Water-wise cities and smart water systems Workshop, Xi'an China, 11-13th September 2018

Sustainable and Resilient Water Infrastructure: The Safe & SuRe Project

www.safeandsure.info

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Pioneering research and skills

Safe&SuRe
Water management

Outline

- **Why** is Safe and SuRe infrastructure needed?
- **What** do we mean by Safe & SuRe?
- **How** can we build resilience & sustainability?
  - Safe & SuRe interventions framework
  - Example framework applications
- **What** is the relationship between reliability, resilience and sustainability?
- **Conclusions**

Safe & SuRe water infrastructure

Safe: *Reliable*

SuRe: *Sustainable and Resilient*

Aim of the S&S research project:
To develop a new paradigm for 'Safe & SuRe' urban water management in the UK in response to emerging challenges and global uncertainties

Why?

Global threats

An era of unprecedented variability?

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Safe&SuRe
Water management

Safe & SuRe

Reliability / Safety

Resilience

Property vs. Performance

Sustainability

Reliable

Reliability – key properties

Fail safe

Monitored

Capacity

Active

Hard

Compliant

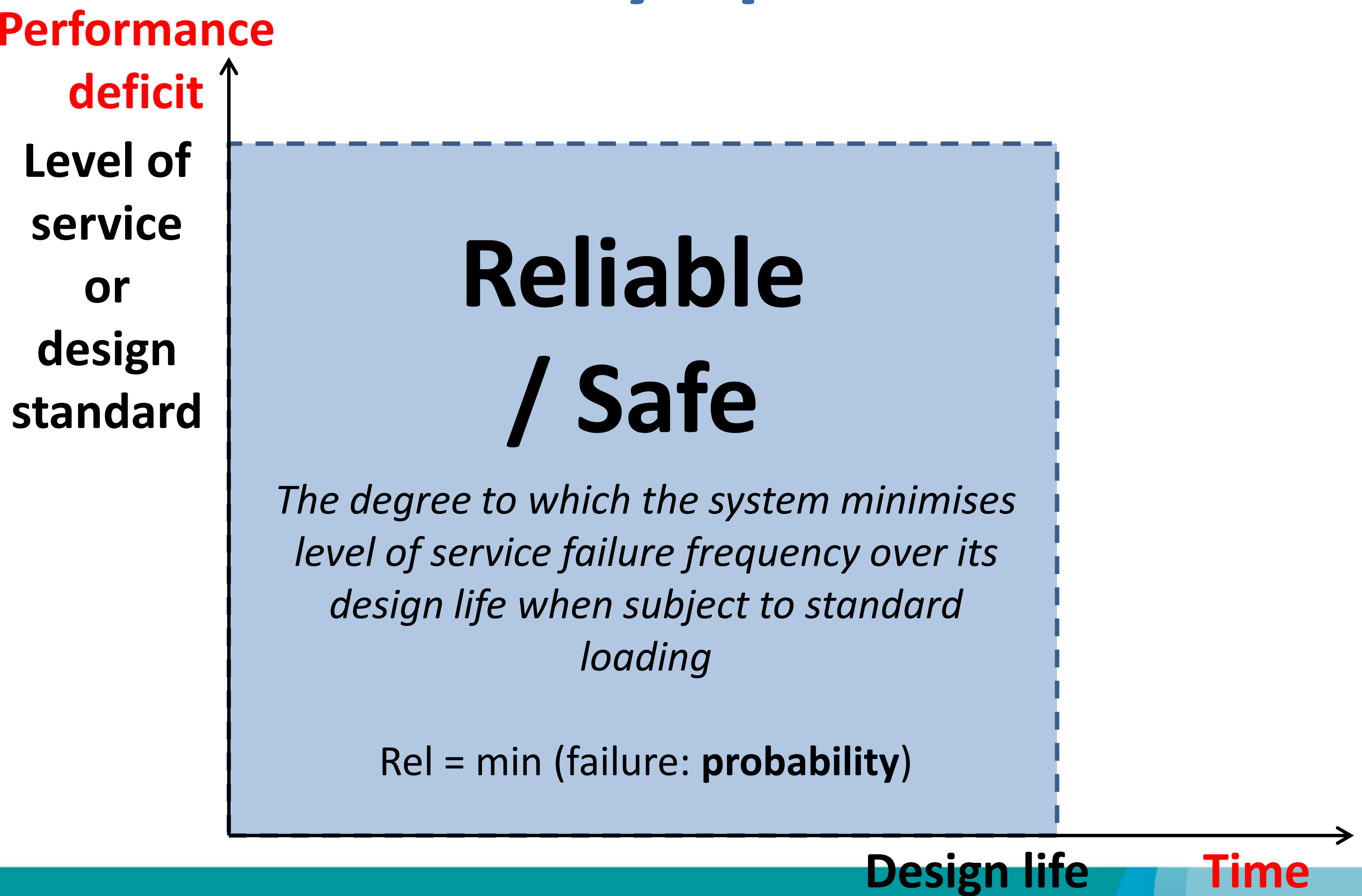
Efficient

Resistant

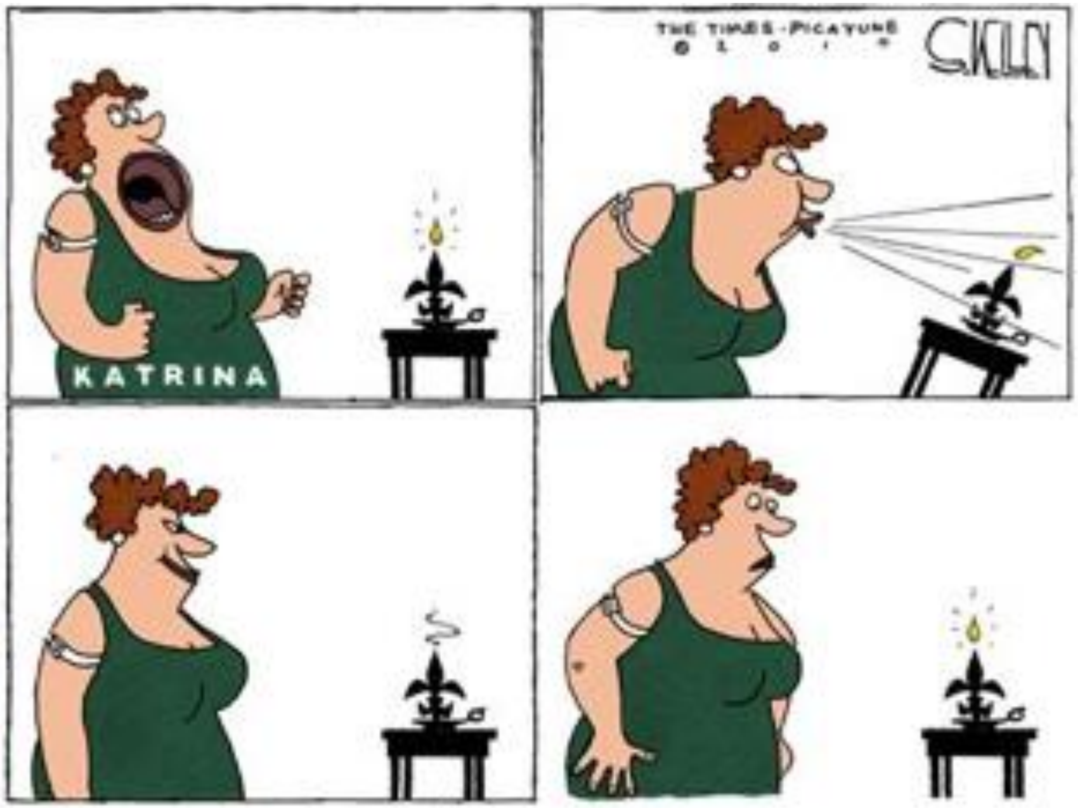
Strong

Stable

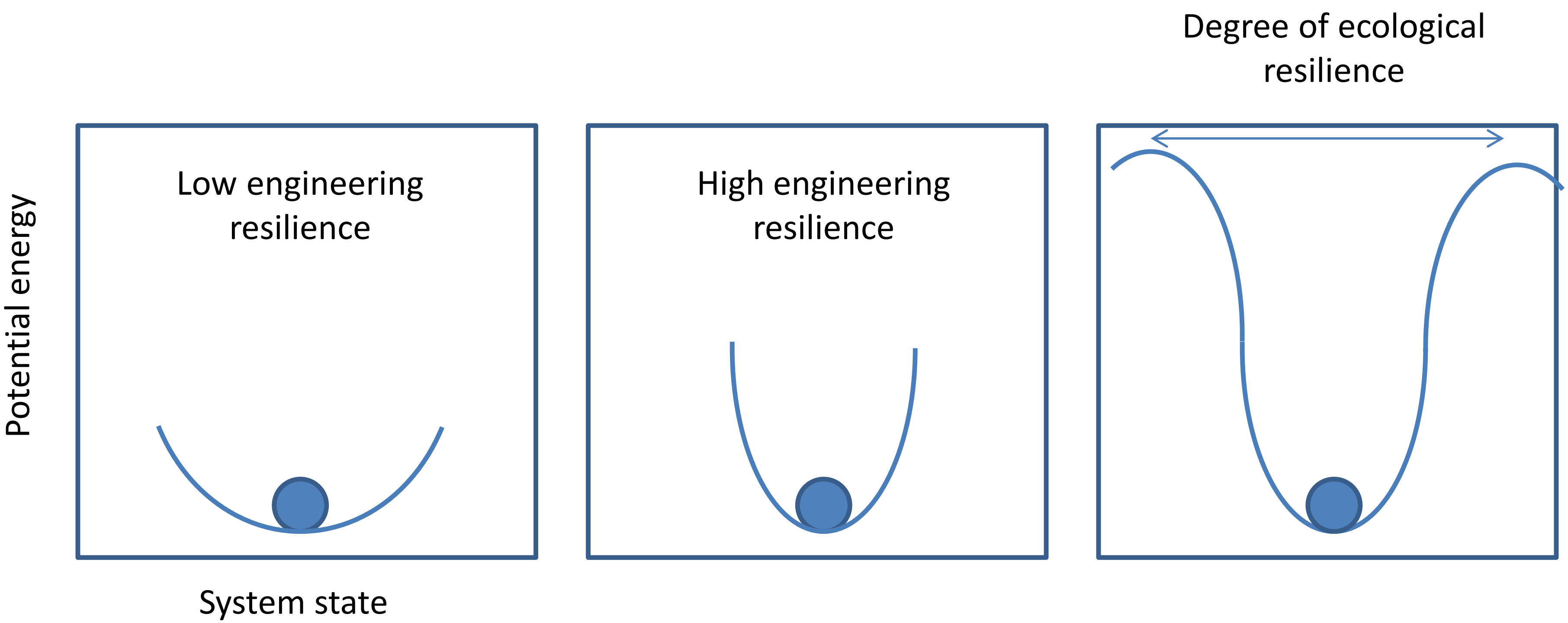
Reliability - performance



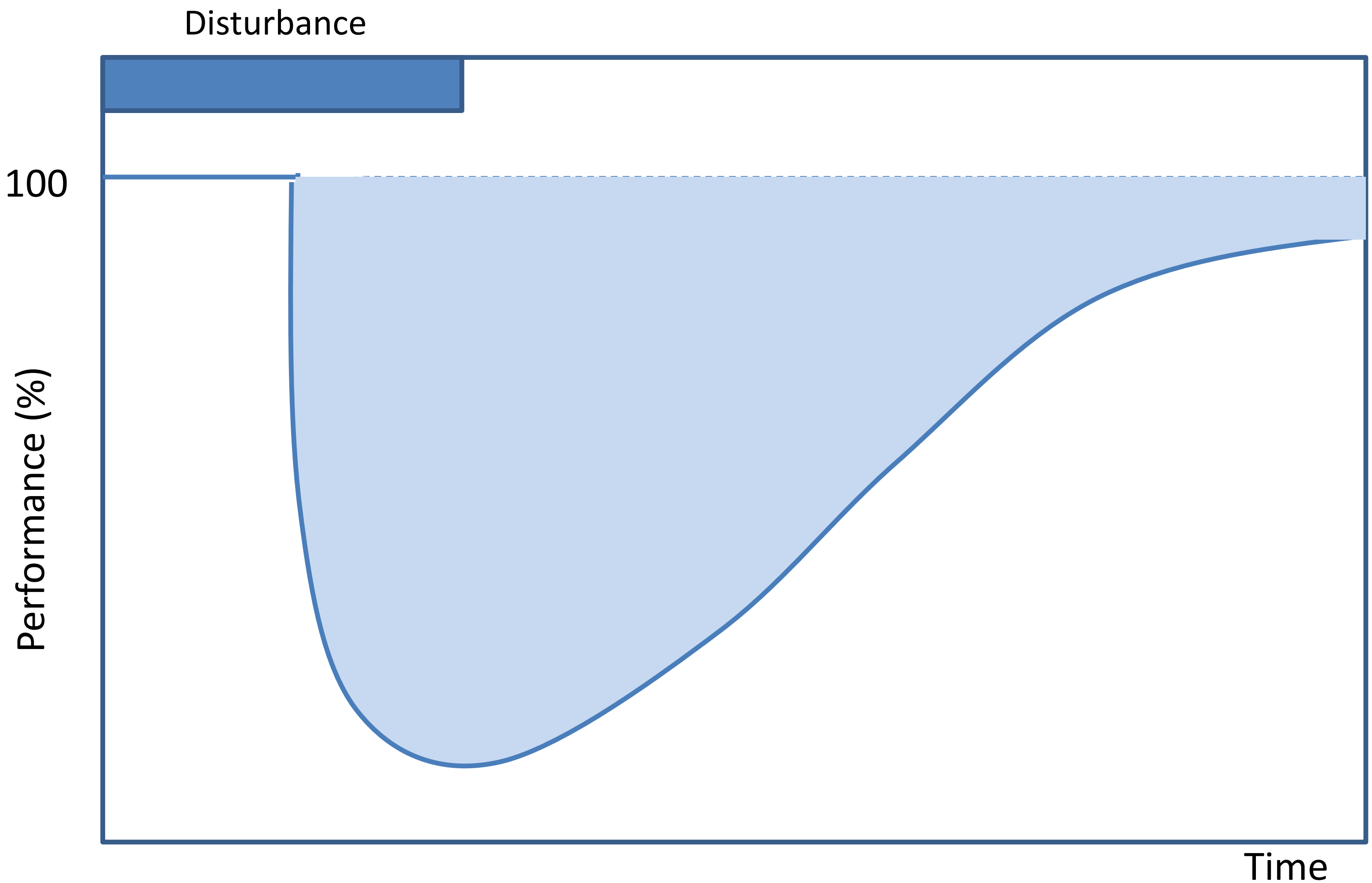
Resilient



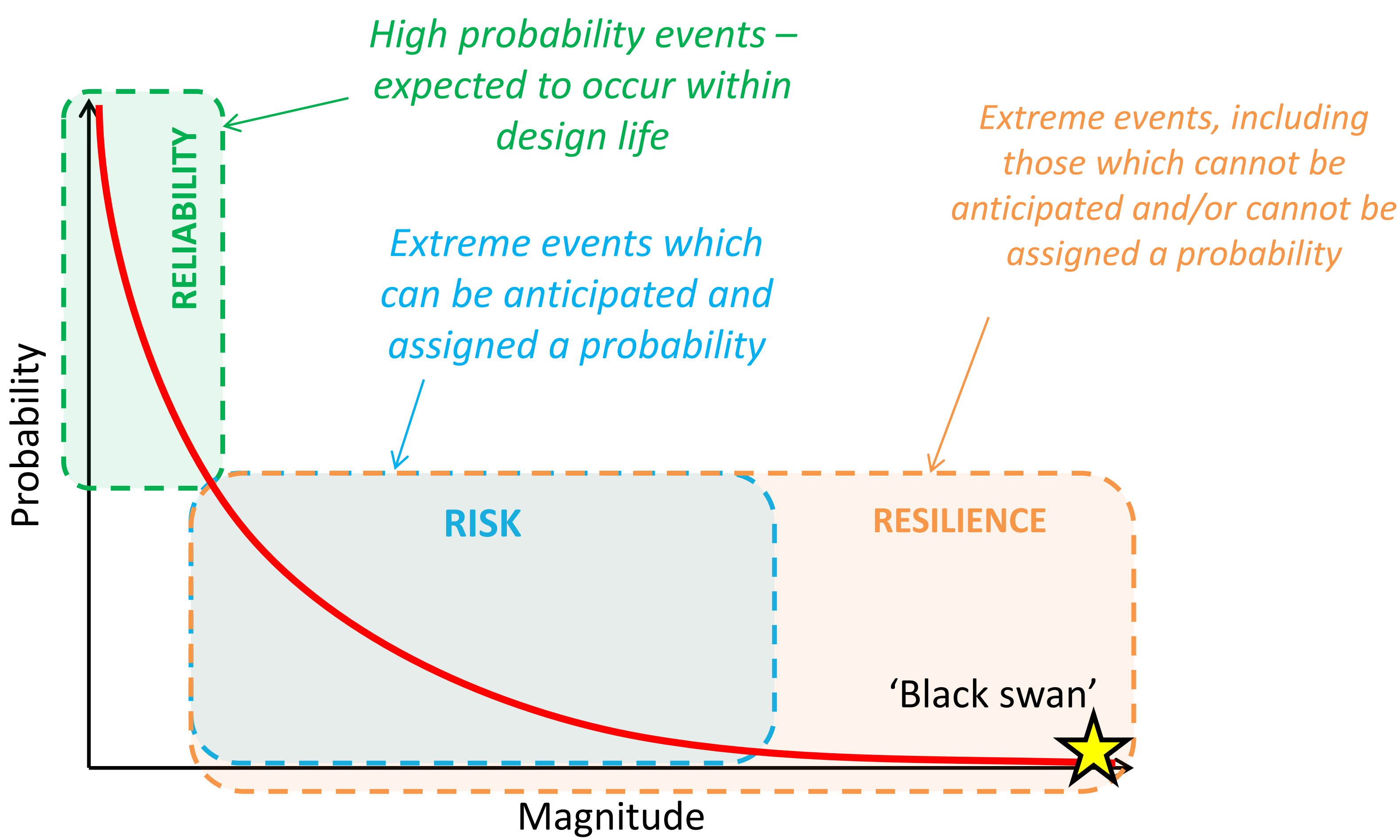
Basic concepts



System performance response curve



Resilience definition and dimensions



Resilience – key properties

Safe to fail

Interconnected

Reserves

Diverse

Redundant

Multi-purpose

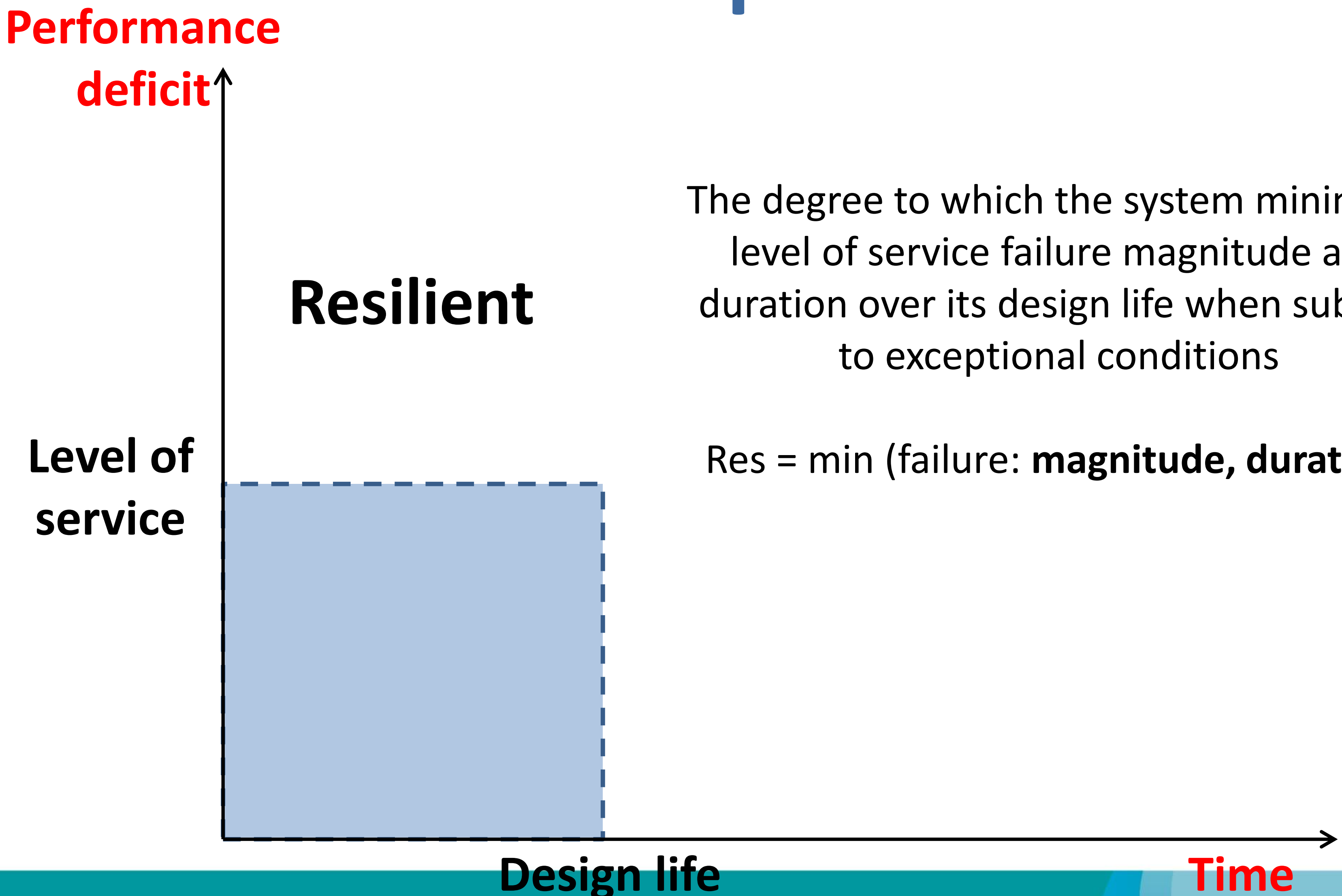
Integrated

Recoverable

Flexible

Replaceable

Resilience - performance



The degree to which the system minimises level of service failure magnitude and duration over its design life when subject to exceptional conditions

Res = min (failure: **magnitude, duration**)

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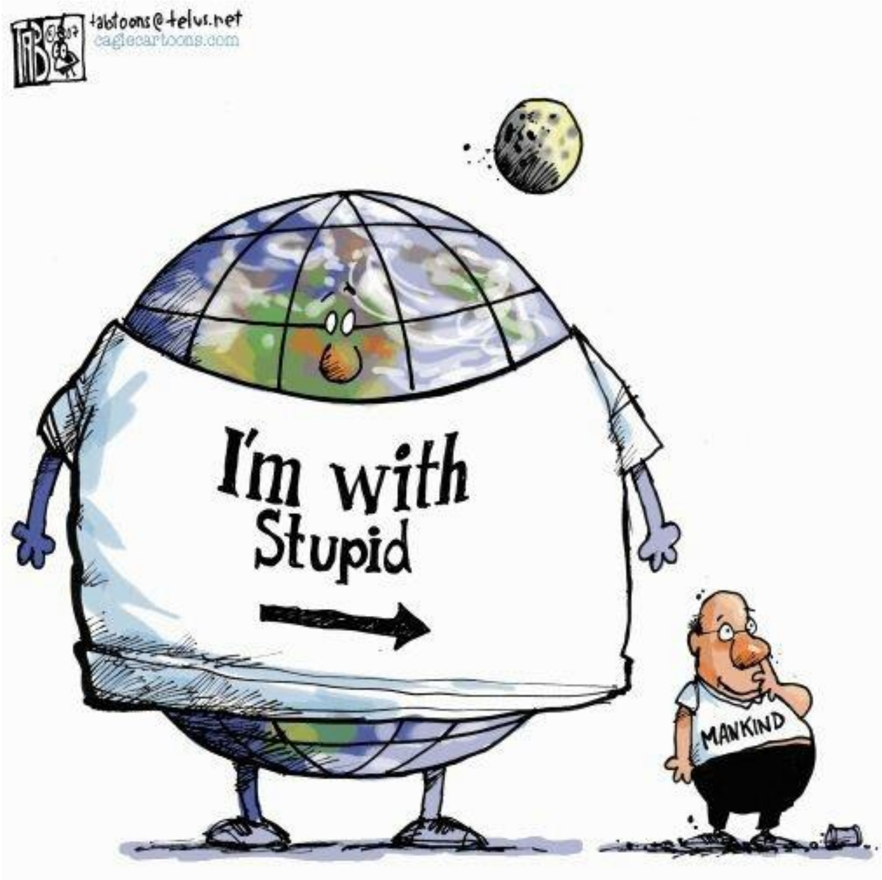
Safe&SuRe Water management

Resilience definition & dimensions

Dimensions	**Properties** - *State of the system* - *Related to design and operation of system* - *General resilience*
	Performance - *Function of system* - *Related to level of service* - *Specified resilience*
Performance definition	*The degree to which the system minimises the level of service* ***failure magnitude and duration*** *under unexpected or exceptional loading conditions* **'Safe to fail'** **'Bouncebackability'**
Properties definition	**Flexible, duplicated, interconnected, dispersed, diverse, multi-purpose**

Butler, D., Farmani, R., Fu, G., Ward, S., Diao, K., Astaraie-Imani, M., (2014). A new approach to urban water management: Safe and SuRe, Procedia Engineering, 89, C, 347-354. doi: 10.1016/j.proeng.2014.11.198

Sustainable



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Safe&SuRe Water management

The unknown destination?

BUTLER, D., MEMON, F.A, MAKROPOULOS, C., SOUTHALL, A. & CLARKE, L. (2010). WaND. Guidance on Water Cycle Management for New Developments, CIRIA Report C690, ISBN 978-086017-690-9, 143 pp.

Sustainability – key properties

Simple

Affordable

Natural

Low energy

Recycled

Low impact

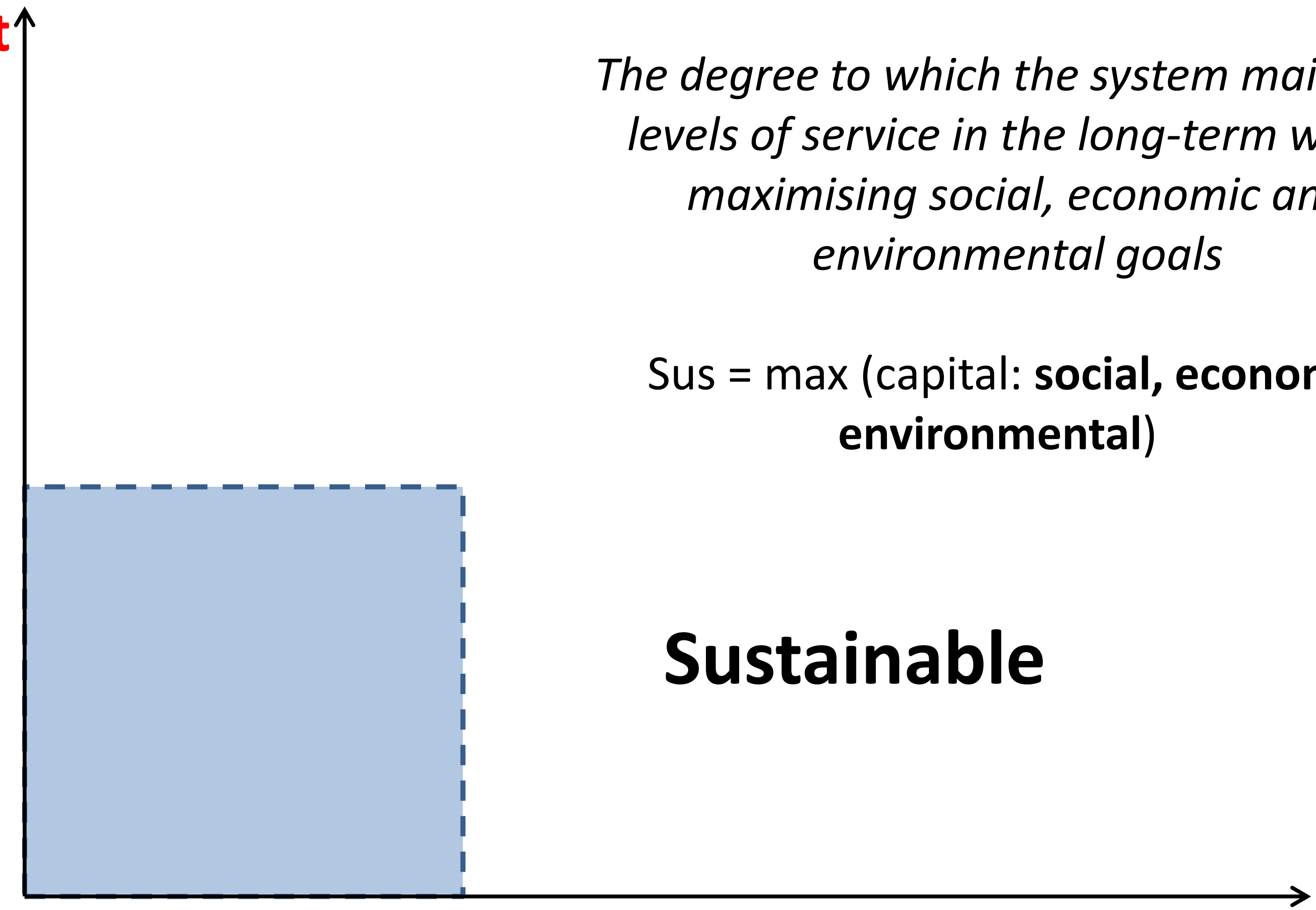
Renewable

Low resources

Inclusive

Equitable

Sustainability - performance



The degree to which the system maintains levels of service in the long-term whilst maximising social, economic and environmental goals

Sus = max (capital: **social, economic, environmental**)

Sustainable

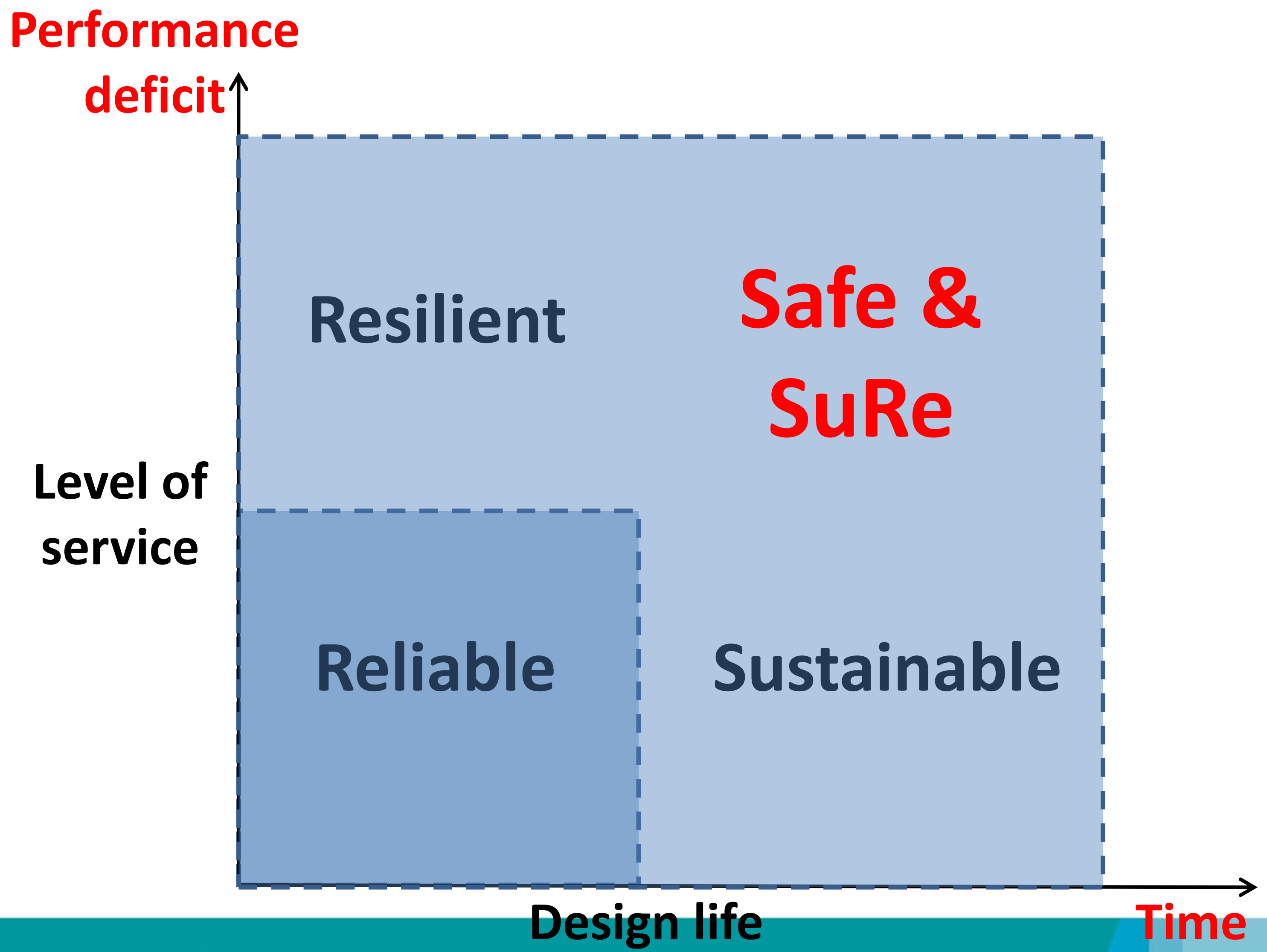
Sustainability definition & dimensions

Dimensions	**Properties** *- State of the system* *- Related to design and operation of system* *- General sustainability* **Performance** *- Function of system* *- Related to level of service* *- Specified sustainability*
Performance definition	*The degree to which the system maintains levels of service in the **long-term** whilst maximising **social, economic and environmental goals*** **‘meeting the needs of the present without compromising the ability of future generations to meet their own needs’**
Properties definition	**Affordable, equitable, non-polluting, low energy, reusable, simple**

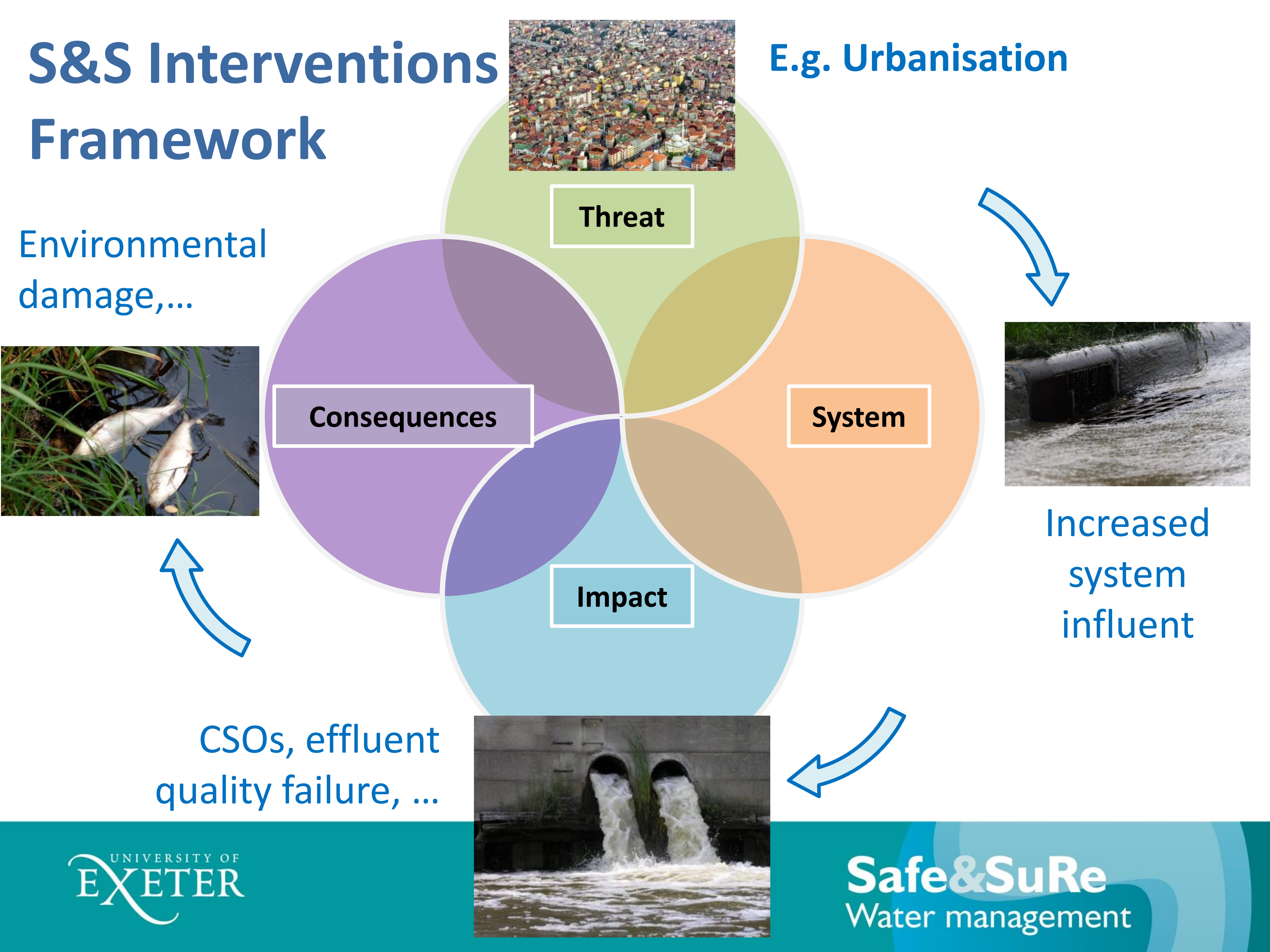
Pulling it all together: Safe & SuRe

BUTLER, D., FARMANI, R., FU, G., WARD, S., DIAO, K. & ASTARAIE-IMANI, M (2014). A new approach to urban water management: Safe and SuRe, 16th Conference on Water Distribution System Analysis, WDSA, Procedia Engineering.

Pulling it all together: Safe & SuRe



How?


S&S Interventions Framework
E.g. Urbanisation
Threat
Consequences
System
Impact
Environmental damage,...
Increased system influent
CSOs, effluent quality failure, ...
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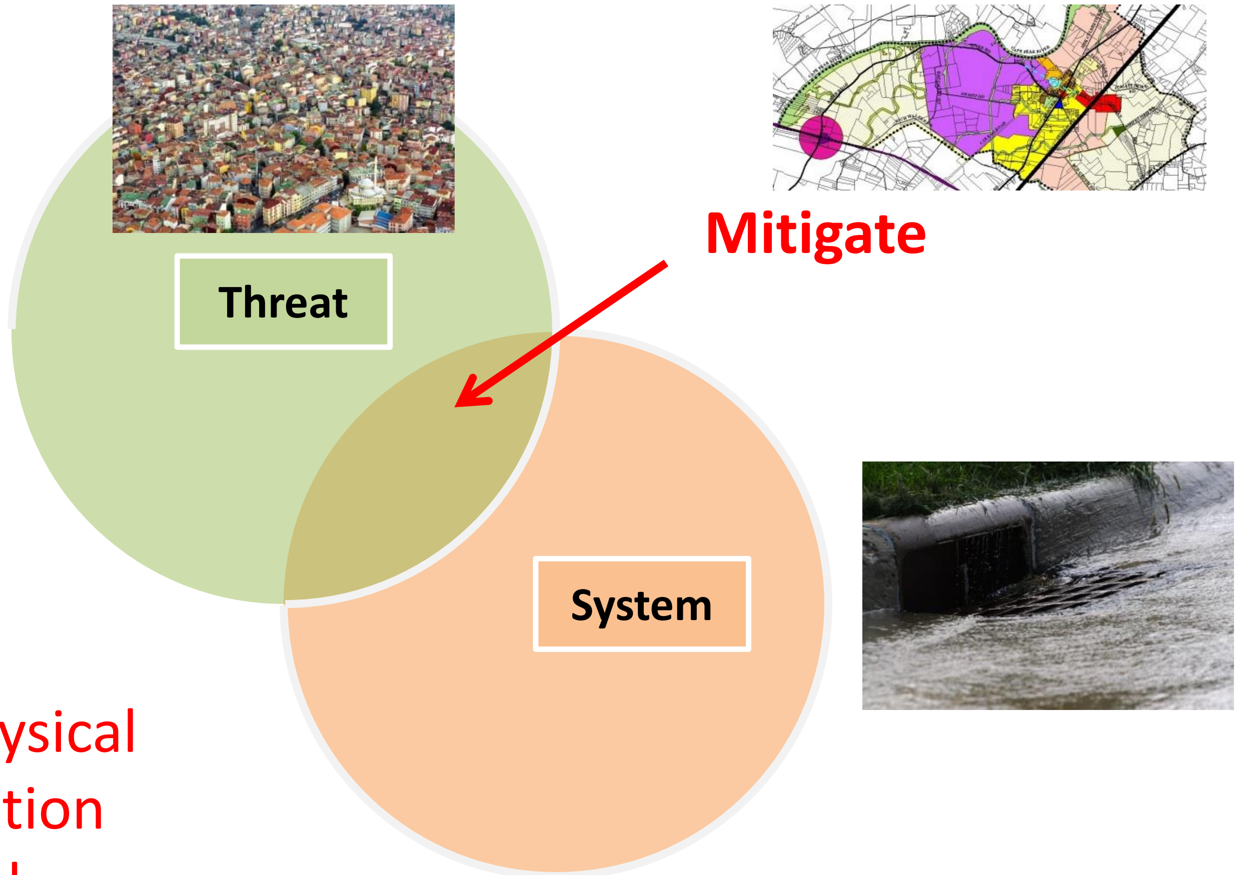
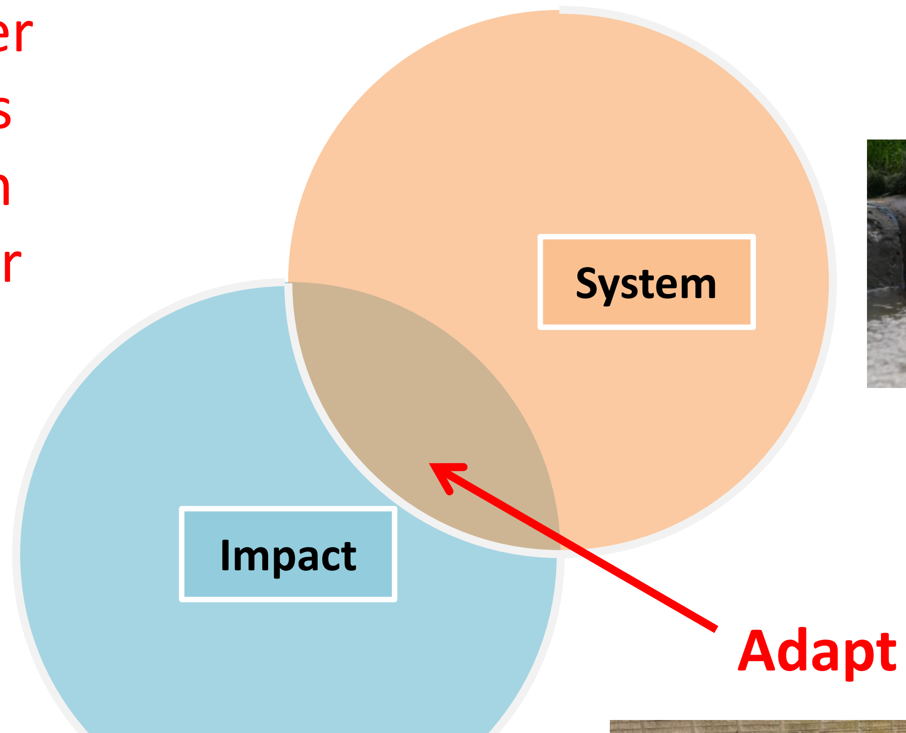
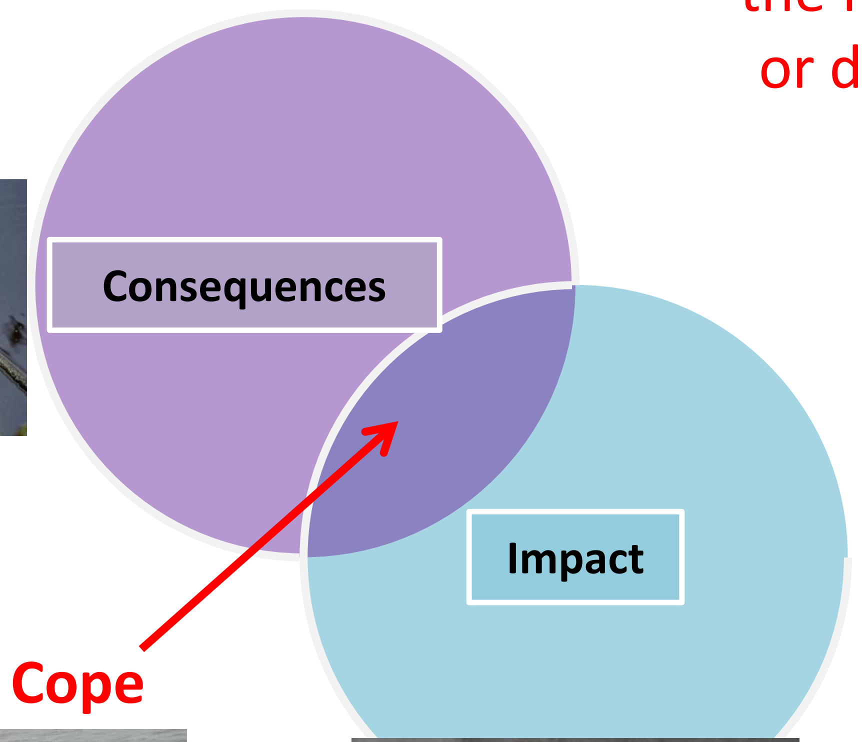


Mitigation: 'Any physical or non-physical action taken to reduce the frequency, magnitude or duration of a threat'

Adaptation: 'Action taken to modify specific properties of the water system to enhance its capability to maintain levels of service under varying conditions'



Coping: ‘Any preparation or action taken to reduce the frequency, magnitude or duration of an impact on a recipient’



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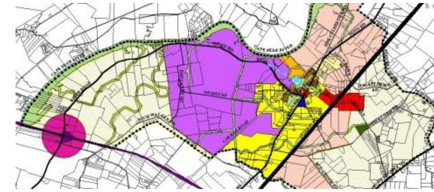
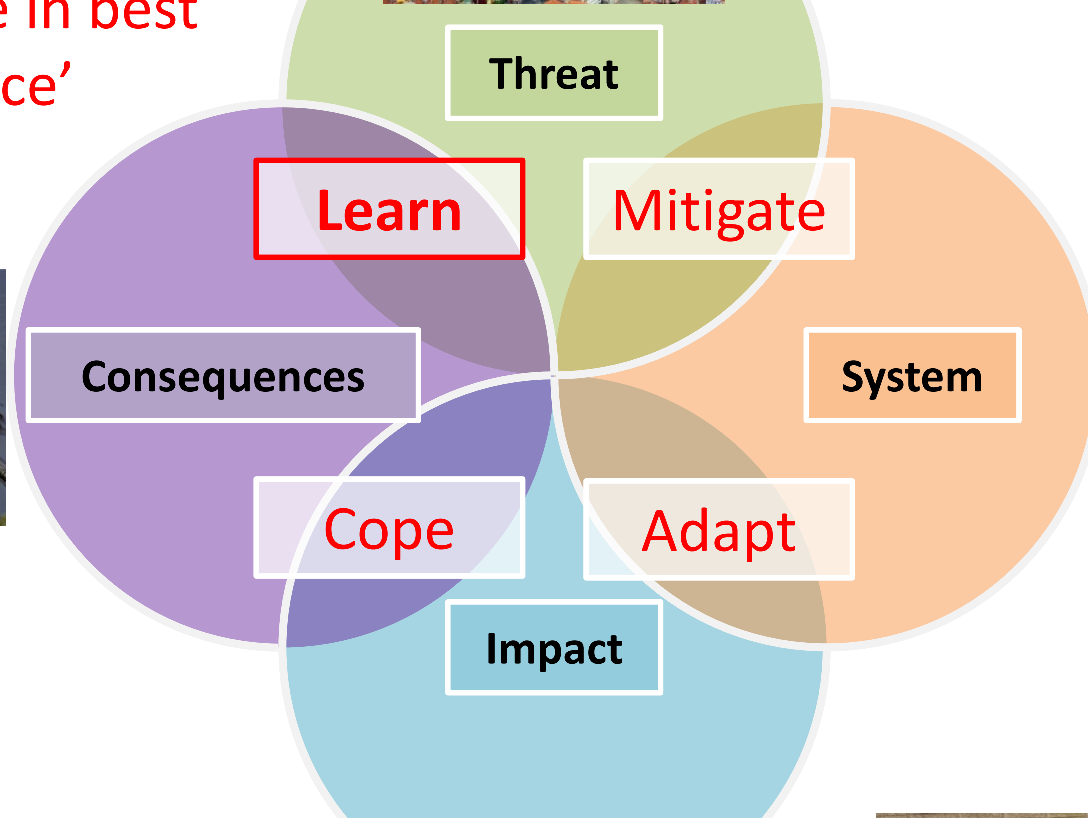
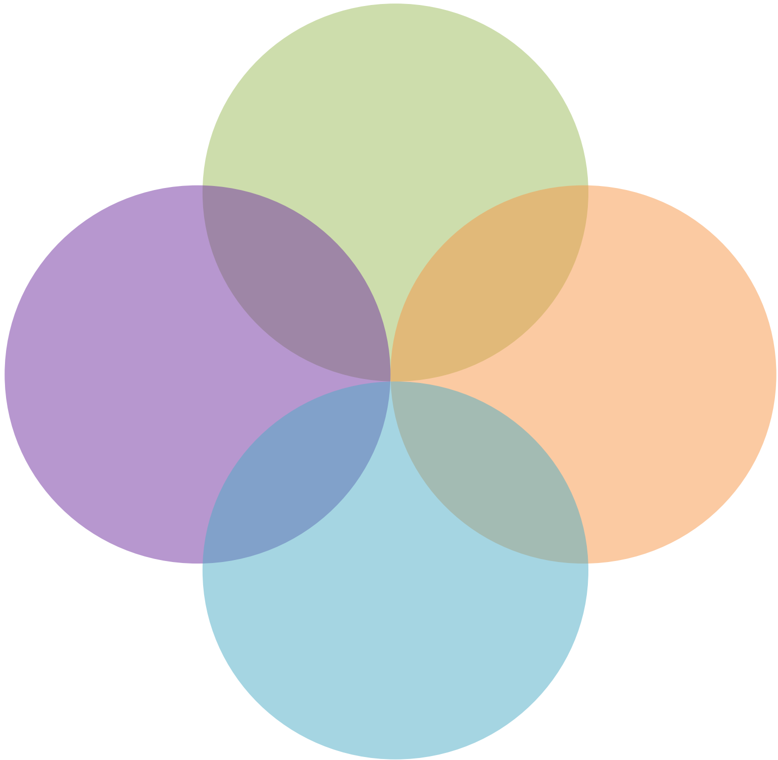
Water management

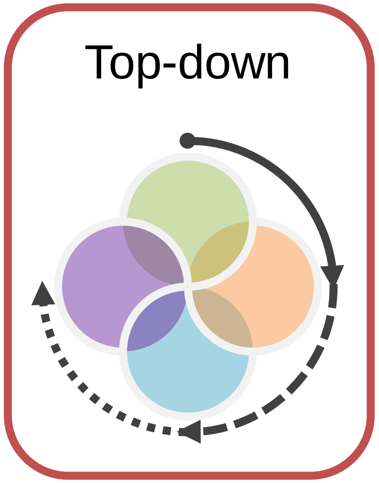
Learning: 'Embedding experiences and new knowledge in best practice'



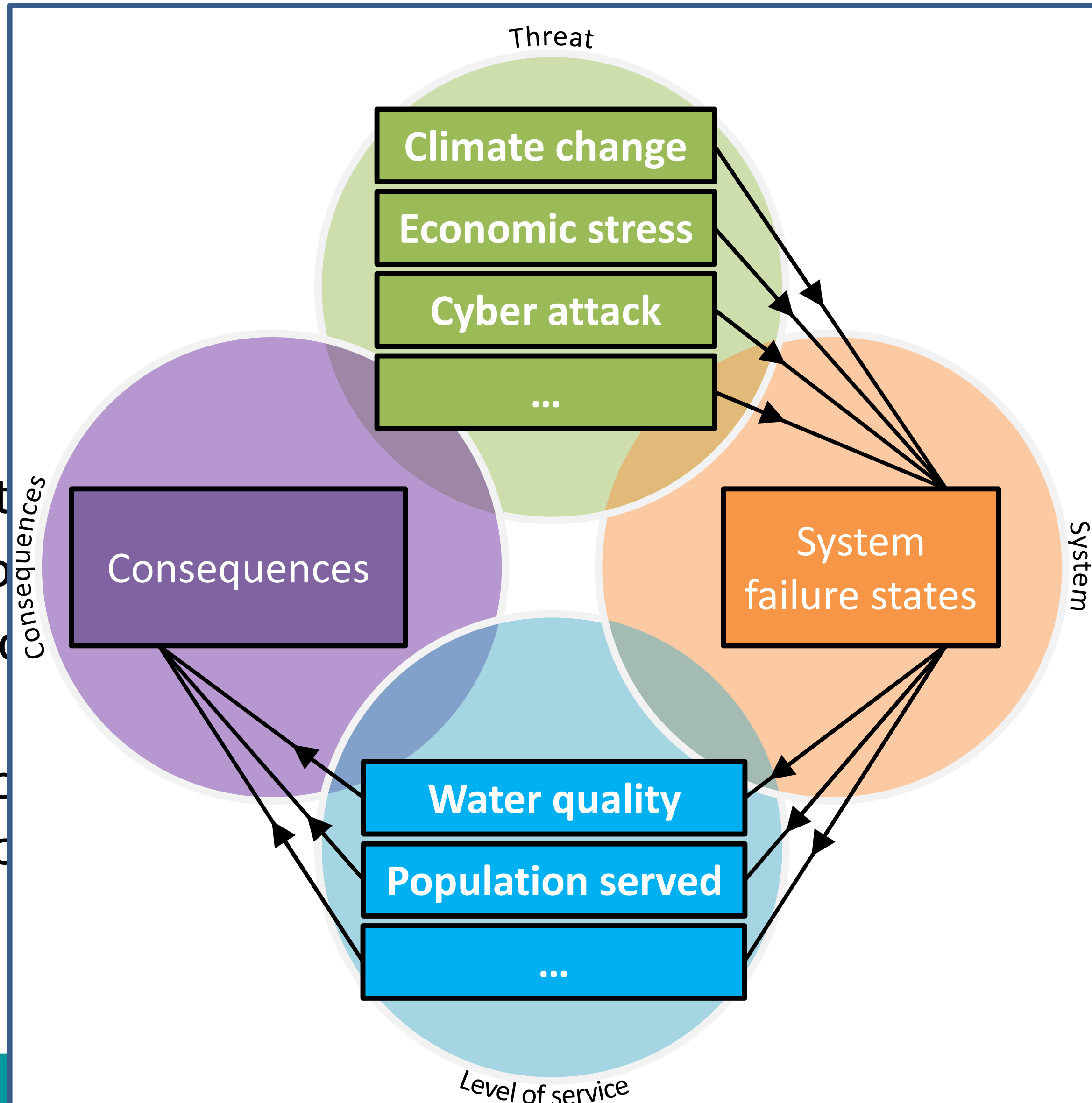


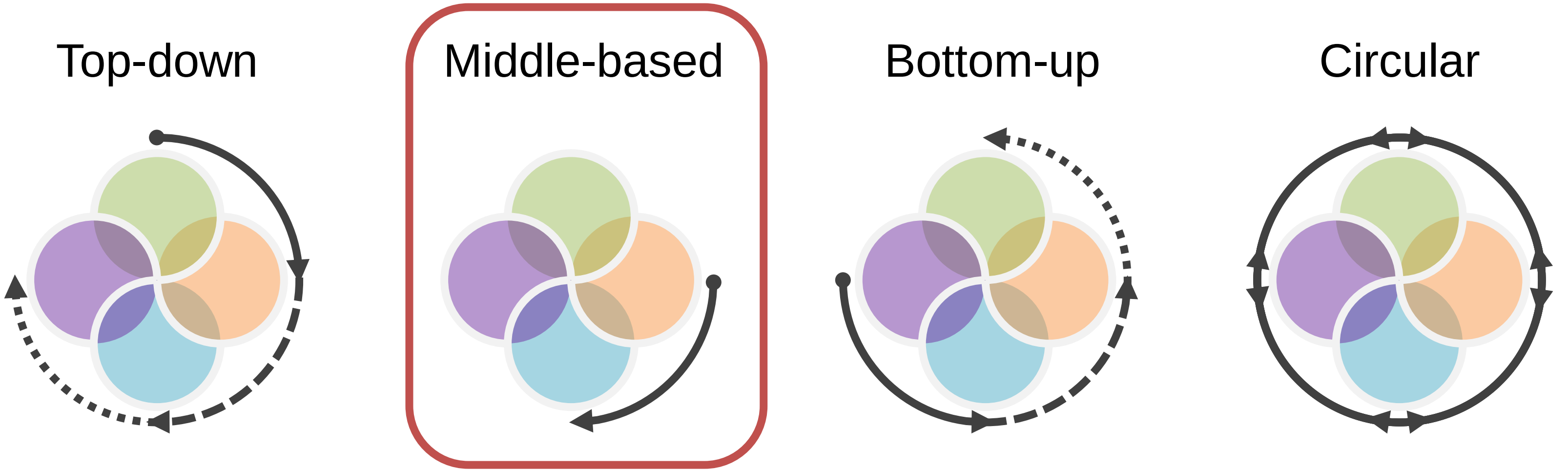
Applying the framework



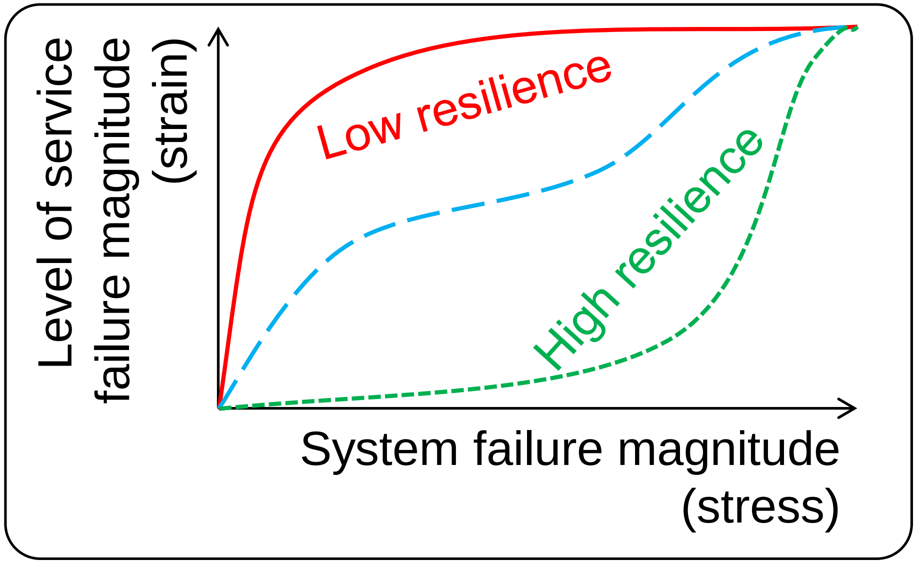


- Threat-based, mitigat
- Relies on identificatio
- Conventional approac assessment
- Addresses response c changes we can reaso (e.g. climate change)
- Widely used





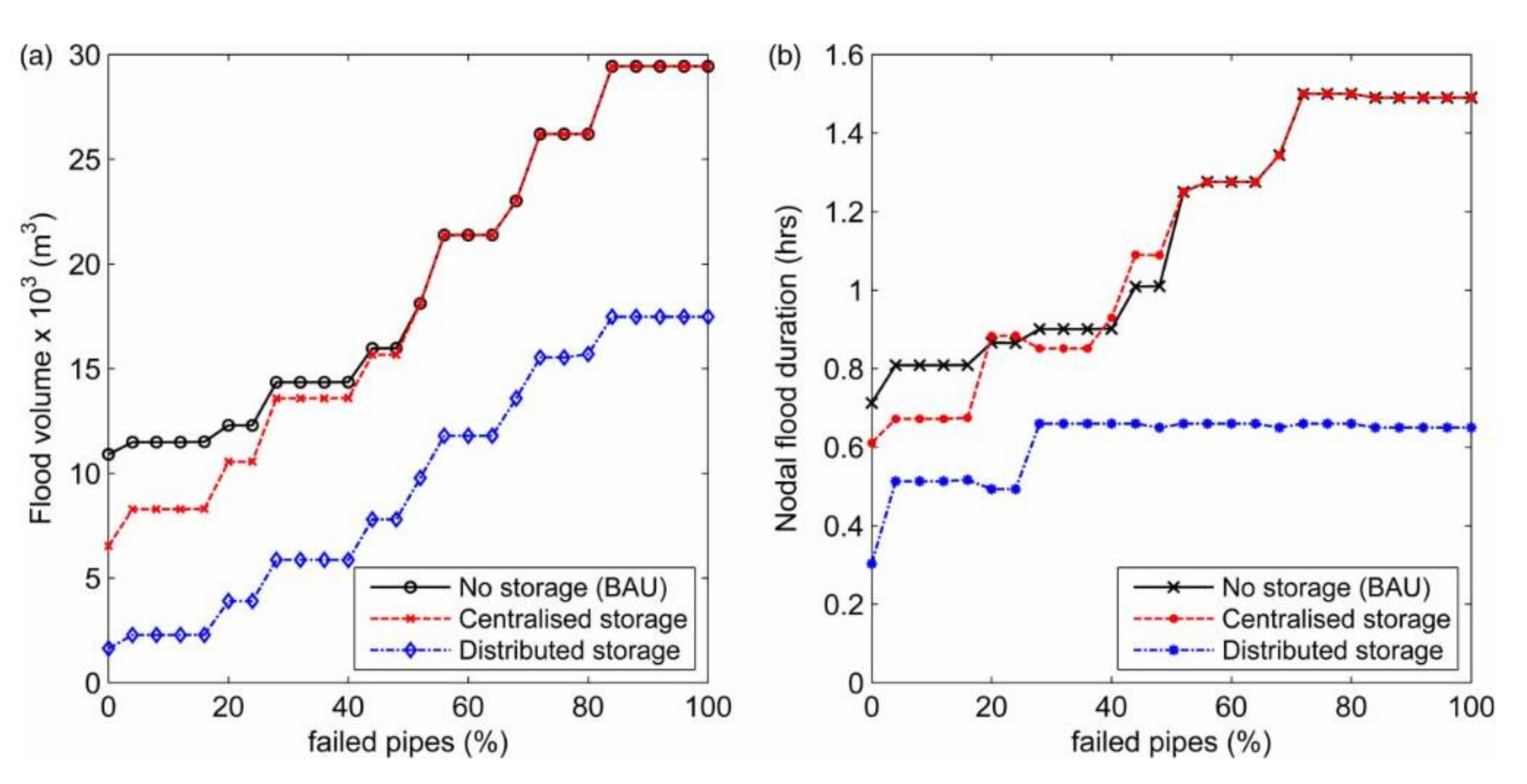
- System failure modes more easily identifiable
- Many threats may result in the same system failure modes → Can be addressed in a single analysis
- Global resilience analysis



Compare systems or interventions:

E.g. Adaptation measures in an urban drainage system

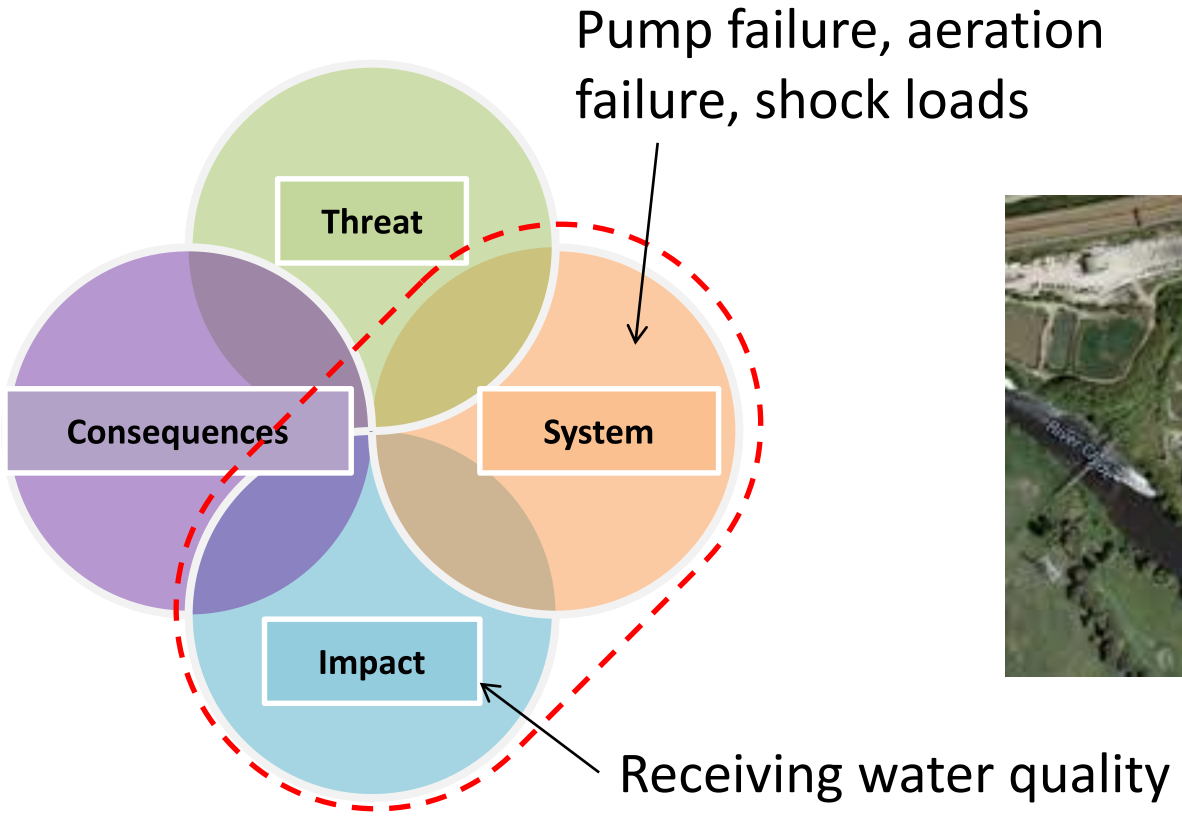
(Mugume et al. 2015)

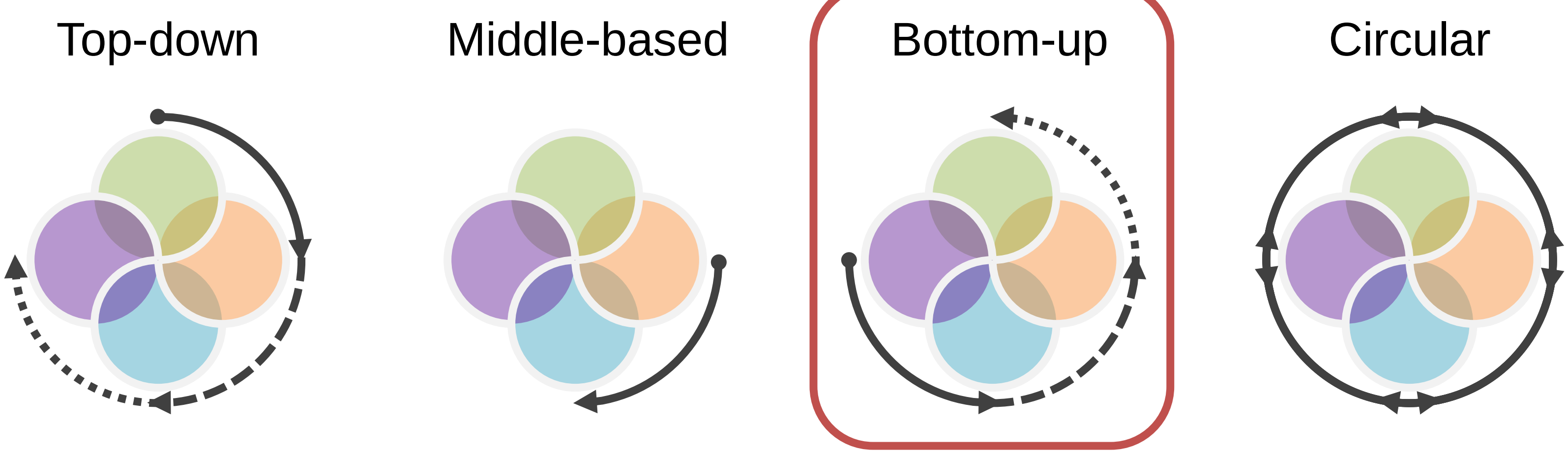


Water management

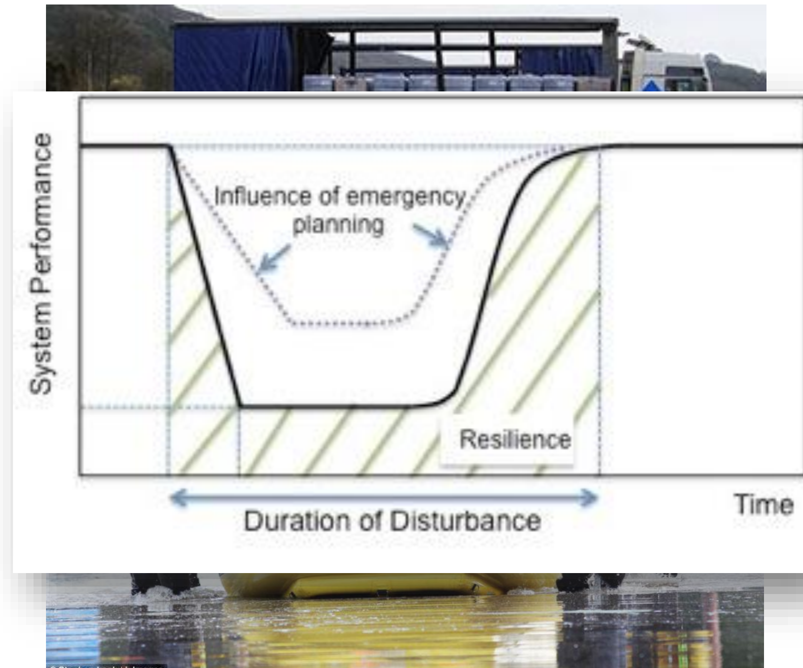
Identification of key system failure modes:

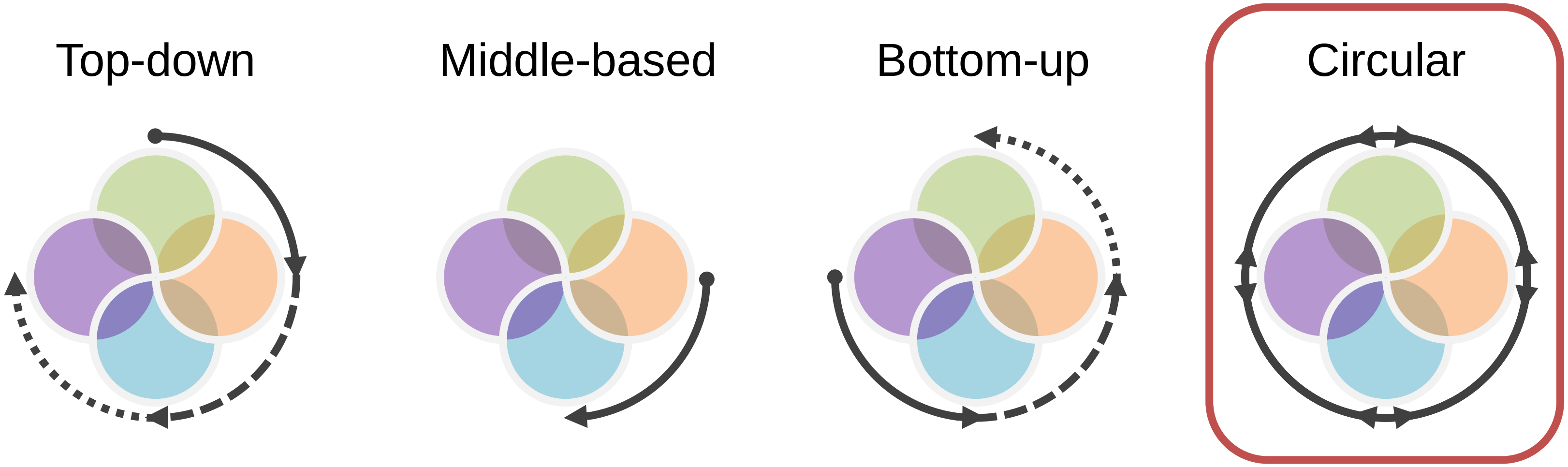
E.g. Resilience of a wastewater treatment plant



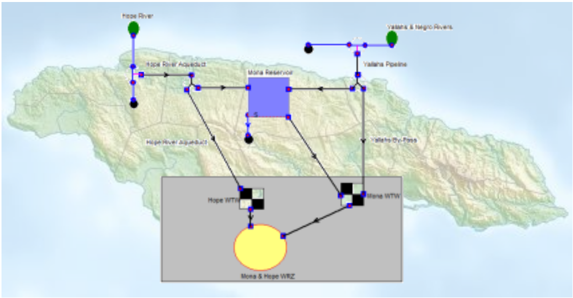


- Consequence-based, coping focussed
- Relies on identification of potential social, economic or environmental consequences
- Focus on reducing vulnerability
- Detailed knowledge of threats or impacts not required





- Focus on **<u>learning</u>**
- Evaluate success of mitigation, adaptation and coping actions to ensure strategies, processes and actions are updated
- Enables improvements to be made across all levels, leading to increased resilience and sustainability
- Process coordination and ownership of responsibilities present a challenge



Safe & SuRe relationships

Potential strategies: mitigation/ adaptation/coping/learning

- **Low tech** (e.g. sustainable drainage).
- **High tech** (e.g. ‘smart’, real time control).
- **Integrated** (e.g. SuDS, Sponge Cities).
- **Scale** (e.g. centralised, decentralised, hybrid).
- **Flexibility** (e.g. option portfolios, incremental build)
- **Fit for purpose water** (e.g. rain, grey, black, yellow).
- **Policy change** (e.g. planning controls, building regs).
- **Behavioural change** (e.g. floodproofing, insurance).

Range of intervention strategies

Combined sewer centralised storage

Sewer **separation**

Roof disconnection / water butts

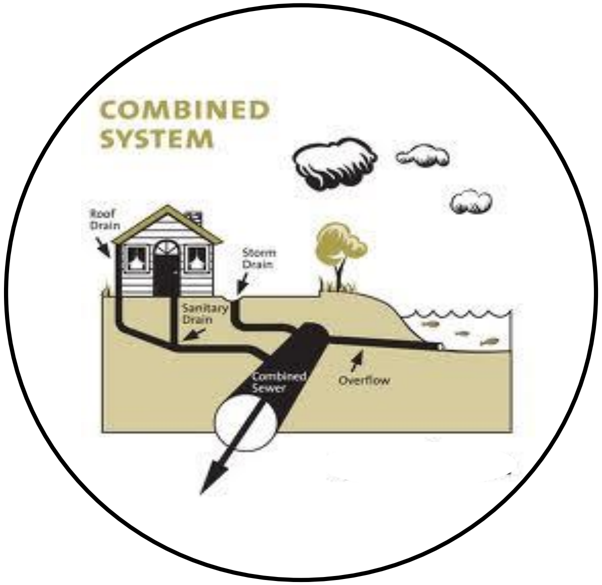
Urban **creep** control / green infrastructure

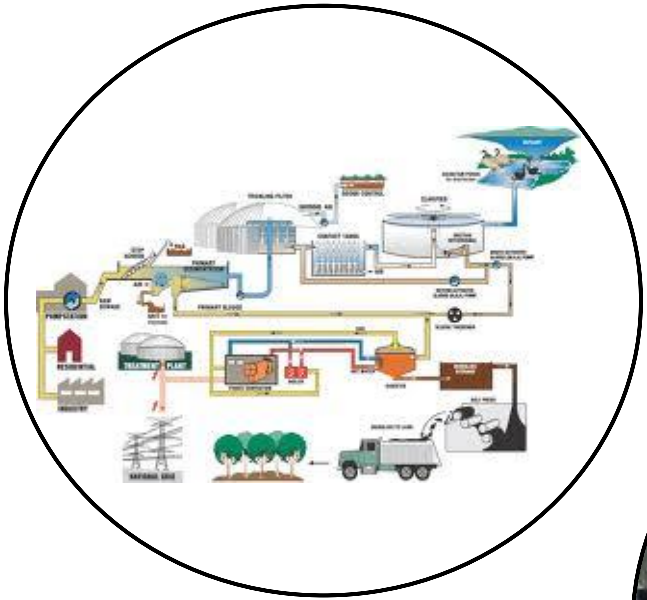
Road permeable pavements / SuDS

Off-grid housing

Integrated urban wastewater system

Sewer System

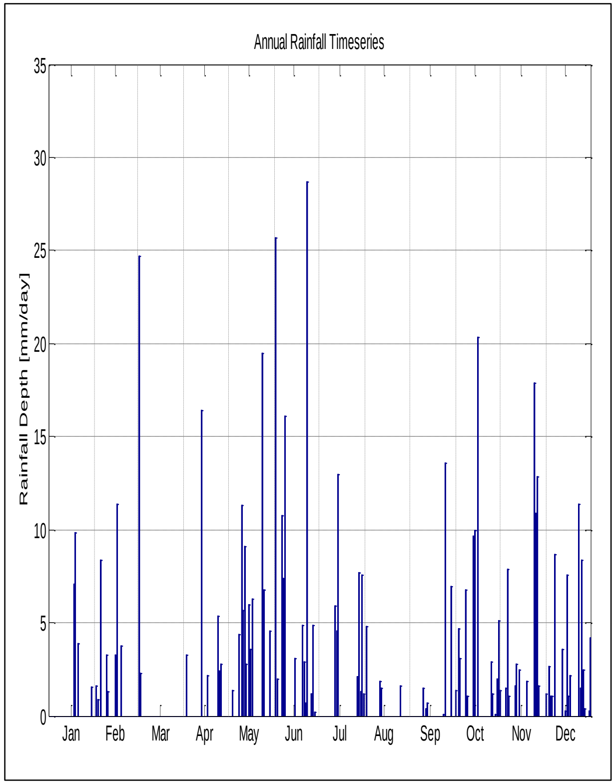


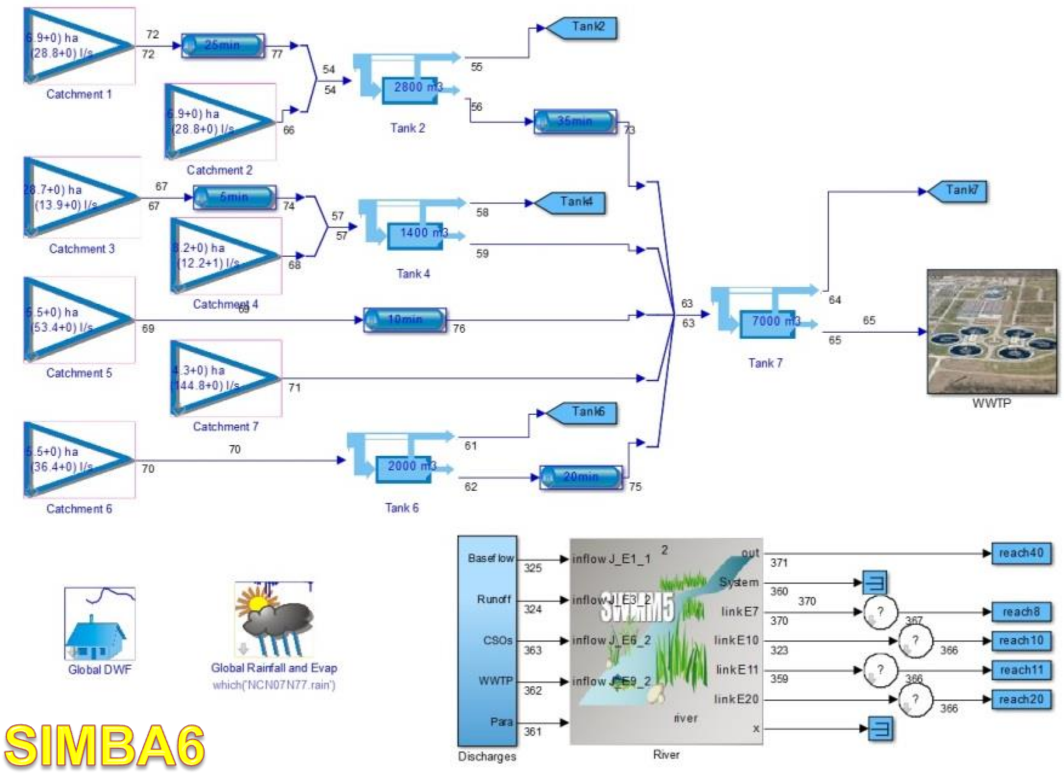


Wastewater
Treatment Plant

River

Modelling and simulation

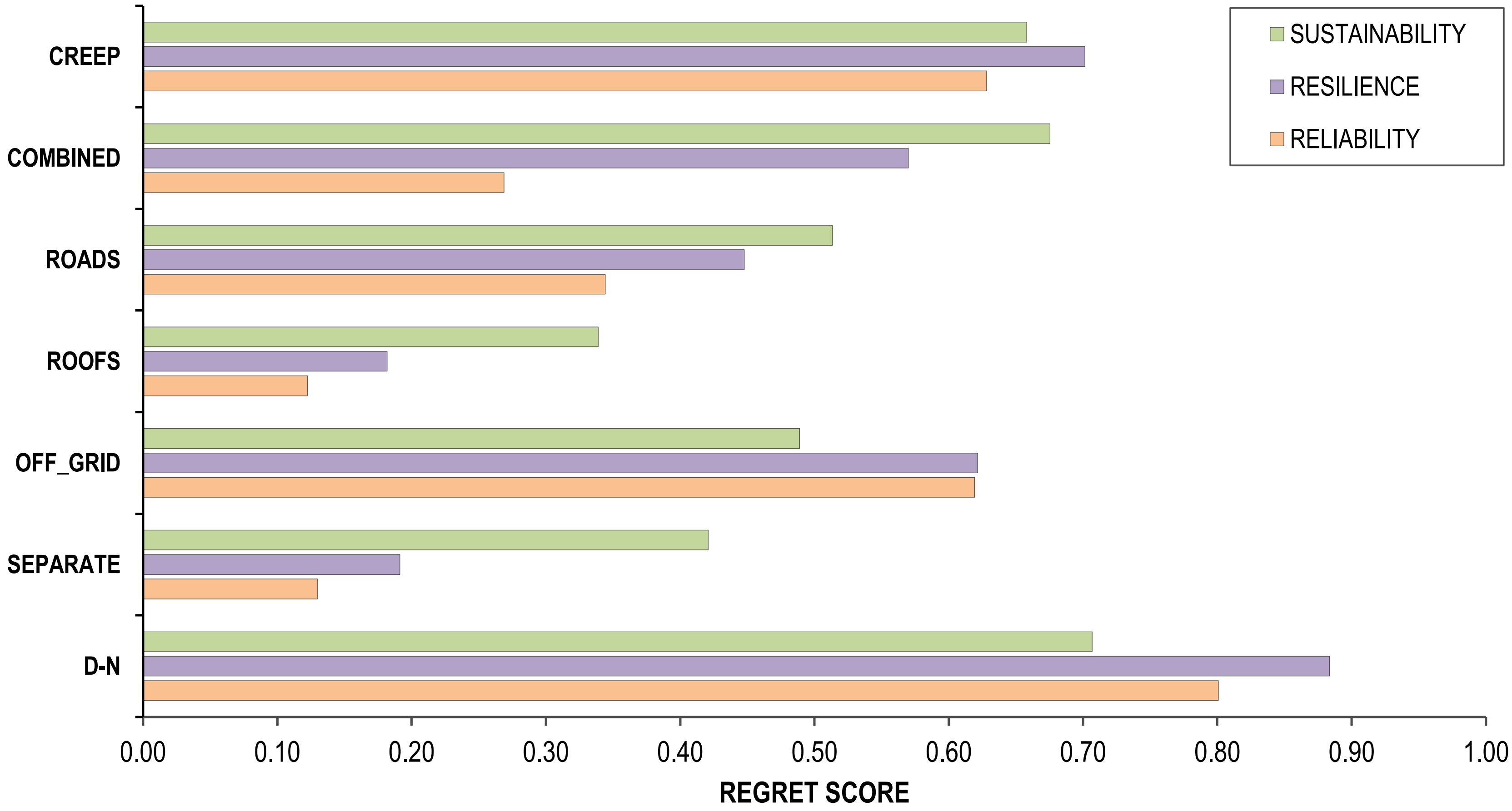




Safe & SuRe performance indicators

Objective	Reliability	Resilience	Sustainability
Flooding	% time flood free	Flood volume (m^3) Time flooded (hours)	Number of properties affected Material damage (£)
Water Quality (DO and AMM)	% time >4 mg/l % time <4 mg/l	6 h minimum (mg/l) 99%ile (mg/l)	Impact to aquatic resources (fisheries, fresh water)
CSO	Frequency of spills (annual events)	Annual spill (m^3) Time of spills (hours)	Aesthetic and health impact of spills
Energy	-	-	Operational tCO_2
River flood downstream	% time flood free	Flood volume (m^3) Time flooded (hours)	Properties affected Material damage (£)
Cost	-	-	Capital cost (£)
Acceptability	-	-	High-med-low

Safe & SuRe interventions?



CASAL-CAMPOS, A., FU, G., BUTLER, D., MOORE, A. (2015). An integrated environmental assessment of green and gray infrastructure strategies for robust decision making, *Environmental Science & Technology*, 49, 14, 8307-8314, DOI: 10.1021/es506144f.

Conclusions

Urban water systems need to be:

– **Reliable** to provide needed services, but not at *any cost.*

– **Resilient** to meet the unexpected and the extreme but with emphasis on *safe to fail*.

– **Sustainable** to ensure *long term* performance within planetary and social limits.

How?

– By developing, evaluating and implementing **Safe & SuRe** socio-technical systems.

– There is no *'one size fits all'* solution or strategy.

Conclusions

Why?

- To manage unprecedented *change*, *uncertainty* and *variability.*
- To prepare for the journey into the *unknown* which we call the future.

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