Global Water Security ⇨ Hydro-epidemiological Studies

Professor Roger A. Falconer

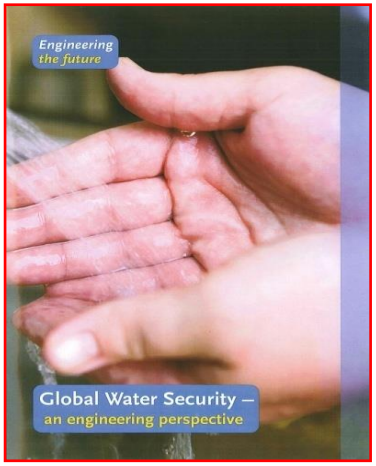
Past President of IAHR (2011-15)

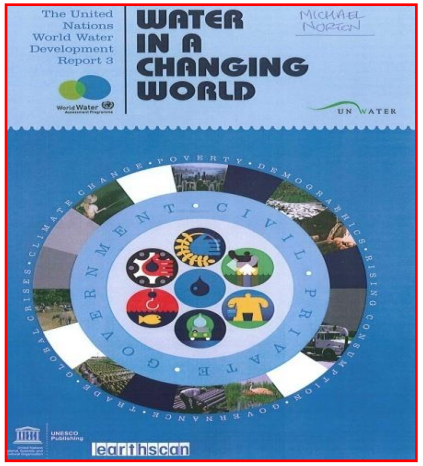
Emeritus Professor of Water Engineering,
Hydro-environmental Research Centre (HRC)
School of Engineering, Cardiff University, UK

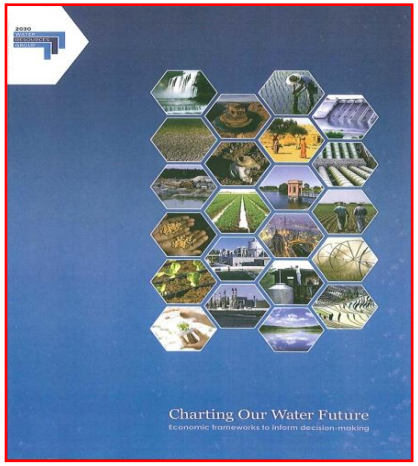
Chair Professor, Hohai University and Yangtze Institute for Conservation and Development, China

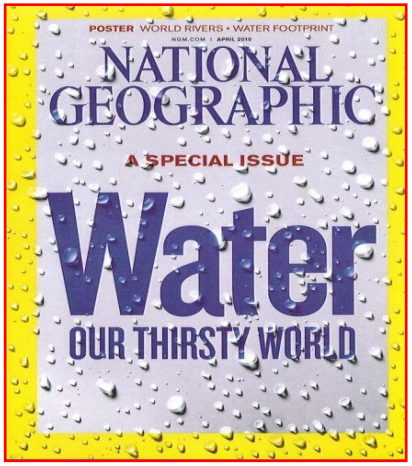
Global Water Security ⇨ Why Global Solutions?

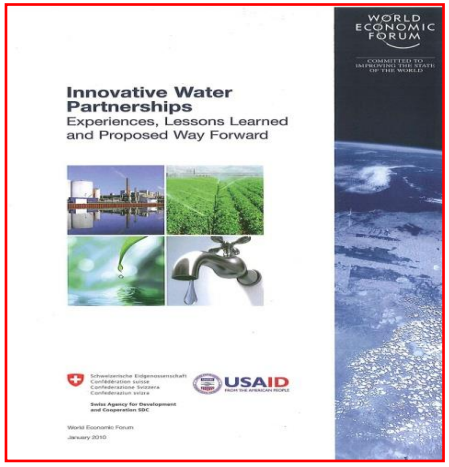
Global Water Security ⇨ Growing Concern

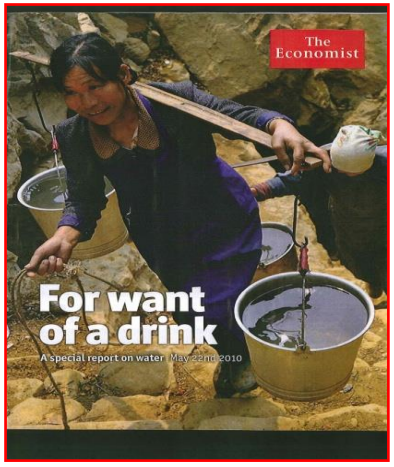












Global Water Security ⇨ Key Challenges

- Climate Change ⇨ global temperature rise on track to be 3-5^{o}C[1] ⇨ above 1.5^{o}C IPCC target
- Floods and Droughts ⇨ more extreme events
- Population Growth ⇨ 81m more per annum[2]
- 70% of world's fresh water locked up in ice
- Aquifers draining more rapidly than recharge rate
- 70% of world's water currently used to grow food
- UN SDGs ⇨ Goal 6 - Clean Water and Sanitation

Note: [1] - UN WMO and [2] - 2020 Census

Global Water Security ⇨ Typical Challenges

Source: http://water.org/learn-about-the-water-crisis/

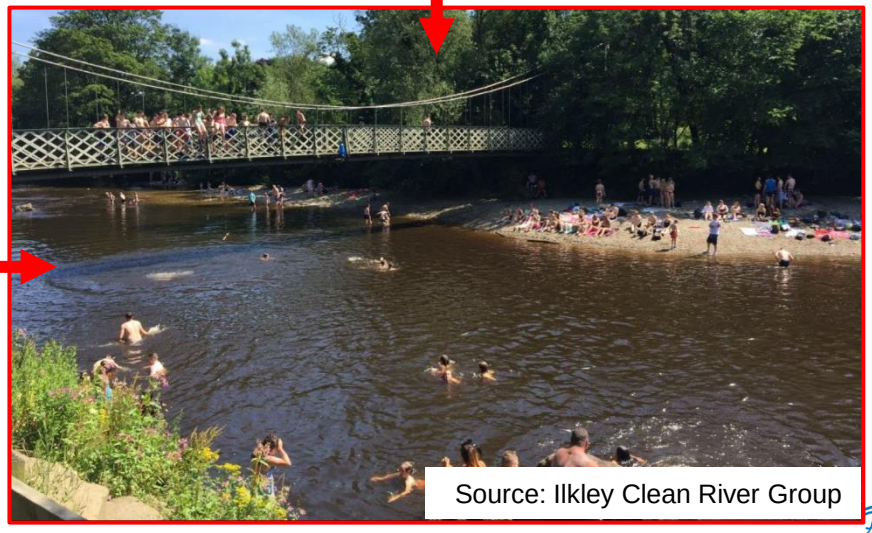
Water Pollution ⇨ R. Wharfe, UK (2020)

Pristine River Wharfe at Bolton Abbey

Cattle in River ⇨ Diffuse Pollution

Source: Ilkley Clean River Group

Combined Sewer Overflow ⇨ Point Pollution

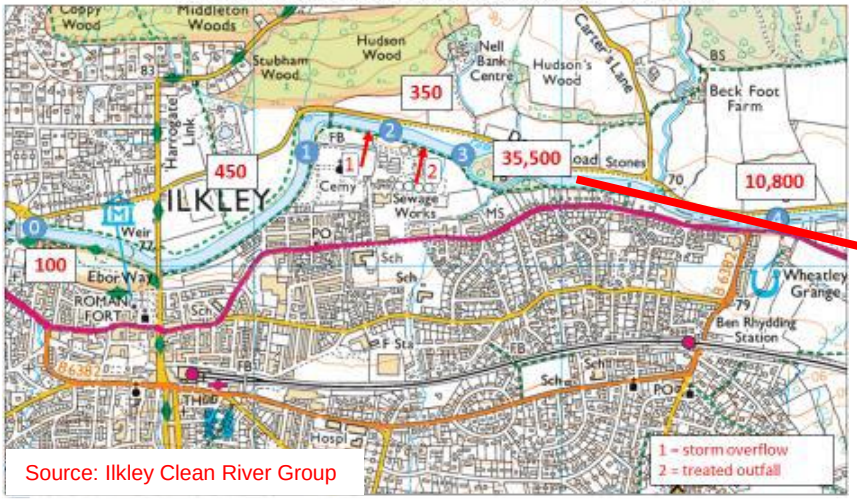


Source: Ilkley Clean River Group

Bathers in River Wharfe - Ilkley

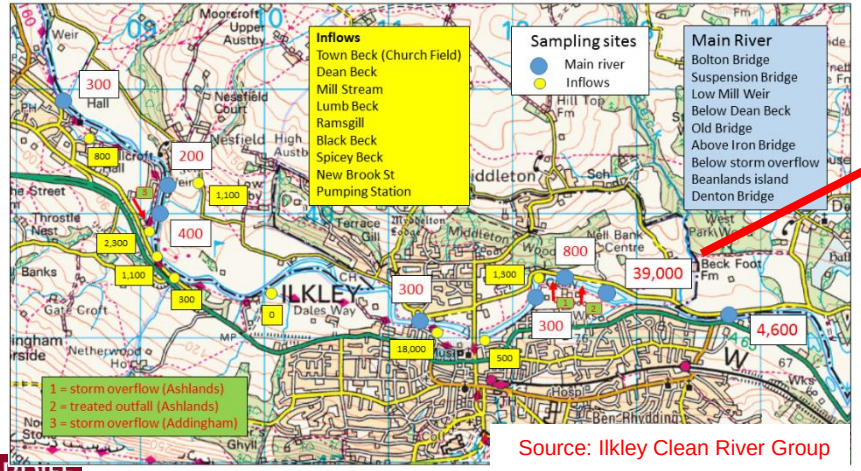
Measured *E. coli* in River Wharfe - Ilkley

E.coli (cfu/100 ml) samples – low flow 10th Jul 2019



Source: Ilkley Clean River Group

E.coli (cfu/100 ml) samples collected 10th Dec 2019



Source: Ilkley Clean River Group

EU BWD Standards for Recreational Waters

Classification	Enterococci (cfu/100ml)	*E. coli* (cfu/100ml)	Percentile
Inland Waters			
Excellent	200	500	95
Good	400	1000	95
Sufficient	330	**900**	90
Coastal Waters			
Excellent	100	250	95
Good	200	500	95
Sufficient	185	500	90

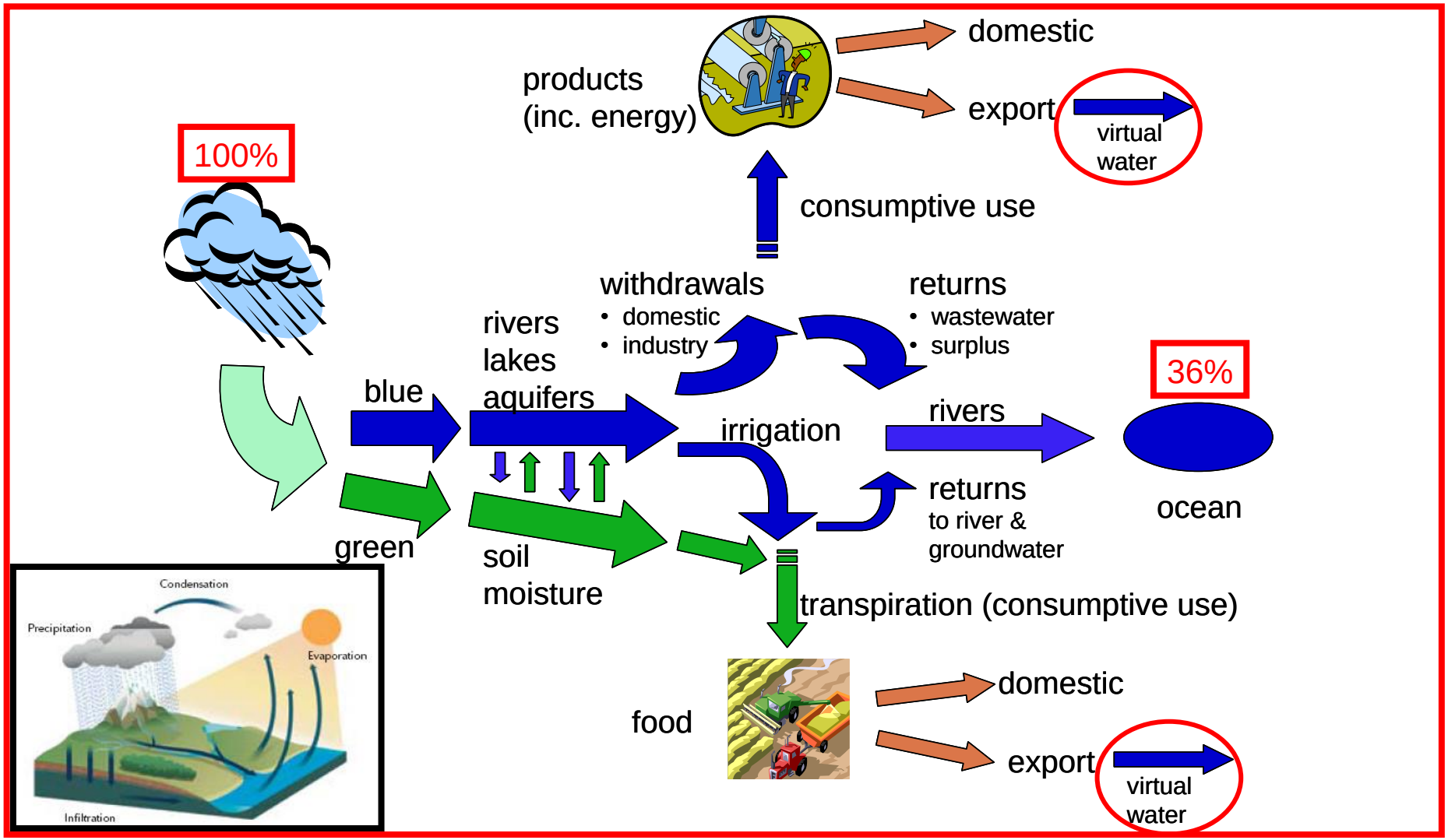
Key observations from *E.coli* samples:

- Levels ≫ downstream of CSOs
- Exceed 'Sufficient' status for Wharfe downstream of Ashlands CSO

UN Sustainable Development Goals ⇨ 2030

Hydro-environmental Engineering and Research (IAHR)
⇨ critical to delivering all 8 targets of UN SDG 6

Water Management ⇨ Water Cycle



Water Footprint of a Nation

- Water Footprint ⇨ water consumed and used to produce goods and services within a nation

- Two components:-

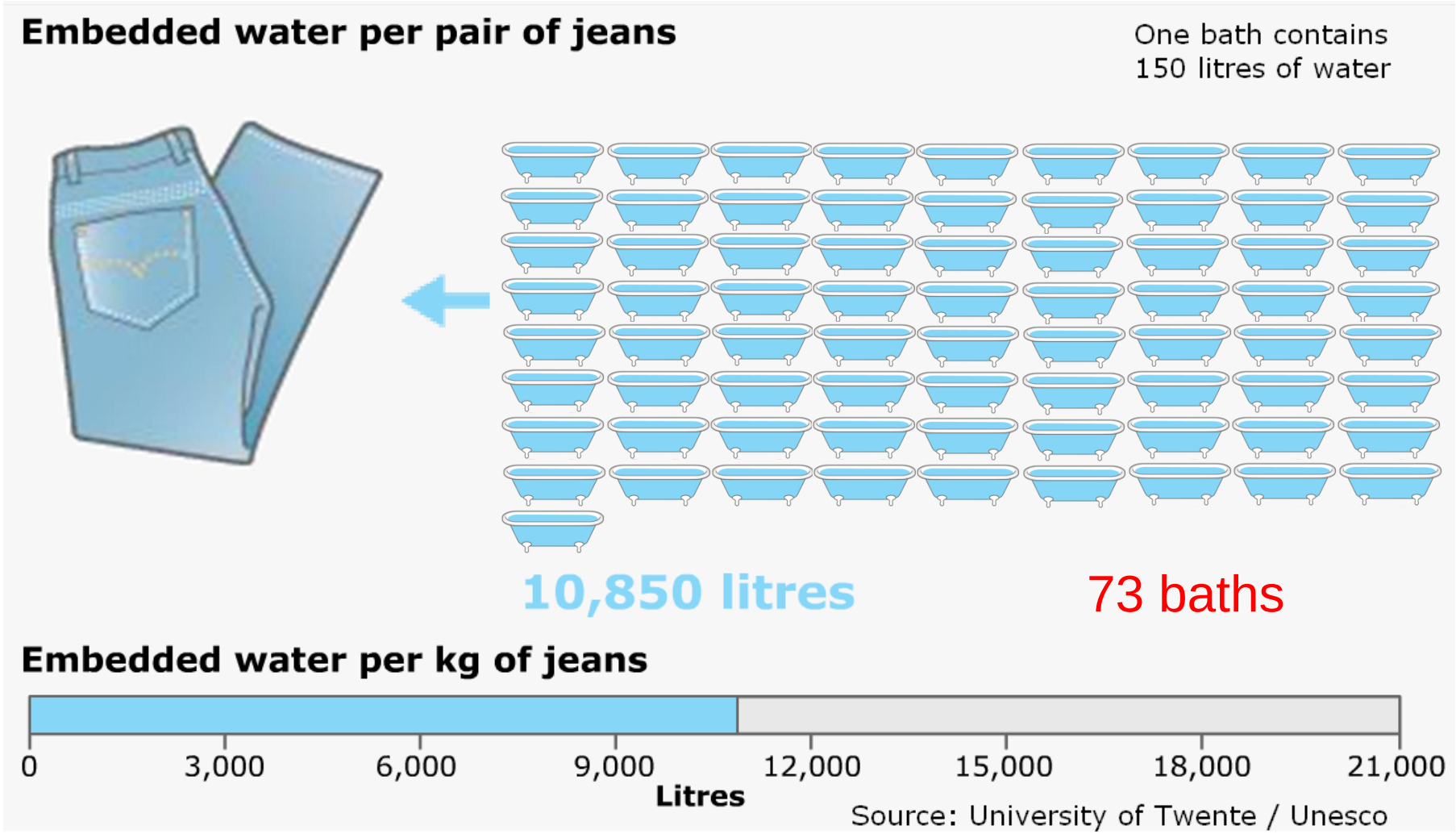
  Internal Water Footprint ⇨ from inside country

  External Water Footprint ⇨ from other countries

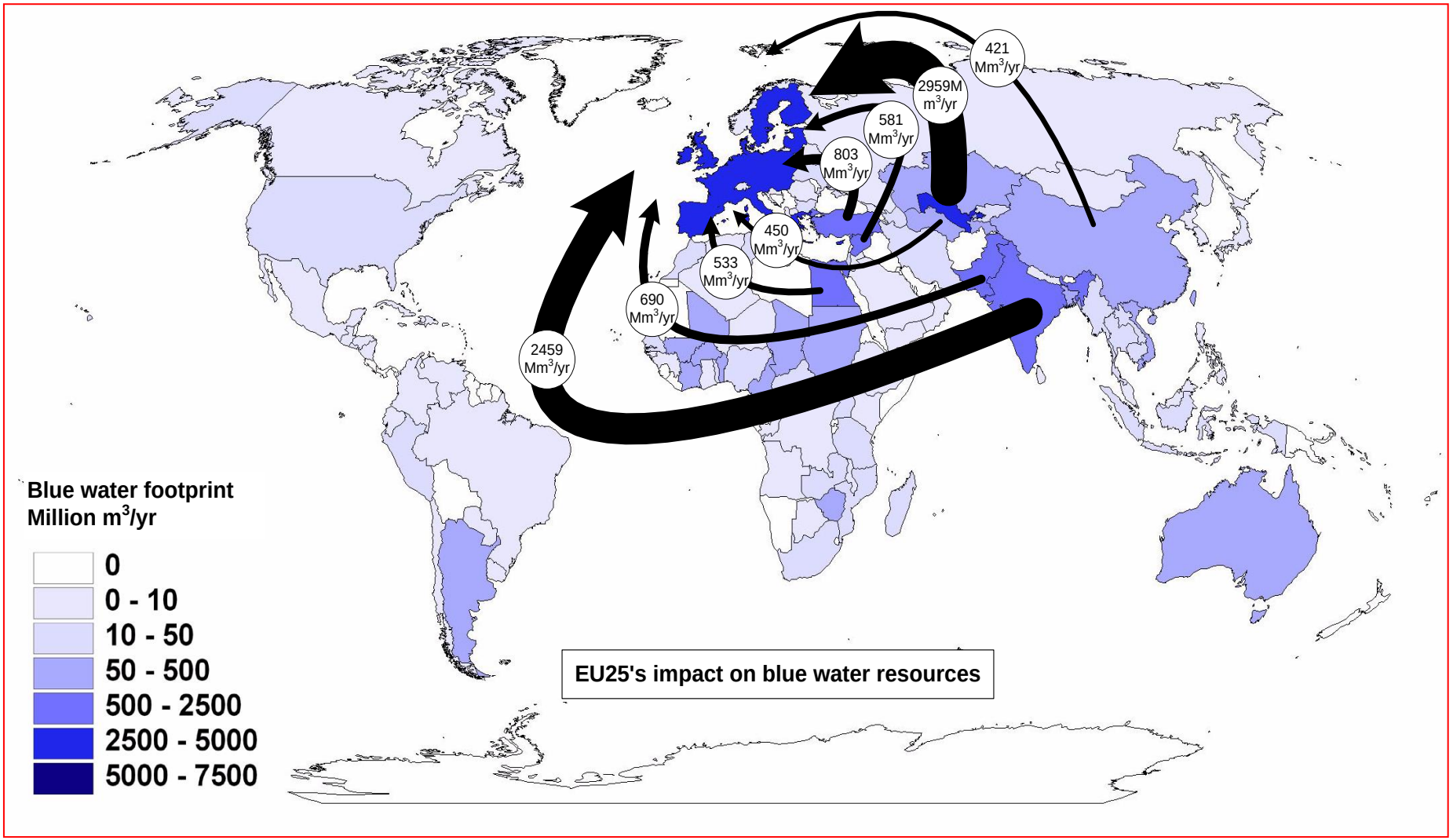
- Water Footprint of a Nation = Water used internally + Virtual water imported* – Virtual water exported*

*Imported/Exported through goods and services

Virtual Water Footprint



Blue WF of EU Cotton Consumption



SOURCE;Hoekstra & Chapagain, 2008]

Virtual Water Impacts ⇨ Shrinking Aral Sea

Consumption in one place can impact drastically on water resources elsewhere

Need to Educate Public ⇨ Culture Change?

Male news reader can wear same suit daily ⇨
Female expected to wear different clothes daily

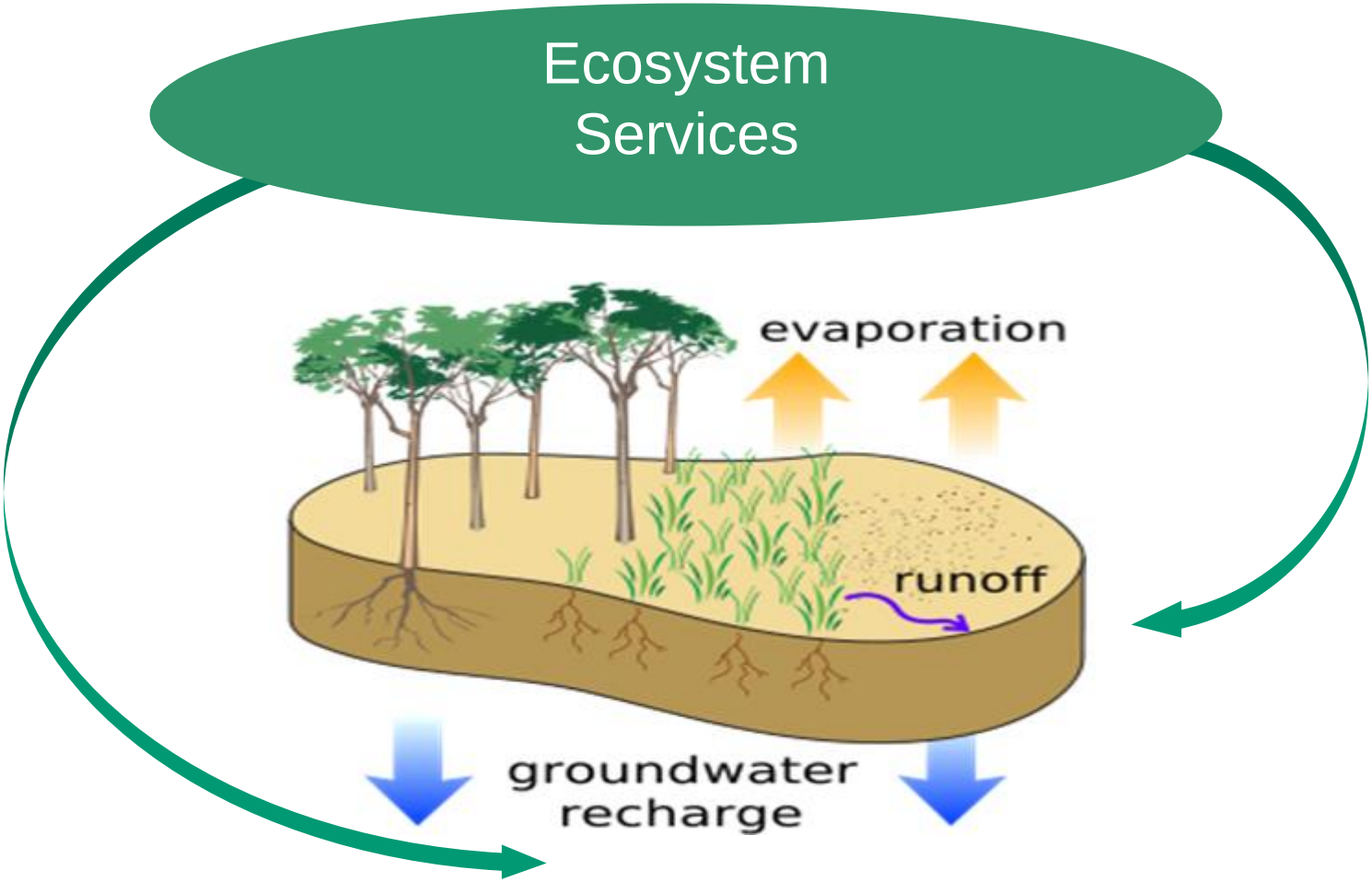
Who Should Pay ⇨ Polluted Discharges?

Polluted water discharges from agriculture need to be treated before returning to river

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

HOHAI UNIVERSITY 1915

Who Should Pay ⇨ Eco-systems Services?



Virtual water costs need to be included in products to maintain blue river water quality

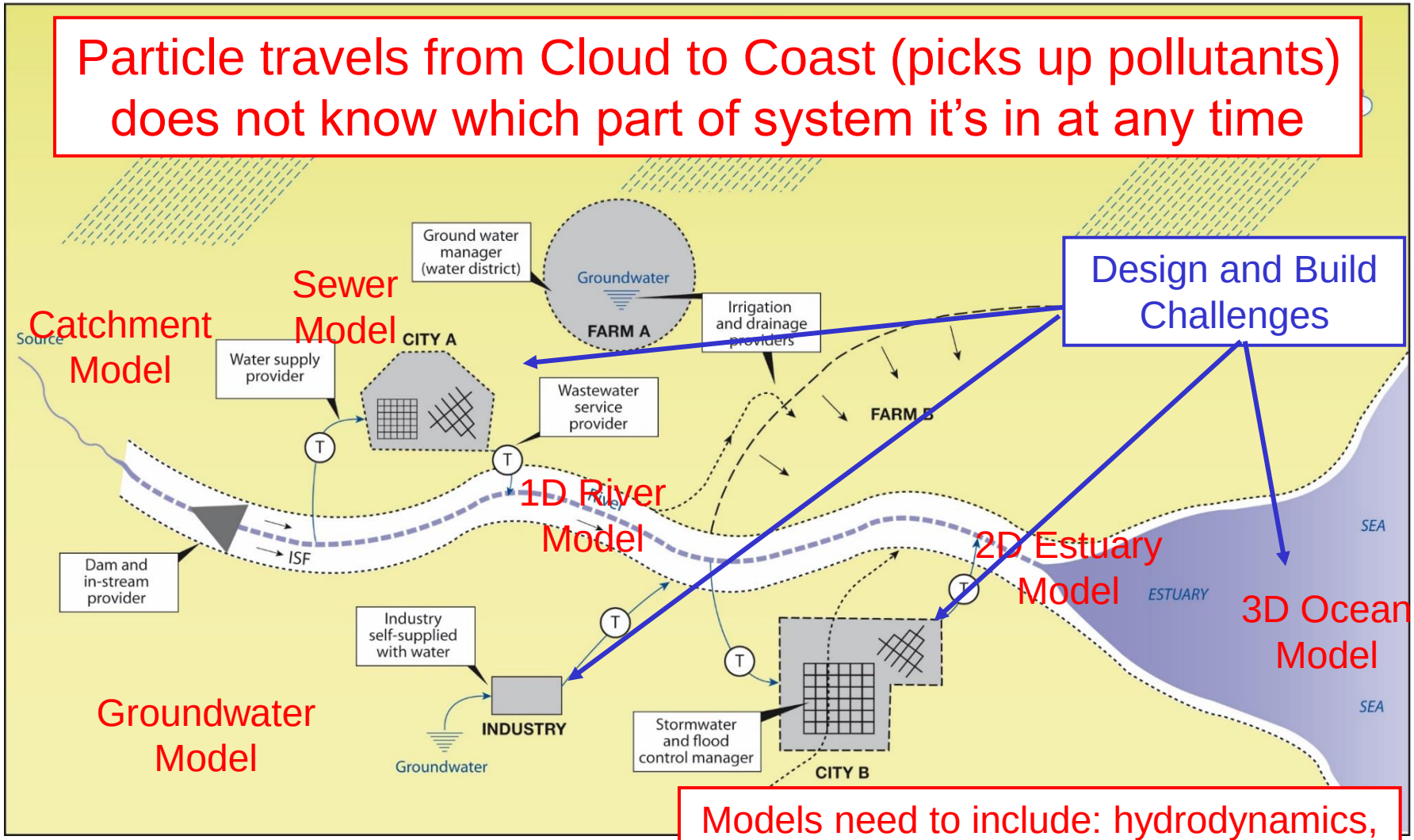
Example Water Solution ⇨ Vertical Farming

Source: https://www.Bloomberg.com/news/features/2017-09-06

Key details:

- High-tech farming ⇨ complex models
- Controlled humidity, temperature etc.
- Pesticide free
- 350 x more food per unit land area
- **Only 1% of water needed for food growth vis-a-vis traditional farming**

Cloud to Coast ⇨ Need Systems Solutions



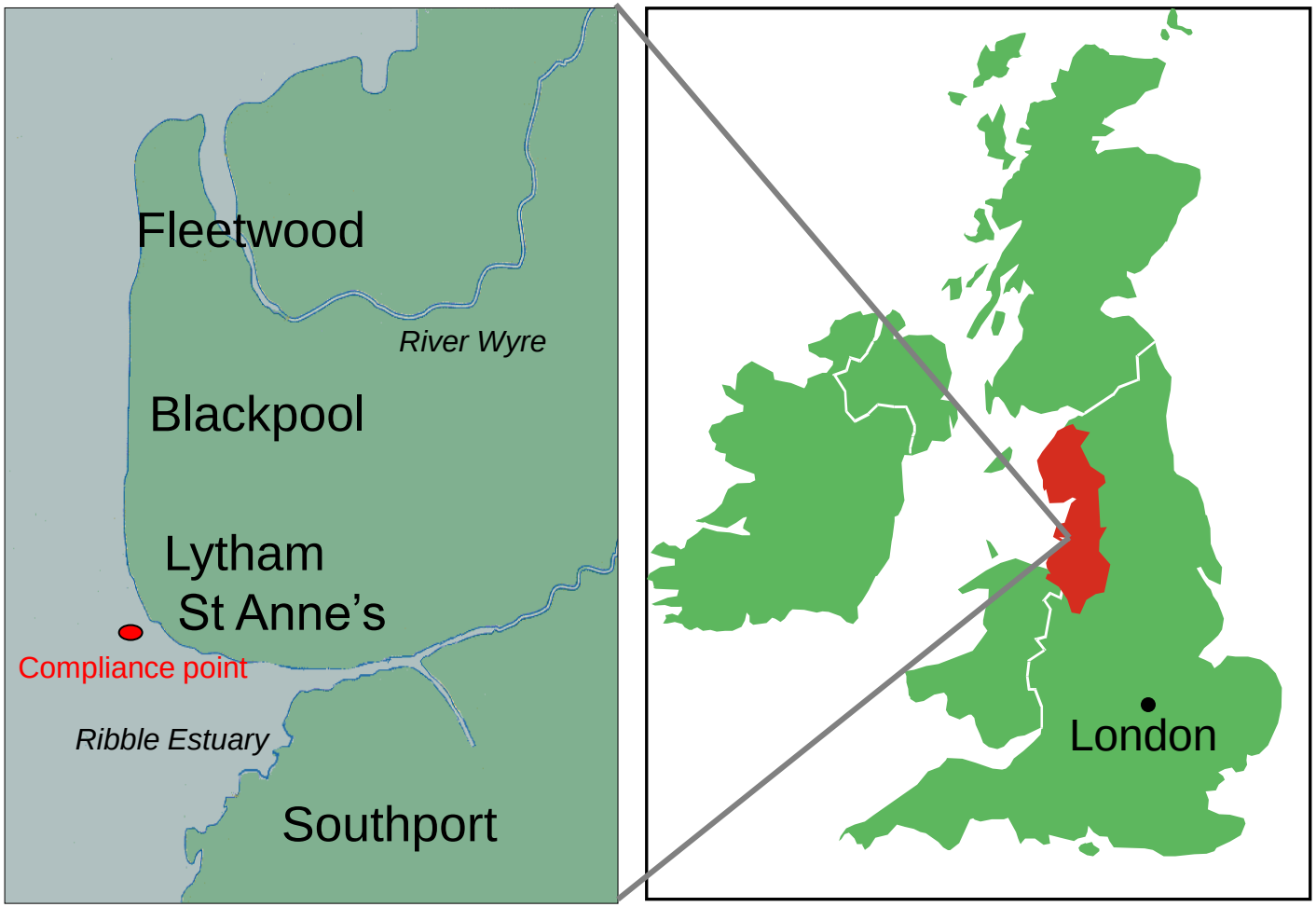
Regional Water Security ⇨

Why System Solutions?

Hydro-epidemiological Studies:

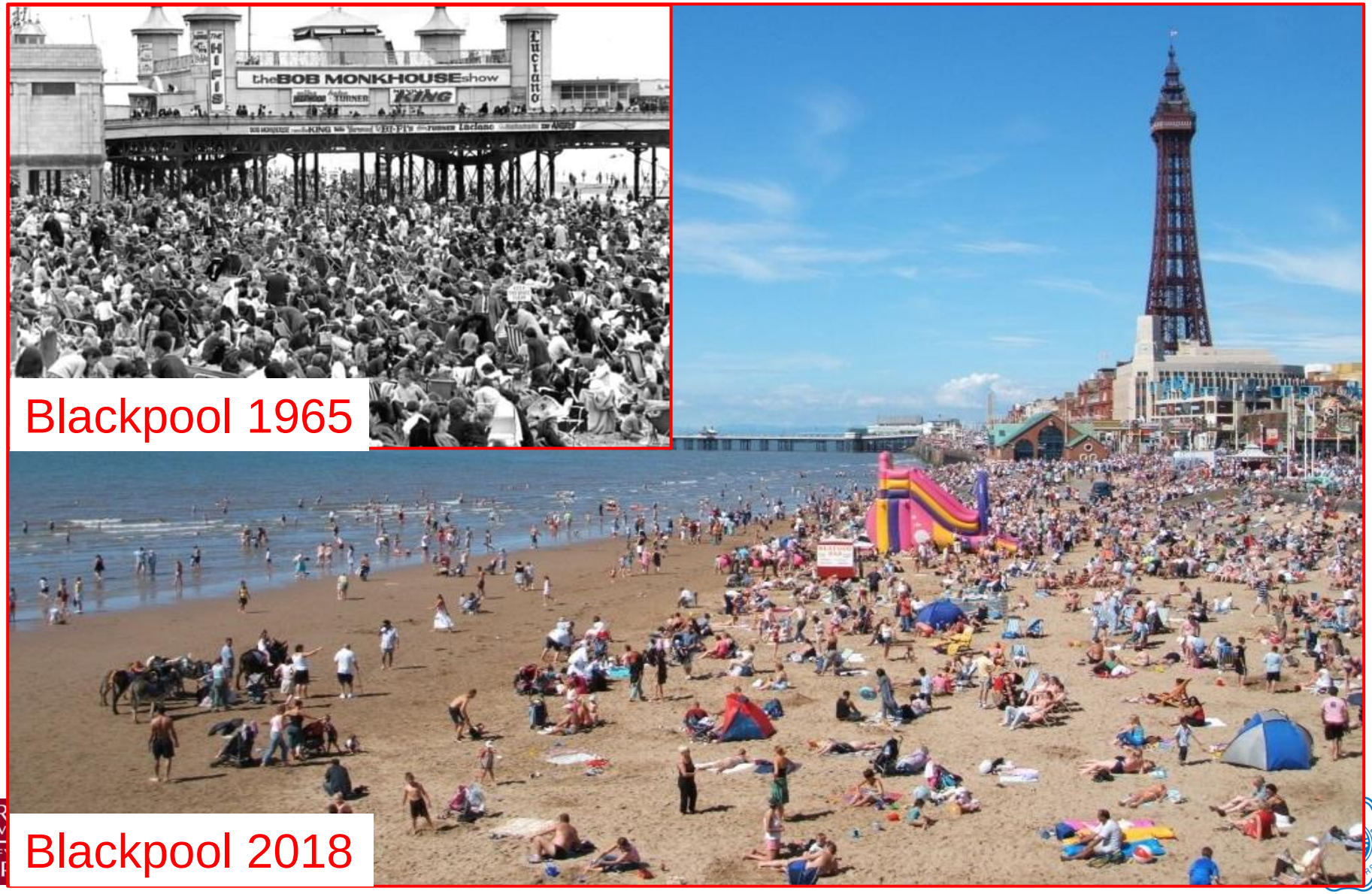
Ribble River Basin & Fylde Coast, U.K.

Ribble and Fylde Coast - NW England



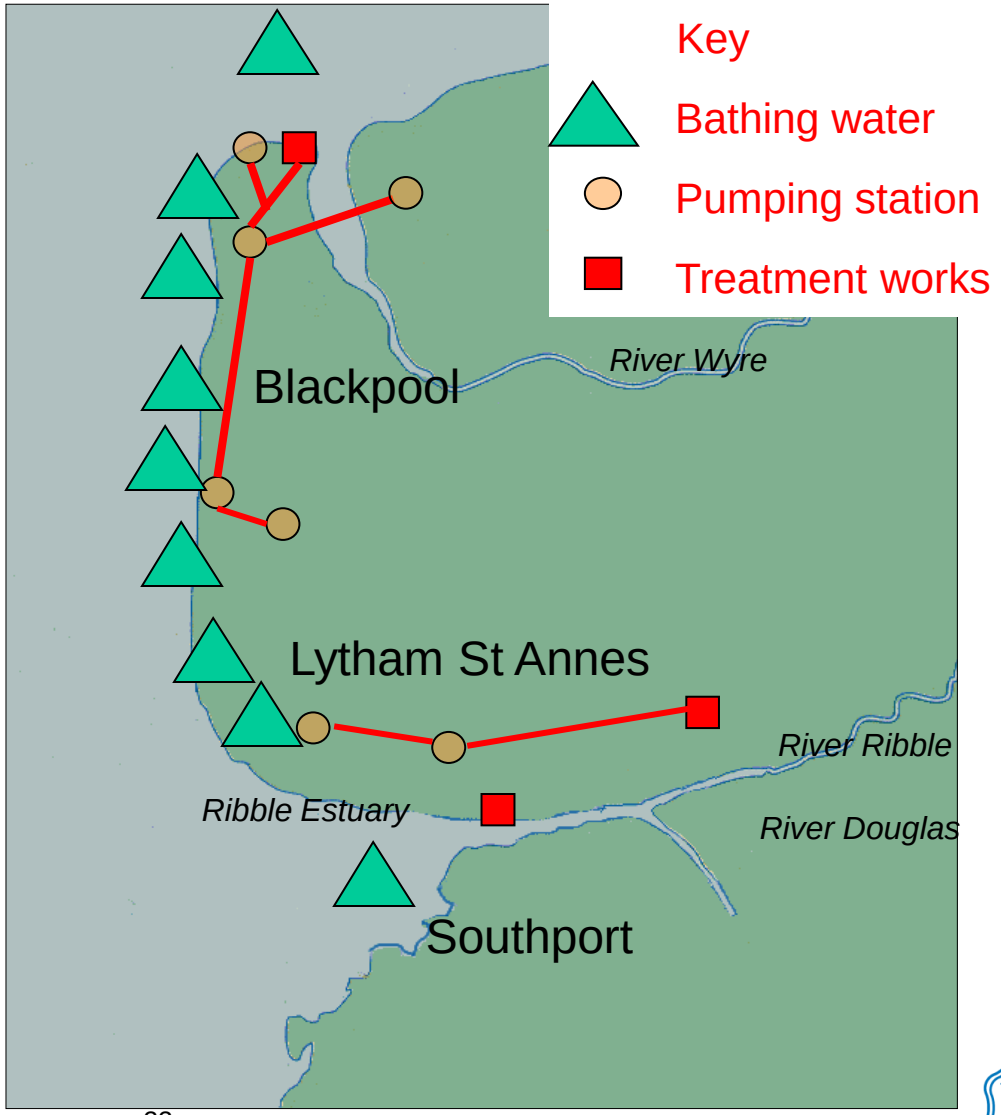
Blackpool ⇨ one of UK's prime tourist beaches

Blackpool ⇨ Prime UK Seaside Resort



Water Assets ⇨ Investments in 1990s

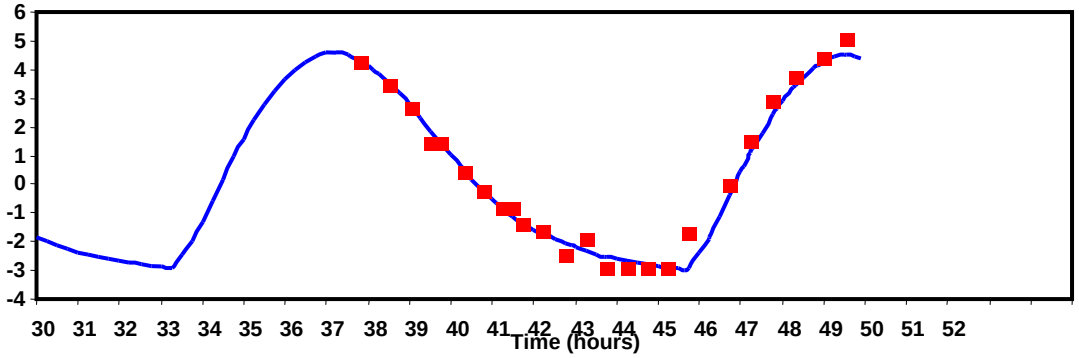
- $800M invested from 1993 – 96
- 3 new waste-water treatment works
- 5 new larger pumping stations
- Still some non-compliance during bathing season

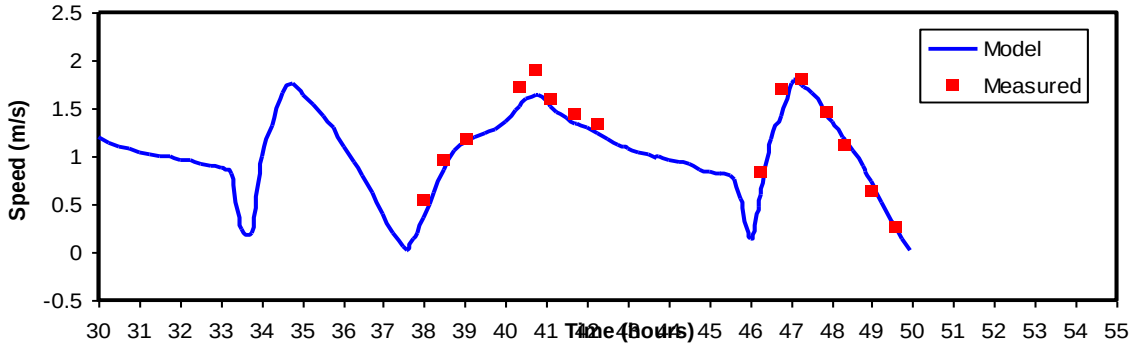


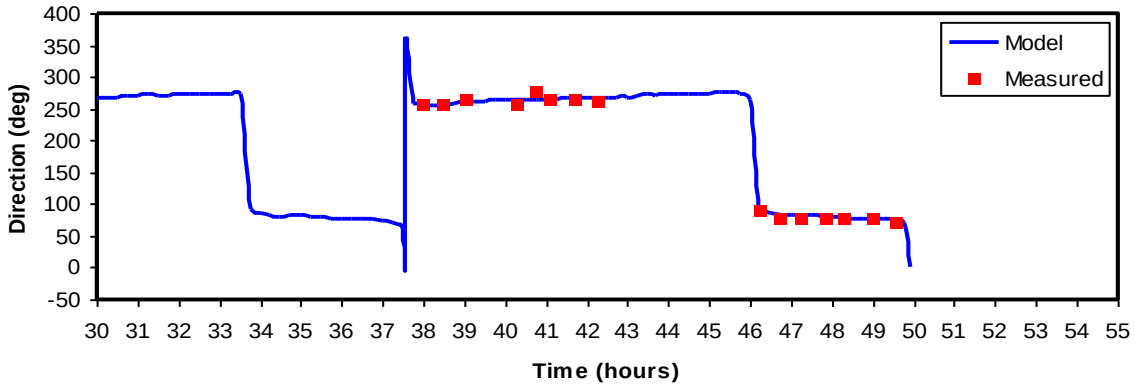
Background & Aim of Studies in Mid-1990s

- Failure to meet 1976 EU Bathing Water Directive
- Main problem ⇨ thought to be Combined Sewer Overflows (CSOs) discharging along coast & river
- Field surveys alone failed to identify main causes of non-compliance with EU BWD
- Aim ⇨ refine HRC hydro-epidemiological models
- Quantify impacts of CSOs and catchment inputs on bathing water compliance along Fylde Coast
- Investigate influence of tides, river & CSO inputs, winds etc. on bathing water quality & health risk

Water Level and Velocity Calibration

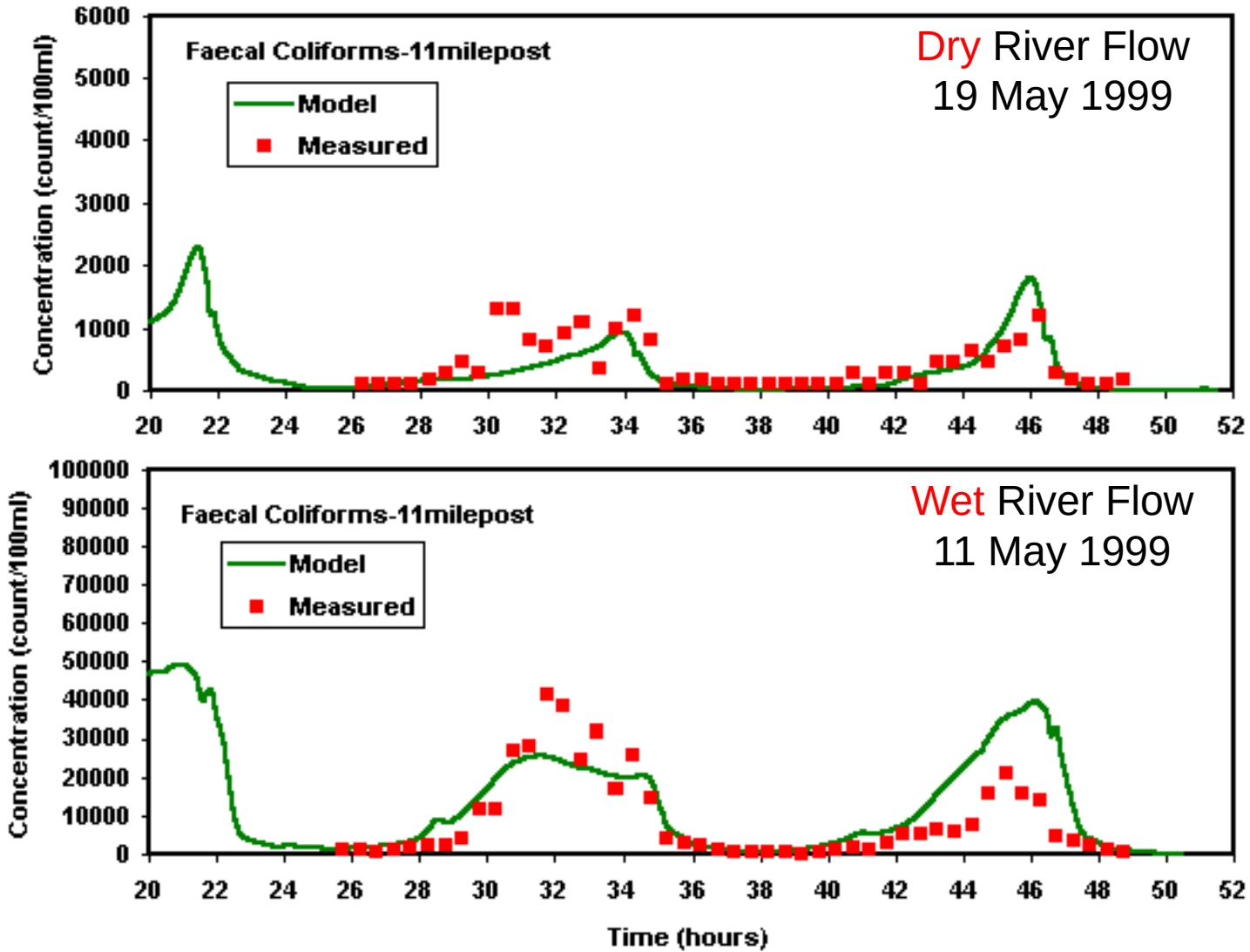






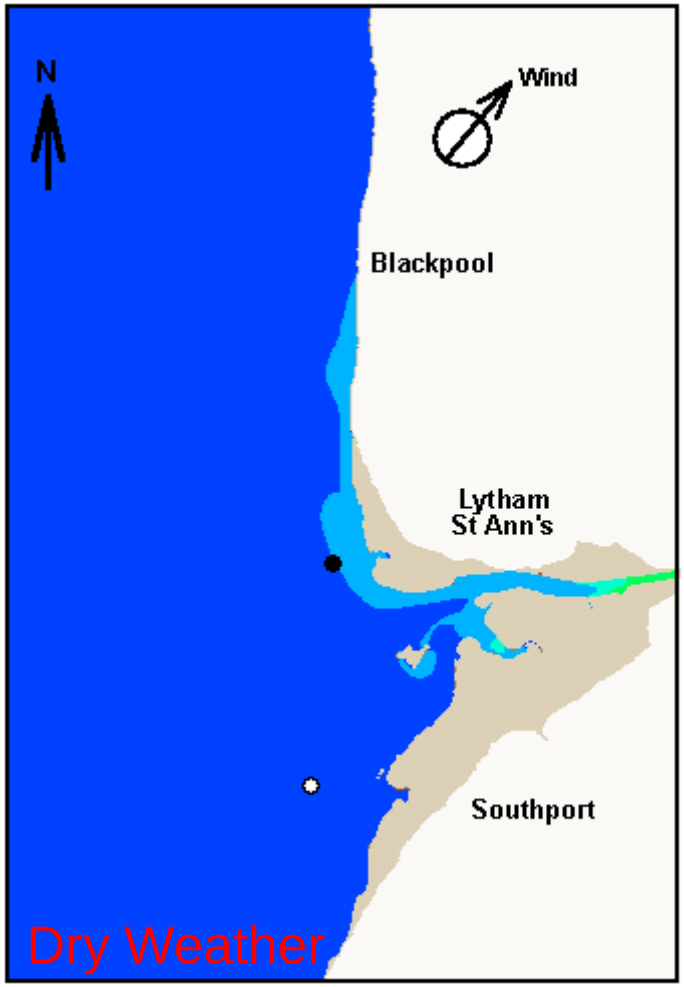
Ribble Estuary: Faecal Coliform Calibration

Model Calibration at 11 milepost



Faecal Coliform Model Predictions

Ribble Estuary and Fylde Coast, UK

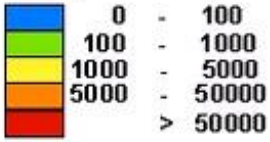


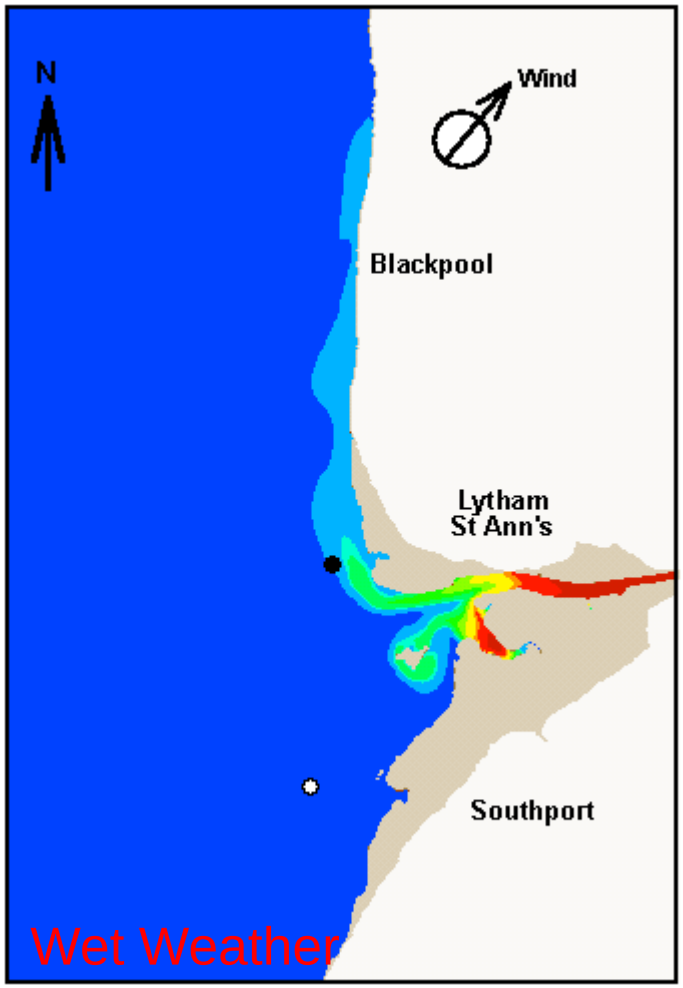
Compliance Points

- St Anne's Pier
- Southport

Simulation Time

49 : 36





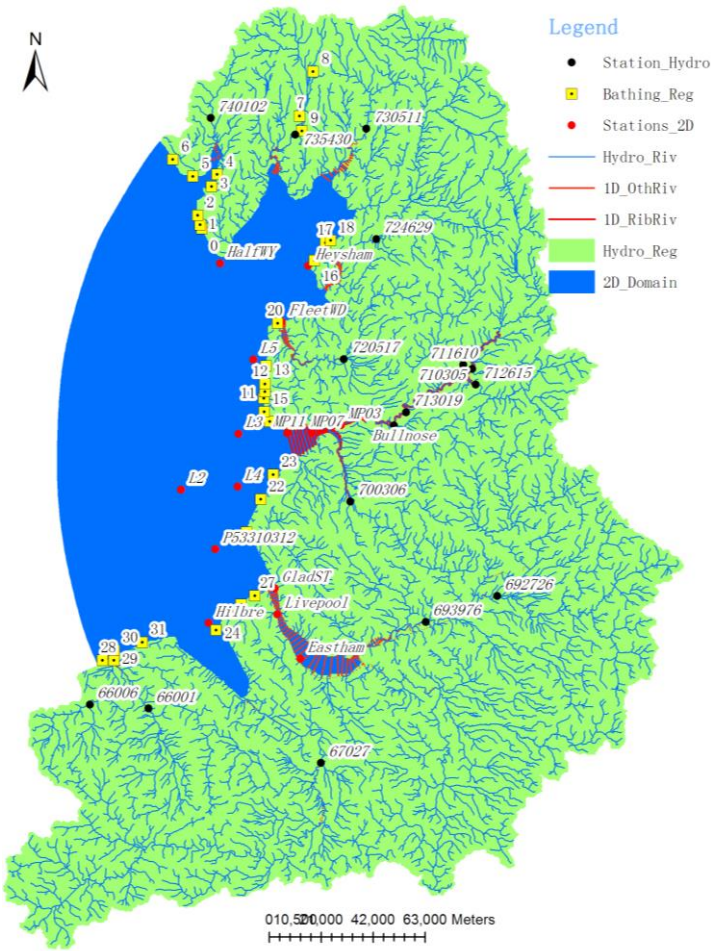
Review of Completed Study (2010-12)

- These studies by HRC researchers gave good model agreement when calibrated separately for linked 1-D & 2-D models, but needed:
  - Different values of kinetic decay rates
  - Different values of dispersion-diffusion coefficients
  - Different flow area representations over linked region
  - Different values and formulations for roughness coefficients in 1-D (k_s) and 2-D (n) models
  - Simplified treatment of decay and source inputs for highly episodic point and diffuse source inputs
  - 3-D modelling of hydro-epidemiology in coastal zone

Major New River Basin Study ⇨ 2011-16

- EU Water Framework Directive 2006, applied from 2015, has much stricter Bathing Water standards
- Concern about impact of recent land use changes on river basin & coastal bathing water quality
- Develop an integrated Catchment-to-Coast model ⇨ with urban & rural inputs and land use changes
- Collect extensive data on *E.coli* loads and fluxes
- Model hydro-epidemiological processes to predict *E.coli* levels & health impact along Bathing waters

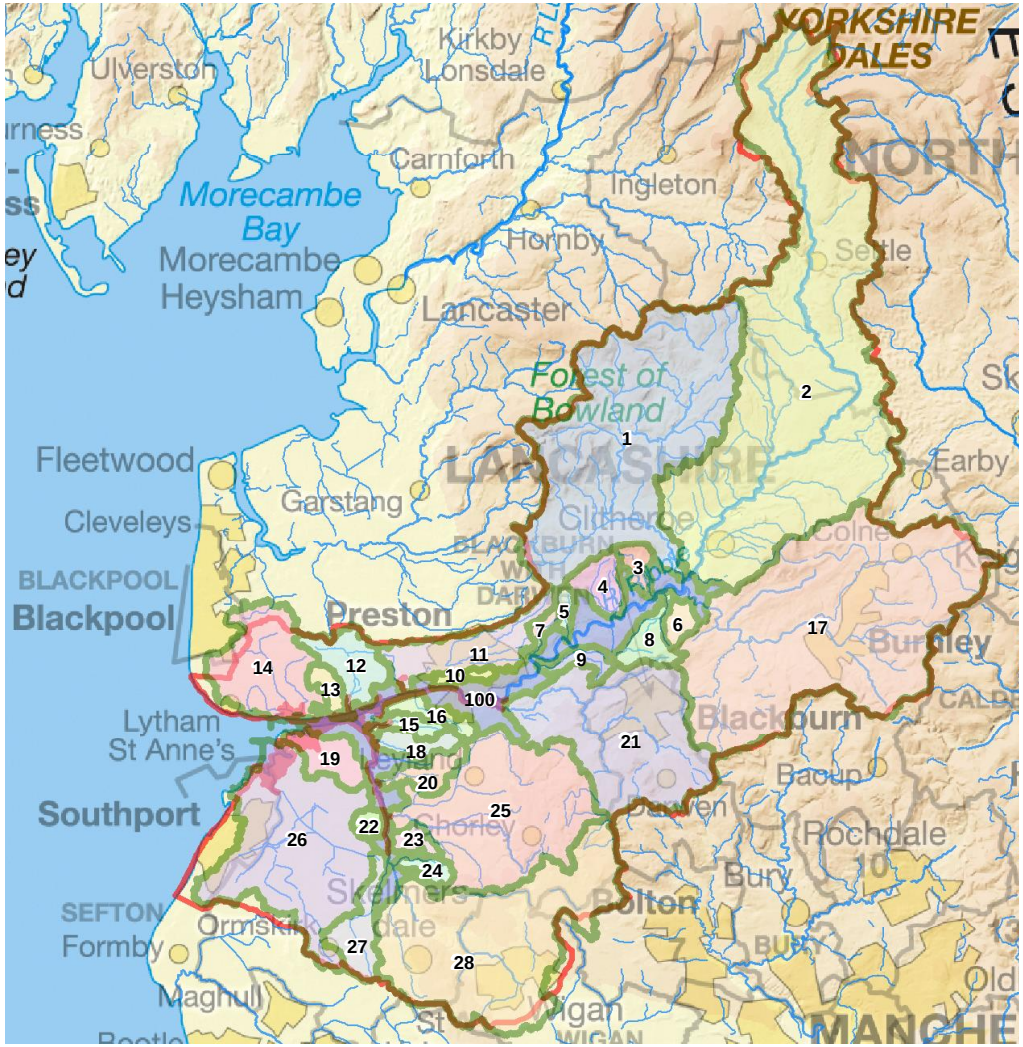
Integrated Model Studies for EU WFD 2015



Study Included:

- Catchment, river and coastal models of flow, sediment & *E.coli* processes
- Extended 3-D coastal model including: tides, sediments & *E.coli* processes
- Climate & land use changes on urban & rural source inputs on river water quality & coastal *E.coli* levels

HSPF Catchment Configuration



- 28 different river basin & catchment types, including:

  (i) rural & urban,

  (ii) steep & mild terrain slopes,

  (iii) various land use types:- arable, pasture & forested

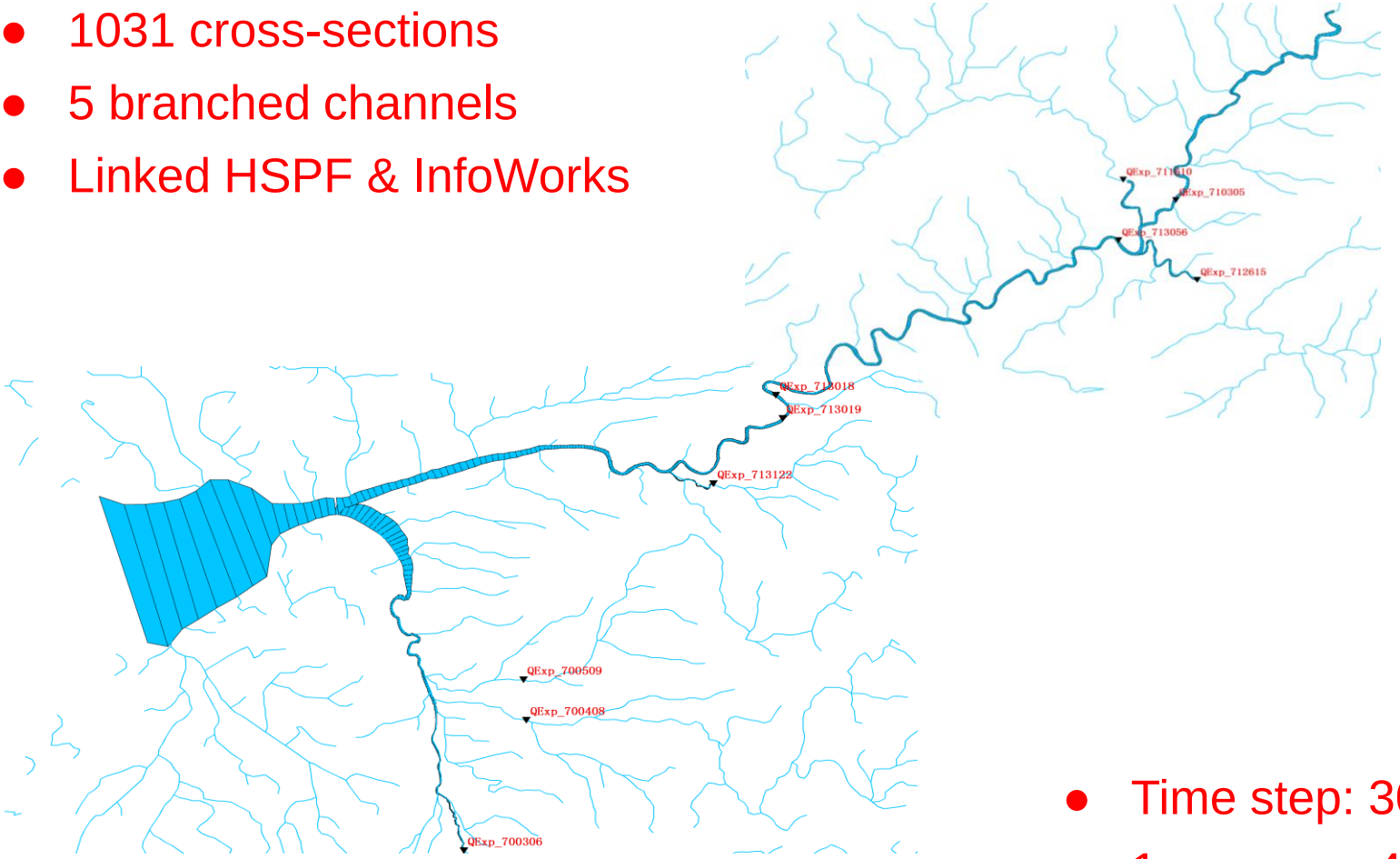
Field Surveys Along Coast and Estuary

- Comprehensive estuarine and offshore surveys
- Drogue tracking, water quality and irradiance depth profiles, and sediment samples from field surveys

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

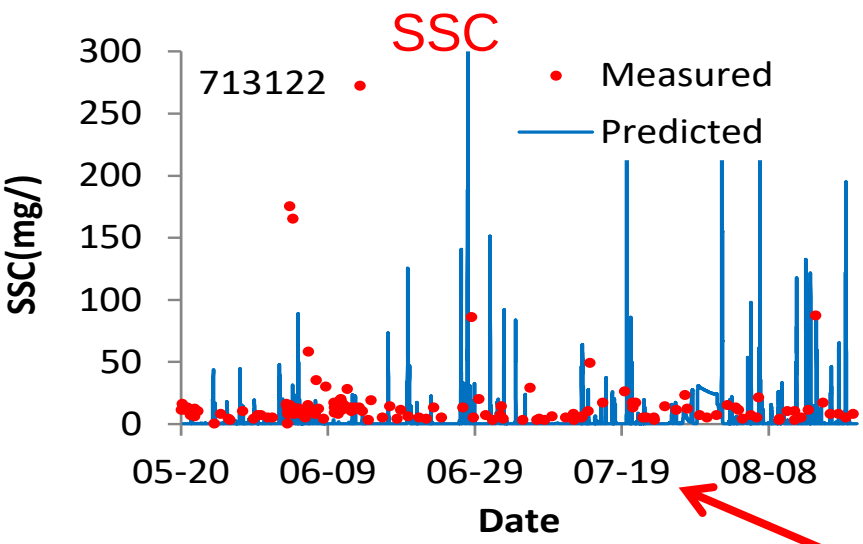
1D RNM ⇨ Model Configuration

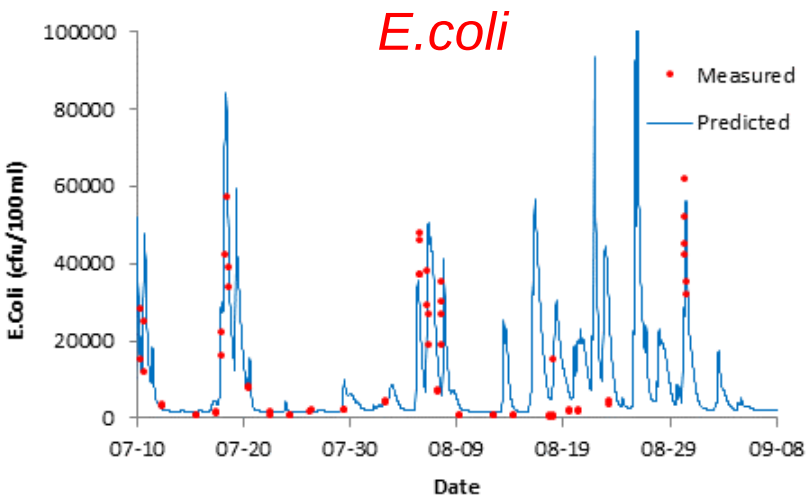
- 1031 cross-sections
- 5 branched channels
- Linked HSPF & InfoWorks

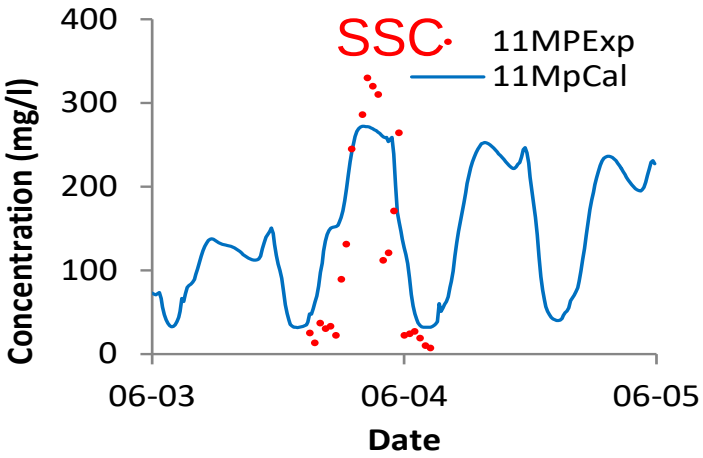


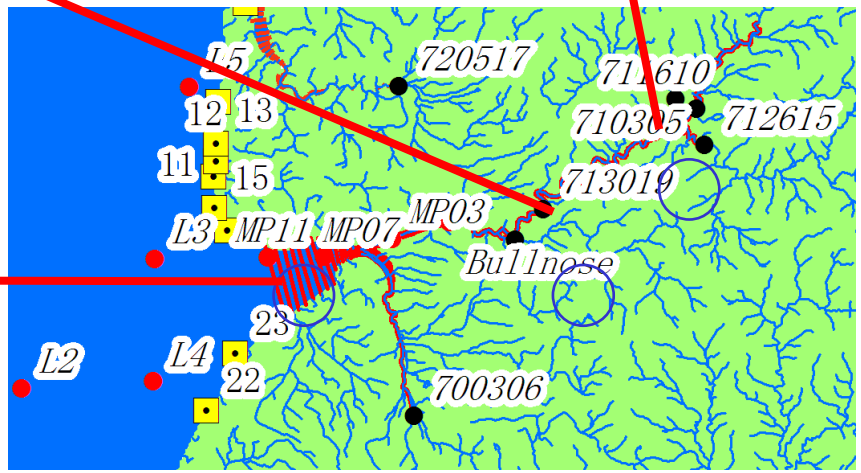
- Time step: 30s
- 1 year run: 40m

1D RNM ⇨ SSC and *E.coli* Verification



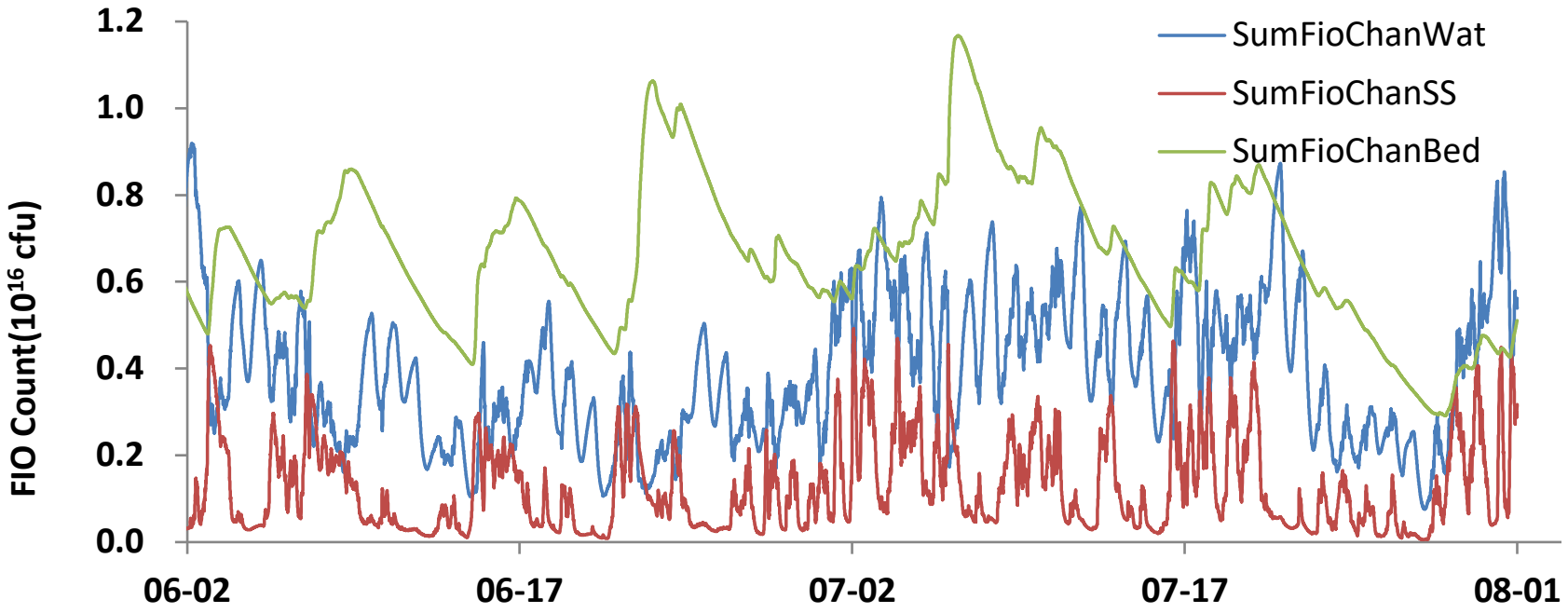






FIO Levels ⇨ River Column, SSC and Bed

- FIO distribution in river water, on suspended sediments and on bed sediments



Bed and Suspended Sediments with adsorption & desorption ⇨ important pathway for FIO transport

Conclusions ⇨ General and Specific

- **Water Security** ⇨ increasing concern, particularly with climate change ⇨ needs **Global Solutions**
- **Water Footprint** & **Virtual Water** ⇨ needs to be better understood by politicians, industry & public
- **Water Security** needs systems-based solutions at Global & Regional (Catchment to Coast) Scales
- **Hydro-epidemiological** studies show *E.coli* levels depend on hydraulics, biochemistry & source inputs
- **Sediment Transport** ⇨ Ad-/de-sorption of *E.coli* provides key FIO transport process in wet weather

Thank You

Professor Roger A. Falconer

Email: FalconerRA@cardiff.ac.uk