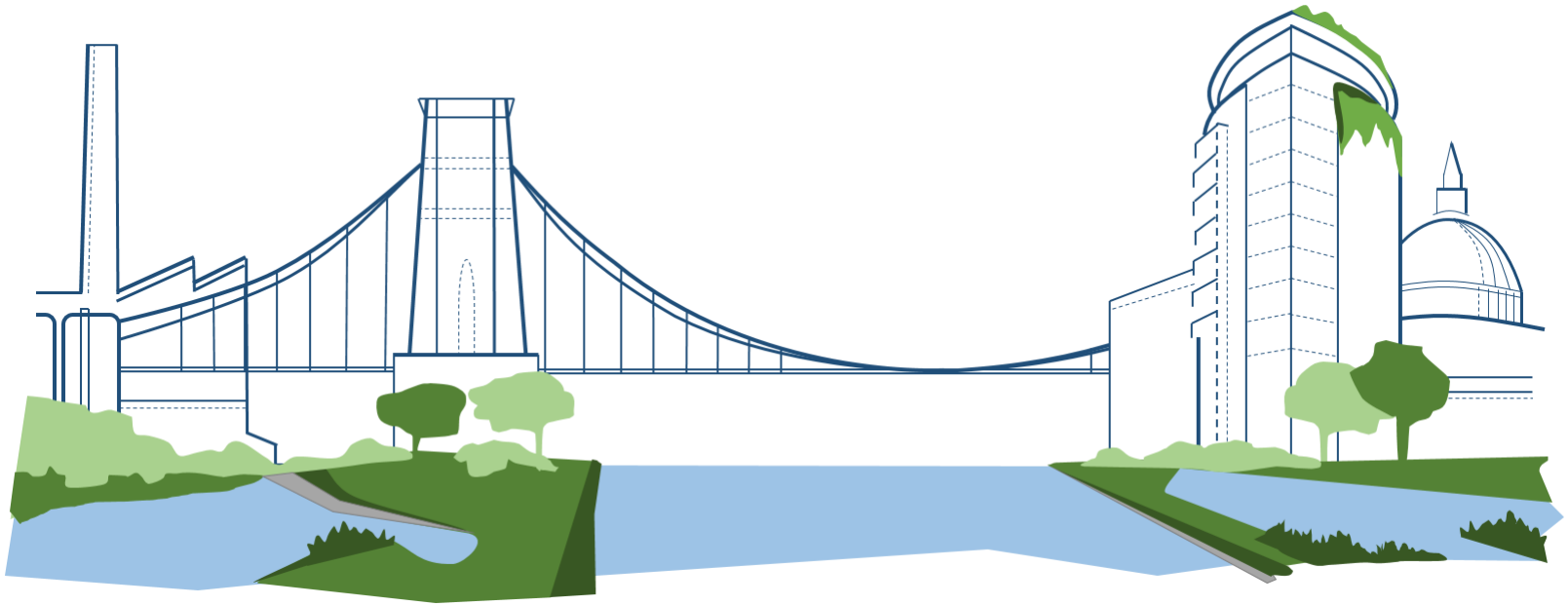
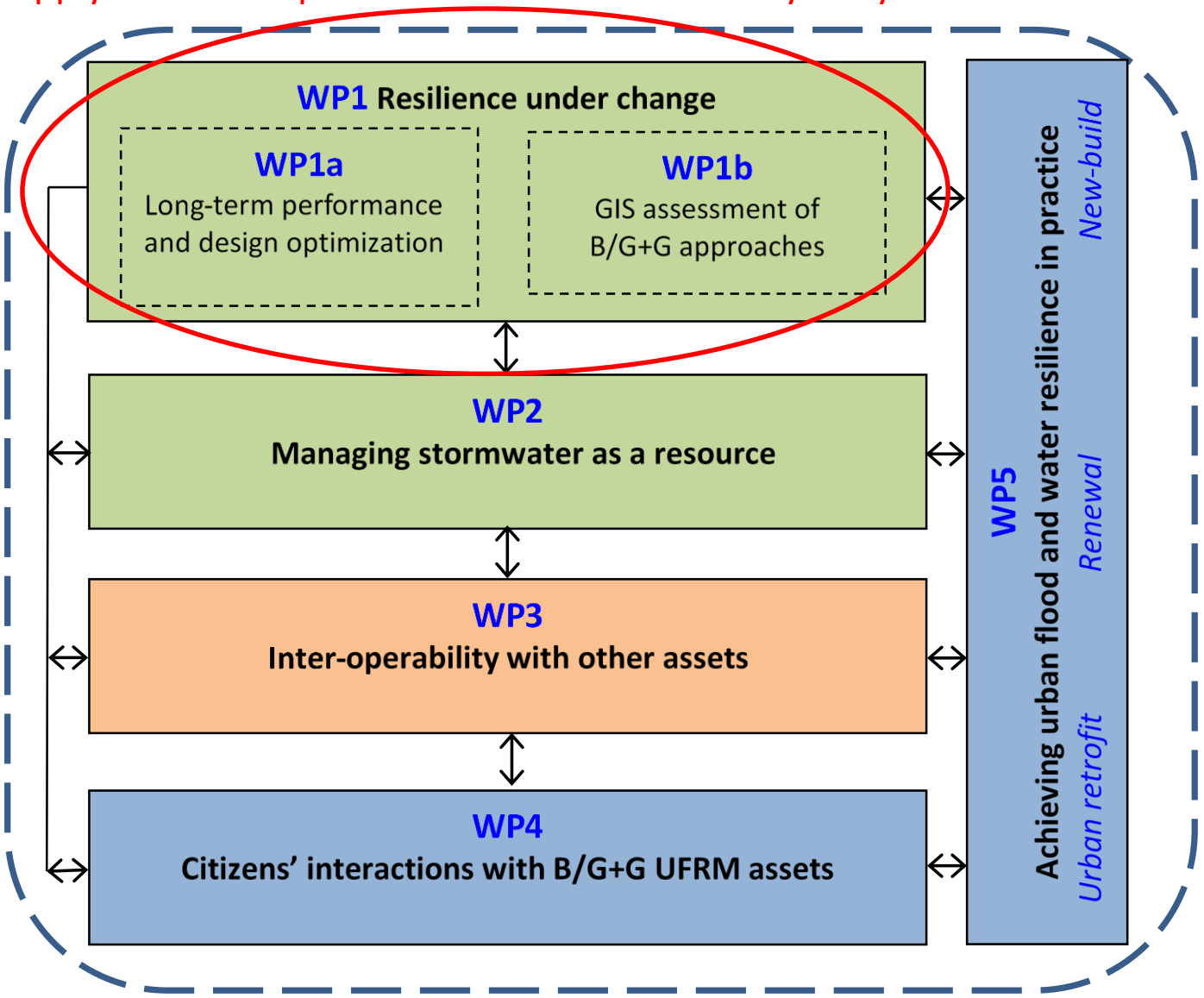
Flood modelling of Newcastle: getting the pipes and infiltration right

Steve Birkinshaw
Newcastle University



Develop and apply a new comprehensive model of urban hydrosystems



urban flood resilience

Aim: Develop and apply a new comprehensive model of urban hydrosystems.

- Land use change
- Sustainable drainage systems (SUDS)
- Climate Change

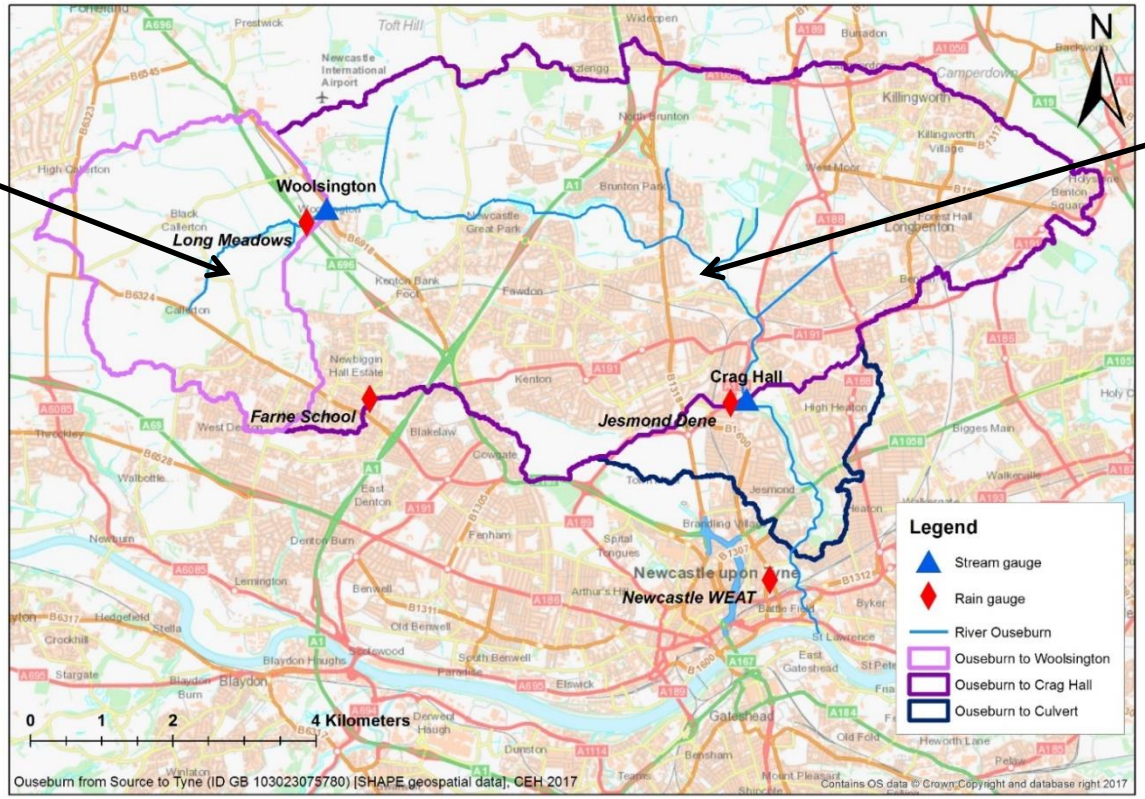
Scenario testing

Achieve urban flood and water resilience

Newcastle Ouse Burn catchments

Rural

Suburban



urban flood resilience

Aim: Develop and apply a new comprehensive model of urban hydrosystems

CityCat Hydraulic Model[1]
- 1m DEM
- Surface Water and Sewer Network
- Event based

Coupling

Shetran Hydrological Model[2]
- 50m DEM
- Subsurface hydrology
- Continuous model

1. Glenis et al. (2018) A fully hydrodynamic urban flood modelling system representing buildings, green space and interventions. Environmental Modelling & Software, 109, 272-292
2. Ewen et al. (2000) SHETRAN: distributed river basin flow and transport modeling system. Journal of Hydrologic Engineering, 5, 250-258

urban flood resilience

Issues

1. Green/Impermeable Areas

2. Soil Moisture

3. Sewer Network

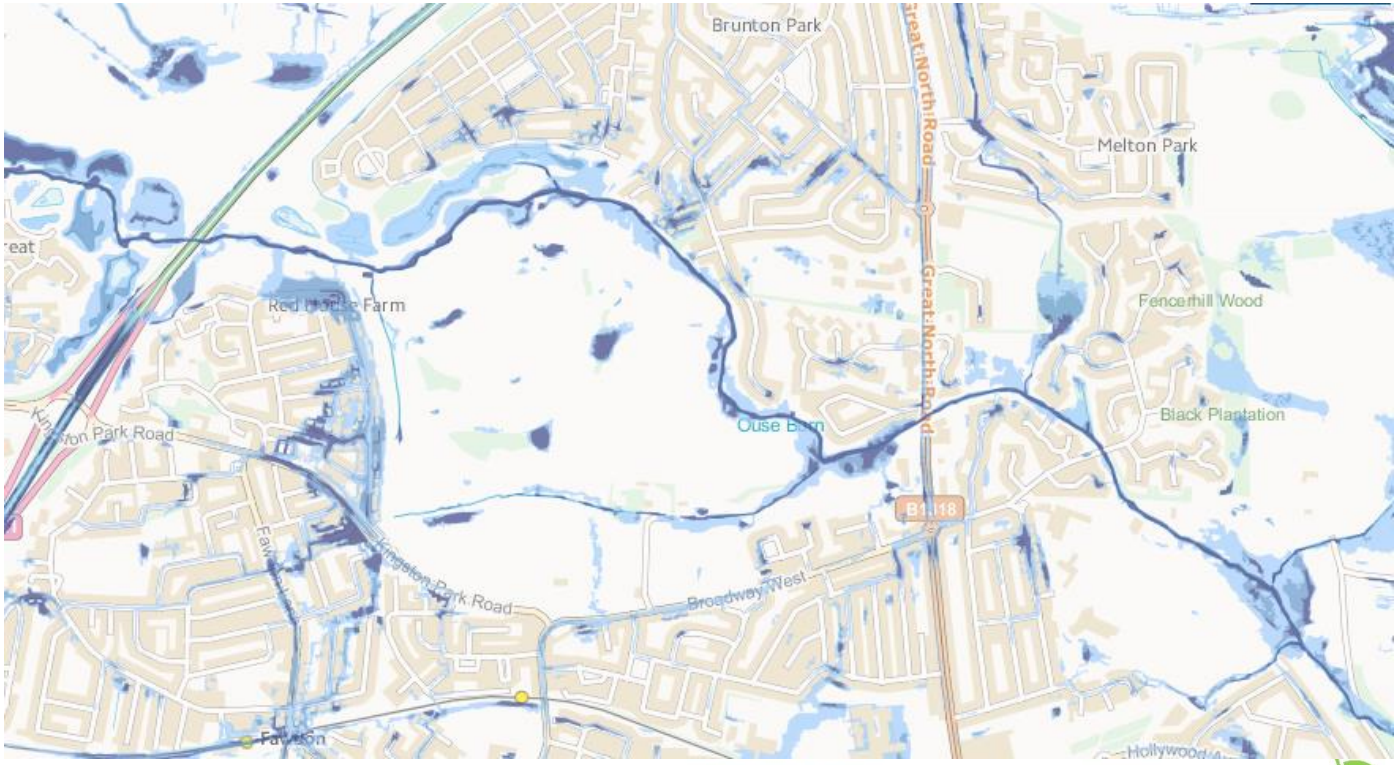
"Getting the right results for the wrong reasons"

urban flood resilience

How do other models account for these issues:

EA Interactive Flood Map

- Green Areas and Soil Moisture - reduce rainfall by 30%
- Sewer system - 12 mm/hr of rainfall removed



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Issue 1 - Green/Impermeable Areas

1. Impermeable/green areas

What is the green area in a city?

What is the effective green area?

Sources:

https://www.bbc.co.uk/news/uk-scotland-38522414

https://www.theguardian.com/cities/gallery/2017/jan/05/green-space-uk-largest-cities-mapped

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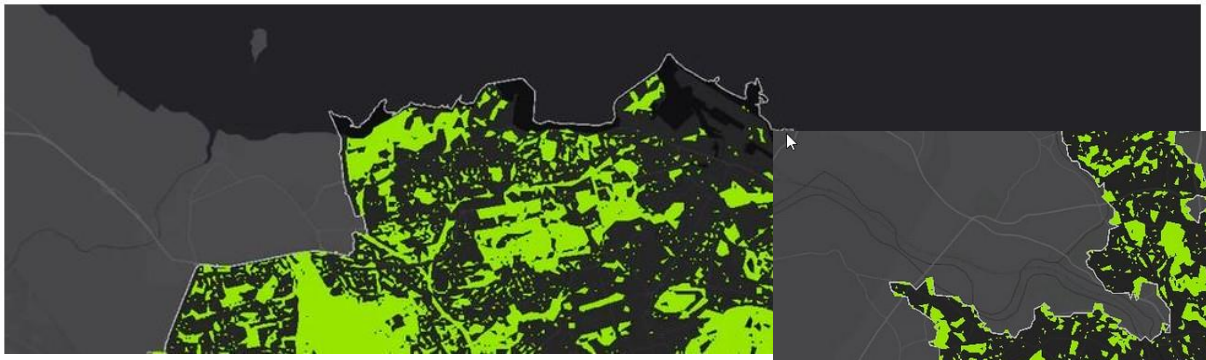
Edinburgh and Glasgow top UK list of green space cities

5 January 2017 | Share



Satellite data
(CEH Land Cover Map
ESRI Landsat8 Map)

No map for Newcastle (only top 10 biggest cites)

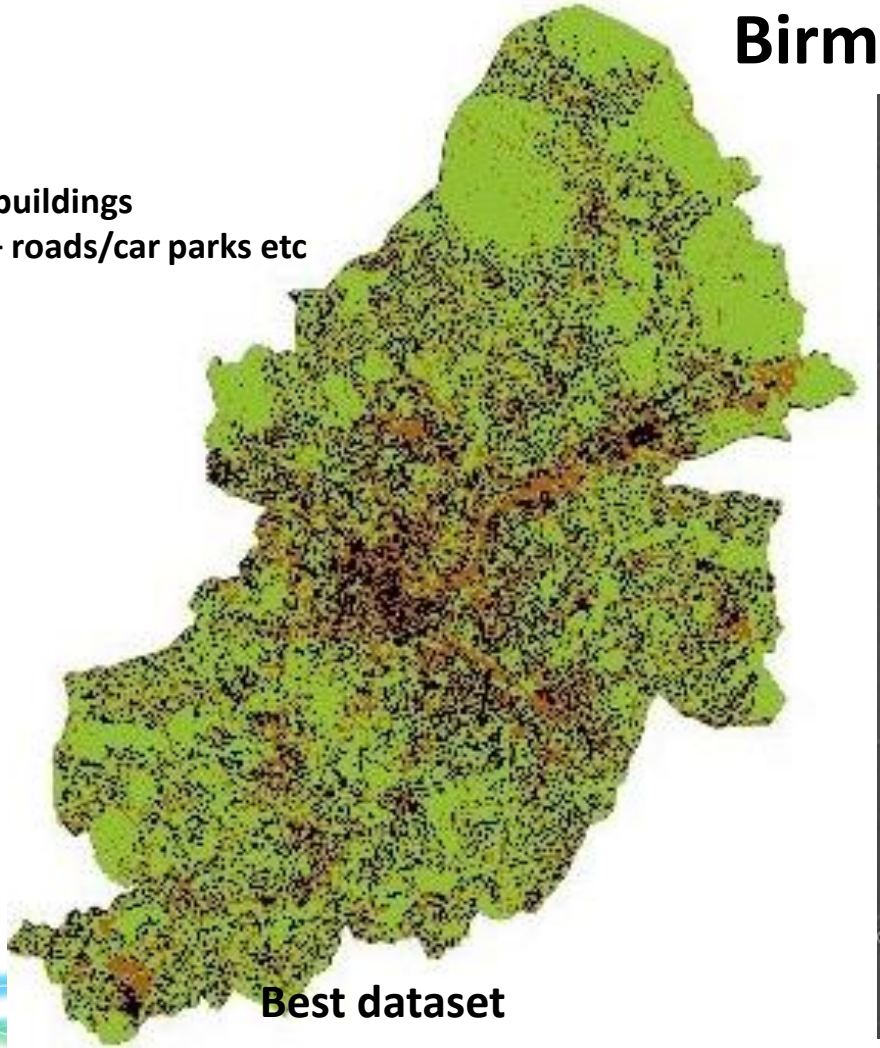
1. Impermeable/green areas

OS data (~ 1m resolution) - 64.9% green

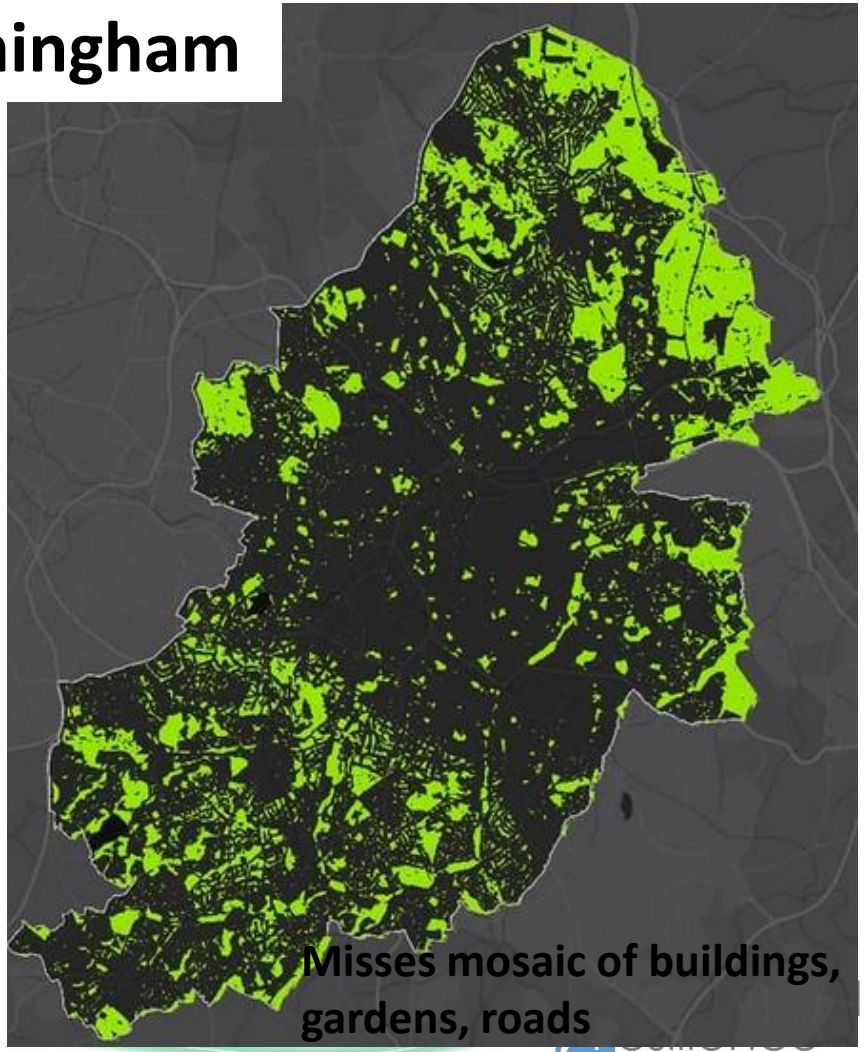
Satellite data (30m resolution) - 24.6% green

Birmingham

Black – buildings
Brown – roads/car parks etc

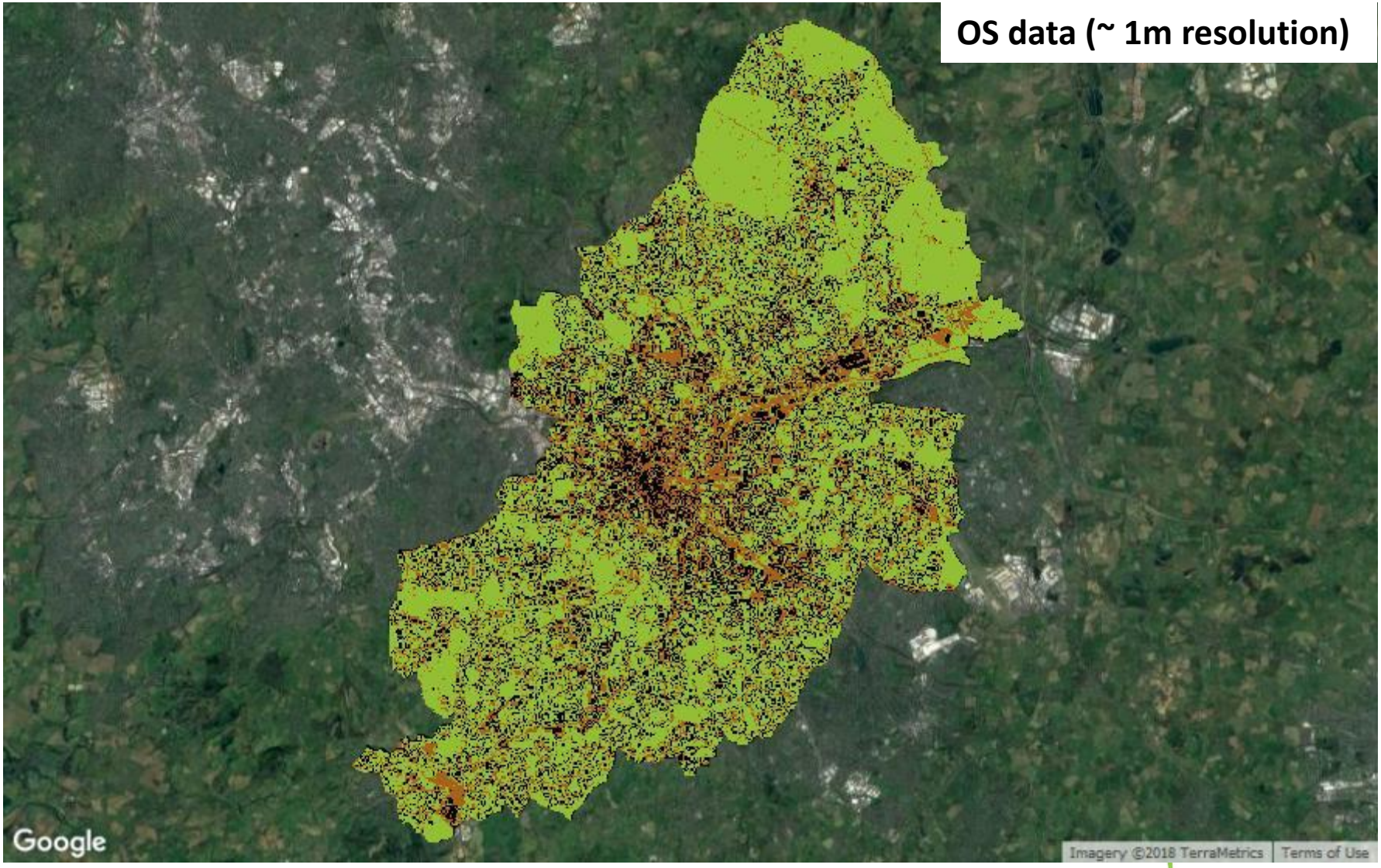


Best dataset



Misses mosaic of buildings, gardens, roads

1. Impermeable/green areas



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1. Impermeable/green areas

urban flood resilience

1. Impermeable/green areas

Birmingham City Centre

OS data (~ 1m resolution)

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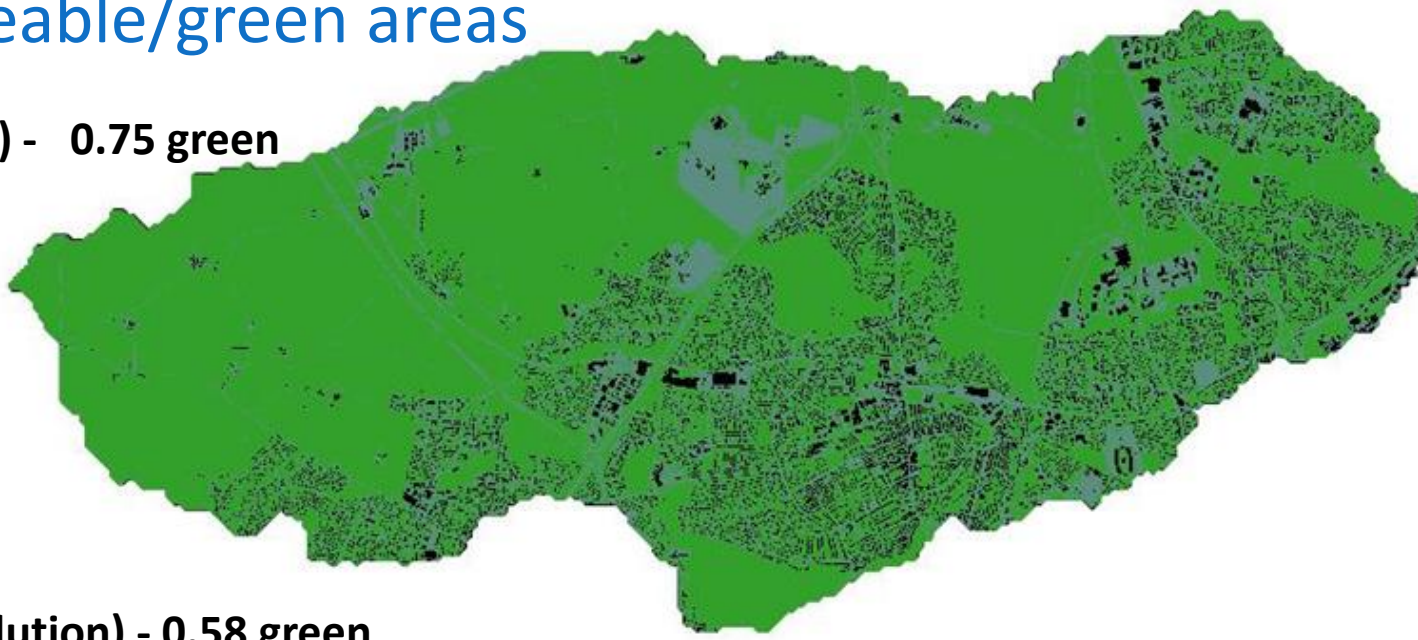
1. Impermeable/green areas

1. Impermeable/green areas

OS data (~1m resolution) - 0.75 green

Black – buildings
Grey – roads/car parks etc.



Satellite data (25m resolution) - 0.58 green

Black – Impermeable

1. Impermeable/green areas

South Gosforth – Google Earth

1. Impermeable/green areas

South Gosforth – OS data (~1m resolution)

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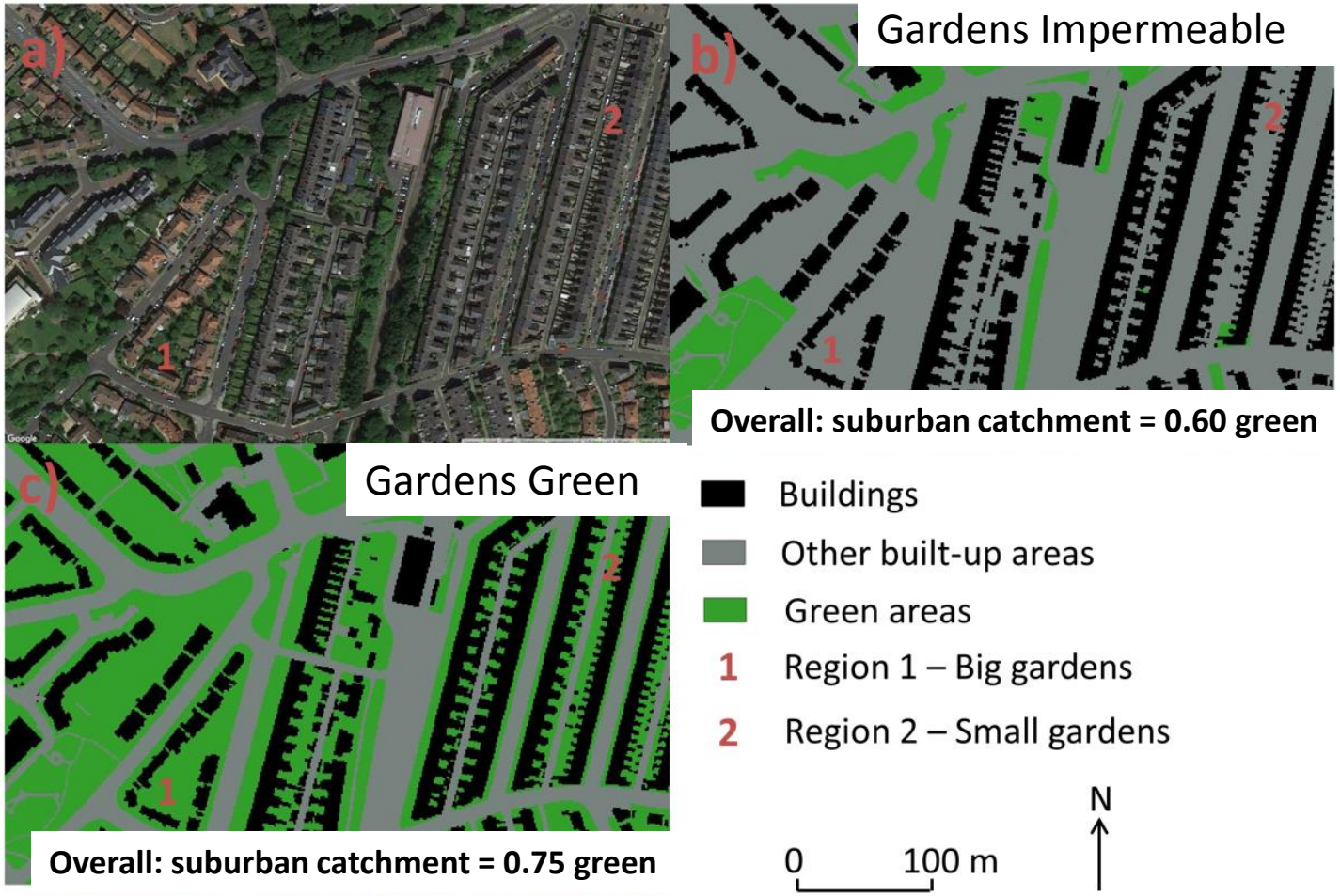
1. Impermeable/green areas

South Gosforth – OS data (~1m resolution)

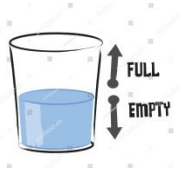
urban flood resilience

1. Impermeable/green areas



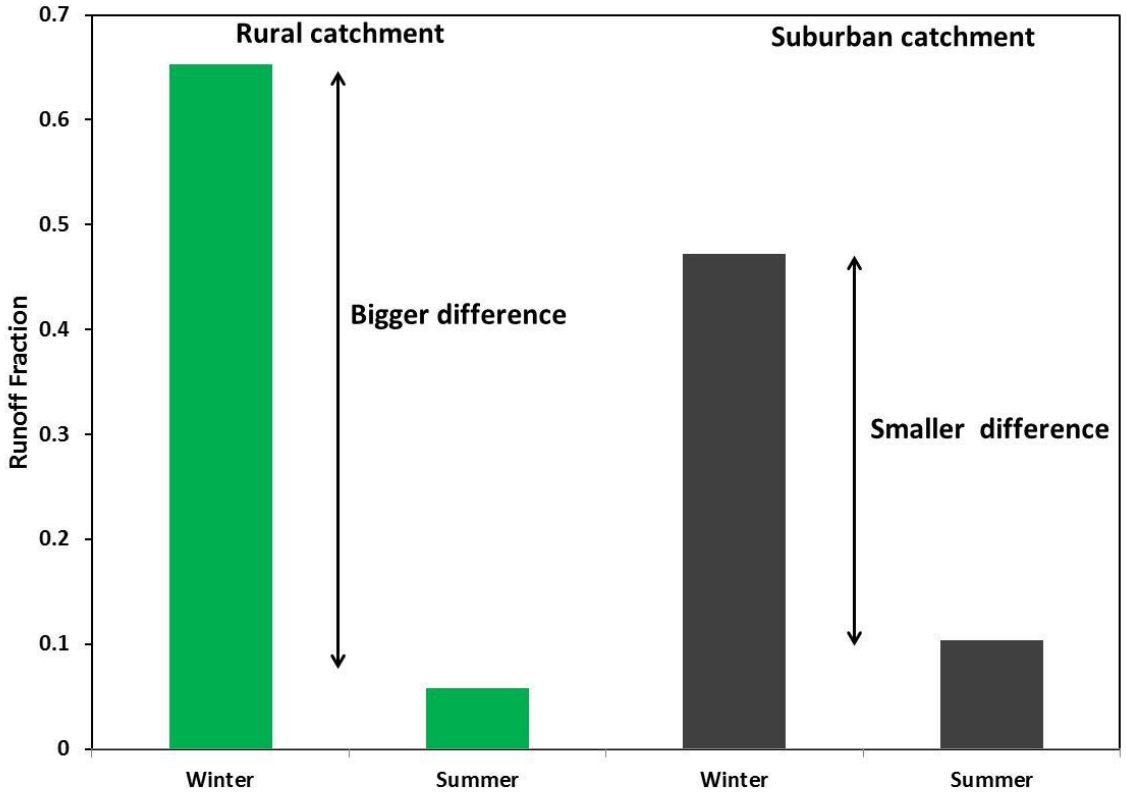
Issue 2 - Soil Wetness

2. Soil Wetness



How wet/dry is the soil at the start of a rainfall event (antecedent conditions)

Consider a single winter event and summer rainfall event



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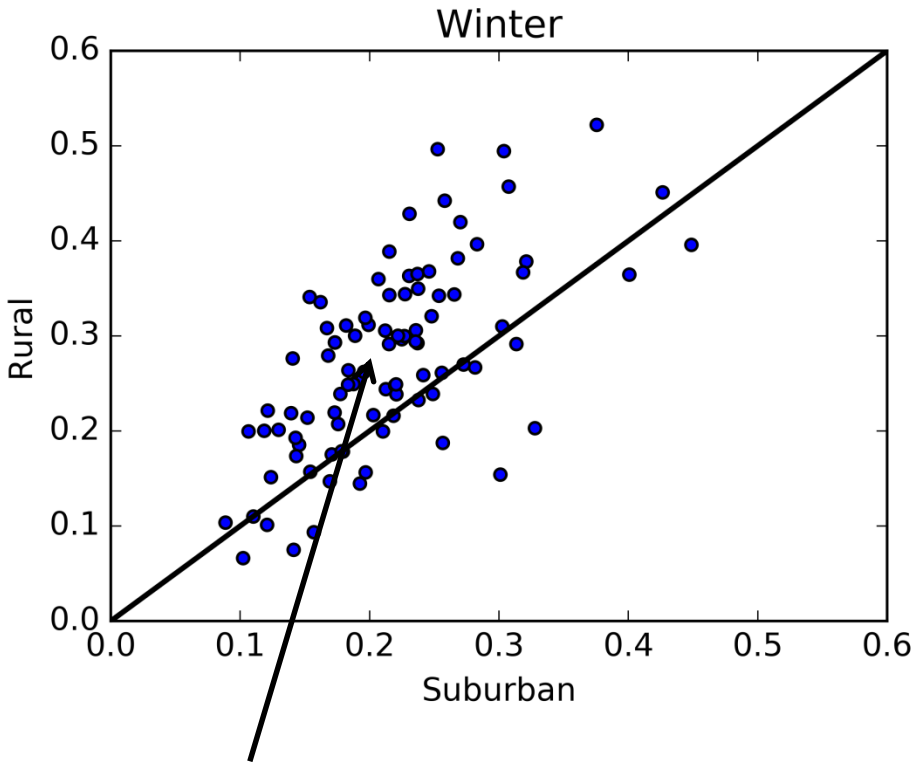
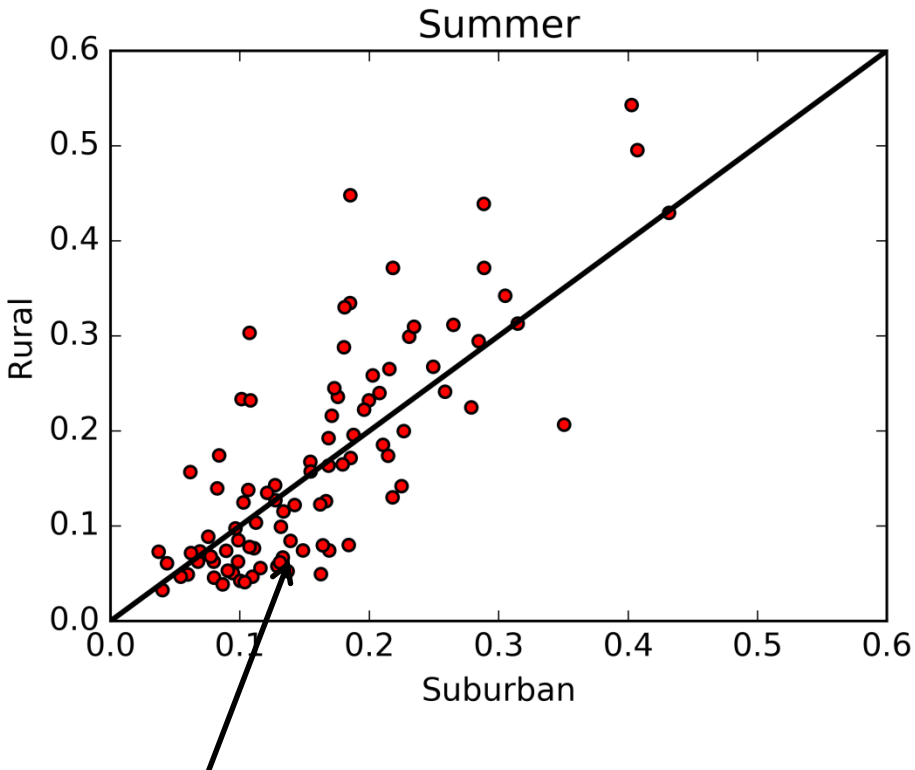
2. Soil Wetness

Runoff Fractions for the 100 biggest Winter(blue circles) and summer events (red circles)





Wet soils at the start of rainfall event

Dry soils at the start of rainfall event

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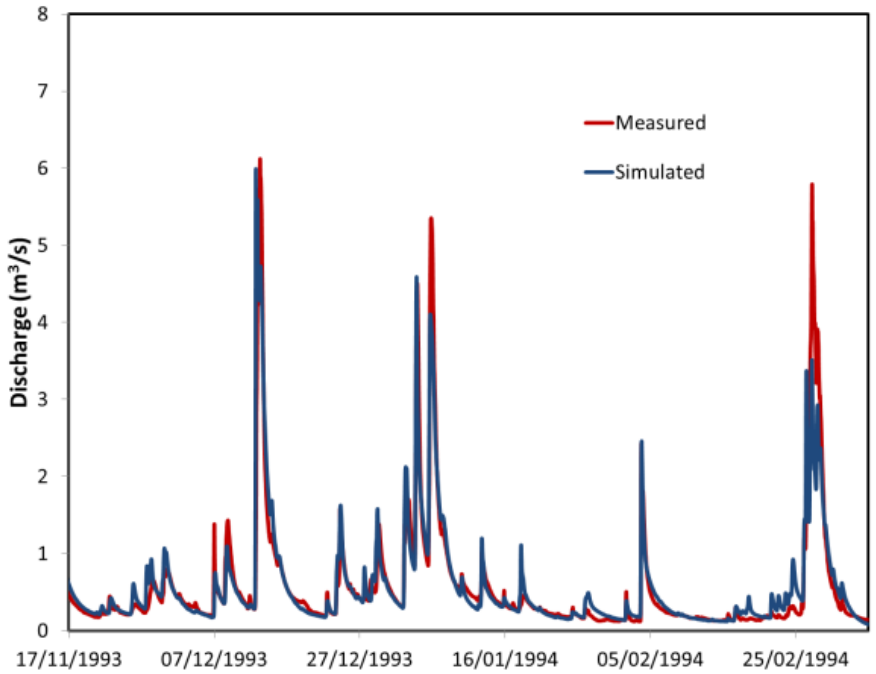
2. Soil Wetness

Hydrology Model (100m resolution)
- Continuous simulation 1991-2014
- Excellent correspondence between measured and simulated discharge

Soil wetness at start of rainfall event

Hydraulic Model (2m resolution)
- Fine resolution modelling for each event

Hydrology Model Simulation results for one year for suburban catchment



1991-2014 NSE = 0.89 for suburban catchment, NSE =0.87 for rural catchment

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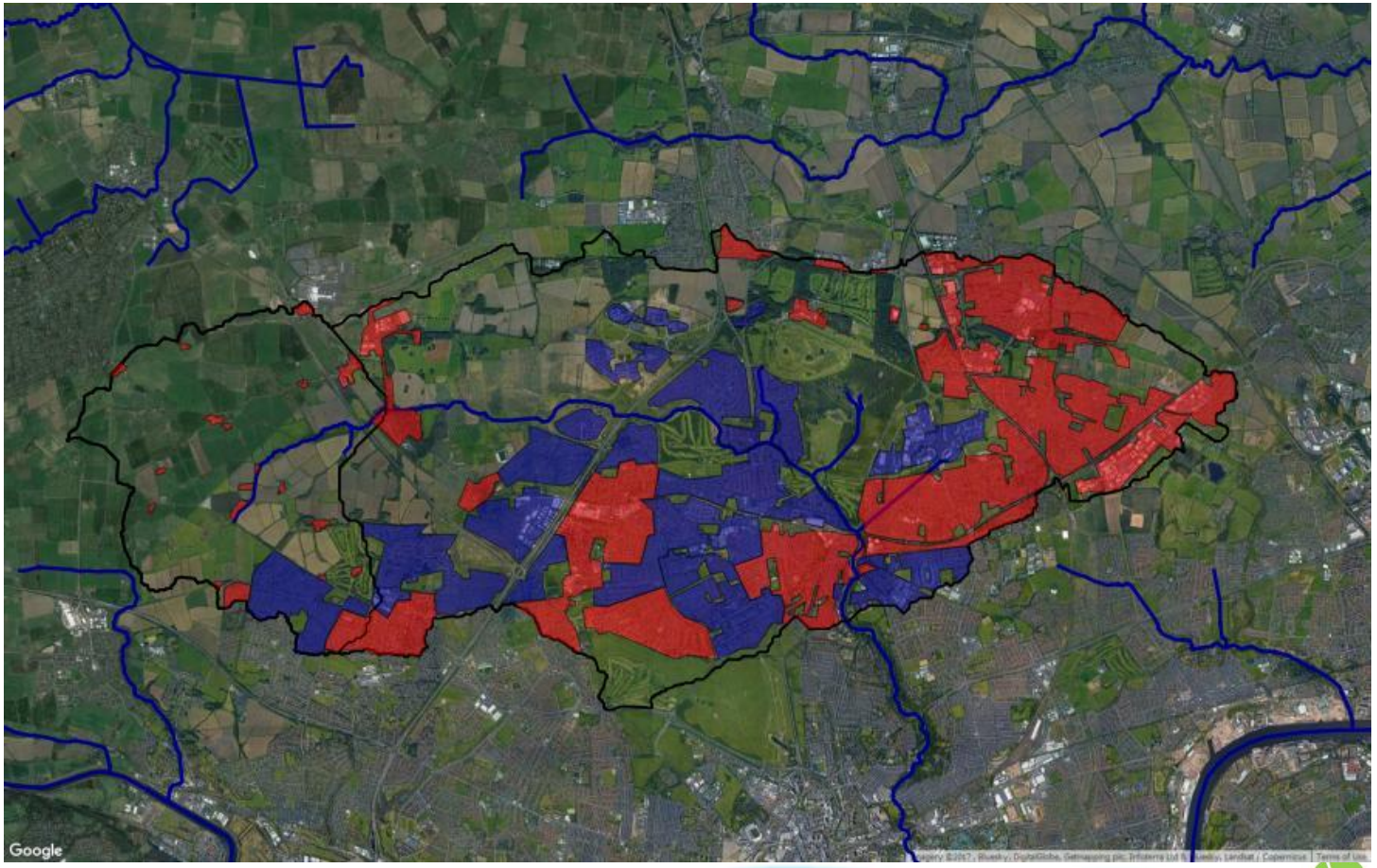
Issue 3 - Sewer System

3. Sewer Network

Source: https://www.newcastle.gov.uk/sites/default/files/wwwfileroot/planning-and-buildings/planning-policy/ouseburn_swmp_2015.pdf

Red – combined sewers (55% of urban area)
Blue - separate sewers (45% of urban area)



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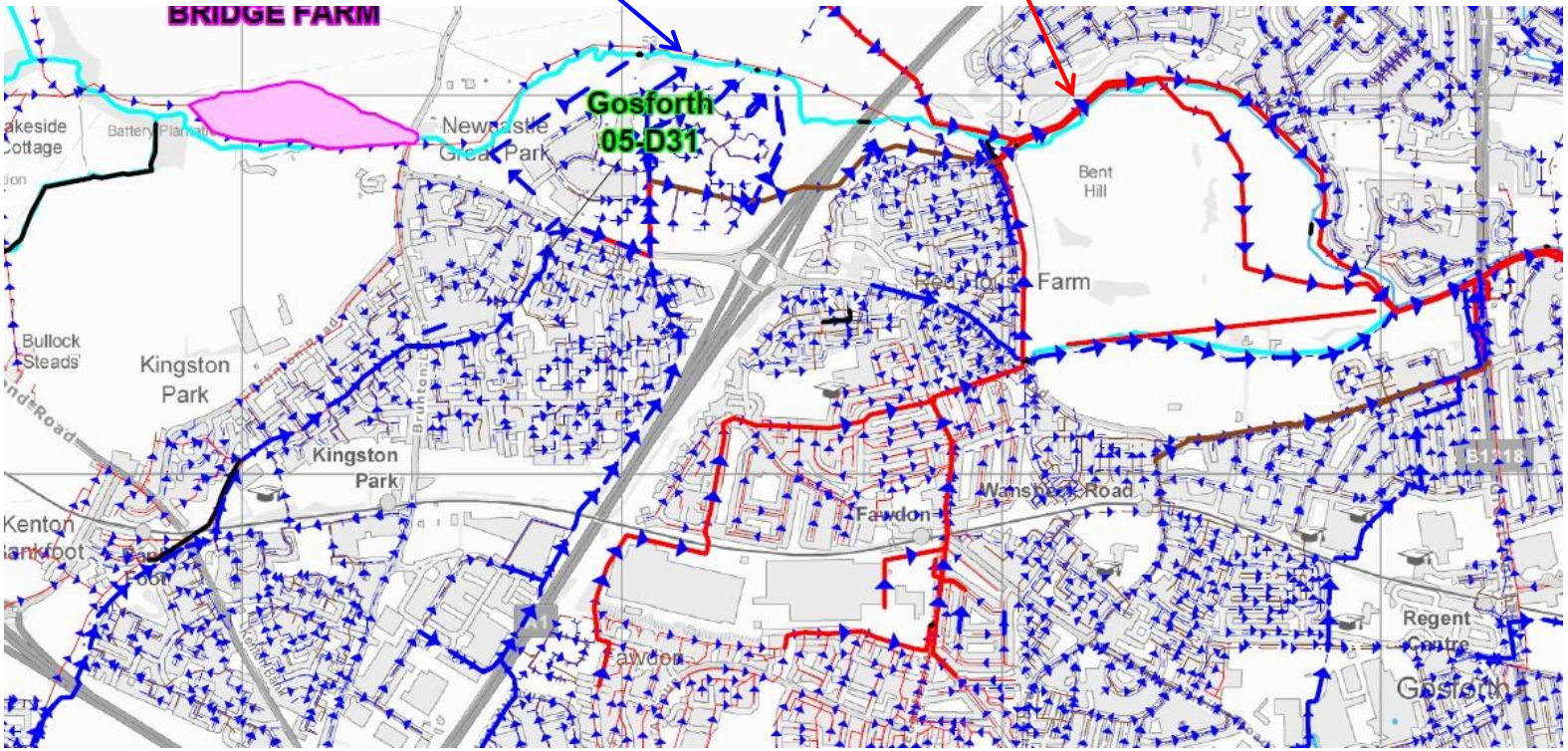
3. Sewer Network

Source: https://www.newcastle.gov.uk/sites/default/files/wwwfileroot/planning-and-buildings/planning-policy/ouseburn_swmp_2015.pdf

Combined Sewers – Storm water to waste water treatment works

Separate Sewer –Storm water to river network



Pipes can be added to CityCat hydraulic model

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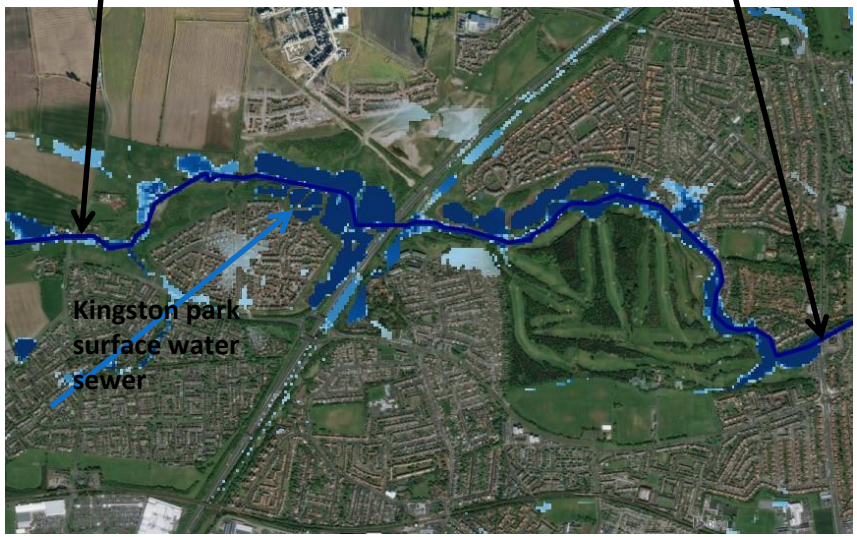
3. Sewer Network

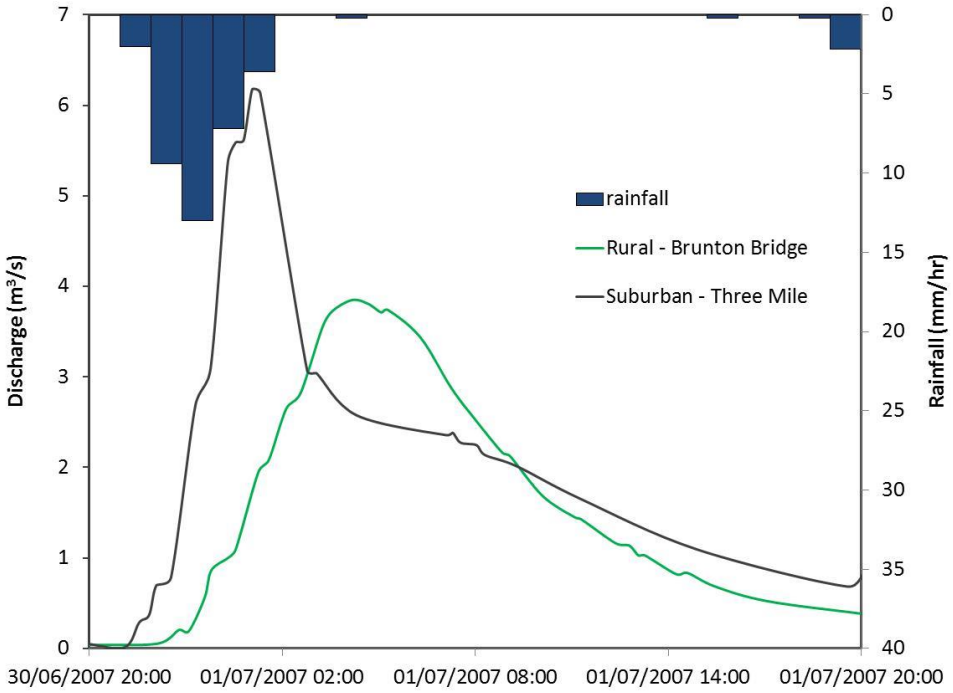
Separate sewers from Kingston Park plus other estates increase the peak flow and reduce the lag time.
Importance of SUDS ponds

Rural catchment - Brunton Bridge

Suburban catchment – Three Mile



CityCat simulation showing water depth and SUDS features along the Ouse Burn



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Conclusions

Aim: Comprehensive model of urban hydrosystems

1. Good measurements
   - Urban Observatory
   - Northumbrian water
2. Urban detective
   - Understand how water is moving round the urban environment (three issues)
   - Effective green area journal paper
3. Good models and good modellers
   - “Right results for the right reasons”
4. Scenario testing to achieve urban flood and water resilience

urban flood resilience

Acknowledgement

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Ebbsfleet Development Corporation

Newcastle City Council

ciria

Environment Agency

UKWIR

Department for Infrastructure An Roinn Bonneagair

Public Health England

water industry forum

sniffer knowledge brokers for a resilient Scotland

RTPI mediation of space · making of place

HR Wallingford Working with water

ARUP

ATKINS

NWG living water

Royal HaskoningDHV Enhancing Society Together

Stantec

Ricardo Energy & Environment

SWECO

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