

Flood Resilient Infrastructure: Can a Changing Landscape Drive Innovation in Design?

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Tom Saville

Associate | Civil Engineering

Arup Manchester

ARUP

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1. Definitions and context
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What is resilience?

“Infrastructure resilience is the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.” Dept. Homeland Security

“Flood resilience involves designing or adapting an infrastructure asset, so that although it comes into contact with floodwater during floods, no permanent damage is caused, structural integrity is maintained and, where operational disruption occurs, normal operation can resume rapidly after a flood has receded.” CIRIA C688



Context

Designs are **expected** to be more resilient, main drivers:-

- Future Impact of climate change better understood
- Natural disasters ‘seem’ more frequent. Recent events have made asset owners question their robustness, even if not been affected.
- Clients want to re-use assets and extend their working life due to global economic downturn
- Regulators/insurance companies put more pressure on organisations to reduce incidents of failure
- Better understanding of true cost of disruption and financial penalties of lost service /quality of life
- Government, LA, EA, SEPA etc. have less money.

Natural hazards and Infrastructure Failure

Geo-physical hazards:

- Seismic - (Tsunami, Earthquake events);
- Settlement / subsidence;
- Geo-technical (rock fall, landslide, debris flows)

Hydro-meteorological (severe weather) hazards:

- Hurricane/Tornado/Windstorm;
- Severe cold/Snow/ice/blizzards;
- Heatwave;
- Water loss / drought;
- Flooding (pluvial, fluvial, groundwater, coastal/tidal surge);
- Variables – like climate change and acid rain etc.

Wider issue than just flood resilience

The Designers' Journey

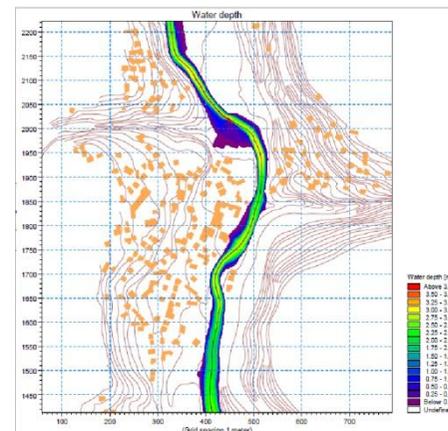
Start: Small and Simple



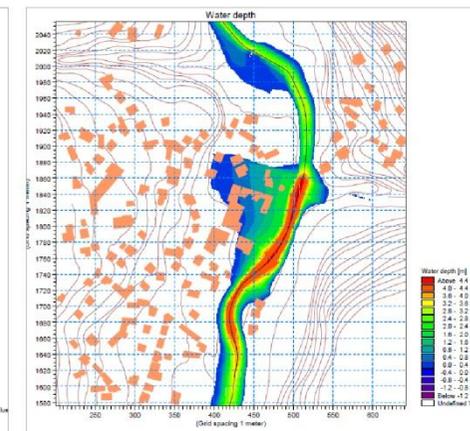
End up dealing with complex solutions and unknowns, applying statistical based analysis and complex modelling



The following pictures illustrate the both researched flood scenarios in Nikolaevo.



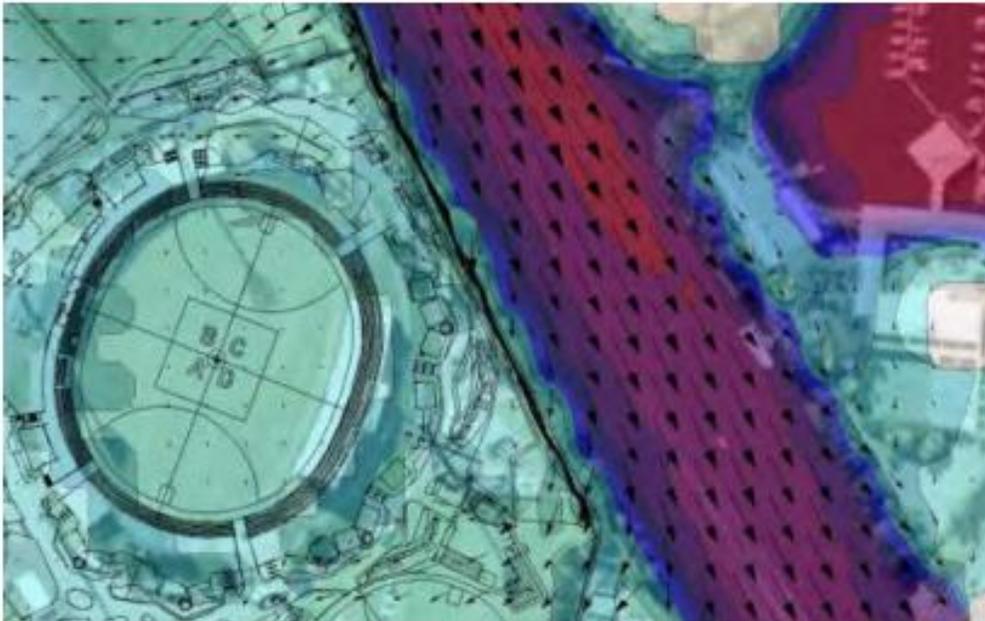
Pic.1 Flood hazard cased by dambreak of the Nikolaevo 2 dam



Pic.2 Flood hazard cased by dambreak of the Nikolaevo 2 dam + a blocked bridge

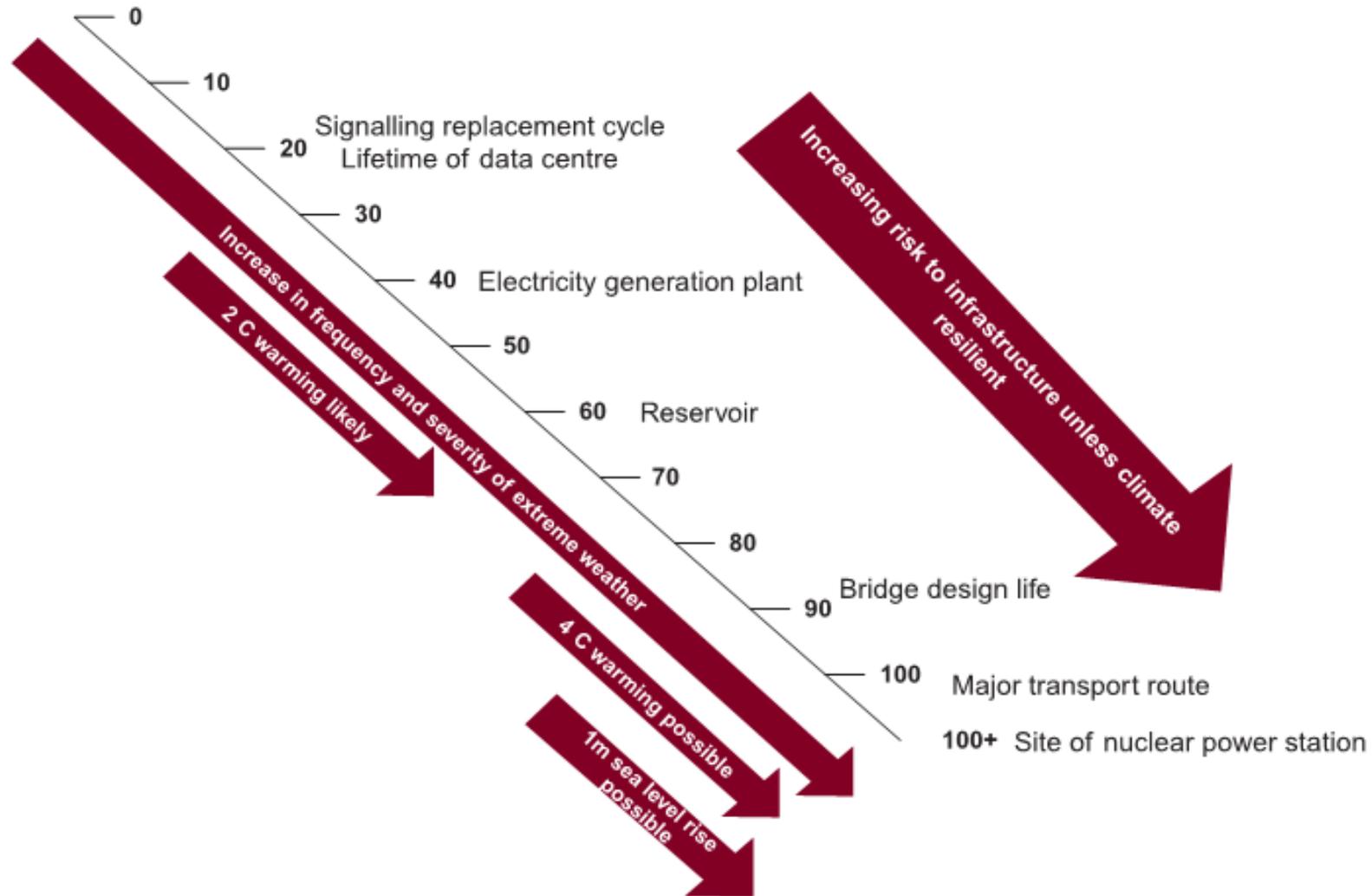
Hazard assessment – now and in the future

- Sources
- Mechanisms
- Pathways
- Depths, durations, velocities



Design Life vs Climate Change

Lifetime of infrastructure with illustrative climate change timescales for the UK



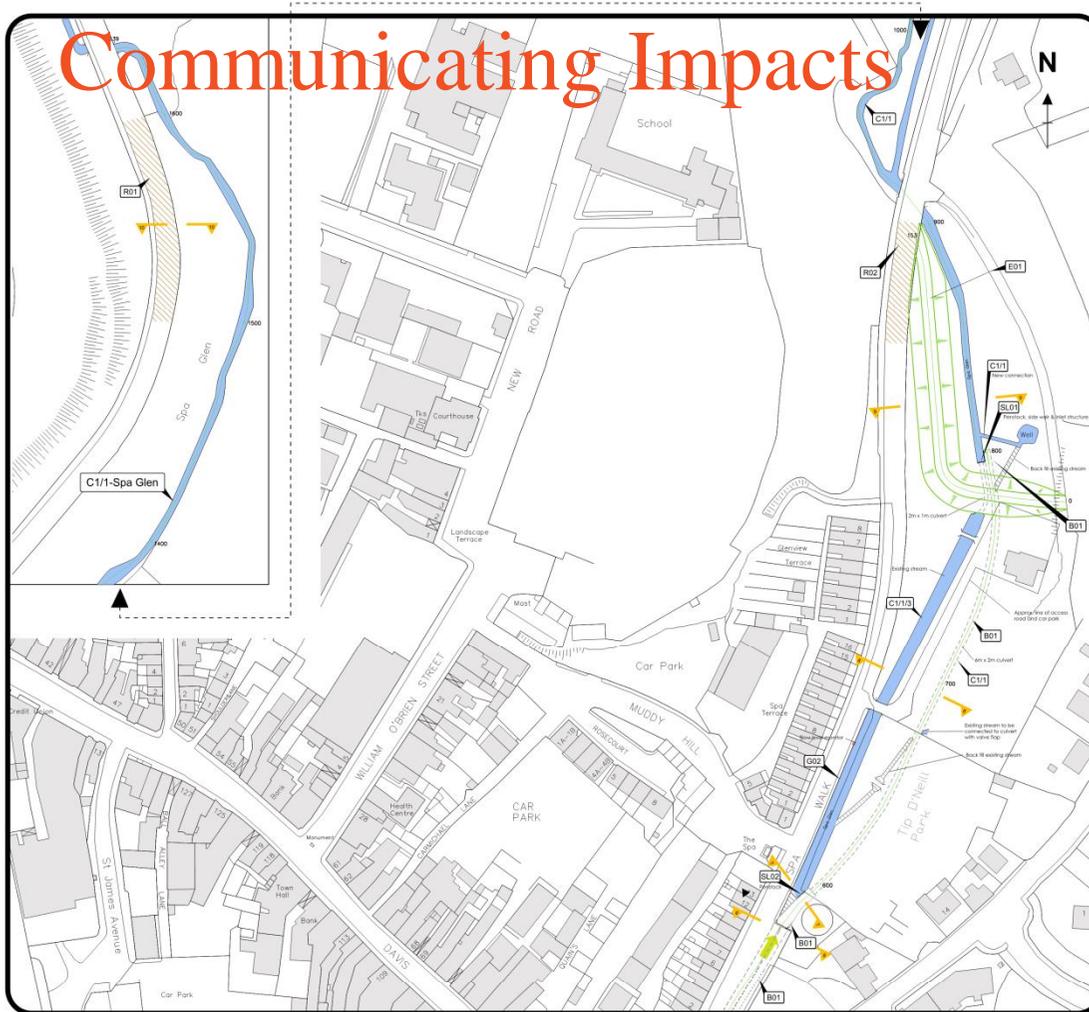
Adapted from AEA, 'Adapting the ICT Sector to the Impacts of Climate Change', 2010

Communicating Impacts

3D Visualisation| Munster Blackwater River (Mallow) Drainage Scheme



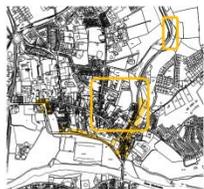
Communicating Impacts



Mallow North



Scale 1 : 1000 at A1



Key Plan

Schedule Ref.	Chainage (m)	General Description of New Works
C1/1 E01 R01	810 0 to 153 1500 to 1600	New stream connection to well Embankment to flood defence level (48.7m O.D.) Works to N72. Side overflow weir, Armco barrier, stock-proof fencing, bank stabilisation works and modification to road levels
R02	850 to 900	Modification to vertical alignment of road and installation of drainage features on N72
B01 G02	802 0 to 1639	Drainage inlet structure with control overflow Pruning and maintenance of channel and culverts

Schedule Ref.	Chainage (m)	General Description of New Works
B01 B01 SLO1	576 to 802 576 802	2m by 6m wide concrete box culvert 6m wide entrance chamber structure to double box culverts 3.3m wide penstock to allow existing Spa Glen stream to be isolated from high downstream water levels
SLO2	594	4.5m penstock to allow existing Spa Glen stream to be isolated from high downstream water levels
B01	494 to 576	Widening of existing double box culvert using new 3.5m x 1.5m culvert on northern leg (part shown)

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Scheme 1 : Munster Blackwater River (Mallow North) Drainage Scheme

Drawing No : S1/1



Tip O'Neill Park

Before



Tip O'Neill Park

After

Key to plan

- Chainage distance (m)
- Photo/visualisation location
- Proposed flood defence embankment
- Minor works to N72
- Existing culvert
- Proposed culvert
- Schedule reference
- Location of cross section

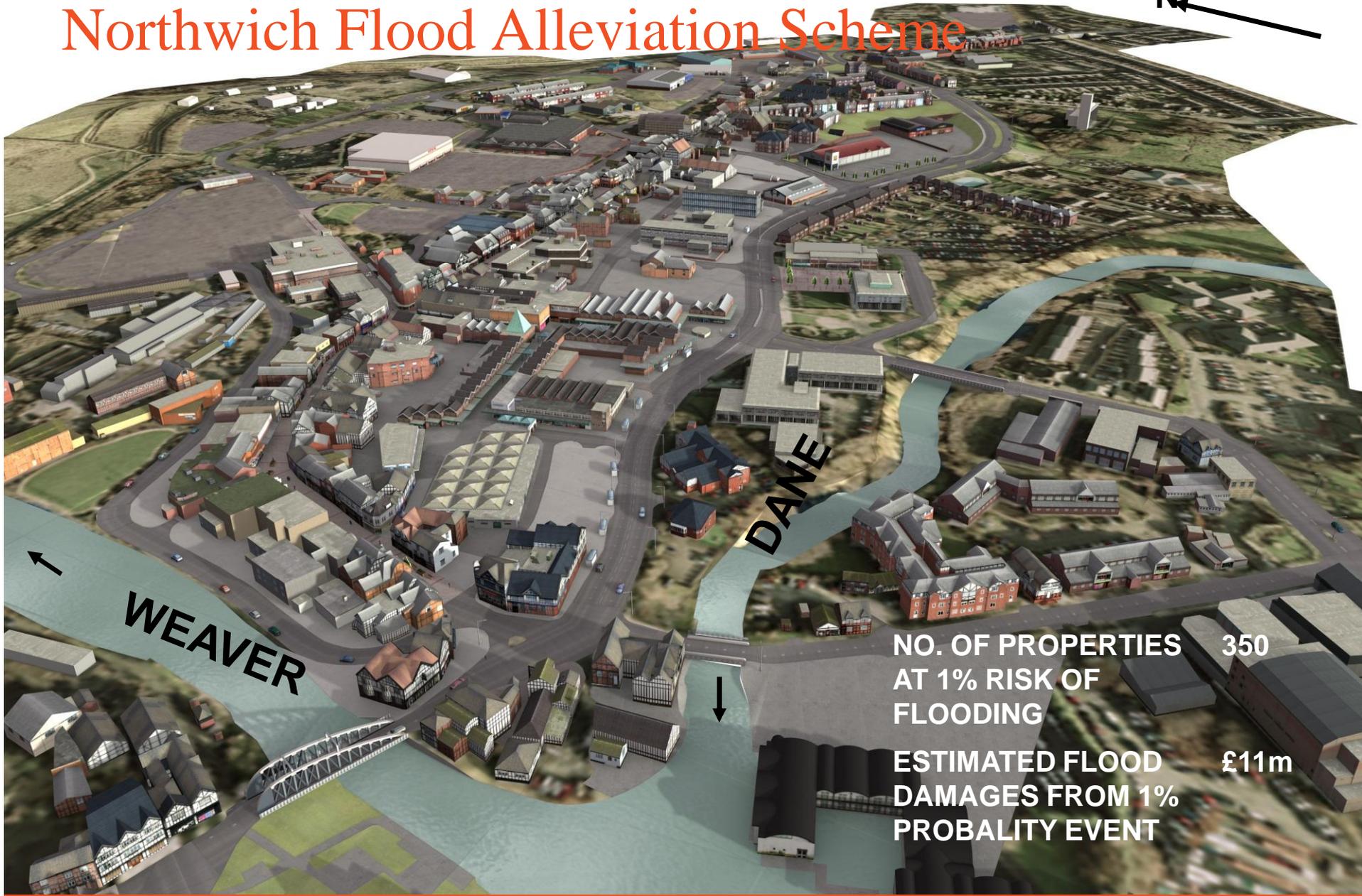
ARUP

OPW

ARUP Consulting Engineers
15 Oliver Street
Cork

OPW
01 81 Stephens Green
Dublin 2
Ireland
Tel: +353 21 427 7870
Fax: +353 21 427 2345

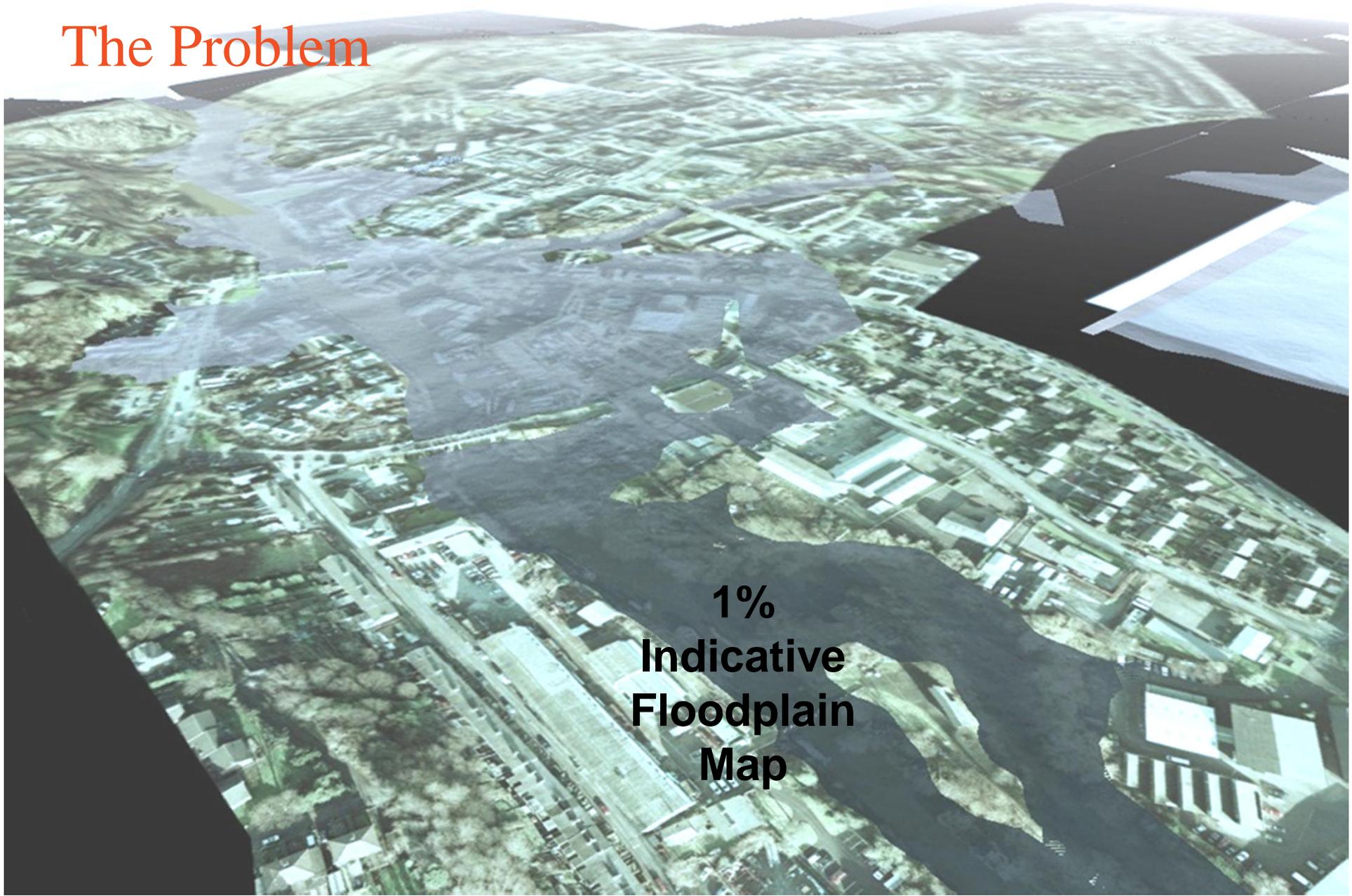
Northwich Flood Alleviation Scheme



NO. OF PROPERTIES AT 1% RISK OF FLOODING 350

ESTIMATED FLOOD DAMAGES FROM 1% PROBABILITY EVENT £11m

The Problem



**1%
Indicative
Floodplain
Map**

Northwich Flood Alleviation Scheme

Context

- Design carried out in 2006 but not cost-beneficial enough
- Late 2012 è Change in government funding Autumn Statement
- Feb 2013 è 99 Schemes, £120m grant aid to reduce flood risk in England & Wales, £2.2m allocation to Northwich
- è Fast track project, perceived as shelf ready Agency asking specific questions on the past work done
 - è Arup site visit
 - è Project awarded to Arup to develop Business Case (PAR) and subsequent Detailed Design
- Match funding from LPA(CW&C), EA, Defra è £4.6m

Leeds Flood Alleviation Scheme

The Challenge

- § To lower the flood profile
- § To reduce the scale of interventions
- § To reduce the visual impact
- § To allow for increased human interactivity with river
- § To reduce intervention on tributaries
- § To reduce impacts on surface water drainage
- § To maintain navigability

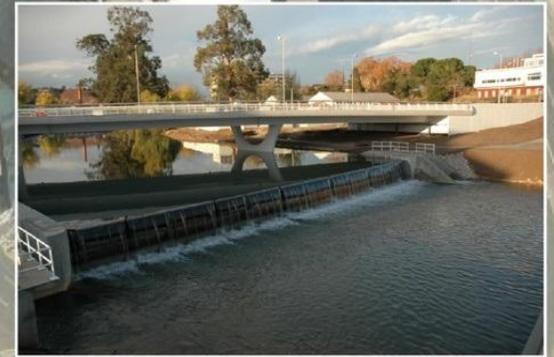


Leeds Flood Alleviation Scheme



**PROPOSED CROWN POINT
MOVING ADJUSTABLE WEIR**

Length of crest.....	32m
Crest level.....	23.6mOD
Lowering to.....	21.6mOD (2m fall)
Downstream bed level.....	21.3mOD



Obermeyer example gate with 3m adjustment, Portugal

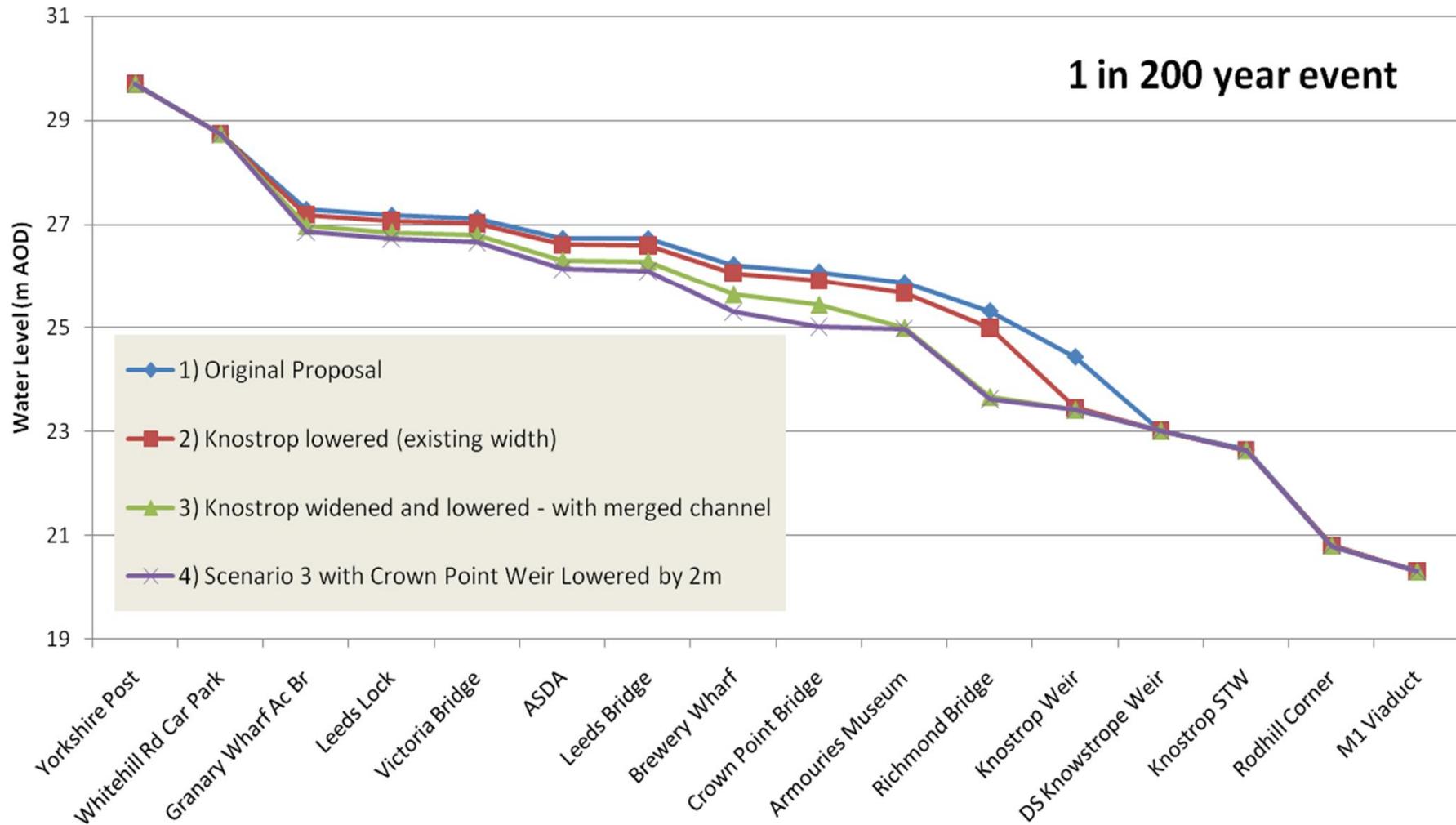


Obermeyer example gate with 3m adjustment, Portugal



Obermeyer example gate with inflatable bladders, Portugal

Reducing flood profiles



Reductions in wall height

	Change	Right Bank old height	Left Bank old height	Right bank new height	Left Bank new height
Yorkshire Post	-0.004		0.7		0.696
Whitehill Rd Car Park	-0.003	0.6	0.7	0.597	0.697
Granary Wharf Ac Br	-0.429	0.8	0.8	0.371	0.371
Leeds Lock	-0.446	0.8	0.9	0.354	0.454
Victoria Bridge	-0.463	0.8	1.7	0.337	1.237
ASDA	-0.59	0.6	1	0.01	0.41
Leeds Bridge	-0.63	1.2	0.7	0.57	0.07
Brewery Wharf	-0.92	2.1	1	1.18	0.08
Crown Point Bridge	-1.059	1.3			
Armouries Museum	-0.887	1.9			
Richmond Bridge	-1.702	2.4			
Knostrop Weir	-1.022	0.9			
DS Knowstrop Weir	-0.006				
Knostrop STW	-0.006	1.6			
Rodhill Corner	-0.004	0.1			
M1 Viaduct	-0.004	0.7			



Ulley Reservoir Failure, Doncaster



New Songdo City

Resilient to:-

- Monsoon
- Water quality issues and Algal Blooms
- Changes in Salinity and osmotic shock
- Massive temperature variations
- Availability of materials and workmanship standards

How? Multi-disciplinary team, using local experts where necessary, design of hard engineering assets integrated with soft robust landscape, analysis of risks at each design stage from concept -> Construction



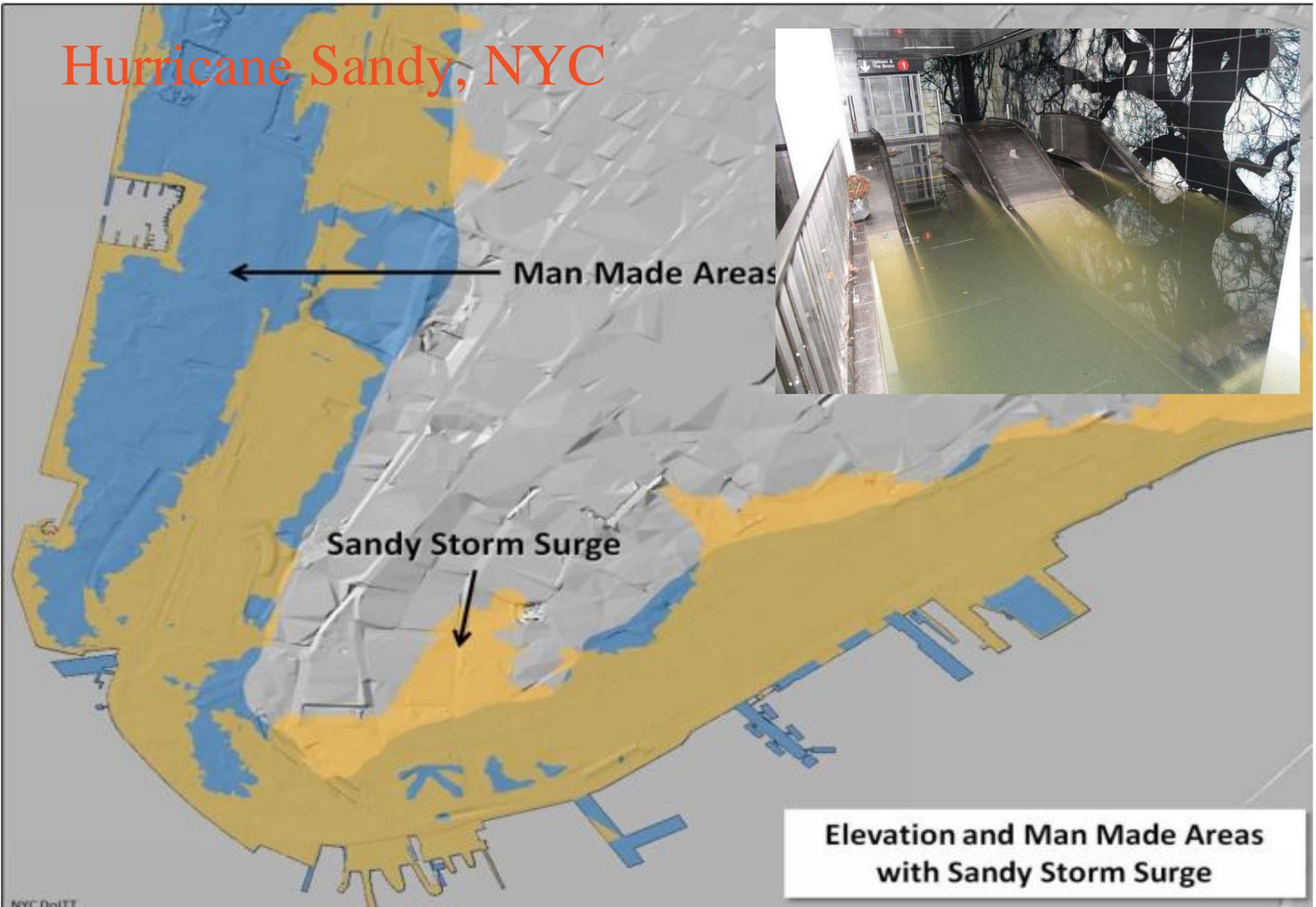
Arup NY Civil Engineering Post-Sandy Resilience

December 4, 2013

Vincent Lee PE LEED AP ENV SP



Hurricane Sandy, NYC



Examples of Near-term Solutions



Lower pan into manhole



Tighten center bolt to secure

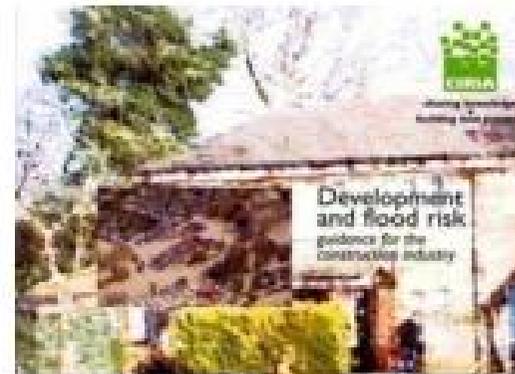




ART DOING DOUBLE-DUTY AS FLOOD PROTECTION?

Industry Guidance Developed by Arup

CIRIA C624 'Development and Flood Risk; guidance for the construction industry', 2004



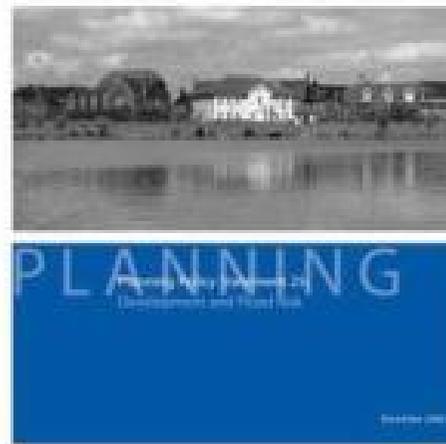
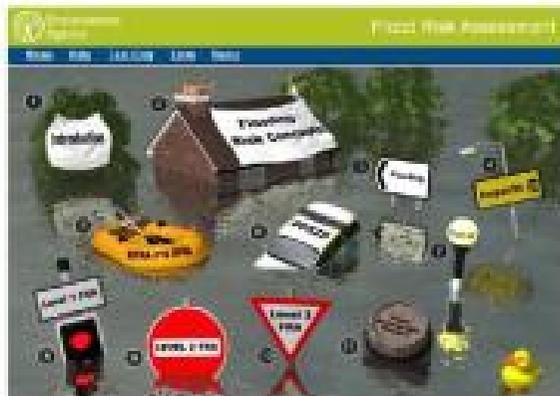
PPS25 'Development and Flood Risk' Practice Guide', 2007

Cityflood Guidance Document on Urban Surface Water Management Planning



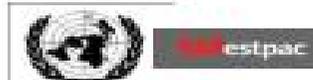
Planning shapes the places where people live and work and the country we live in. It plays a key role in supporting the Government's wider economic, social and environmental objectives and for sustainable communities.

On-line training in flood risk assessment for EA development control staff



CIRIA Report C688

Flood Resilience for Critical Infrastructure – CIRIA Report C688



The future challenges

1. Designing for resilient infrastructure is a developing science and the landscape will change. Data on likelihood, risk and consequence of failure must be gathered and understood to assess problems.
2. Designs not limited by exceedance events and that can be adapted
3. Solutions to fit with our environment. Used <1% but present 100%
4. Opportunity for engineers to introduce dual purpose uses, multifunctional solutions through innovation, advancement in materials and better understanding of combined probability, risk and consequence
5. Other safety critical industries such as nuclear and rail are leading innovation in this field and we need to catch up
6. Use of tools such a Monte Carlo Simulation, GIS, Gap Analysis, Statistical Risk Assessment