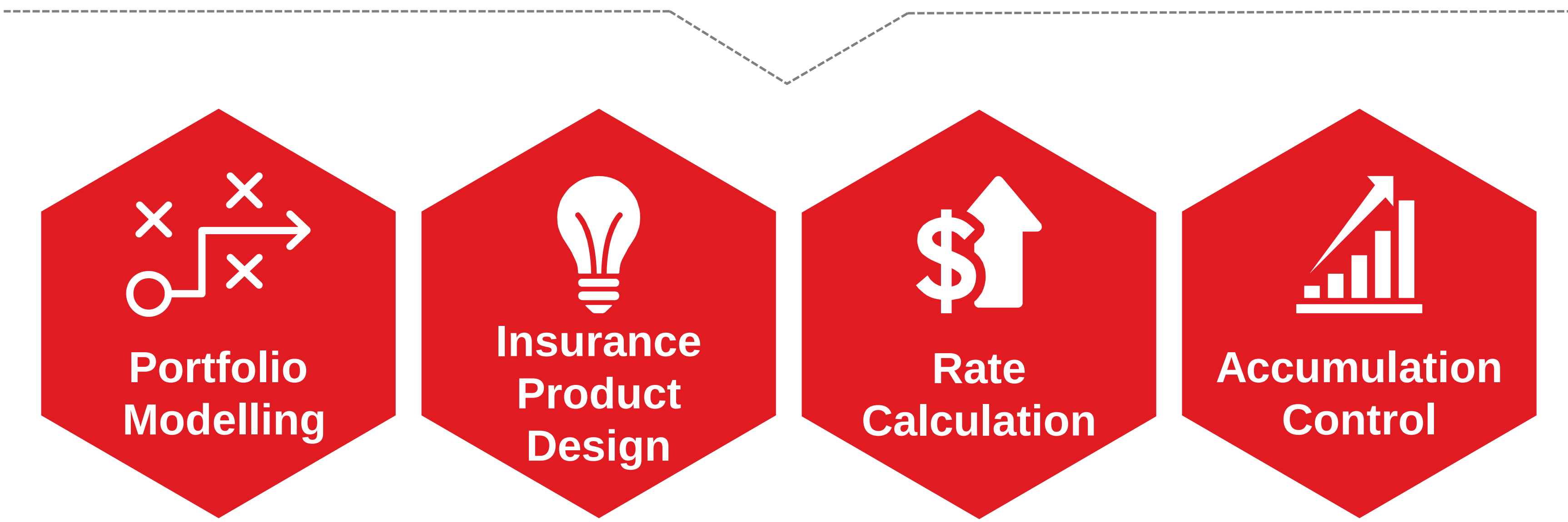
Today

Insurance Strategies

- Reinsurance purchasing
- Product innovation
- Personal and commercial lines rate calculation
- Catastrophe modelling intelligence to drive risk selection
- Underwriting strategies for new and existing perils
- Expanding your portfolio through efficient accumulation control

IF Thailand flood model - use cases

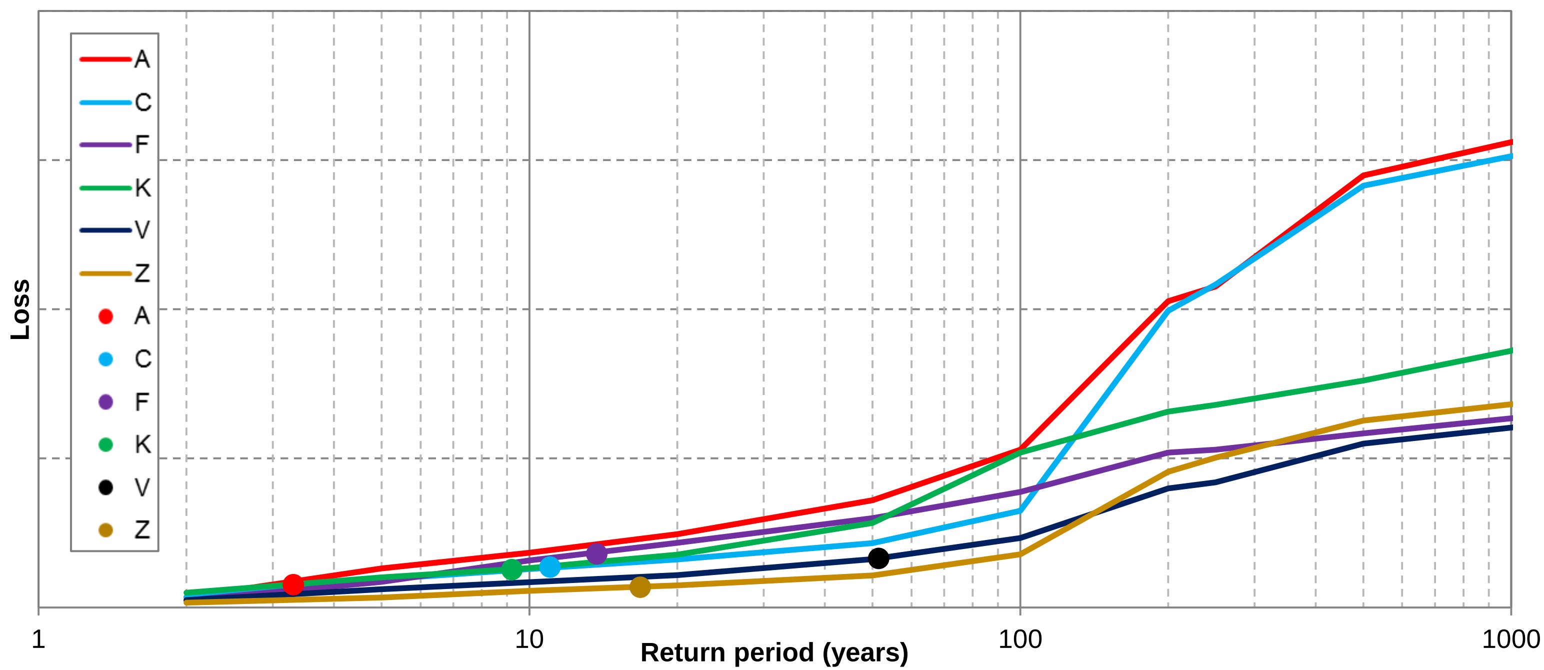
The hazard and risk data derived from Impact Forecasting Thailand probabilistic flood model can be used for accurate underwriting and risk assessment



Portfolio modelling

- Traditional use and primary purpose of probabilistic catastrophe models
- Provide aggregate view on the portfolio losses
- Assessment of **solvency capital requirement or reinsurance capacity**

Modeled Flood Losses



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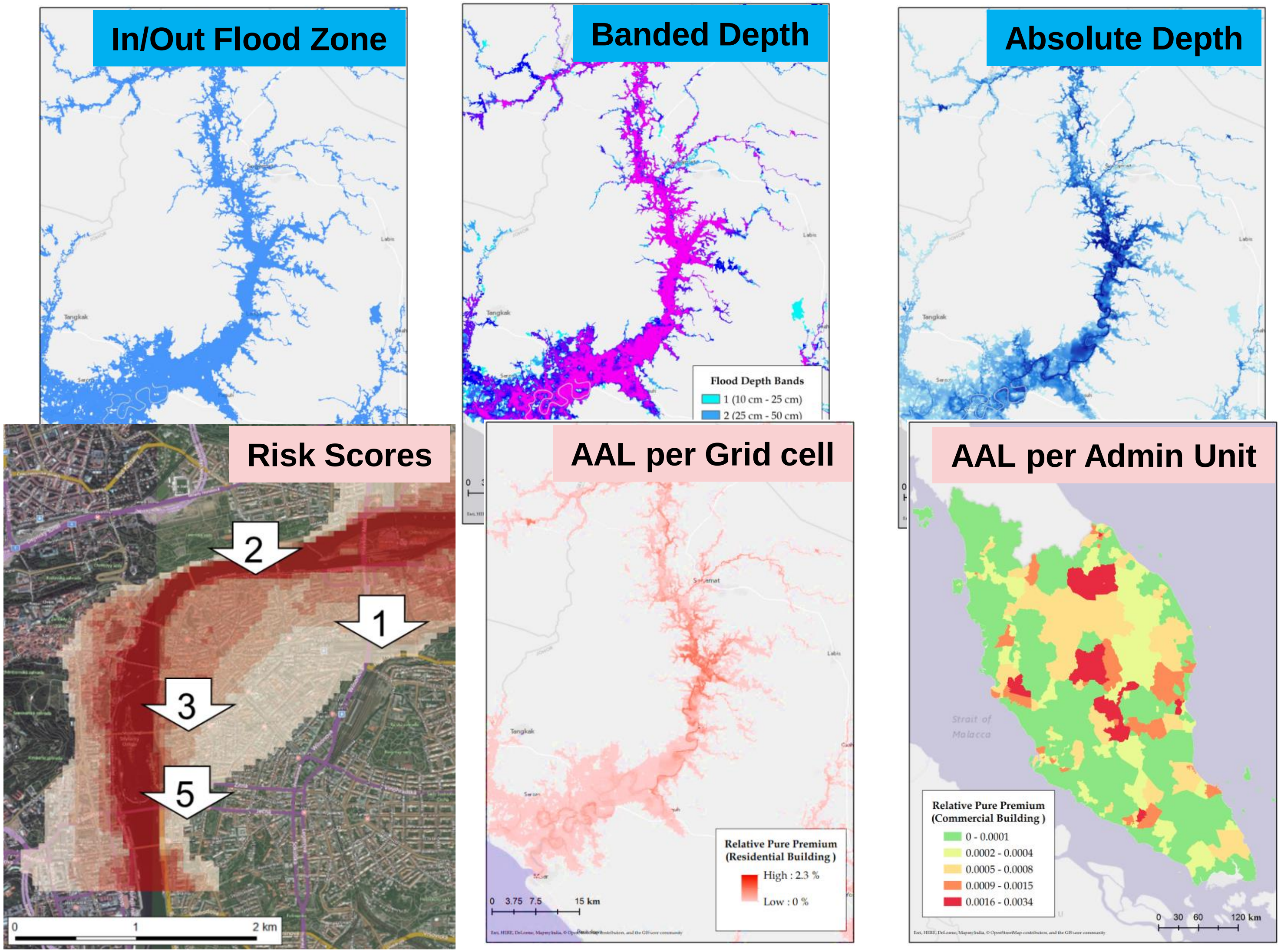
Insurance product design

- Models can be effectively used to determine **effect of insurance conditions**
- **High spatial variation** of the flood risk triggers high spatial variation of the insurance conditions' effect on losses
- **Key for attractive & profitable product design**
  - Full limit possible in low risk areas
  - Effective limits enable insurance within high risk zones

Residential building house
TSI 1,000,000 THB

Limit MYR (% TSI)	Deductible MYR (% TSI)	Loss cost MYR (pure premium)	Loss cost reduction
Full limit	**No deductible**	**10,000**	**0%**
Full limit	1,000 (0.1%)	9,950	0.5%
Full limit	2,000 (0.2%)	9,900	1%
Full limit	5,000 (0.5%)	9,700	3%
Full limit	10,000 (1%)	9,400	6%
500,000 (50%)	No deductible	9,900	1%
100,000 (10%)	No deductible	5,200	48%
10,000 (1%)	No deductible	600	94%

Primary underwriting- Data Available

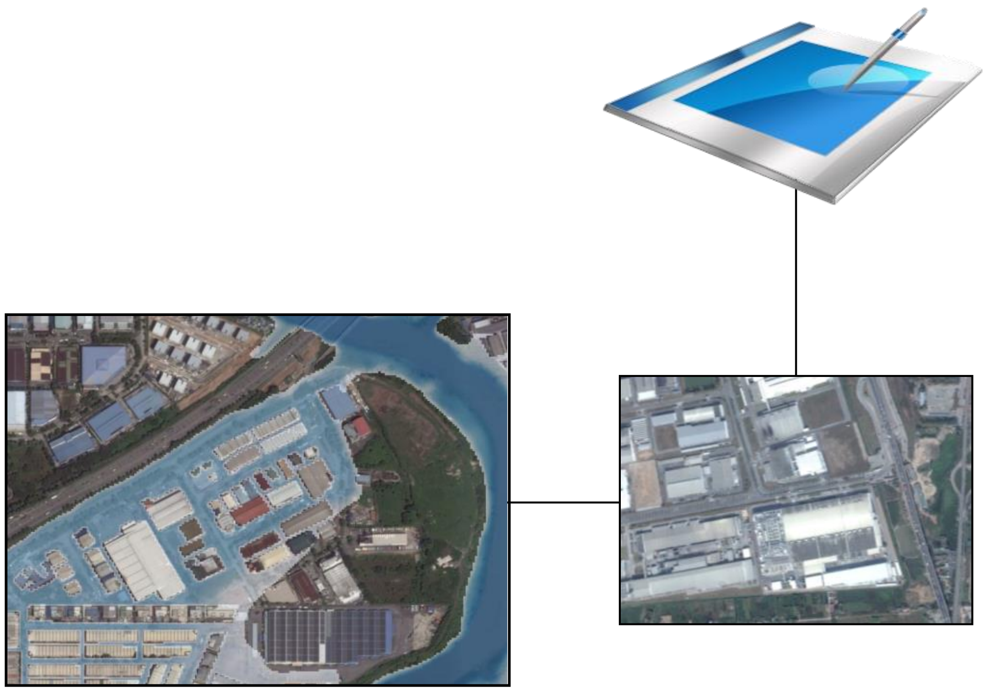


Whatever your appetite, consume the right data !

Underwriting and rate calculation

- **Probabilistic** models based on **high resolution hazard** maps can be effectively used for location-wise flood loss (pure premium) assessment
  - Differentiated by risk type – property parameters

- **Risk data for rating** – by admin unit, full resolution maps or zones



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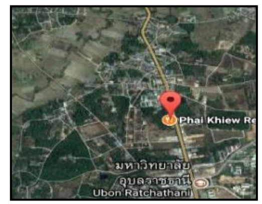
Underwriting and rate calculation

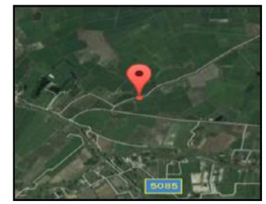
Client A in Thailand – underwrite two residential building policies:

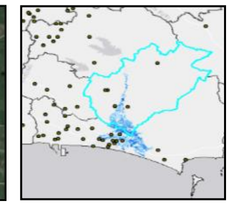
Policy X: 6,500,000THB; address: Khok Khram, Amphoe Bang Pla Ma, Chang Wat Suphan Buri, 7215
Policy Y: 3,825,000THB, address: That, Warin Chamrap District, Ubon Ratchathani, 34190
Policy Z: 14,000,000THB, residential bulding in BAN KHAI district

1. Geocoding:

Policy X: located on coordinates: **15.134478, 104.885723**
Policy Y: located on coordinates: **14.412087, 100.175926**
Policy Z: still on BAN KHAI district







2 . Use of flood hazard data:

	RP 20	RP 50	RP 100	RP 250	RP 500	RP 1000
Policy X	20cm	65cm	79cm	96cm	106cm	117cm
Policy Y	0	0	0	275cm	303cm	328cm

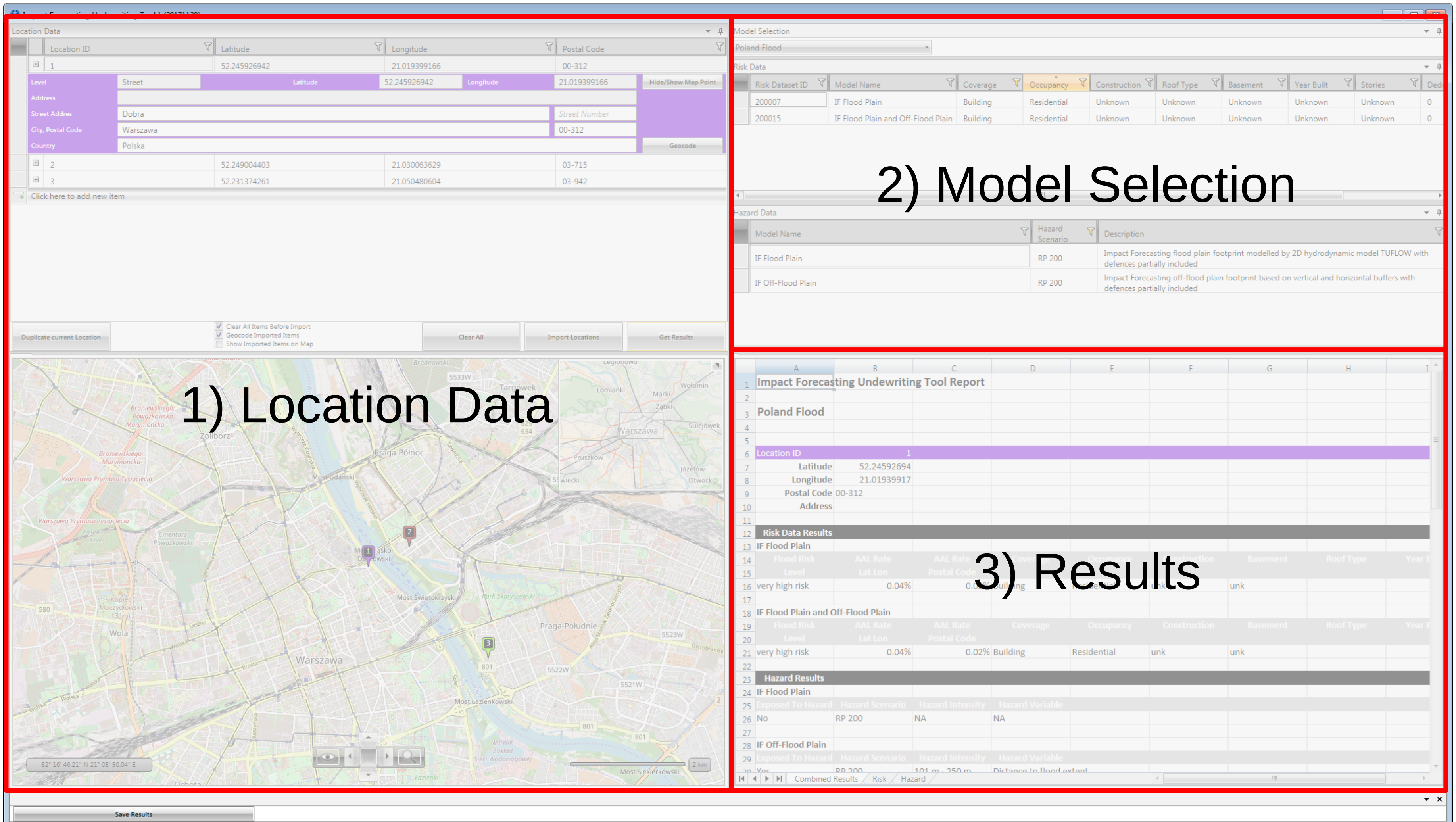
3a. Use of flood risk maps

Policy X: mapped pure premium for L&L => Relative PP = 0.04916, **absolute PP** = 6,500,000 * 0.04916 = **319,540 THB**
Policy Y: mapped pure premium for L&L => Relative PP = 0.00019, **absolute PP** = 3,825,000 * 0.00019 = **726.75 THB**
Policy Z: taking mean pure premium for BAN KHAI dstrt = 0.00217; **absolute PP** = 14,000,000 * 0.00217 = **30,380 THB**

3b. Assessing technical rate (Company A loading = 100%)

Policy X: **Technical premium = pure premium + loading** (expenses + profit) = **639,080 THB**
Policy Y: **Technical premium = pure premium + loading** (expenses + profit) = **1,453.5 THB**
Policy Z: **Technical premium = pure premium + loading** (expenses + profit) = **60,760 THB**

A note on simple Underwriting Tool



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Accumulation control

Client A in Thailand

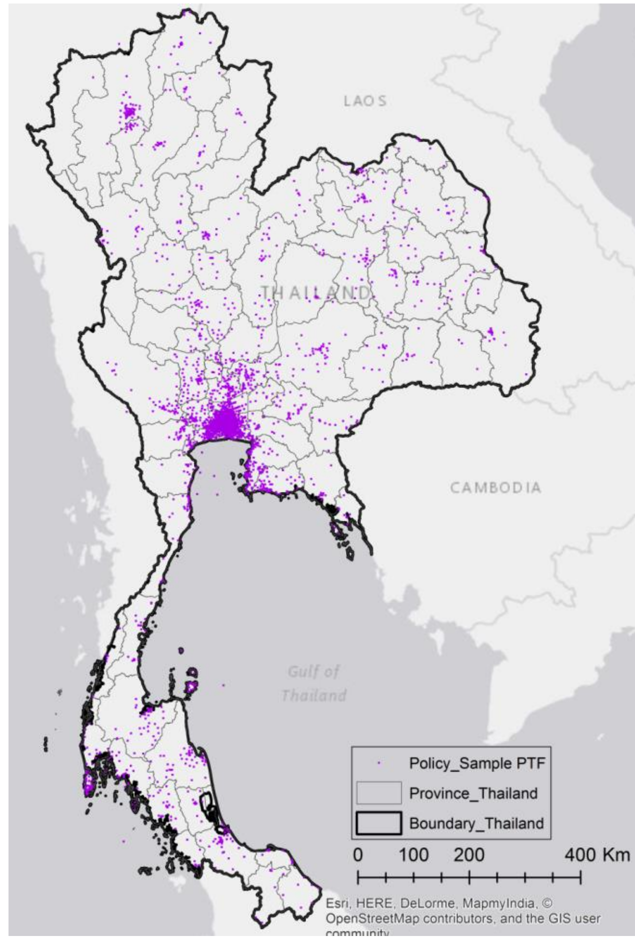
- Accumulation study on **Province** level

Total insured value summary:

	TIV [THB]	% of total
Portfolio	373,630,796,310	100.00%
Geocoded	371,980,161,469	99.56%
Floodable	130,338,461,323	34.88%

Policies count summary:

	TIV [THB]	% of total
Portfolio	13,218	100.00%
Geocoded	13,185	99.75%
Floodable	4,728	35.86%



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Accumulation control

- Existing approach: Insured values accumulation
- With IF flood model: Modelled loss accumulation

  - Simple risk map overlay and pivoting provides:

ID	Province Name	TIV_abs.	TIV_rel.	No.Polic_abs.	No.Polic_rel.	ModLoss_abs.	ModLoss_rel.	Loss Ratio	Effectivity
10	BANGKOK	140,935,335,638	37.72%	4264	32.26%	277,467,846	63.69%	0.197%	169%
11	SAMUT PRAKAN	22,867,412,526	6.12%	1021	7.72%	21,515,482	4.94%	0.094%	81%
20	CHON BURI	21,335,868,586	5.71%	584	4.42%	141,201	0.03%	0.001%	1%
12	NONTHABURI	19,047,591,979	5.10%	590	4.46%	15,353,415	3.52%	0.081%	69%
13	PATHUM THANI	15,940,335,520	4.27%	600	4.54%	38,665,338	8.88%	0.243%	208%
21	RAYONG	14,847,045,657	3.97%	341	2.58%	11,410,727	2.62%	0.077%	66%
83	PHUKET	13,096,307,803	3.51%	315	2.38%	121,295	0.03%	0.001%	1%
14	PHRA NAKHON SI AYUTTHAYA	10,918,523,618	2.92%	273	2.07%	6,326,074	1.45%	0.058%	50%
73	NAKHON PATHOM	9,678,937,902	2.59%	386	2.92%	10,589,194	2.43%	0.109%	94%
74	SAMUT SAKHON	9,670,707,931	2.59%	489	3.70%	6,635,550	1.52%	0.069%	59%
84	SURAT THANI	7,371,087,131	1.97%	347	2.63%	27,796,014	6.38%	0.377%	323%
	...								
25	PRACHIN BURI	6,298,933,246	1.69%	128	0.97%	27,976	0.01%	0.000%	0%
	...								
22	CHANTHABURI	493,737,472	0.13%	38	0.29%	2,295,497	0.53%	0.465%	399%
	...								
48	NAKHON PHANOM	20,720,608	0.01%	16	0.12%	164,952	0.04%	0.796%	683%
	...								
91	SATUN	19,194,251	0.01%	15	0.11%	273,439	0.06%	1.425%	1222%
	...								
	TOTAL	**373,630,796,310**	**100.00%**	**13218**	**100.00%**	**435,661,529**	**100.00%**	**0.117%**	**100%**

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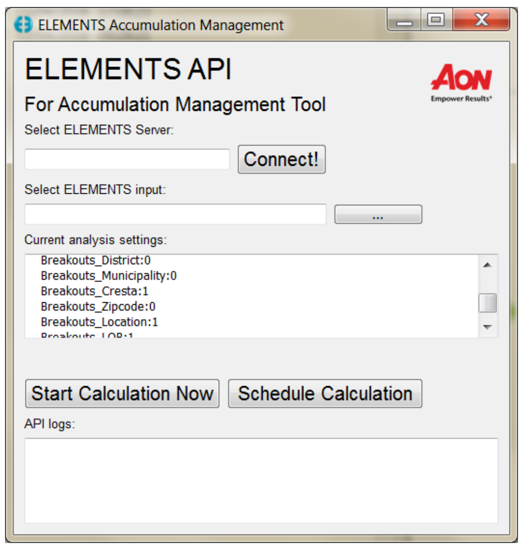
A note on APIs

- Hazard/ Risk metrics on demand
- Seamless process run in the background once a month / quarter
  - Set of predefined reports: TIV, charged premium, technical premium, top drivers
  - Automated

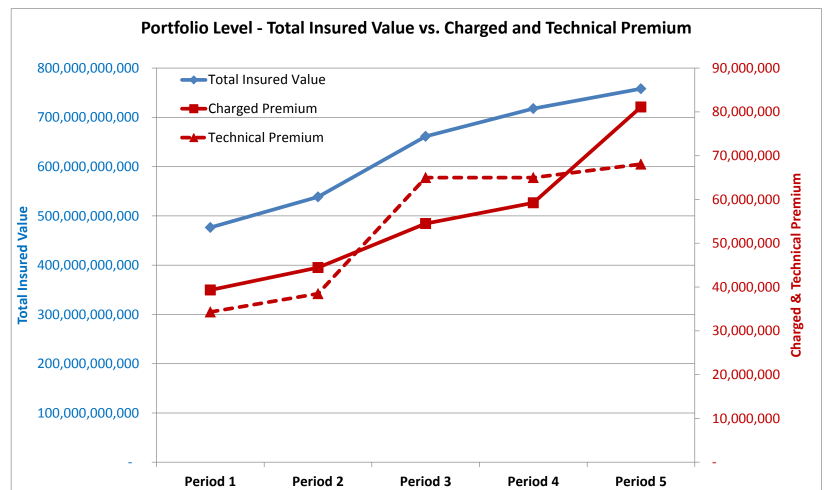
Your Data Warehouse

1 or 0 click automated model run in ELEMENTS the background



Standard report produced and shared

Accumulation zone	TIV	TIV as % of Total	Technical Premium	TeP as % of Total	TeP vs TIV
Alberta	183,444,220,487	38%	3,872,363	11%	29%
British Columbia	45,685,528,481	10%	6,169,619	18%	188%
Manitoba	12,097,283,070	3%	2,393,552	7%	275%
New Brunswick	9,724,355,798	2%	4,728,356	14%	675%
Newfoundland and Labrador	5,682,801,327	1%	311,801	1%	76%
Nova Scotia	14,239,949,475	3%	686,132	2%	67%
Ontario	145,966,611,062	31%	11,172,888	33%	106%
Prince Edward Island	1,990,107,623	0%	12,756	0%	9%
Quebec	28,023,954,049	6%	4,199,351	12%	208%
Saskatchewan	29,728,182,513	6%	767,154	2%	36%
Total	**476,582,993,885**	**100%**	**34,313,972**	**100%**	**100%**



Agenda

- **Section 1** Impact Forecasting – An Overview
- **Section 2** Impact Forecasting Thailand Flood Model
- **Section 3** **Use cases**
- **Section 4** **Conclusions and Benefits**

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Conclusions and key benefits

True rating recommendation

Probabilistic models offer better insights when compared with just hazard maps

Accumulation

Using physically defined zones allow better utilization of underwriting limits

Unified toolkit and data

for primary underwriting portfolio monitoring and modelling provides a key to comprehensive and consistent workflow

Impact Forecasting probabilistic flood model enables more accurate underwriting and risk assessment

- Portfolio Modelling
- Insurance Product Design
- Rate Calculation
- Accumulation Control


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