ENVIRONMENTAL
MONITORING
SOLUTIONS

VIRTUAL STORAGE SYSTEM

FOR FLOOD PROTECTION AND OTHER APPLICATIONS

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INDUSTRY'S ENVIRONMENTAL PARTNER

SERVICES TO THE WATER UTILITIES, TIER 1 CONSULTANTS, CONSERVATION AND RESEARCH

- Catchment Based Monitoring
  - StormCatcher
  - Remote water quality and nutrient monitoring and sampling
  - Workforce resourcing and management
- Flow and Load Surveys
  - Sewer flows
  - Wastewater treatment works
  - Large scale flow measurement
- Hydrometry – Specialist Flow Rate Measurement
  - Natural and urban environment
- Product Supply and Equipment Hire

MORGAN SINDALL

Thames Water

United Utilities

ems ENVIRONMENTAL MONITORING SOLUTIONS

MWH®

mouchel

Scottish Water
Always serving Scotland

EMS INNOVATION

- Remote Monitoring
- SMART Wastewater Networks
- Innovative Sensors
- Contract Innovation

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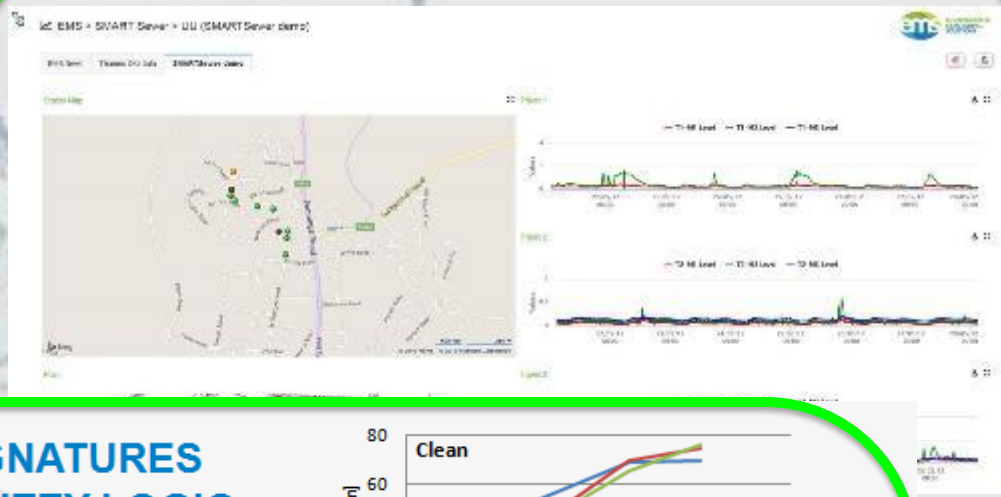
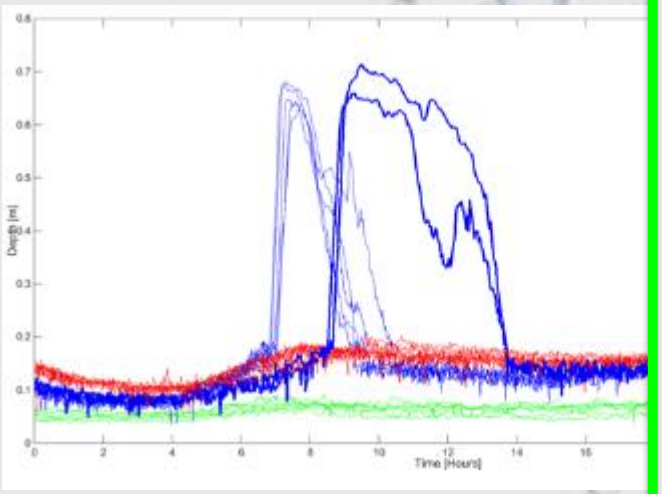
SMART SEWER

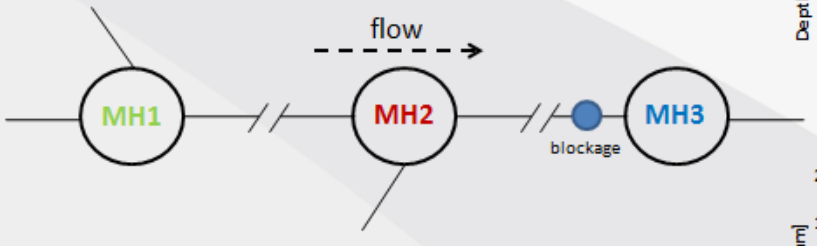
Project Co-funded by

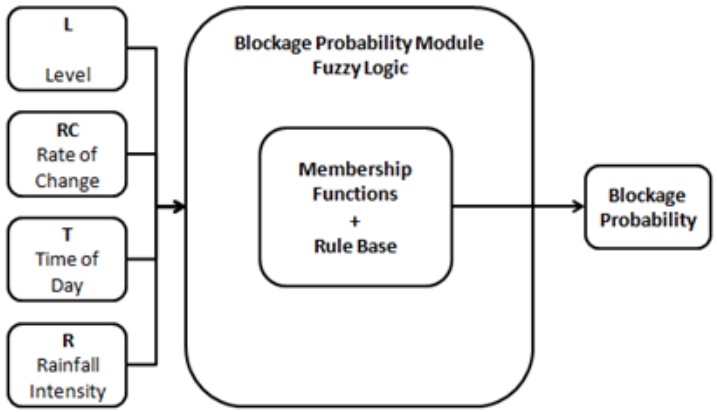
Innovate UK
Technology Strategy Board

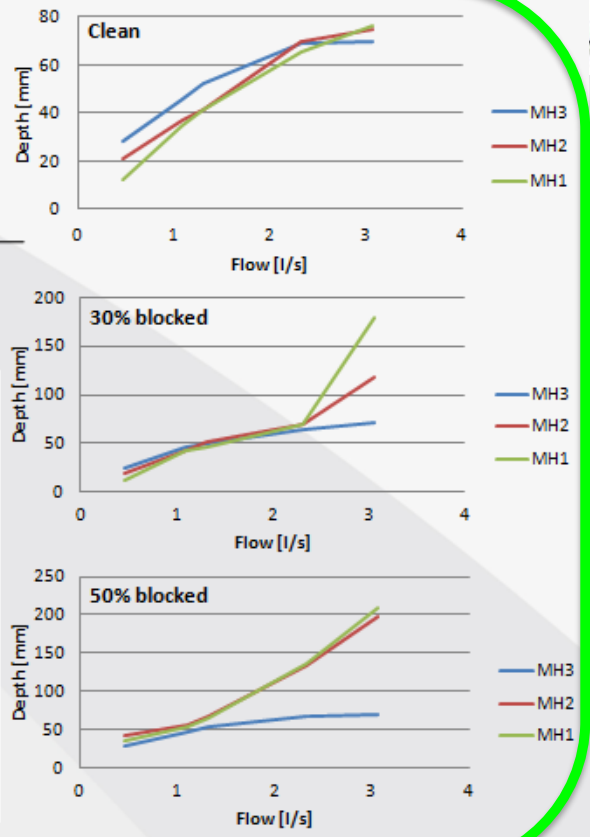




BLOCKAGE SIGNATURES DETECTED BY FUZZY LOGIC







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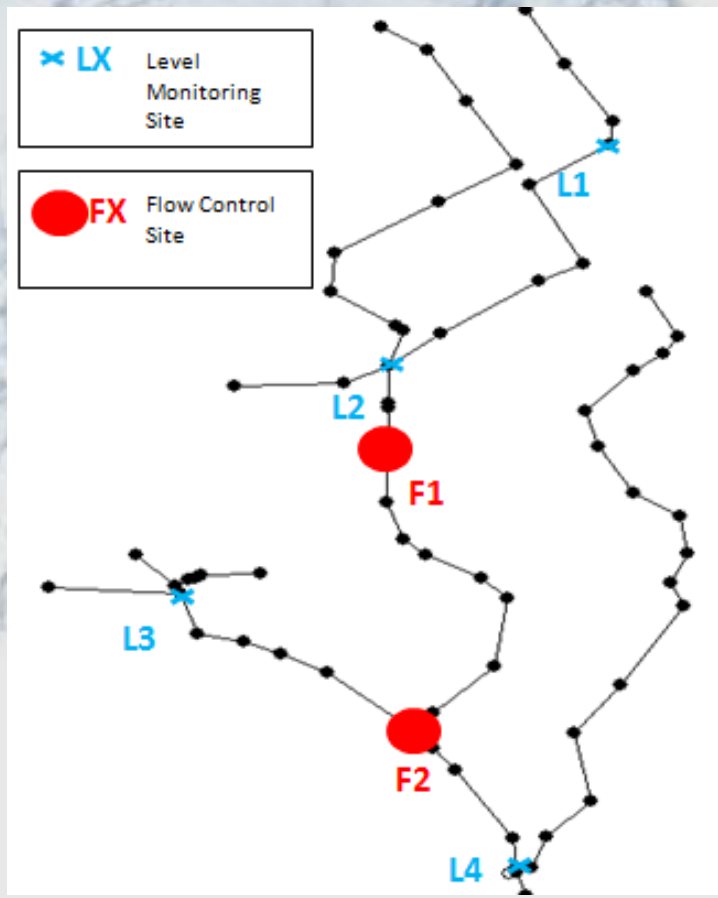
Cost Effective Neural Technique for Alleviation of Urban Flood Risk

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 641931

- **Universities**
  - Sheffield (UK)
  - Coimbra (Portugal)
  - EAWAG (Switzerland)
- **SMEs**
  - EMS (UK)
  - Steinhardt (Germany)
- **Water Companies**
  - Veolia (France)
  - Águas de Coimbra (Portugal)



Local real-time-control to utilise existing upstream capacity to avoid flooding

CENTAUR

- to reduce flooding and flood risk
- utilises existing storage capacity of pipes
- by local monitoring and control

- light-touch
- innovative
- cost-effective

- **C**ost **E**ffective **N**eural **T**echnique to **A**lleviate **U**rban flood **R**isk
  - at project inception, we anticipated using Artificial **N**eural Networks in the Control Algorithm

- However, we've settled on **F**uzzy **L**ogic**!**

ENVIRONMENTAL MONITORING SOLUTIONS

TODAY'S PRESENTATION

- Fuzzy Logic in wastewater applications
- The CENTAUR development story

TRL 1	Basic principles observed and reported.	concept and modelling	2015
TRL 2	Technology concept and/or application formulated.		
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- Other uses of CENTAUR, e.g. rainwater capture and sewage recycling

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FUZZY LOGIC IN WASTEWATER APPLICATIONS

FUZZY LOGIC: BACKGROUND

- Embedding structured knowledge (experience, expertise, heuristics) into workable models

- When to apply Fuzzy Logic:
  - human (structured) knowledge is available
  - mathematical model is unknown or impossible to obtain
  - analytical models are too complex, can’t solve the problem with reasonable time / cost / accuracy
  - process substantially nonlinear
  - lack of precise information

- Typically applied in generic decision-making processes or at the higher levels in hierarchical control

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FUZZY LOGIC: WASTEWATER

- FL particularly suited to wastewater detection or control applications:
  - phenomena can be understood
  - but they are shrouded in variability
- FL Algorithms can capture
  - expert knowledge
  - the conclusions of lab and field experiments
  - modelling outputs
  - ……and can cope with their variability

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FUZZY LOGIC: BACKGROUND

Property	Fuzzy Logic
Transparency	"glass box" - contain linguistic rules which reflect real system knowledge
Data and Knowledge Sources	easily deployable - without training data requirements - ideal for uncertain problems with imprecise information - can take information from many data sources
Suitability	suitable for detection and control systems - with existing expert knowledge

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FUZZY LOGIC: WASTEWATER EXAMPLES

- **Detection**
  - blockage detection
  - state detection of overloads in anaerobic wastewater treatment
  - CSO failure

- **Control**
  - pump station control and optimisation (energy use)
  - treatment process control (additives)
  - control of an activated sludge plant (using fuzzy reasoning)
  - energy saving and nitrogen removal optimisation in the aeration process
  - in-line control of non-linear pH neutralization

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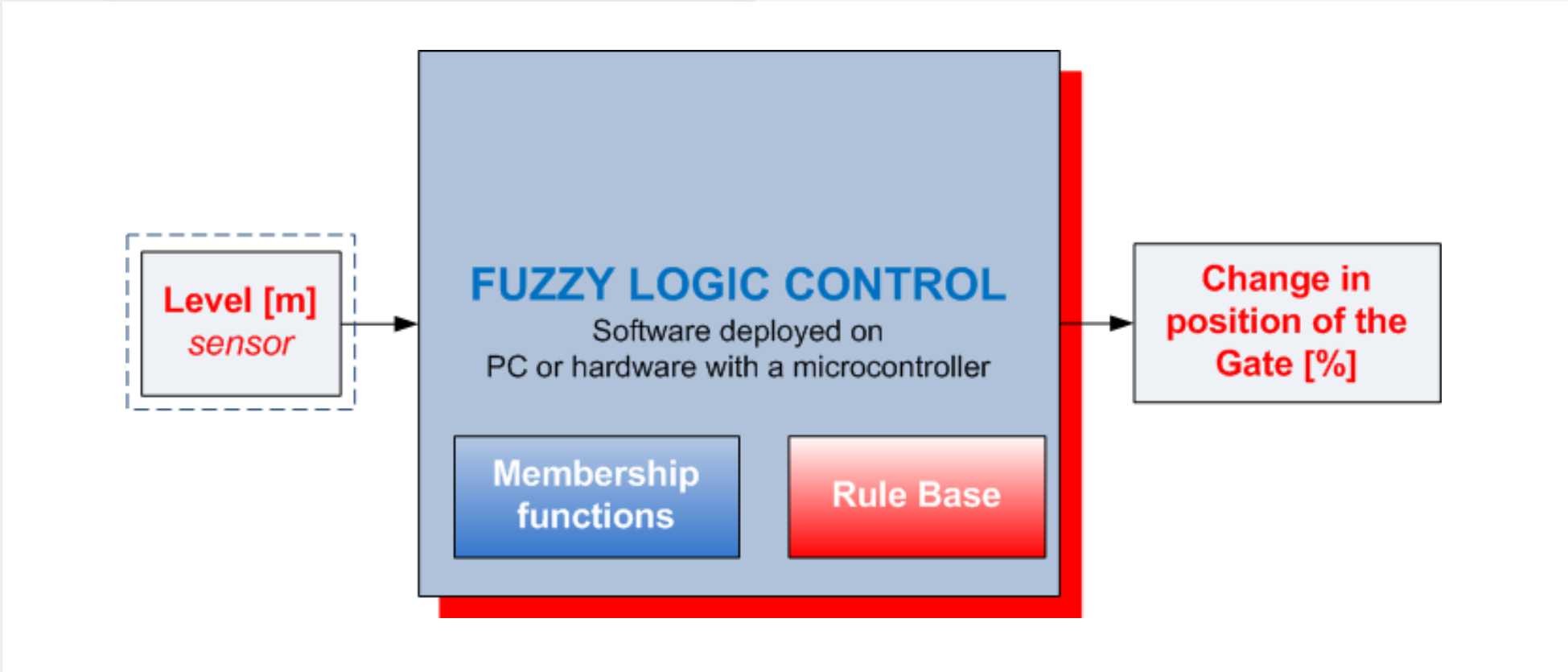
FUZZY LOGIC: IMPLEMENTATION IN CENTAUR



DEVELOPMENT OF CENTAUR TO TRL3

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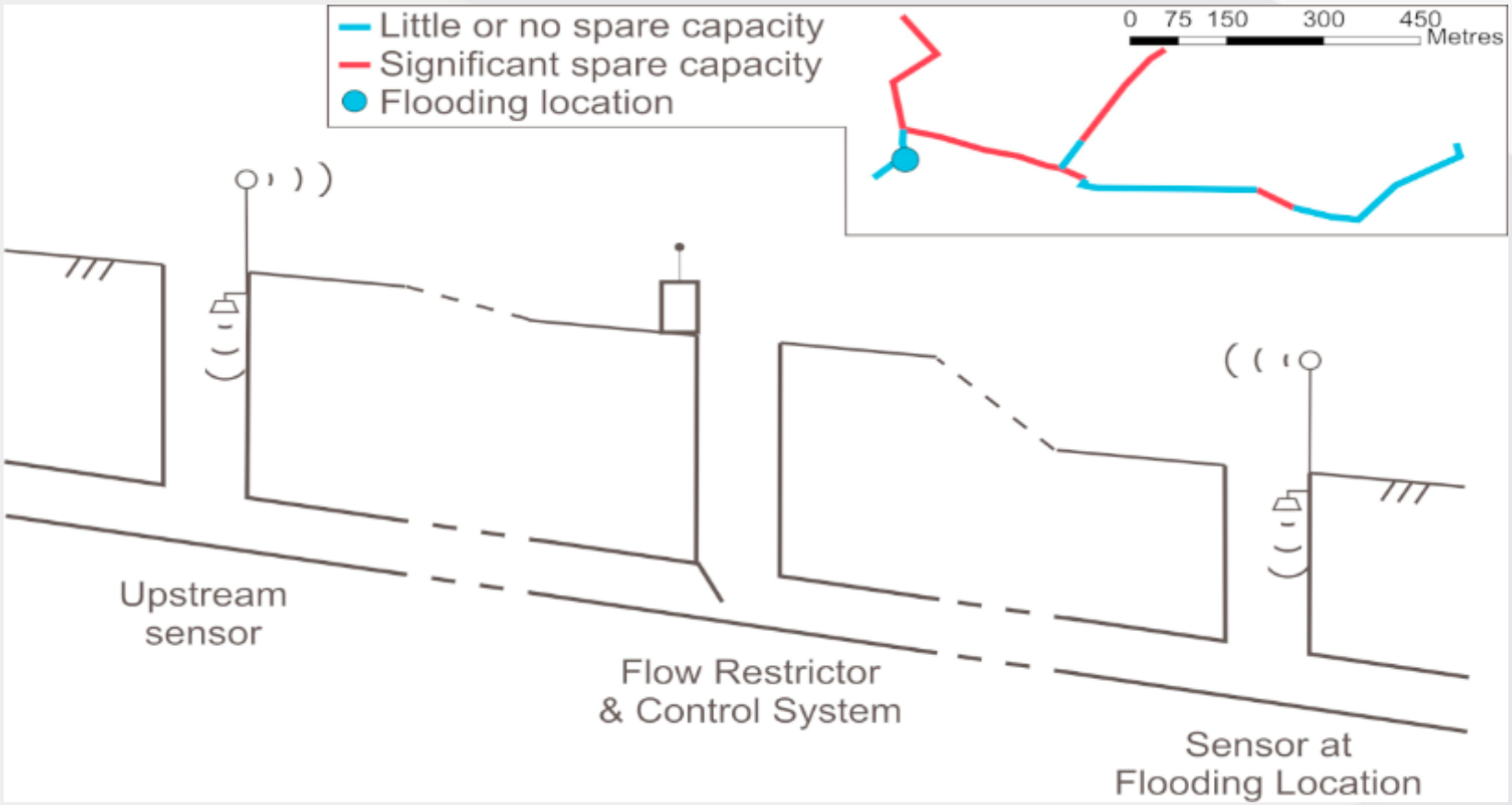
BASIC PRINCIPLES (TRL1)

1. reduce downstream flood risk at known flood locations
2. data driven – local sensor network
3. installation in existing infrastructure
4. instead of capital intensive intervention at many times the cost



NOTE: minimal transfer of flood risk upstream, e.g. the Coimbra system was designed so flooding only occurs upstream during a 1/100yr storm

TECHNOLOGY CONCEPT (TRL2)

- **CONCEPT**
  - local, data-driven control by intelligent algorithm, to reduce flooding / flood risk

- **EXISTING RTC SYSTEMS**
  - system-wide approach, “heavy-touch” approach
  - often based on predictive modelling – calibrated network hydrodynamic model

- **SYSTEM**

  - **hardware**
    - depth sensors
    - flow control device
    - central control hub
    - modems, wireless network

  - **software/firmware**
    - specialist operational firmware
    - control algorithm
    - web-enabled remote configuration
    - off-line, web-hosted system auto-optimisation

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INITIAL PROOF OF CONCEPT (TRL3)

Rainfall event return period (years)	Existing Flood Volume (m3)	Residual Flooding (m3) – after installation of active control	Captured flood volume with simulated CENTAUR device [%]
0.5	17.5	0.0	100
1	45.2	0.0	100
2	95.1	0.0	100
5	213.4	0.0	100
10	356.4	48.1	87
20	559.2	264.7	53
30	710.9	424.8	40

In this modelled example, flood risk is significantly reduced

- without CENTAUR flooding occurred in one in 6 months event
- with CENTAUR, no flooding until 1 in 10 year event

PROTOTYPE DEVELOPMENT AND DEPLOYMENT IN LAB (TRL4-6)

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PROTOTYPE CONFIGURATION

server

3G

Lora

CCH

roadside kiosk

Controller

PLC

Repeaters

Xbee

Gate Control Station

ground level

Level Monitoring Station

Target m/h

Control m/h

Upstream m/h

Actuator & Gate

Pressure Transducers

Pressure Transducers (triple redundancy)

Pressure Transducers

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FAIL-SAFES

Failure Modes

- Bad level data from an LMS (2 of 3 sensors to agree within a tolerance)
- Communication time-out between CCH and LMS
- Loss of communication with a Flood Control Station (where there is more than one FCS)

Response

- CCH sends 100% open control signal (to all gates)

Physical Fail Safe

- Ultimately, there are physical fail-safes in place; through-flow and overflow mechanisms built around gate

LMS = Level Monitoring Station
CCH = Communication and Control Hub
FCS = Flow Control Station

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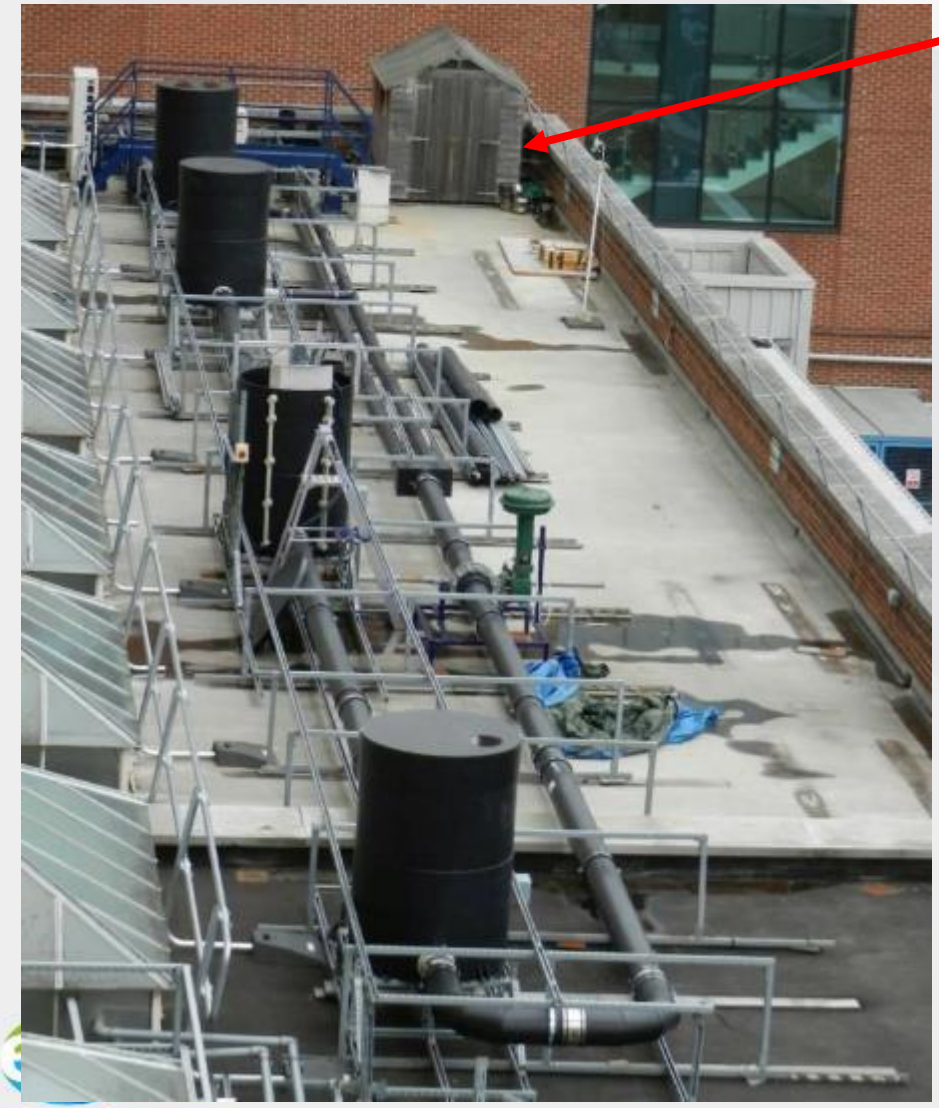
LABORATORY TESTING



Nerve Centre

(true British engineering)

PROTOTYPE DEPLOYMENT IN THE FIELD (TRL7)

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FLOODING IN COIMBRA

- June 2006: Return period = 50 years
- October 2006: Return period = 20–50 years
- September 2008: Return period = 5 years
- December 2013: Return period = 5 years

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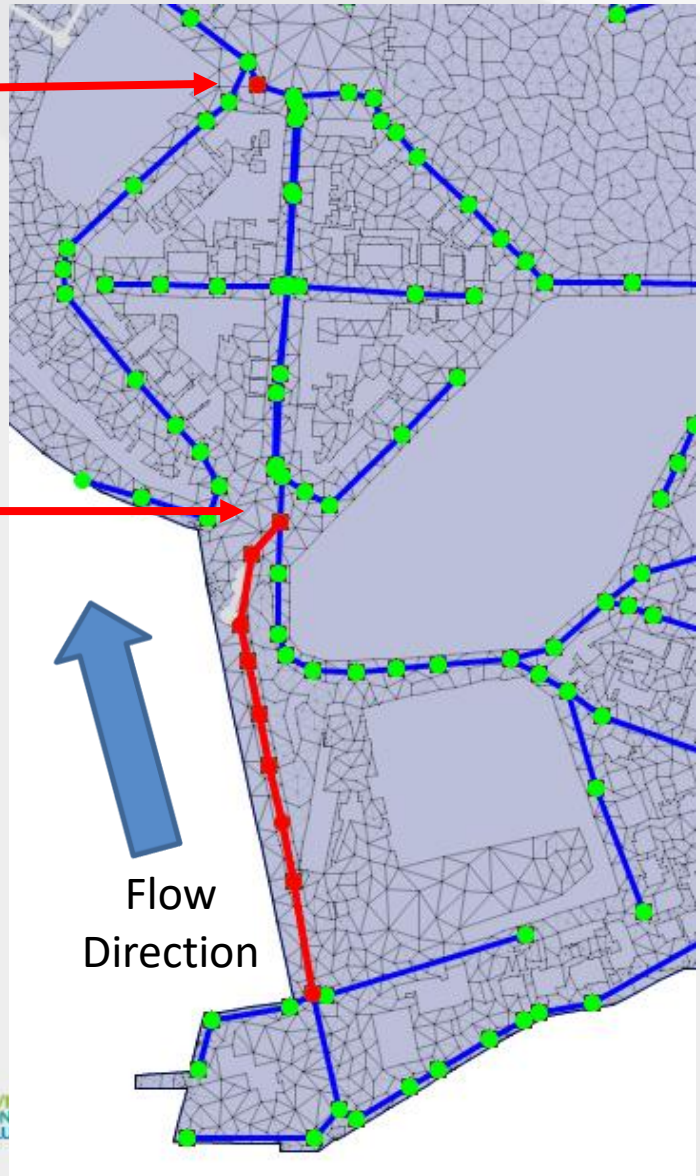
COIMBRA DEPLOYMENT

protected site

flow control site



COIMBRA DEPLOYMENT

Level Monitoring Station

Repeaters

Control Hub (Linux PC)

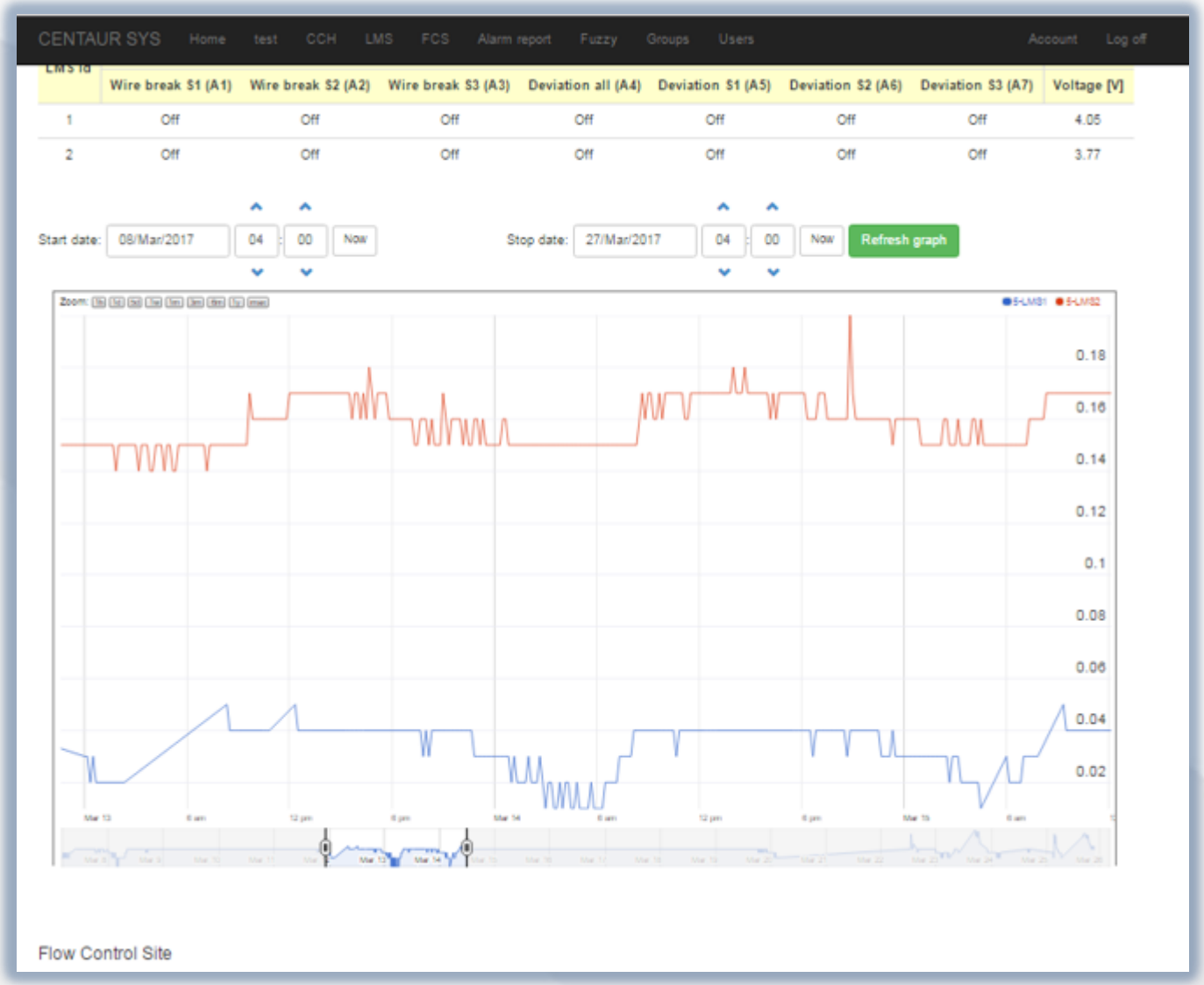
Gate PLC

Gate Control Station, Repeater

Gate

OPERATIONAL VISIBILITY

- Levels can be observed in near-real-time
- On screen alarming
- SCADA interface could be easily configured



online DASHBOARD for Coimbra system

BETA VERSION DEVELOPMENT AND DEPLOYMENT IN FIELD (TRL8)

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- testing of beta version in lab in May/June

- deployment in Toulouse in July, France (Veolia)

MARKET DEPLOYMENT AND ALTERNATIVE USES

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GO TO MARKET FOR END OF AMP6, AMP7

- Some flood benefits may need bringing online quickly to hit AMP6 ODI targets
- CENTAUR may be factored into AMP7 plans

OTHER “ECONOMIC” USES

1. Re-analyse on-the-shelf studies
    - where larger engineered solutions aren’t cost-beneficial
    - CENTAUR may make these cost-beneficial
2. To give flood-risk benefit to defer major spend
3. To reduce flood risk at sites that haven’t historically flooded but are known to be risks
4. To “increase capacity” to accommodate urban creep

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DIFFERENT USES

- Limiting CSO spills
- Regulating flows into pumping stations and treatment works
  - energy intensive assets
- Complementary solution
  - e.g. to reduce the size of an intended storage tank
  - e.g. in combination with SUDS
- **Rainwater capture and sewage recycling**

- *It may sometimes be possible to achieve multiple benefits through a single deployment*

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RAINWATER CAPTURE AND SEWAGE RECYCLING

INTELLIGENT WASTEWATER NETWORK

- 50 years down the road……..
- ……..the wastewater network may eventually become autonomous and self-regulating
  - monitoring technologies: detection of anomalies, prioritising actions
  - control technologies
- **However, networks in different parts of the world have to fulfil different functions**

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EASING PRESSURES ON INFRASTRUCTURE

- Pressures on infrastructure
  - climatic change (e.g. more peaked storms, lower rainfall)
  - population growth and urban expansion

- CENTAUR can be implemented in existing infrastructure to:
  - mitigate the impact of climate change - protection from flooding
  - secure an adequate sewage buffer for recycling
    - a virtual reservoir
    - in dry and wet weather conditions

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VIRTUAL STORAGE - SINGAPORE EXAMPLE

- Population, 5 million
- water-scarce country due to limited land area
  - half of water supplies are imported from Malaysia
- current strategies: i) desalination, ii) efficient rainwater capture, iii) recycling of sewage
- new options for water supplies are needed
- during heavy rainfall, much of the rainwater discharges to the sea.

"*Climate change increases the probability of both intense rainfall and prolonged periods of drought. So if we and indeed if water utilities and authorities all over the world simply embark on business-as-usual, climate change will reduce yield of reservoirs and of water catchments all over the world in the decades to come.*"

(Environment and Water Resources Minister Vivian Balakrishnan, SIWW Jun 2016)

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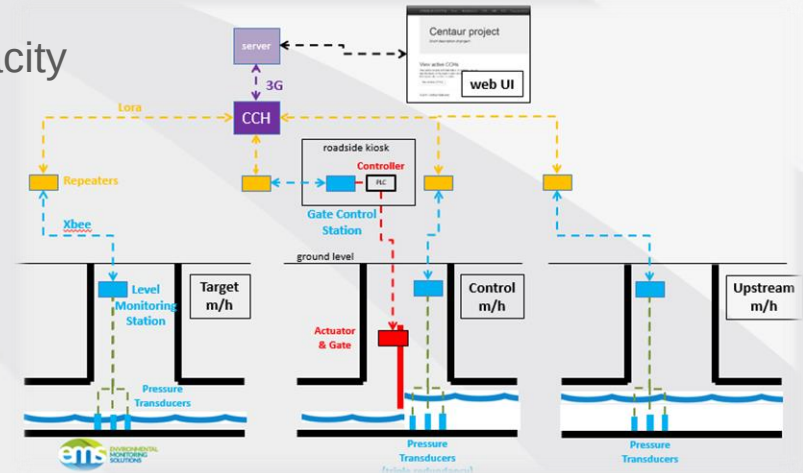
VIRTUAL STORAGE - SINGAPORE EXAMPLE

- Sewage recycling:
  - “NEWater” technologies are transforming wastewater to qualities better than tap water
  - 30 percent of Singapore's water supply is currently met by recycled water

CENTAUR SOLUTION

- Existing network capacity utilised as storage (“virtual storage”)
- Gates in parallel or in series depending on topology
- Gates “talking” to each other to
  - prevent flooding downstream
  - detain flow until there is a spare downstream or reservoir capacity
- Gates can be removed or added to optimise capacity
- Flexible, low maintenance, cost-effective solution



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SUMMARY

Development Story

- There is lots of work going on at TRL3
- … and some to TRL6
- … however, benefits are at TRL8 and TRL9
- We would like to see more commitment and uptake at high TRLs (particular by the UK water companies)

Intelligent Wastewater Networks

- Operational and economic benefits
- Many applications, increasing with climate change and urbanisation
- Fuzzy Logic and other AI will bring about these benefits
- Not possible without robust and reliable monitoring and comms technologies as the enablers

THANK YOU FOR YOUR ATTENTION

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