EPSRC Project
Dissemination Seminar
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Health impacts of flooding

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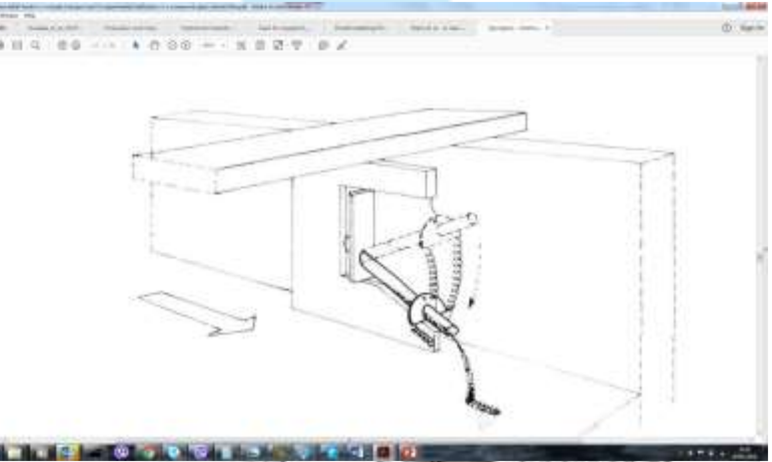
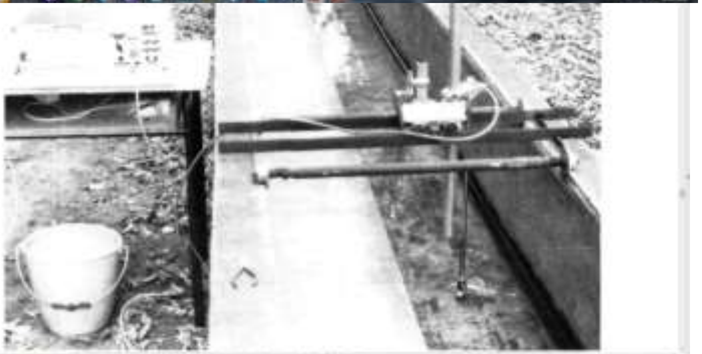
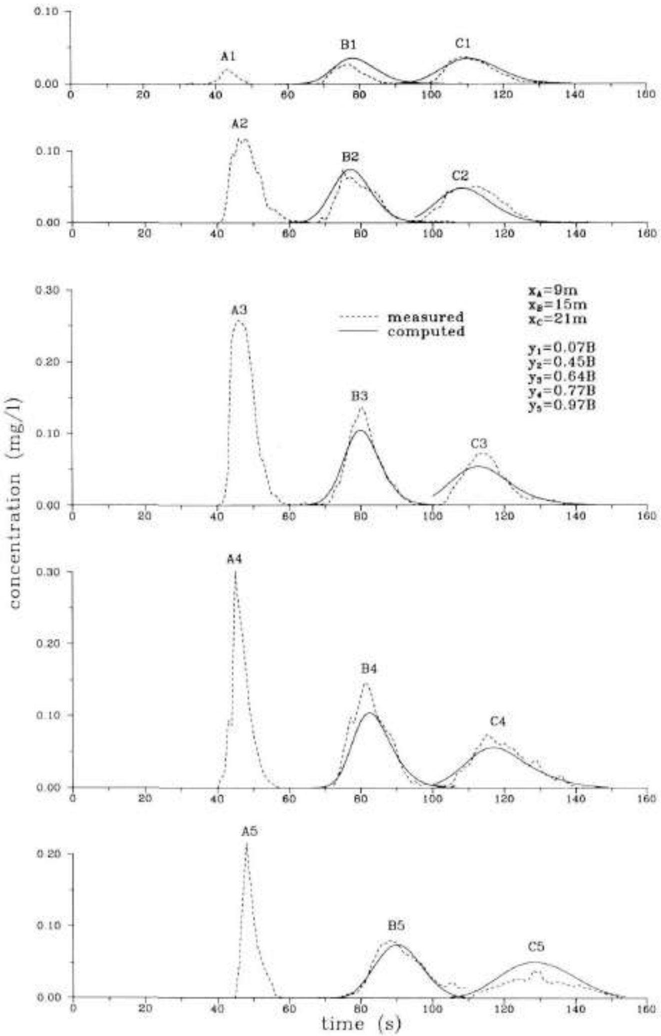
Summer 1986







A1
B1
C1
A2
B2
C2
A3
B3
C3
A4
B4
C4
A5
B5
C5
measured
computed
x_A=9m
x_B=15m
x_C=21m
y_1=0.07B
y_2=0.45B
y_3=0.64B
y_4=0.77B
y_5=0.97B
concentration (mg/l)
time (s)

Outline

1. New modelling-based methodology for assessing health impacts exemplified by cholera

   (CORFU case study: Dhaka)

2. Direct coupling of models; pathogens relevant for Europe; health risks in green areas

   (PEARL case study: Copenhagen)

3. Mapping of hazards and risks of waterborne infections

   (PEARL case study: Bangkok)

Flood impacts typology

	Tangible	Intangible
Direct	• Physical damage to assets Buildings Contents Infrastructure	• Loss of life • Injuries • Waterborne diseases • Loss of ecological goods
Indirect	• Loss of industrial production • Traffic disruption	• Inconvenience of recovery • Vulnerability of population

What’s new here?

- Standard practice: estimates based on statistics
- Novel comprehensive methodology combining:
  - Deterministic modelling of WQ (transport of pollutants)
  - Field measurements
  - QMRA (Quantitative Microbial Risk Assessment)
  - Observation (or estimation) of exposure
  - Dose-response relationships
  - Population data, Monte Carlo simulation (sampling)
- End result:
  - Probability of infection / number of sick people / DALYs / $$$

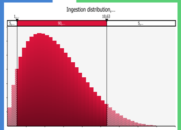
Methodology

Modeling the concentration

- Water quality
  - Dilution
  - Measurements
  - Literature

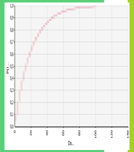
Exposure

- Ingestion during
  - Wading
  - Cleaning



Dose/Response

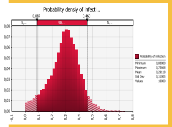
$Pinf = 1 - \exp(- \quad d)$



MonteCarlo simulation

- Sampling 10.000 times in distributions

Probability of infection



Number of sick people

Dhaka, Bangladesh

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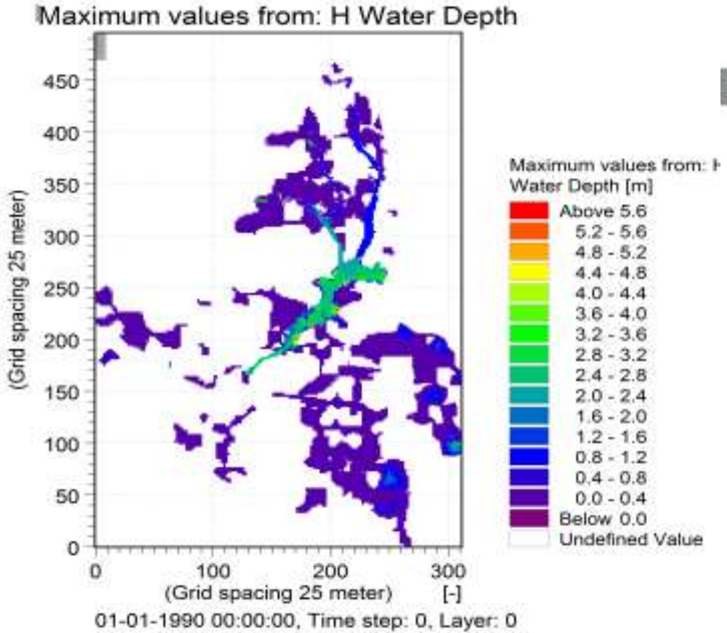
CORFU

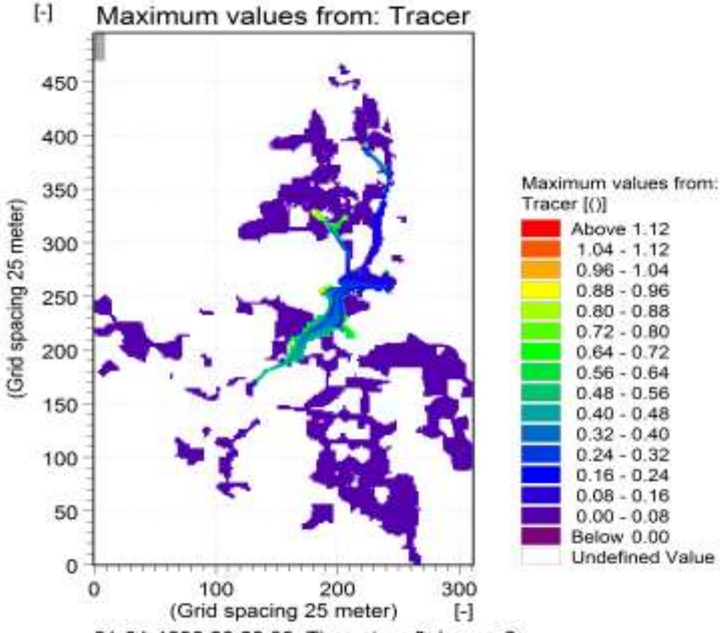
Urban flooding
MIKE FLOOD

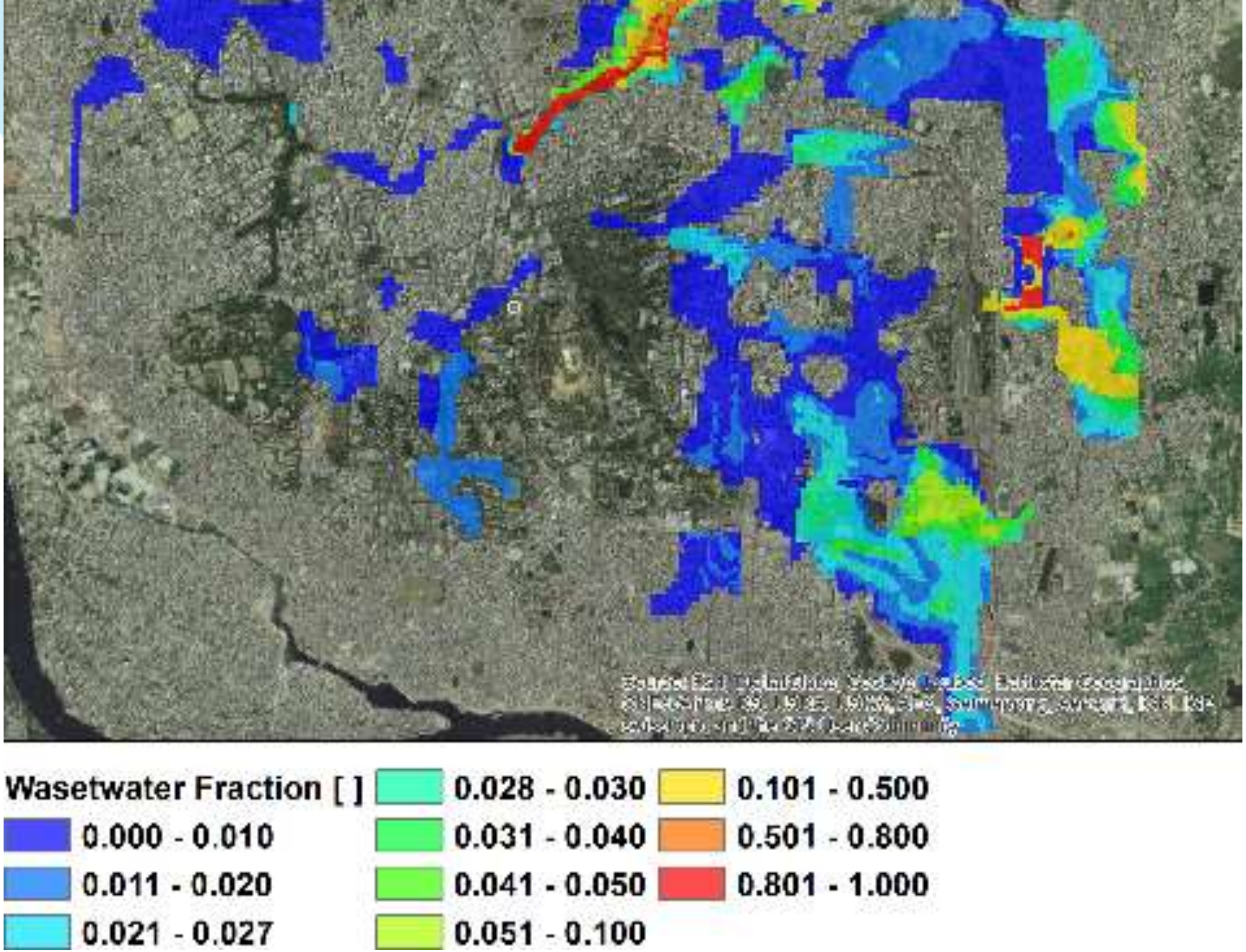
Sewage
EcoLab

Water Quality
Advection-Dispersion



DHI





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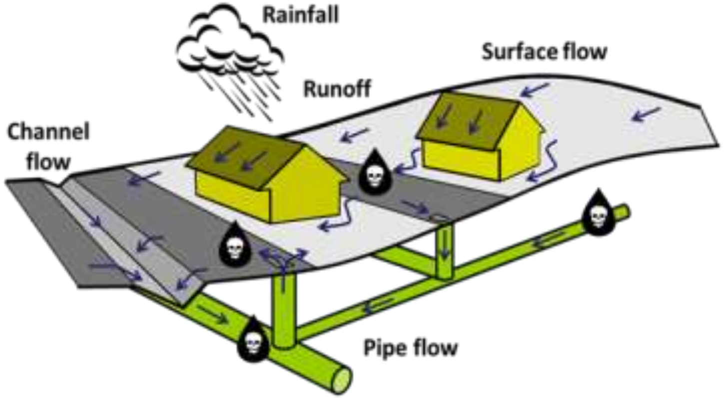
CORFU

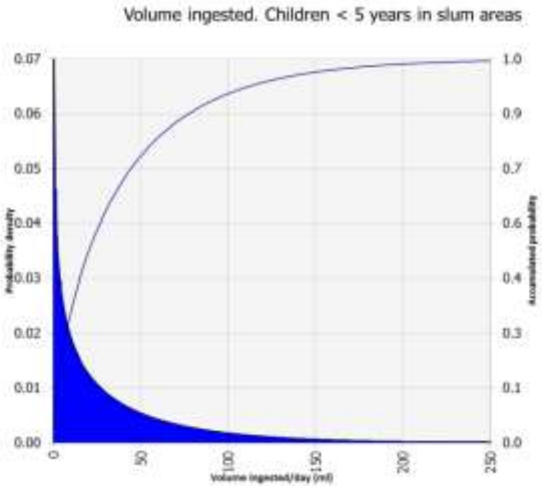
QMRA

1. Exposure quantification
   - Exposure groups
   - PDFs for ingestion per exposure group
2. Illness probability estimation
   - Uses dose-response relationship and Monte Carlo Simulation
   - Uses average concentrations and PDFs
   - Gives probability P_{ill}

Measure *c* in wastewater



Estimate dilution of wastewater during floods



Estimate volume *V* ingested

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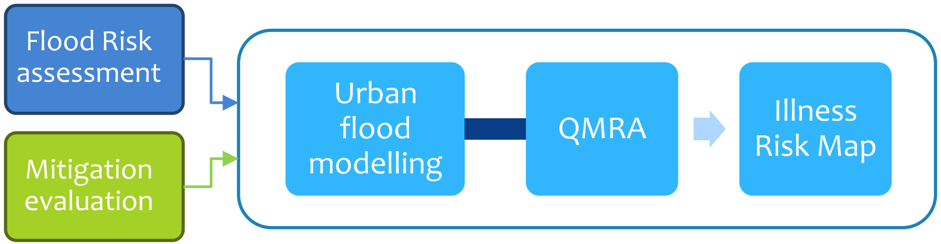
Current Method

- For a developing country (Dhaka, Bangladesh)
- Looking at Cholera

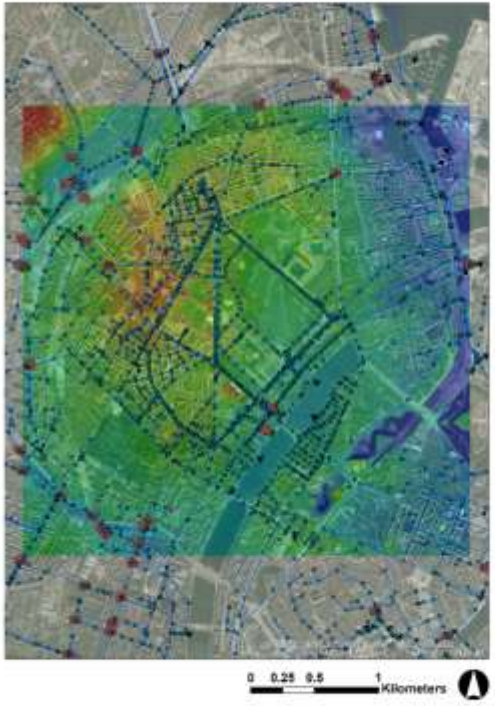
Improved Method

- For a European country
- Other relevant pathogen (e.g. Norovirus)



Copenhagen, Denmark

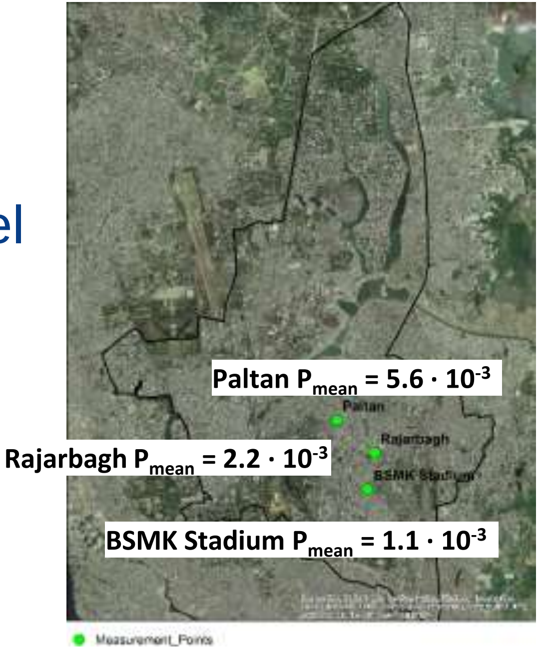
1. Exposure scenarios in a European context



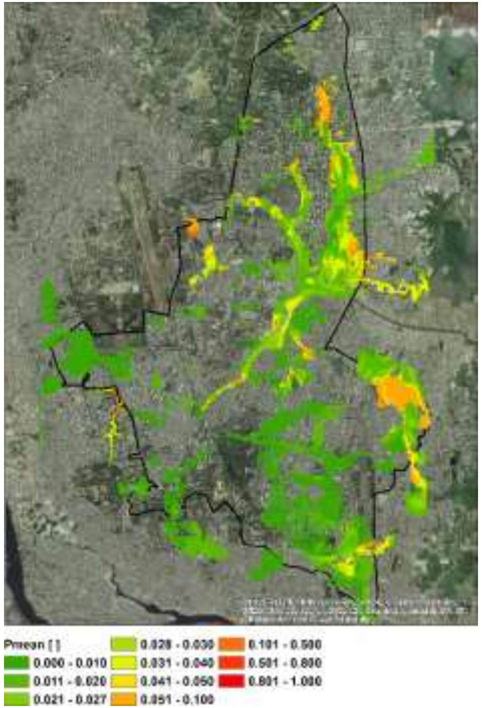
2. Direct coupling between the flood model and QMRA.

- Integrated in the model
- Spatially-distributed, time-varying results

From this:



To this:



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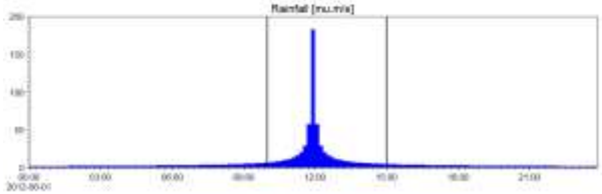
3. New pathogens

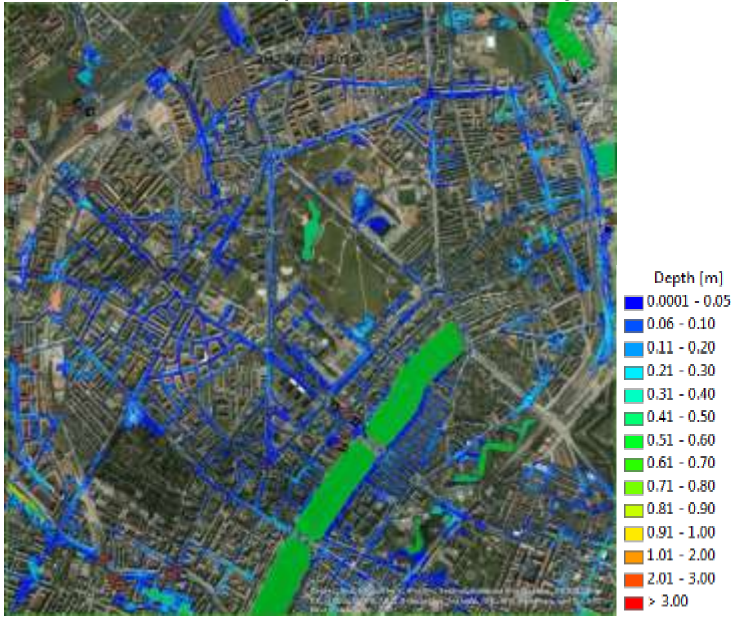
4. Quantification of health risks in flooded green areas

How long before the park is safe to use again?

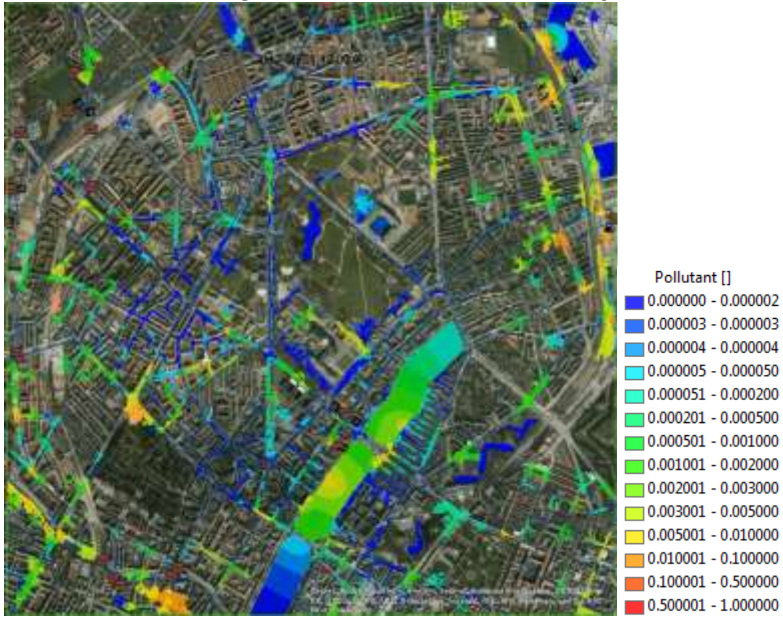
Results



Calculated water depths for Future 100-year rain



Calculated sewage dilution for Future 100-year rain



Illness Risk

- Monetized health impacts

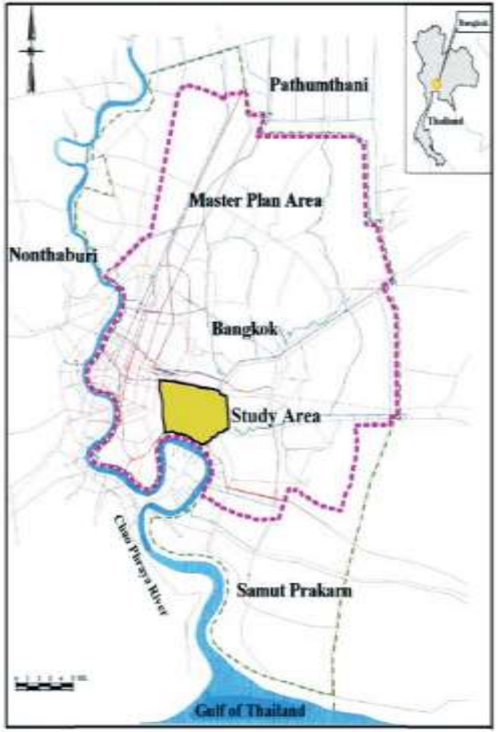
Illness probability values

Population data

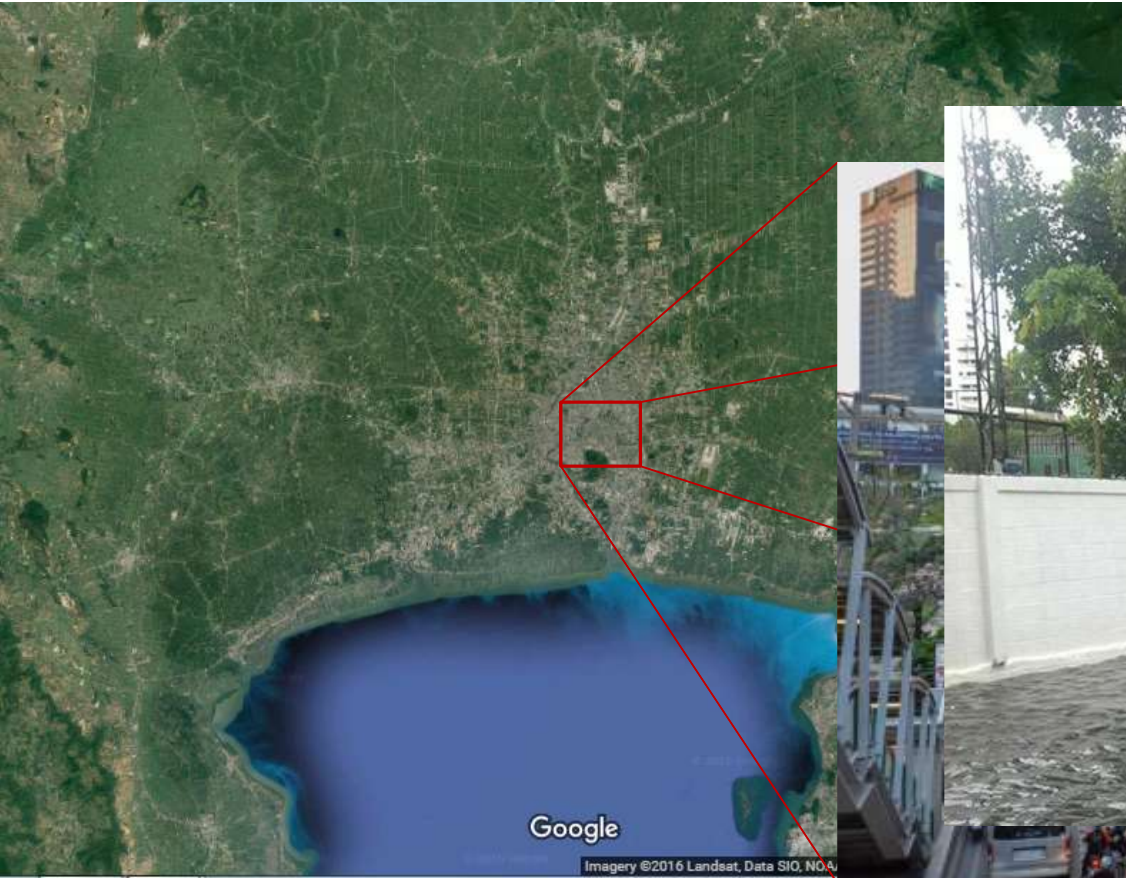
Health impacts

- Usually considered intangible
- Can be monetized
- DALYs

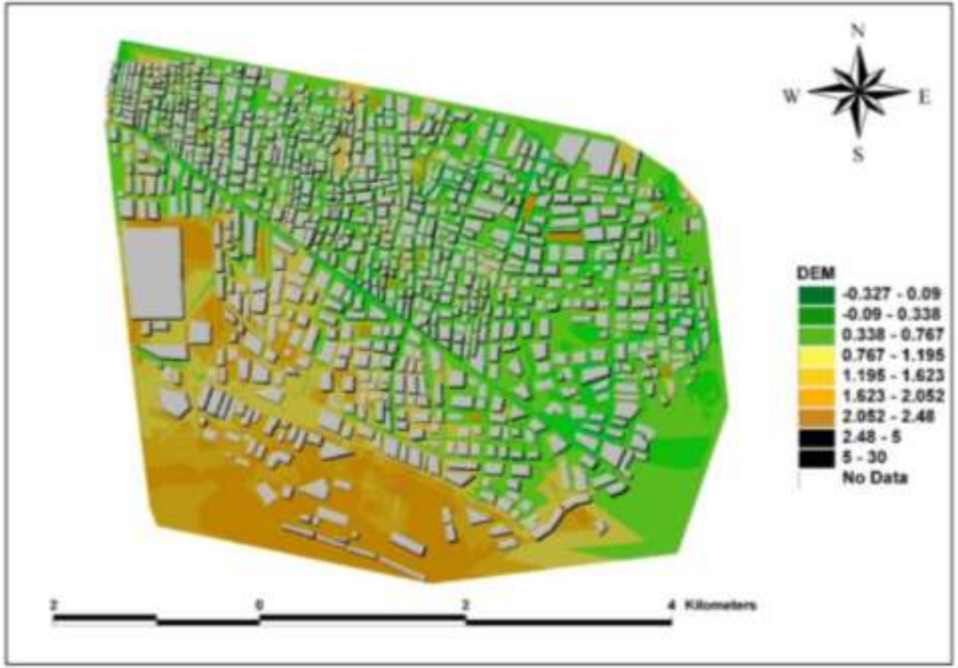
Bangkok, Thailand

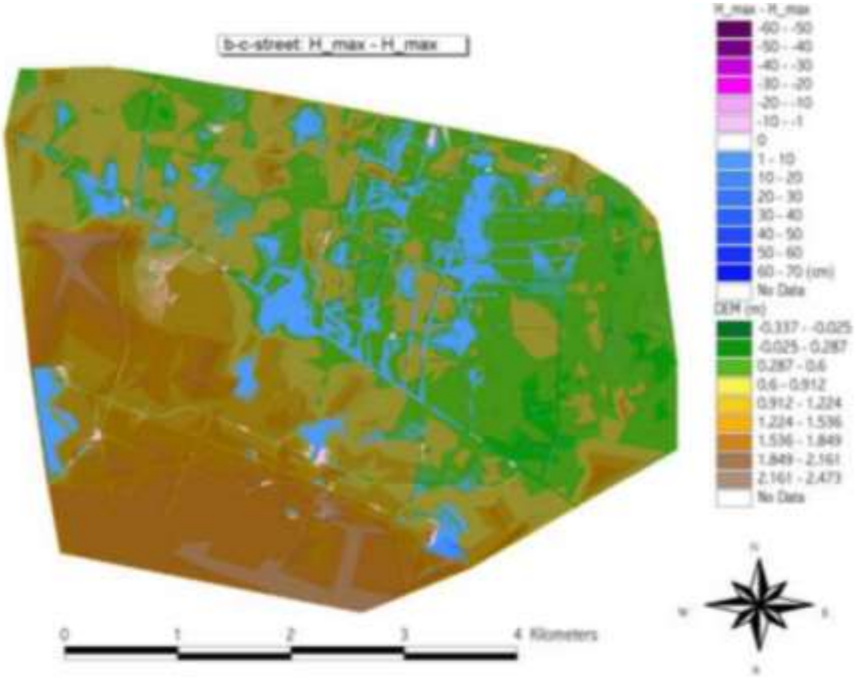


Sukhumvit area in Bangkok



Flood modelling



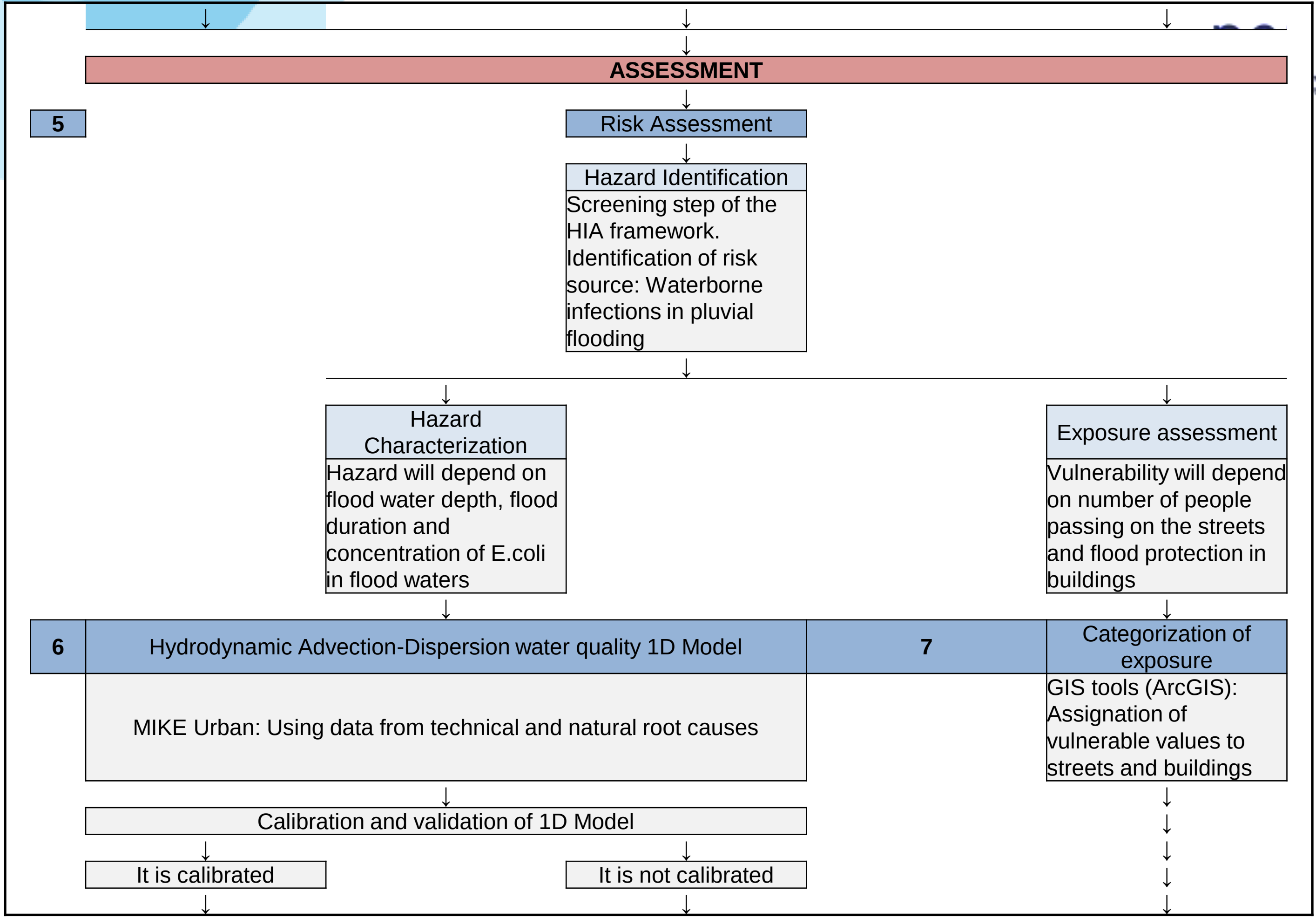


Methodology and results

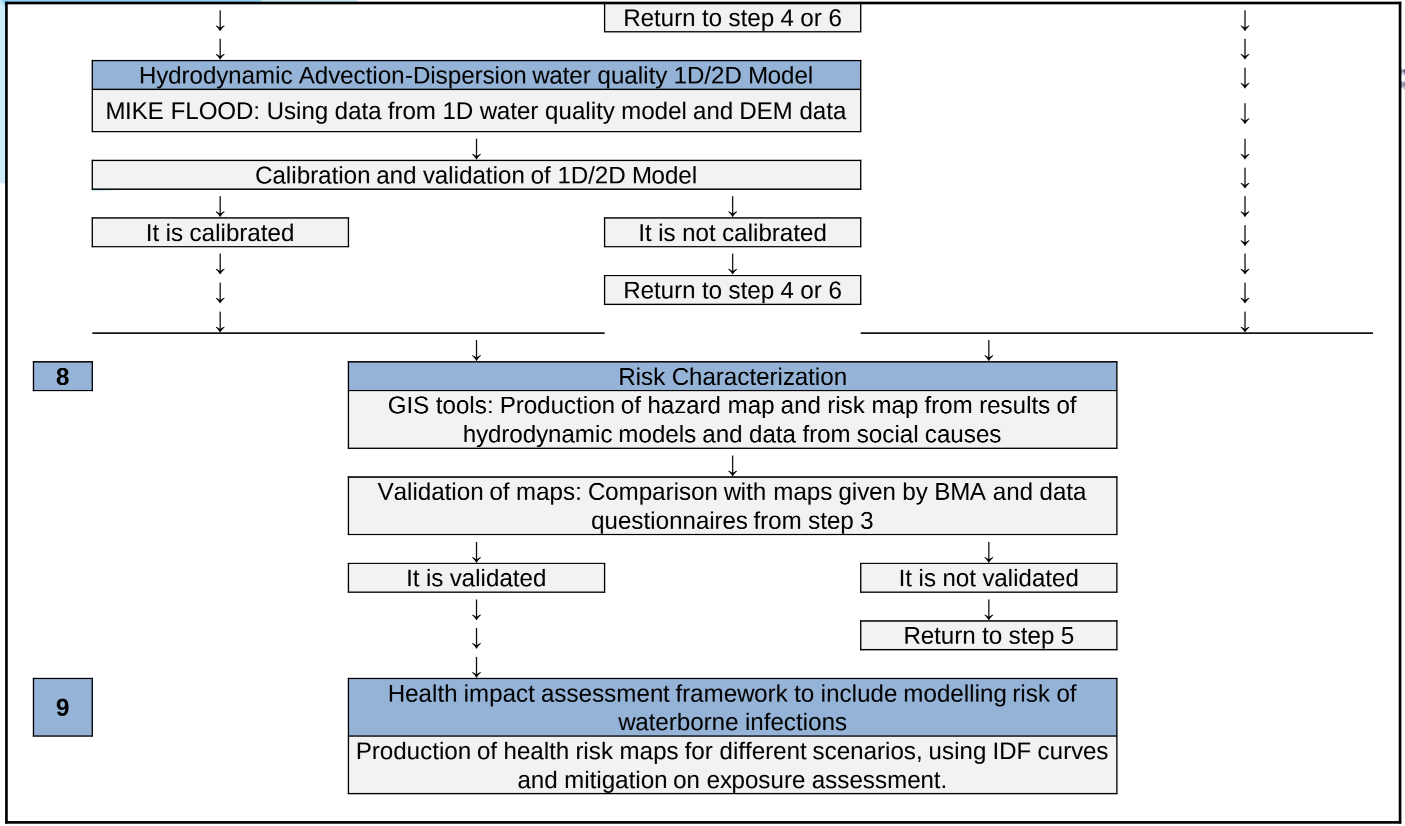
FRAMEWORK FOR THE HEALTH IMPACT ASSESSMENT OF WATERBORNE INFECTIONS MODELING

STEP	SCOPING		
1	Type of flood		
	Pluvial / Fluvial / Flash / Groundwater / Coastal		
2	Impact to be analyzed		
	Waterborne Infections		
3	Root causes of the specific Impact		
	Technical	**Natural**	**Social**
	Presence of contaminated flood waters on the streets: Flood depth Flood duration	Increase in precipitation intensity. Concentration of pollutants in flood waters	Ingestion or exposure of people to contaminated flood waters
4	Data	Data	Data
	Spatial Data: Catchments, manholes, pipes, pump stations, weirs, outlets	Water quality data: Concentration of E.coli in flood waters and DWF waters	GIS tools: Number of people passing on the streets. Flood protection in buildings
	Digital elevation data.	Meteorogical Data: Precipitation data, IDF curves	Questionnaires to people in flood prone areas about waterborne infections

Methodology and results



Methodology and results



Bangkok – Risk to Public Health

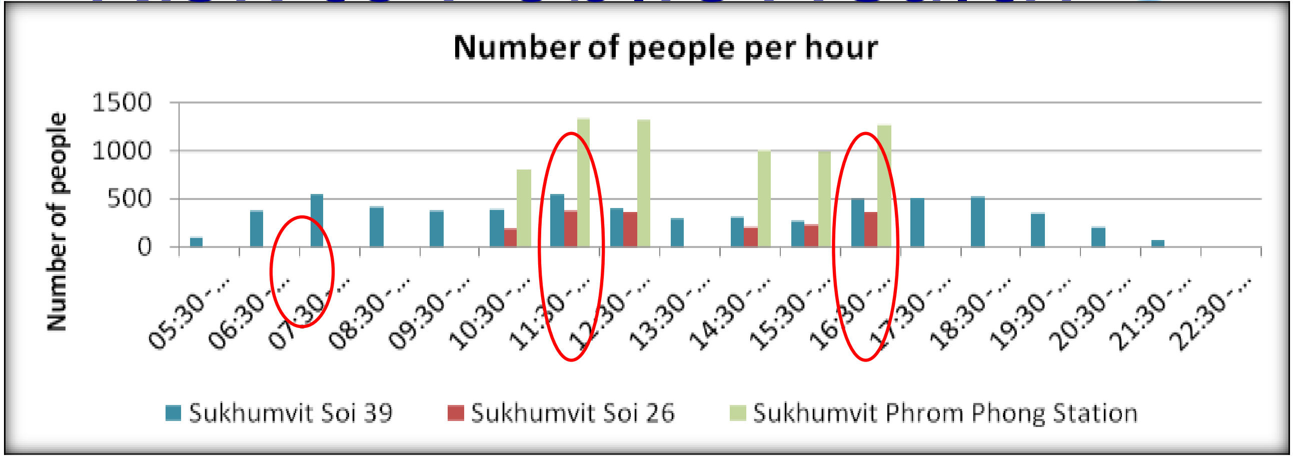
- ***People Counting:***
- People were counted every 5 minutes.
- Soi 39 (06:00 - 22:00)
- Soi 26 (10:30 - 17:30)
- Phrom Phong (10:30 - 17:30

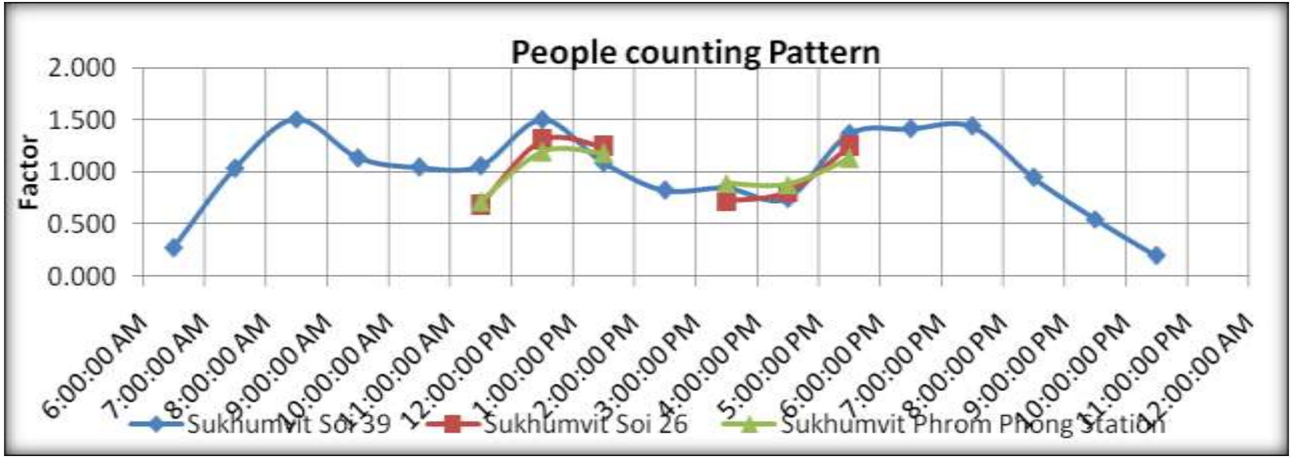
Peaks of number of people passing at both sides of the street at 08:00, 12:00 and 17:00.

- Lunch time
- Beginning and ending of working hours.

The more number of people on the street → The higher the vulnerability to contact with flood waters

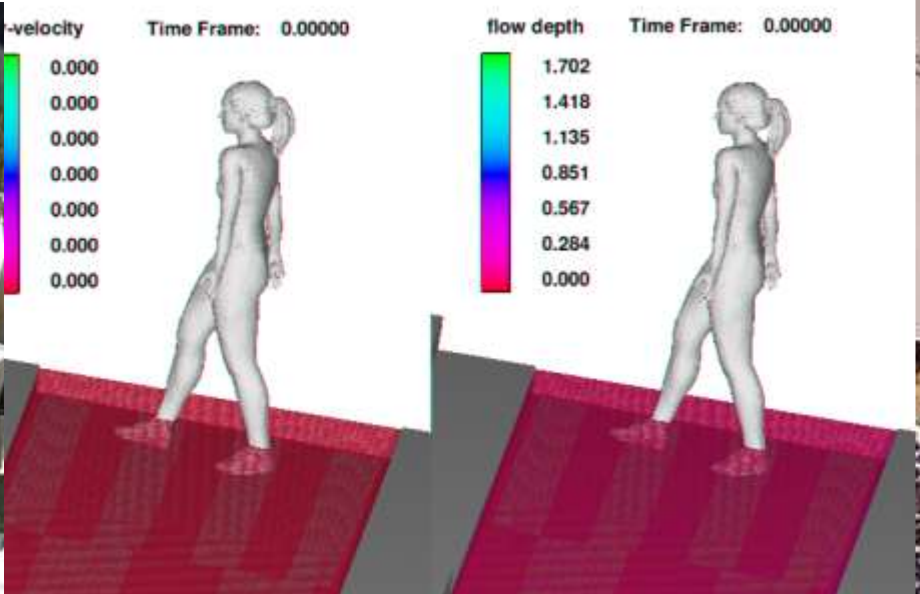
Estimation of the number of people in one day by knowing only one hour.





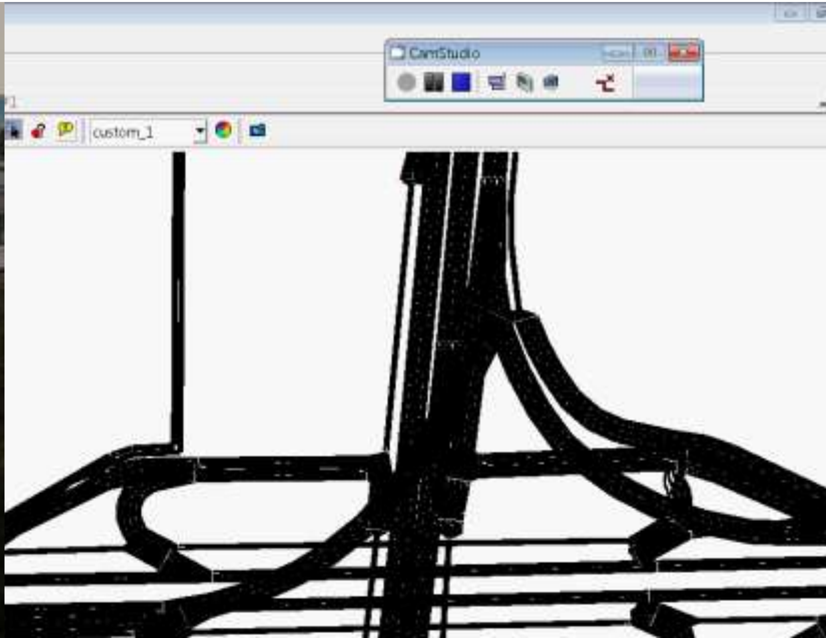
Multi-hazard variables

- Water depths + flow velocities = **casualties, injuries**



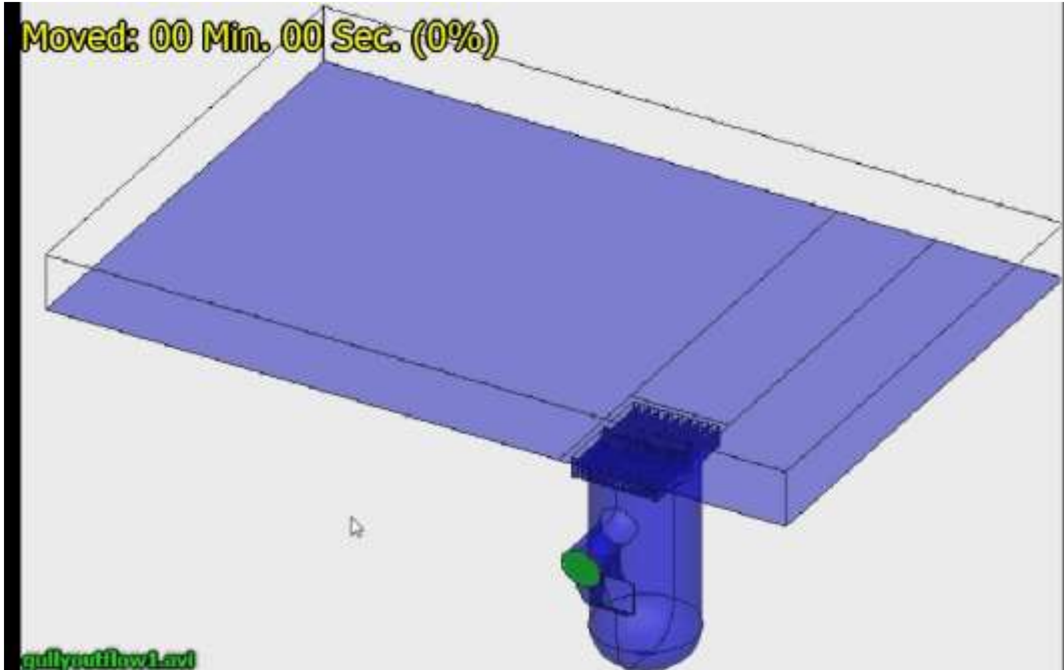
Multi-hazard variables

- Water depths + flood duration = **traffic disruption**



Multi-hazard variables

- Water depths + concentrations = health impacts



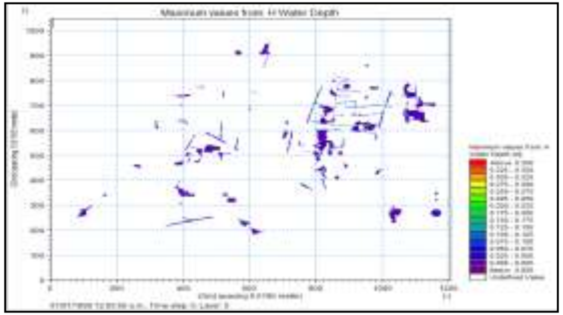
Methodology and Results

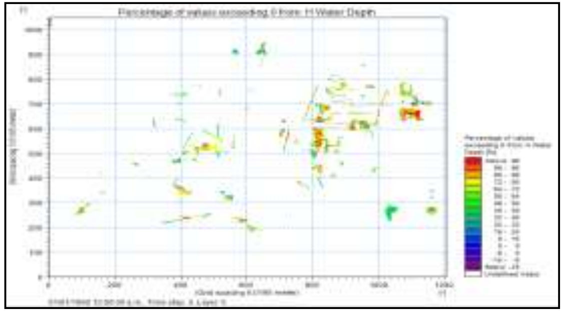
- **Hazard Map of waterborne infections**

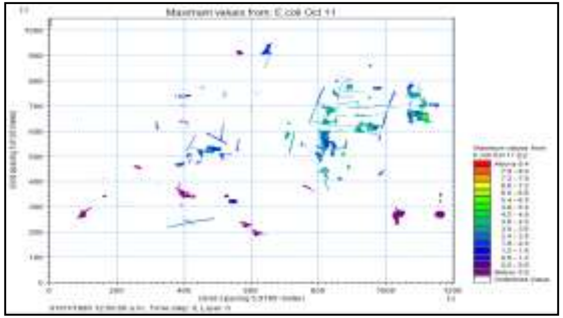
Maximum flood water depth is obtained in meters

Maximum flood duration is calculated in minutes

Maximum E.coli concentration is obtained in 10^6 MPN/100ml

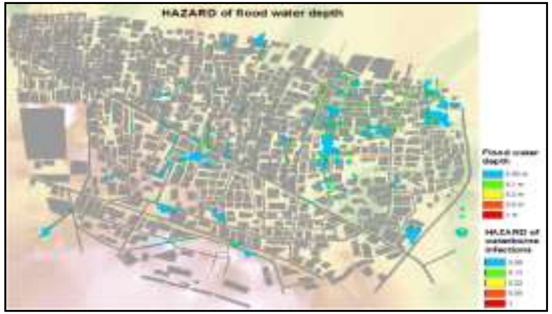






From the hazard characterization in step 5

Hazard of flood water depth



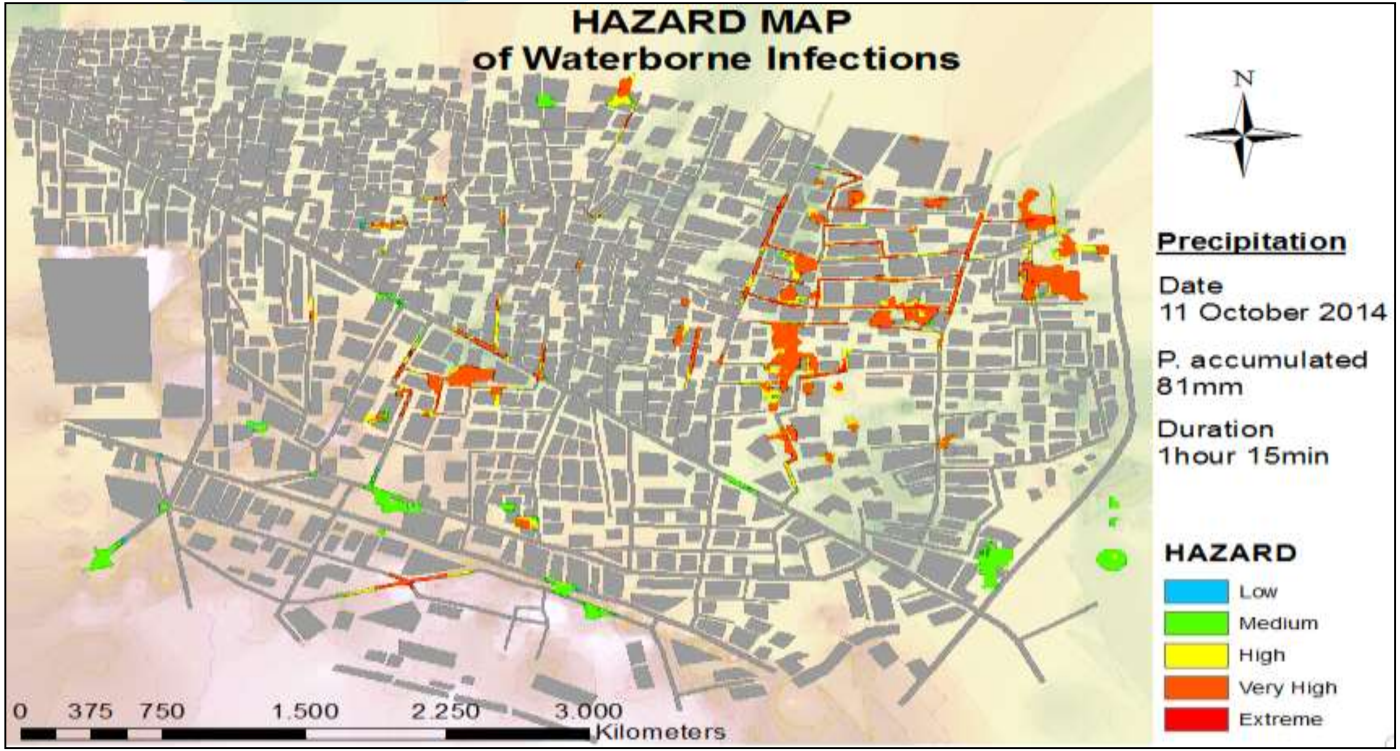
Hazard of flood duration

Hazard of concentration of E.coli

METHODOLOGY AND RESULTS

- **Hazard Map of waterborne infections**

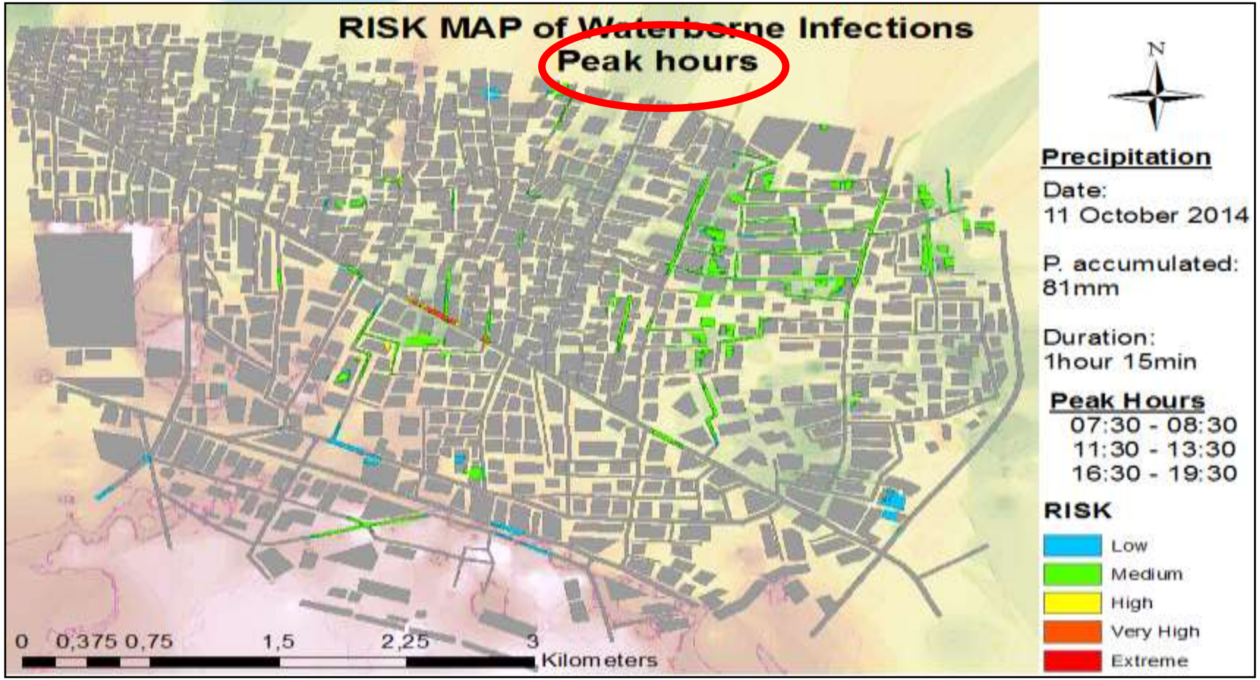
(Average of the three components)



The total hazard is more sensitive to the variations in the flood water depth, since in most of the cases the flood duration exceeds 60 minutes and the maximum E.coli concentration exceeds 1 * 10^6 MPN/100ml.

METHODOLOGY AND RESULTS

- **Risk Map of waterborne infections**



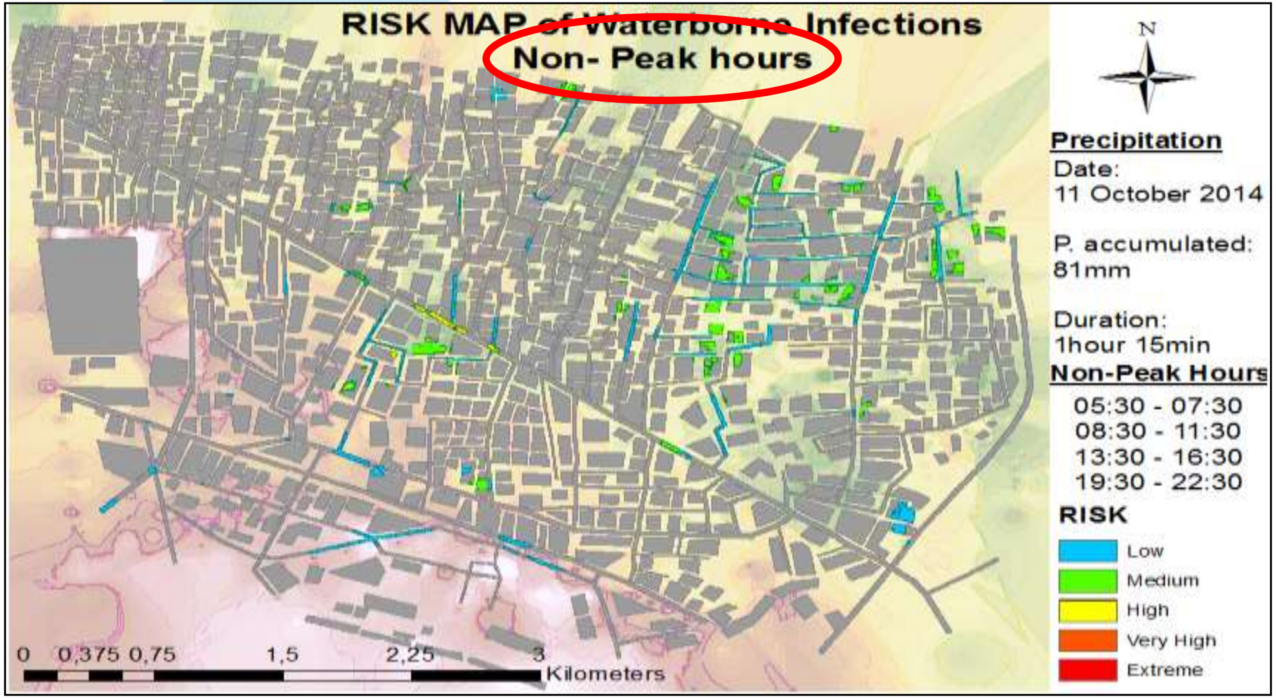
Waterborne disease due to fecal-oral, water-washed, skin and eye, water-based, penetrating skin and ingestion infection.

At peak hours:

- The risk can be high and very high in some parts of the Sukhumvit main road.
- Most of the streets and buildings present a medium risk of waterborne infections.
- The risk is low in few streets and buildings.

Methodology and Results

- Risk Map of waterborne infections



Summary

- Novel methodology for assessment of health impacts of sewage on streets
- Highly dynamic and complex process
- Range of data and simulations involved
- Coupling of deterministic models, MCM ad observations
- Three case studies with different issues

Acknowledgements

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- Dr Zoran Vojinović, IHE
- Dr Sutat Weesakul, AIT/HAII

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Other videos

- Dr Eduardo Martinez-Gomariz, CETaqua
- Prof Taisuke Ishigaki, Kansai University

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